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THE COMMERCIALISATION OF UNIVERSITY PATENTS: A CASE STUDY

by

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ABSTRACT

THE COMMERCIALISATION OF UNIVERSITY PATENTS: A CASE STUDY.

The role of universities has evolved over the centuries. The most recent manifestation is the 'Entrepreneurial University' which engages with industry through various knowledge transfer practices and seeks to commercialise its research. First adopted by US universities this model has been replicated by universities in Europe, Australia and Asia.

One of the consequences of this rise in the 'entrepreneurial university' has been a sharp increase in patenting by universities. However, both the number and proportion of exploited patents is small. Given the costs of patenting this represents a significant waste of resources.

The primary aim of this thesis is to explain why some patents are exploited while others are not. This, in turn, involves exploring the actors who are involved in the decision to patent a scientific discovery and take it forward to exploitation. By identifying the factors that promote and hinder patent exploitation this will assist Technology Transfer Offices in deciding which inventions to patent.

The study uses qualitative methods incorporating a case study approach. The patent portfolio from the University of Strathclyde is used as the case study. Interviews with six directors of technology transfer offices in universities in Scotland and England were undertaken to understand the general process of commercialisation. Two samples of patents from the University of Strathclyde's patent portfolio, one comprising patents that were commercially exploited, and the other comprising unexploited patents, were examined in order to understand the different outcomes. Exploited patents included both those that were licensed to established and those that were used to start new spin-off companies.

The study finds that whether a patent is commercially exploited, and way in which it is exploited is influenced by three factors: (i) the entrepreneurs and the inventors, their characteristics and motivations. (ii) the characteristics and nature of the technologies (scope, stage) (iii) the TTOs' lack of resources and a due diligence system. The study concludes with proposals for how TTOs can enhance their decision-making process regarding which discoveries to patent in order to improve the overall effectiveness of the commercialisation process in universities.

LIST OF ABBREVIATIONS

ATP	Advanced Technology Programme
AUTM	Association of University Technology Managers
BTG	British Technology Group
DTI	Department Trade and Industry
IP2IPO	Intellectual property to Initial Public Offering
IPO	Initial Public offering
IPR	Intellectual property rights
JVSO	Joint Venture Spin-off
MIT	Massachusetts Institute of Technology
OECD	Organisation for Economic Cooperation and Development
SBIR	Small Business Innovation Research
SIDR	Strathclyde Institute For Drug Research
TTO(s)	Technology Transfer Office(s)
UCF	University Challenge Fund
UK	The United Kingdom
UNICO	UK Universities Companies Association
UOS	The University of Strathclyde
US	The United States of America
USO(s)	University spin-off(s)

CHAPTER 1

THE EMERGENCE OF THE ENTREPRENEURIAL UNIVERSITY

> *"The role of our universities in the economy is crucial. They are powerful drivers of innovation and change in science and technology, the arts, humanities, design and other creative disciplines. They produce people with knowledge and skills; they generate new knowledge and import it from diverse sources; and they apply knowledge in a range of environments. They are also the seedbed for new industries, products and services and are at the hub of business networks and industrial cluster of the knowledge economy" (Charles, 2003).*

1.1 INTRODUCTION

For many centuries universities were regarded as isolated institutions conceived for cultural conservation, preservation and transmission (Etzkowitz, 2002). Over time, the traditional role of universities has broadened but remained confined to teaching, research, and services. Research was only undertaken insofar as it supported the original goals of teaching (OECD, 1982). Education and research were done for their own sake as an end in themselves. Universities accepted a relatively small percentage of school leavers and trained them for elite positions in society. Services provided by universities were mainly to assist public domain activities (OECD, 1982) that were related to public services. The Industrial Revolution brought a change in the concept of knowledge. Research from universities became more empirical and practical, displacing the knowledge of theology. The role of universities changed from serving the state in managing society to serving industry and commerce by providing a pool of skilled workers. As industry's demand for skilled workers increased, more universities were established.

Research and development in universities became integrated with the main function of teaching and provided leadership for newly emerging industries (OECD, 1982).

After World War II, academic research became the main agenda for industrial innovation (Etzkowitz, 2002). R & D results in the form of patents could contribute to local economic development if they were efficiently exploited. The role of the university has therefore changed from 'mode 1' which is the production of theoretical knowledge to 'mode 2' which is research that results in practical knowledge (Fisher and Klien, 2003). Mode 2' research is associated with a more interdisciplinary, pluralistic, 'network' innovation system in contrast to the previous system in which major corporate or academic institutions were less closely linked with other social institutions.

A further shift has been towards the entrepreneurial university (Etzkowitz et al., 2000; Etzkowitz, 2002; Etzkowitz, 2003). In this new role universities 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. Universities are therefore now operating like private firms by selling and privatising their knowledge (Coupe, 2003). Their networking with industry and government which Etzkowitz et al., (2002) called a 'triple helix' becomes crucial. This model emphasises the increased interaction between universities, government and industries, and has required changes in the internal culture and norms of universities as well as in government policy related to the commercialisation of university technologies (Etzkowitz, 2003).

The success of Massachussetts of Institute Technology (MIT), Columbia University, and Stanford University in commercialising their research, either through spin-off or licensing, encouraged governments to believe that universities could be agents for industrial innovation, sources of high technology entrepreneurs and contribute towards both regional economic development and national innovation policies. This encouraged more and more universities to adopt this entrepreneurial ethos. The success of the entrepreneurial university model can be seen in the Route 128 area around Boston (Dorfman, 1983; Tornatzky, 2002; Etzkowitz, 2002). The Route 128 consists of eight universities (Boston College, Boston University, Brandies University, Harvard University, MIT, North-eastern University, Tuffs University and the University of Massachusetts Boston employing 50,750 people in financial year 2002). In 2002 in the Boston area of the US, 264 patents and 280 commercial licenses were executed and 41 spin-off companies were created (Boston Report 2003). The employment rate in the area grew by 4 % between financial years 2000 and 2002. This area was the leader in transistors, military equipment/research, semiconductors and minicomputers in the 1970s (Saxenian, 1994).

Silicon Valley, like Route 128, was famous for electronic measuring devices and receivers for military use post World War II. The Science Park was first developed in Stanford University as an important incubator for high tech companies. In the 1980s, a new generation of semiconductor and computer start-ups emerged alongside the established companies Hewlett Packard and Intel. Recently, Google Inc. was founded in 1999, and originated from Stanford University. In 2005, it had $6.1 billion gross revenue and an operating income of $2.0 billion. The company has 5,680 employees and $8.0 billion in cash and its equivalent. It went to an IPO in August 2004 with an offer price of $85 and climbed up to $414 per share by the end of 2005 (Eisenmann and Herman, 2006).

The success of the US universities in exploiting university research has been replicated by universities in Europe, Australia and Asia. In the UK, the Cambridge area (Segal Quince Wicksteed, 1990; Bower, 1992) is the densest site in Europe for high technology firms, many of which emanated from the university of Cambridge. In the 1970s and 1980s the university was the main source of high tech companies. The spin-offs process has now become multigenerational 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 century, there were more than 1,200 technology firms employing 36,000 people, approximately 10% of the total Cambridgeshire workforce (Garnsey and Heffernan, 2005). The same process has taken place at the University of Twente, in the Netherlands, Linkoping University in Sweden, and Katholieke University Leuven, in Belgium (Ndonzuau et al., 2002). Japan also started to generate spin-off creation from its universities following government legislation, which removed university ownership of intellectual property in 1998 (Rubin et al., 2003).

1.2 THE FACTORS THAT AFFECT THE MODERN ROLES OF UNIVERSITY

Etzkowitz et al. (2000) and Gray (1998) pointed out that the entrepreneurial university has emerged from various types of educational activities that could generate money for universities. It is not limited to R & D output and aligned with economic development, but it is also reinforced through innovations in undergraduate and continuing education as well as through consultancy, mass student recruitment, and higher tuition fees. However, in this thesis, the focus is on how an entrepreneurial university transforms its research into Usable products through either licensing to establish companies or through spin-off companies.

Several factors have pushed universities into becoming more entrepreneurial. These factors are discussed briefly below.

1.2.1 Reduced funding from central government

Central governments, in the US, European and Asia have reduced the amount of funding to its universities in real terms since the early1980s (Bower, 1992; Etzkowitz, 2002). This is because of the cost of opening up university education to the masses, and the increasing cost of scientific research. There is now more competition amongst university for research funding. Universities have been encouraged by government to raise funding from the third stream sources. This has encouraged universities to review their R & D activities and aim 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.

1.2.2 Control from government and change in universities mission.

The modern mission of universities involves multiple roles and objectives (Lazzeroni and Piccaluga, 2003). They need to commit to quality teaching and research, but at the same time they need to be innovative and involved in their local regional development (Young, 2004). This is a further pressure on universities to be entrepreneurial (Etzkowitz, 2000, 2002). Teaching and learning should be led by results of research. Interdisciplinary research and boundary spanning research centres or units should be established, which mediate with the outside world on behalf of the university by disseminating their knowledge via commercialisation of intellectual properties and consultation and specialised short courses should be aimed at local industries.

1.2.3 Increased support from government

The US government realised the importance of universities as an asset for future local development, and has undertaken various strategies to facilitate entrepreneurial universities. This has occurred since World War II. Government funding is still the largest but the proportion is reducing. In 2003, the federal government accounted for only 56 % of the funding for R & D in universities compared to 68% in 1972 (National Science Board, 2006). The National Science Foundation (NSF) was established to fund large scale projects (Etzkowitz, 2002) and collaboration projects with industry are encouraged. Some research centres were also established to commercialise university R & D, such as the National Centre for Manufacturing Science (NCMS) and the Advanced Technology Programme (ATP) (Mowery, 2003). Besides the new Bayh-Dole Act[1] legislation, the government also took on the role of venture capitalist by extending federal research funding to transform research into Usable products through the Small Business Innovation Research Programme (SBIR), which was introduced in 1977. The objective was to stimulate technological innovation and to increase private sector commercialisation of innovations derived from federal research and development (Etzkowitz, 2002).

The UK government has also put various strategies in place to support entrepreneurial universities. Three parliamentary White Papers have been published (1998, 2000 and 2001) dealing with universities roles in their local communities. The

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[1] Under Bayh Dole Act, the government relinquishes the right to seek the patent and allows the right to obtain a patent to be contractually transferred from the inventor to the university. The Acts allow universities to claim worldwide patent rights on inventions made under United States government grants and contracts. The regulations also require universities to establish Technology Transfer Office to facilitate commercialisation activities (Mowery et al., 2002).

main theme in the White Papers was the need to improve the funding of science education, and improve knowledge, skills and incentives for knowledge transfer (DTI, 2003). The UK has a strong science, engineering and technology base, especially in biotechnology and ICT but, exploitation research is generally weak (DTI, 2003; Nickell and John Van Reenen, 2003). There is a proposal to double the UK R & D budget from the present level of 1.87% of GDP. Similarly in EU, there is a current proposal to bring the present budget of 2% GDP to 3% GDP in line with Japan and the US (Potocnick, 2005).

The government gives direct support and provides various grants to universities to strengthen links with industries and to integrate entrepreneurism, the third role of universities, into the main stream. For example the UK's University Challenge Funds and Scotland's Proof of Concept Fund, are given to universities to develop inventions up to prototype level. Incubator facilities are provided to support new firms especially those from the universities until they are able to compete with the outside market.

Moreover, universities are encouraged to offer entrepreneurship courses to create entrepreneurial awareness among students as well as among academic staff as most[2] do not have any commercial experience. In summary, the new roles of universities are as follows (Lazzeroni and Piccaluga, 2003:46);

1. Knowledge factory: as an organisation oriented towards basic research and would be involved in the production of new knowledge. It can be measured through scientific publications and evaluated by peer groups as well as patents.
2. Human capital factory: Providing large numbers of quality graduates and PhD students.
3. Technology transfer factory: as an organisation, which interacts with the business world and favours the exploitation and transfer of scientific results. It can be measured by a series of indicators such as the contract research revenues, the creation of spin-off companies, the number of patents held and transferred, consultancy contracts, and the creation of

[2] Most, and similar term in this thesis, is defined as fraction of a quantity which constitute more than 70%.

joint U-I research laboratories which involve tacit knowledge flows and formalised contracts.

4. A territorial development factory: collaboration with local authorities and industrial associations to foster local and regional economic development.

1.3 PATENTING

To maximise the exploitation of R & D results from universities, the US government has introduced the Bayh-Dole Act in the late 1980s (Etzkowitz, 2002), which allows universities to have rights on their intellectual property. With this right universities can exploit and encourage their R & D results or 'Mode 2' knowledge and gain income from licensing their intellectual property rights. Consequently, many universities in the US have established Technology Transfer Offices (TTO) to facilitate patenting and licensing activities. The number of TTOs increased from 25 in 1980 to 200 in 1990, which underlines how universities have devoted their attention to these activities (Etzkowitz, 2002).

In the 1980s, following the case of Chakrabaty (1980), where the US Supreme Court ruled that live engineered micro organisms was patentable, research in genetic engineering and biotech has exploded. These industries have a strong relationship with universities (Young, 2004). Since the end of the cold war US government funding has shifted to civilian R & D, with a focus on health related research. Thus, university research in this area became important and partnerships with industry have grown (Young, 2004).

A similar phenomenon has occurred in the UK universities. In 1985, UK universities were given the right and responsibility to exploit their intellectual property and to ensure that public funded R & D results were transferred to the private sector. The devolution of the rights from the state-agency British Technology Group (BTG) to universities gave universities the financial incentive to generate income from their intellectual properties rights (Etkowitz et al., 2002). Technology Transfer Offices were established to facilitate the intellectual properties exploitation. This phenomenon has spread to European, and Asian universities.

Patenting is an important tool of measurement of the productivity of scientific research (Lazzeroni and Piccaluga, 2003). As universities change to become more entrepreneurial, they must identify inventions that have commercialisation potential and seek patent applications as a preliminary step to exploiting them through licensing or the creation of a new spin-off company.

The Bayh-Dole implementation in the US, the devolution of BTG in the UK, and the Chakrabaty Case have led to an increase in the number of patents in universities over time. However, by no means all granted patents are commercially viable. As a rule of thumb for every 100 disclosures that go to the Technology Transfer Office (TTO)[3], 25-30 of them will be subject of patent applications. However, only 10% of granted patents are commercialised either through licensing to an established firms or through a spin-offs. This percentage is below the OECD (2002) which reported that 20% to 40% of patents are licensed. Moreover, only half of the patent portfolio earned income. In the US, before the Bayh-Dole Act, the federal government had accumulated 30,000 patents, of which only 5% were licensed (Mowery et al., 2004). In a more recent survey by Association of University Technology Transfer Management (AUTM) (2004) it was reported that only 22.4% of the total of 27,322 active licenses earned any income (Pressman, 2004). And of those only a few licenses generate significant income for universities (Jensen and Thursby, 2001; Grafft and Heirman, 2002; OECD, 2002). Recent data on the UK universities reveals that 66% of respondents had existing License, Options and Agreements (LOAs) yielded income, 34% of them did not receive any income (UNICO, 2005). These statistics question the effectiveness of the patenting activities in public universities in the UK.

1.4 RESEARCH RATIONALE

A review of the literature on the patenting and licensing activities of universities reveals that no study has ever been carried on the reasons why some patents are commercially exploited and others are not. Nor has there been any investigation of the decision making process of university TTOs in relation to the commercialisation of patents. This study attempts to fill these gaps in the literature. The study will answer two research questions:

[3] Based on Interviews with Technology Transfer Officers in Scottish Universities

i) What explains why some of the university patents are exploited and others are not?

ii) What are the features of exploited patents and unexploited patents?

The research objectives which will address the research questions, deal with the following issues:

i) To identify how, why and who are the actors involved in the decisions to patent a discovery or new inventions through to exploitation.

ii) To identify the factors that influence and hinder patent exploitation.

An increased understanding of these issues will help TTOs and policy-makers improve the effectiveness of the patenting and commercialisation process.

1.5 ORGANISATION OF THE THESIS

This thesis is organised into nine chapters. The introductory chapter has provided an introduction and background to the study and explains the reasons for undertaking the research. The research problem and the research questions have been identified. Chapter 2 reviews the relevant literature. The first part of this chapter reviews the patent process, the importance of patents and the motivation factors that lead academics to patent their inventions or otherwise. The second part of the literature review is focused on university licensing activities. It specifically focuses on the reasons why university patents have been licensed to established companies or to new university spin-off companies. Chapter 3 outlines the methods used to collect the data for analysis. A case study approach has been adopted in this research and the justification for this is given here. The chapter also provides a critical review of the analysis technique used in the study. In Chapter 4 the commercialisation process of university intellectual property is examined. Seven universities were studied and interviews were conducted with the TTO director of each university. This gives a better understanding of the general process of university commercialisation activities and differences in practice.

The following four chapters report on the research findings. Chapter 5 examines unexploited patents. This chapter examines the features of this type of patent and who were involved in the patenting process. The factors that inhibited patent exploitation are discussed and propositions are suggested. Chapter 6 presents the case of patents that were licensed to spin-off companies. The features of the patents that are exploited through this route are examined. The actors involved in the decision to seek patent protection and the decision to commercialise are identified. Chapter 7 presents information on patents that were licensed to established companies. The features of these patents and identification of those who were involved in the decision making to seek patent protection and to commercially exploit the patent are described. The factors as to why certain routes were chosen are highlighted. Chapter 8 compares the similarities and differences between these three categories of patents. The characteristics of the inventors and the maturity of the technologies, the role of the TTO, funding and industrial experience of the researchers all play a part and a description is given as to how they influence the decision-making and the routes to exploitation.

Finally Chapter 9 draws together the conclusions and recommendations of the study and identifies the implementation opportunities for practitioners. Limitations of the study and potential areas for further research are also discussed.

The next chapter, the literature review of patenting and commercialisation process will be discussed.

CHAPTER 2

LITERATURE REVIEW

2.1. INTRODUCTION

This thesis is concerned with the commercialisation of patents that have been generated by university research. The appropriate starting point is therefore to review and to examine how universities commercialise their patent portfolio.

2.2. PATENTING PROCESS

A patent is a specific type of intellectual property comprises of patents, copyrights, designs, know-hows, trademarks and confidential information (Adam, 2003). Foltz and Penn (1990:2) defined a patent as;

> *"a government granted and secured legal rights to prevent others from practising (i.e. making, using, or selling) the inventions covered by the patent; and, since a patent is a personal property, it can be licensed, sold, mortgaged, willed, or inherited."*

Knight (1996:2; 2001:2) defined a patent as

> *"a legal grant by the government of a country to inventors of the idea, invention and/or technology, the right to exclude others from making, using, or selling the invention, for a limited period of time."*

The UK Patent Office's (2006)definition is as follows:

> *"a patent for an invention is granted by government to the inventor, giving the inventor the right for a limited period to stop others from making, using or selling the invention without the permission of the inventor."*

Patents are territorial rights. A UK patent will only give the holder rights within the United Kingdom and rights to stop others from importing the patented products into the United Kingdom. Since a patent is a property it also has a value that needs protection.

2.2.1 The term of a patent

The term of a patent is the amount of time a patent is in force after it is granted, assuming maintenance fees continue to be paid. Term can also mean the amount of time a patent is active, and includes both the examination time plus the time the patent is in force (Knight, 1996; Knight, 2001). Different countries start the term of patent at different times. A patent from a European country has a term of 20 years; however, the patent is in force only from the grant date until 20 years after filing. Therefore, the actual time the patent is in force can be much less than 20 years because the real in force date is the date after filing and not the granted date. In Japan, the patent term is 15 years from the date the examined application is published for public review (and possible opposition), but not more than 20 years from filing. However, the 20-year period will become standard in most industrial countries as the result of global patent harmonisation efforts. In the United States since 1861 and prior to 8 June 1995 the term of patent has been 17 years after issuance. However, since then the US law changed the term to 20 years after the filing date (Knight, 1996; Knight, 2001).

2.2.2 Types of patent

The US Patent Office (USPTO) categorises five basic types of patent, which include: utility patent, utility model patent, design patents, plant patents, and business model patents. Of these, utility patents are the most commonly sought and they are the source of the growth in the number of patents. They are commonly used to protect computer software developments and new inventions.

1. **Utility Patent.** Utility patents protect the functional part of a machine or process. Utility patents are viewed as a patent on new machines, new compositions of matter, new manufactures, or new methods or processes of making machines, compositions of matter or manufactures. A 'machine' is normally thought of as a mechanical invention having moving parts, while a 'manufacture' is normally considered to be a mechanical invention having no moving parts, such as a hammer

or screwdriver. 'Compositions of matter' are normally new chemicals, polymers and the like (Knight, 1996; Knight, 2001). These patents are more difficult to obtain and more valuable than design patents. Nowadays with advances in technology, computer software and human genes fall into this category of patent (Knight, 1996; Knight, 2001; Allen and Wong, 2003; OECD, 2004).

2. **Utility Model Patent.** Some countries, for example, Japan, Germany and Korea, allow utility model patents, which can be thought of as small, more specific utility patents. Utility model patents usually have a shorter life than utility patents, and were originally intended to provide some quick, inexpensive legal protection for a small invention. From a practical standpoint, a utility [patent] is narrowly claimed, or very specific to a particular product or machine (Knight, 1996).

3. **Design Patents.** Design patents are used to protect new, original ornamental designs for an article of manufacture. The subject matter of a design patent can be related to the configuration or shape of an object, to the surface ornamentation on an object, or both. Normally design patents consist of a drawing of the ornamental design and a simple claim to the design, which is illustrated in the patent (Knight, 1996). Examples of design patents include eye-glasses, the design of a vase or the design of a door handle. A design patent application may only have a single claim. A separate application must be filed for each independent design, as multiple designs cannot be supported by a single patent claim. Design patents are valid for 14 years from the date of application (Allen and Wong, 2003).

4. **Plant Patents.** Plant patents protect new and distinct varieties of asexually reproducing plants. The plant for which a patent is being sought must be uniquely different from any plant existing naturally in nature. This patent is good for 20 years from the date of application (Allen and Wong, 2003). The type of plants eligible for patent protection normally includes cultivated sport, mutants, hybrids and new seedlings, other than tuber-propagated plants or those found in an uncultivated state. In some countries the plant must be capable of industrial application.

5. **Business Method Patents.** The business method patents are actually a type of utility patent and involve a classification of process. USPTO declared that business method patent will only apply to fundamentally different ways of doing business and embedded processes must produce a useful, tangible, and concrete

result. Examples of this kind of process are application software designed to automate the portfolio management system by an organisation. A typical example is the method and system for placing orders via a communication network introduced by Amazon.com.

2.2.3 The importance of patent

Patent protection is important to inventors whether they are individuals or organisations. According to Taylor and Silberston (1973) cited in Macdonald and Lefang (2003);

> *"patent is the outcome of a bargain between the inventor and society which society grants the inventor certain rights to his invention in return for the inventor's disclosure of whatever it is he has invented".*

Thus, a patent creates incentives for further research and development (Mazzoleni and Nelson, 1998; Thumm, 2004) and the patent owner will be given exclusive rights to use the technology (Sullivan, 1995; Knight, 1996; Knight, 2001; Jackson, 2003; Panagopoulos, 2003). The owners of a patent are therefore able to commercialise the technology without hindrance from competitors. Mazzoleni and Nelson (1998) reported that established companies were unlikely to engage in further development of a university invention unless they had proprietary rights or the patent was licensed to them exclusively. New venture companies do not have any strong assets, marketing and distribution systems. Hence patents are regarded as a valuable resource for the competitive advantage of a company before it can sustain itself in the market (Shane, 2004). According to Zahra and Bogner (1999) patents held by a company can be a predictive index of a firm's performance and a large number of patents shows that the company is innovative.

In addition, a patent is an important asset to a company to prevent their competitors having an advantage and as an assurance of monopoly power before investing in development and commercialisation. This is supported by Colyvas et al. (2002) who reported that intellectual property rights (in terms of patents) are likely to be most important for embryonic stage inventions, and unimportant for inventions that were basically "ready to use" straight out of the laboratory.

2.2.4 Why universities patent

Universities patent inventions for two main reasons. First, patenting inventions gives universities a stock of technologies. University inventions are the main source of this stock. Many universities encourage and some of them oblige their staffs to patent their inventions especially if government has funded the research. Universities rely on inventors disclosing their discoveries to the Technology Transfer Office (TTO). Disclosures are considered as intermediate inputs to a patent, which than can be licensed to an established company or to a spin-off company (Thursby and Thursby, 2002). More disclosures lead to more patents available to be exploited (Thursby et al. 2001). This is confirmed by Shane and Di Gregorio (2003) who studied AUTM data from 1994 to 1998 from 101 universities and 530 spin-offs and found that more quality disclosures led to the creation of more spin-offs. Second, technologies that have been patented are easier to commercialise.

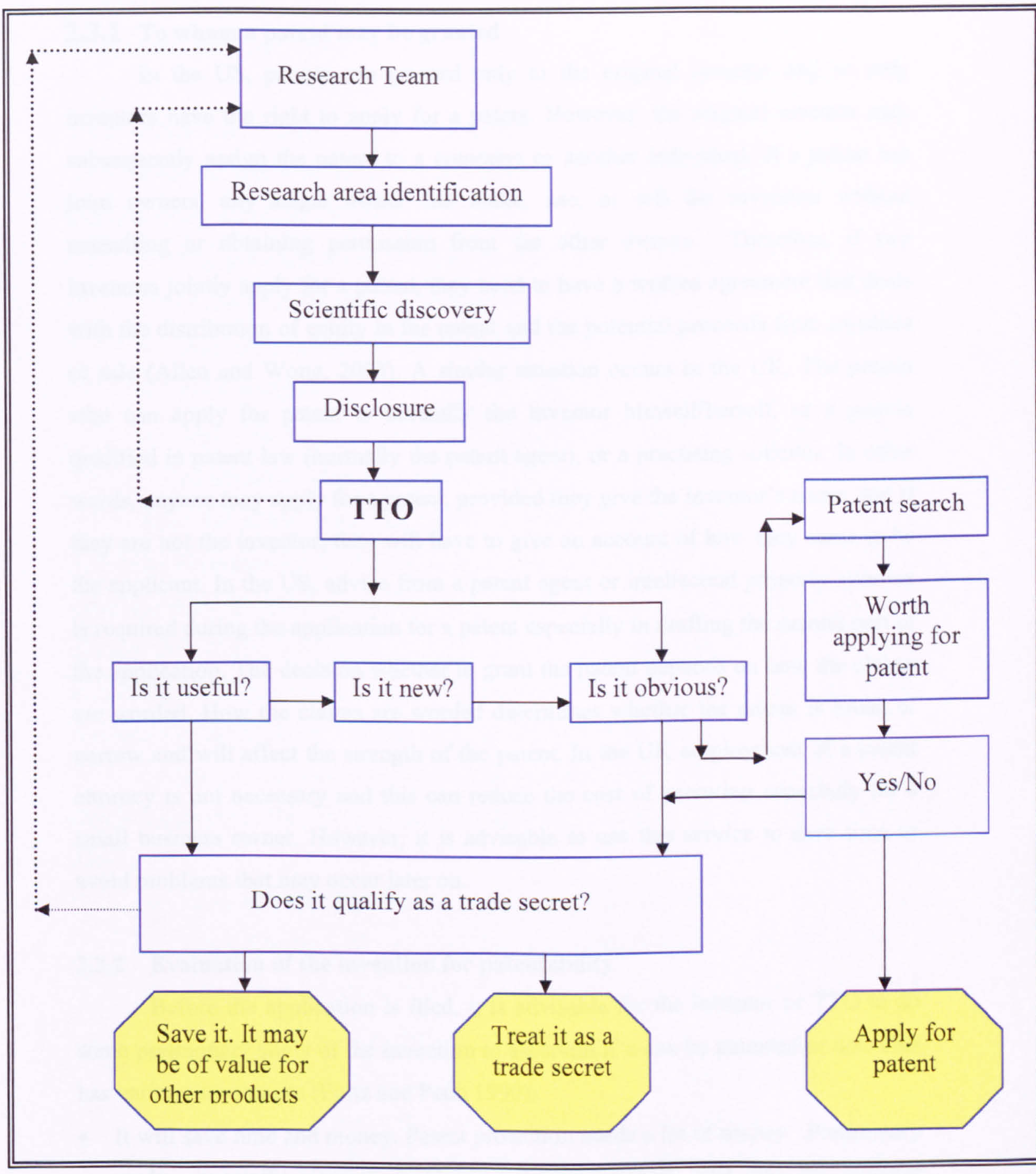
Universities have insufficient resources to transform the technologies into u'sable products. Because of a lack of resources, universities need industrial partners to bring the inventions into the market place. Thus, patents are important tools in bridging these two different worlds (Mazzoleni and Nelson, 1998). Universities will license their patents to companies in order to transform the technologies. Companies prefer to license inventions that have patent protections, except in the case of special technologies and circumstances, when the inventions may be exploited without patent protection being sought (Mazzoleni and Nelson, 1998; Blackburn, 2004).

The strength of a patent determines the route of commercialisation to be chosen. Strong patent protection, radical technologies and broad scope of a patent encourage exploitation through spin-off formations (Shane, 2000b; Shane, 2001a; Shane, 2001b; Nerkar and Shane, 2003; Shane, 2004). On the other hand patents that have weak scope of protection, and represent incremental technology tend to be exploited through being licensed to established companies (Shane, 2000b; Shane, 2001a; Shane, 2001b; Shane, 2004) (see Section 2.5 for more detailed discussion).

2.3. THE PROCESS OF PATENTING

Six stages are identified in the process of patenting. The general flow chart of the patent process is illustrated in Figure 2.1. The figure shows that the research

Figure 2.1: Flow Chart of patenting process



(Source: Modified from Foltz and Penn, 1990)

results were disclosed to TTO office. The TTO and the inventors will negotiate to patent if the technologies fulfil the three basic requirements: is it useful; is it new; and is it obvious. The TTO proceeds for patent application if it worth patenting or keep the technologies as a trade secret or saved as value for other product, or not to patent if the technologies did not fulfil the three basic criteria.

2.3.1 To whom a patent may be granted

In the US, patents are granted only to the original inventor and so only inventors have the right to apply for a patent. However, the original inventor may subsequently assign the patent to a company or another individual. If a patent has joint owners, any single owner can make, use, or sell the invention without consulting or obtaining permission from the other owners. Therefore, if two inventors jointly apply for a patent, they need to have a written agreement that deals with the distribution of equity in the patent and the potential proceeds from royalties or sale (Allen and Wong, 2003). A similar situation occurs in the UK. The person who can apply for patent is normally the inventor himself/herself, or a person qualified in patent law (normally the patent agent), or a practising solicitor. In other words, anyone may apply for a patent, provided they give the inventor's name, and if they are not the inventor, they will have to give an account of how they came to be the applicant. In the US, advice from a patent agent or intellectual property attorney is required during the application for a patent especially in drafting the second part of the application. The decision whether to grant the patent depends on how the claims are worded. How the claims are worded determines whether the patent is broad or narrow and will affect the strength of the patent. In the UK employment of a patent attorney is not necessary and this can reduce the cost of patenting especially for a small business owner. However, it is advisable to use this service to save time or avoid problems that may occur later on.

2.3.2 Evaluation of the invention for patentability

Before the application is filed, it is advisable for the inventor or TTO to do some preliminary study of the invention to ascertain if it can be patented or not. This has various advantages (Foltz and Penn 1990):

- It will save time and money. Patent protection needs a lot of money. Preliminary study, especially research involving potential markets, will give the inventor information about the future market and prior art of the invention.

- The information gained from the study can be used in the development of an 'Information disclosure statement'.
- Through preliminary study technical information may be obtained that could be useful in carrying out the technical aspects of work.

2.3.3 Prior Art: a major factor of patentability

Prior art refers to the accumulated, published knowledge of all mankind. It includes (Foltz and Penn 1990):

- The prior invention of others (technology which is patented, unpatented, or contained in expired patents)
- Prior commercially available devices
- Prior publications
- Any other prior technical information, which is relevant to the patentability of the invention.

Prior art is important because it is a major factor in deciding whether an invention is patentable. To be patentable, an invention must be new and different from the prior art; this means that the closer the invention is to prior art, the less chance that it can be patented. Patent laws presume that all inventors have knowledge of all prior art so inventors cannot argue that they should get a patent just because they do not know that pertinent, similar prior art existed.

In the US inventors are given a one-year grace period before having to file a patent application. The right to obtain a patent is lost if the party applying or the patent:

- describes the invention in a printed publication anywhere in the world (including the US) more than one year before the patent application, or
- places the invention in public use in the US more than one year before filing the patent application.
- offers the invention for sale in the US or, in fact, sells the invention in the US more than one year before filing the patent application.

However, in the UK and most other countries, the inventor cannot get a patent if the invention has been made public anywhere in the world before a patent application is filed in most of the countries (with the exception that if the invention has been made public in the US.

2.3.4 Patent Infringement

A patent is 'infringed' when the invention covered by the patent is manufactured, used, or sold without permission from the patent owner during the time the patent is in force. Infringement often comes about because the exploitation of an invention requires using technology protected by earlier patents (Foltz and Penn, 1990). The responsibility for detecting infringement lies with the owner of the patent that may have been infringed. The patent owner has the right to sue the infringer in the courts and collect compensation for a past infringement, and obtain an order from the court to prevent further infringement.

2.3.5 Patent cost

Patenting an invention is very costly. It is normal for inventors to patent in all countries when the business becomes more globally focused. The decision to file in many different countries will cost hundreds of thousands of dollars. A single patent held worldwide for the period of 20 years (from the filing date) will cost an estimated US$50 0000 to US$100 000 to obtain and US$250 000 to US$500 000 to maintain (Jenei, 2005) during the 'life' of the patent. Renewal fees have to be paid which increase every year. In addition, costs will be incurred if there is a need to defend the patent in court or to take another party to court for legal infringement. Smaller firms report that they are discouraged from patenting because of the costs of both the filing and potential patent litigation (Cohen et al., 2000). Larger firms are better able to spread the fixed costs of applying for and defending patents over greater levels of output.

2.3.6 Filing globally

One the most difficult tasks involved in filing a patent application is the selection of countries in which to file the application. Theoretically, a company or organisation can obtain patents in all countries to prevent others from making or using that company's inventions anywhere without licence. In most cases a university or a company will want to file its most important inventions worldwide, so the inventions will provide the company or university with a global competitive advantage. Nevertheless, the actual selection of countries in which to file the application will be difficult, because the cost of the patent increases many times over the initial cost of filing in the home country (Knight, 2001).

Knight (2001:162) suggests that in deciding to file globally or not, three factors should be taken into consideration:

i) The competitive value of the patent

ii) The competitive value of the country

iii) The market value of the invention.

Knight (2001:167) gives some guidance as to which countries patent for an invention should be applied for

1. For inventions that would be used in new products, patents should be filed where the market presence of the product is targeted/desired, especially in the biggest market of the product. Any infringement of the patent would make the technology more prominent in these markets, thus, making the copying or selling the patented technology more difficult.
2. If the invention is a new process or new machinery used to make a new product, and the use of the process could be detected in the product, then patent protection for the new process or the new machinery should be applied at the same countries where patents had already been requested for the products.
3. If the invention is a new process or new machinery which is used to make a product, and the use of the process or the machinery cannot be detected in the product, then the patent for the invention should be applied for globally to restrict competitors from using the new invention anywhere in the world without the inventor's permission.

These guidelines for new inventions or new processes or production machinery are basically guides for the enforcement of the patents. Bearing this in mind, for processes or production machinery whose use can be detected in the products, patent protection in the countries where the product is marketed are adequate, but otherwise, only worldwide protection would suffice.

Another important consideration is the duration of the future market potential for any new invention, such as for the next 20 years. All tools to ascertain market potential such as population forecasting, purchasing forecasting and general economic trends should be used. Today, the majority of patents are filed in three major Patent Offices, the United States, Europe and Japan. Japan and the US will continue to be popular filing countries for many types of technology (Knight, 2001).

2.4. PATENTING BY UNIVERSITIES

2.4.1 Trends

Governments recognise universities to be a central player in the national innovation system. They encourage universities to become more actively involved in commercialisation activities. As we noted in chapter 1, this has led to most universities to change their paradigm towards the commercialisation of their research activities by seeking to license their patents to established companies or to spin-off companies, and engage in joint sponsored research or contract research with industrial partners (Mowery and Sampat, 2001; Mowery and Ziedonis, 2002; Mowery et al., 2002; Mowery, 2005).

This shift to a more entrepreneurial university has given new impetus to university patenting and licensing activities. The number of patents from universities is increasing every year and the number of universities involved in patenting and licensing activities has increased remarkably (Henderson et al., 1998; Etzkowitz et al., 2000; Mowery et al., 2001; Mowery and Ziedonis, 2002; Mowery et al., 2002; Etzkowitz, 2002; Mowery et al., 2004; Mowery, 2005). Patenting and licensing activities by US and Canadian universities are far ahead compared to the UK universities. This is because commercialisation activities in the US were started immediately after World War II (Etzkowitz, 2002), whereas the 'entrepreneurial university' era in the UK only began in the 1990s (Gray, 1998). Indeed a survey in 2004 found that 46% of responding institutions in the UK had no patents granted and only 12% of the institutions had more than 20 patents granted per year (UNICO, 2004). Only 6% of the institutions had an expenditure on IP management of more than £500,000 and 21% had no expenditure for this item (Pressman, 2004). The consequence is that the number of patenting, licensing, and spin-off activities in the UK universities is far smaller compared to US universities (Table 2.1).

Table 2.1: UNICO and AUTM survey (2004): total number of patent, granted patent, licensing income and spin-off in the UK, US and Canada universities and research institutions).

	UK Universities		**US Universities**	
	2004	**2003**	**2004**	**2003**
Total number of patent filing	721	729	13 803	13 280
Total patent granted	441	438	3 680	3 933
Licensing income (average per institution)	315k (£)	277k (£)	1.474 b (US$)	1.414b (US$)
Total Spin-off company formed	189	130	462	374

US universities are creating more licensing income relative to their research income than UK universities. For every pound of licensing income made by US universities, they have around £36m of research income. However, for every pound of licensing income made by UK universities, they have around £102m research income. UK universities are creating more spin-off companies relative to their research income than US universities. For every spin-off company produced by UK universities, they have around £11m of research income. While, for every spin-off company created by US universities they have around £50m (UNICO, 2005). However, various commentators have suggested that UK universities have encouraged too many spin-offs with limited growth potential (Levie et al., 2003; Lambert, 2003; Davis, 2003).

2.4.2 The problem to disclose the quantity of the inventions

Patents are the stock of inputs for a university to license its technology. Disclosures from faculties are crucial in order to populate this stock. However, to get the faculty to disclose their inventions is difficult. According to US research, only half of all inventions in universities are disclosed to TTOs (Thursby et al., 2001; Jensen and Thursby, 2001; Jensen et al., 2003). Moreover, majority of the inventions are on at embryonic stage (75% at proof of concept) and only 12% were ready for commercial use. The consequence is that less than half of the inventions were licensed (Jensen and Thursby, 2001).

Inventions disclose at embryonic stage may indicate their low quality[4]. Jensen et al. (2003) has reported that higher quality[5] inventions might not be disclosed to TTOs. The inventors might publish the result or might circumvent TTOs as Siegal et al., (2003) reported. This is because 90% of industry contracts with universities, industry sometimes included 'delay of publication clause' (following Thursby and Thursby (1999) in Thursby and Thursby (2002). This is also the reason that higher quality faculties such as engineering and higher ranked academics disclosed poor quality inventions. Moreover, faculty specialising in basic research may not disclose because they are unwilling to spend time on applied research and development as requested by industries who license the technology (Thursby and Thursby, 2002; Jensen et al., 2003). Quality of invention affects the royalty rate received by a university. Late stage technology receives higher royalties rate when licensed. This is why one of the reasons universities includes sponsored research in a license agreement if a new technology is at early stage of development (Thursby et al., 2001). To induce inventors' involvement and disclosures, royalties and equity to tie the inventors are crucial. Running royalties and small up front fees may be given according to the stage of development and for uncertain technologies.

Inventors who disclose their inventions, the first intention is to patent and commercialise their inventions (Roberts and Peters, 1981). According to Owen-Smith and Powell (2001), inventions are disclosed is based on three factors: i) the inventors' perception of the personal and professional benefits of patenting; ii) the inventors' perception of the time and cost of interacting with TTOs; and iii) their immediate environment, i.e. general view of technology transfer. The study suggested that the decision to disclose patentable knowledge follows a cost benefit analysis. If the cost exceeds the expected benefits, the researcher will rationally reject patenting. The researchers will decide to disclose because they perceive positive personal (pecuniary and curiosity) and professional (prestige, validation of basic research) outcomes from patenting activity. The cost structure includes: i) a negative experience of past patenting by the researcher, ii) a negative view of the

[4] Very early stage inventions or patents that do not give any sign of effect or potential value.
[5] Early or later stage inventions or patents that intended results have been proposed or reliable, and repeatedly reproduced.

level of expertise in the university technology transfer offices; iii) a negative view of the quality of interactions with the university technology transfer offices.

The decision of researcher to disclose inventions is also influenced by their peers group. Bercovitz and Feldman (2004) reported on their study of 15 departments from two medical schools of Duke University and Johns Hopkins University for academic years 1991-1999. Disclosure behaviours for academic years in 1996-1997 and 1998-1999 were examined. A researcher's decisions to disclose his/her invention depends on the norms at the institution where the researchers were trained, as well as the disclosure behaviours of their department chair and peers. Individuals are more likely to disclose their inventions if they were trained at institutions that have long established and relatively successful technology transfer operations and experience. They are more likely to disclose the inventions if they see their peers in the same academic rank disclosed.

2.4.3 Evaluation and selection problem

Once an invention is disclosed to a TTO the next step is for the TTO to access its commercial potential. However, many universities in the US and the UK do not implement a systematic due diligence process during the selection stage (Vohora et al., 2003; Lockett et al., 2005). At this stage, precise identification of which disclosures need patent protection is important (Vohora et al., 2003; Lockett et al., 2005). Universities typically do not practice this system because most of university technologies are at an embryonic stage, and therefore of certain value. However there are some universities that practise this kind of system, though the actual practice differs between universities. A comprehensive systematic selection process has been suggested (Meseri and Maital, 2001; De Coster and Butler, 2004). For example, Meseri and Maital (2001) suggested 20 criteria for selecting a project for technology transfer offices in Israel. The selection criteria are in accordance to the practice being used by MIT and private sectors. The six factors that were scored were market needs, market size, existence of patent, success for R & D stage, level of innovativeness and degree of maturity of the idea. However, the study did not show how to calculate the total score to identify which project should be prioritised. In contrast, De Coster and Butler (2004) demonstrated how to calculate scoring marks to university projects, which looked at a various aspects as practiced by private sector assessments. But the calculation of the score is not a straight forward and is a complicated exercise.

The existence of a scoring system could help university TTOs to provide clearer process of selecting and prioritizing projects to commercialise. However this system itself is insufficient if TTOs staffs are not sufficiently knowledgeable about technology and business. The system is also not effective if the inventors have no entrepreneurial characteristics or lack of the motivation to commercialise their inventions.

If a university has difficulty in accessing financial and managerial resources to assist start-up from the early period, it may practice a selective and supportive strategy to patent or licensing to spin-off or small firms (Roberts and Malone, 1996; Degroof, 2002; Degroof and Roberts, 2004; Powers and McDougall, 2005). It was found that selectivity and entrepreneurial density are significant and positive predictors of the number of licenses exploited through spin-off or small companies. It was found that a policy of selectivity appears to have differential benefits depending on the nature of their external environment for entrepreneurship. In countries or regions with entrepreneurial density (highly access to venture capital, access to expert in science and technology, patenting, and R & D activities) universities can adopt low selective and low support activities. 'Picking winners' is left to the external environment such venture capitalists to select (Degroof, 2002; Degroof and Roberts 2004).

On the other hand, in regions and countries with low entrepreneurial density, universities need to employ high selectivity and high supportive strategies to their patent and licensing activities. However, no evidence that royalty flows related to support or entrepreneurial environment was found.

2.4.4 Influences on the decision to patent

Economists and scholars give a number of reasons why inventors patent their inventions. Patents are recognised as important to safeguarding intellectual property and allow inventors to internalise the benefits of their investment by excluding benefit to others, securing return on investment, and encouraging future technological innovation (Knight, 1996; Mazzoleni and Nelson, 1998; Knight, 2001; Lydia, 2001; Hellmann, 2005; Blind et al., 2006). Industry prefers patented technology before they license it to prevent competitors (Knight, 1996) from working on the same technology. They need monopoly power before they exploit the technology (Knight, 1996; Mazzoleni and Nelson, 1998; Knight, 2001; Lydia, 2001; Hellmann, 2005; Blind et al., 2006). In addition, patents could prevent the duplication of research, and allows newcomers to build on the knowledge of their predecessors (Lydia, 2001). Academics will patent their inventions if the cost of patenting is lower than the benefits, taking into account their perception of the time and resources cost of interaction with TTO (Owen-Smith and Powell, 2001). If the cost is higher than the expected benefit, they will not patent the invention. The cost is higher when they consider the TTO to be inflexible. Organisations will patent the invention if a licensee in the technology is already identified (Craft et al., 2000).

The influence on the decision whether to patent or not can be split into external and internal factors:

i. External influences

External influences are mainly based on technology factors. Technology factors can be divided into the costs to patent and the cost of developing the technology, which in turn is related to the characteristics of technology, maturity of technologies, commercial potential of technologies and technology monopoly.

- **Costs to file for patent application**

The patenting process involves very high costs and all universities have limited budgets, for filing patents (Siegal et al., 2003b). As noted earlier, patent costs are greater if universities are looking for worldwide protection. These costs cover the preparations for patent applications, which include patent searches, preparation disclosures, legal advice, translation costs, and submission fees. Once the patent is granted, maintenance fees have to be paid, and further spending is incurred to obtain foreign patents based on the original application in the home country (Knight, 1996; 2001). This may involve high costs as the application may require translations and adoption to each country's law that the application is made. The most significant costs are those of patent agents and patent lawyers, and the documents required for the filing of the applications. By comparison, the fees payable to the patent office are small.

- **Cost to develop the technology**

Another cost that may be more important and substantial, and could affect a decision to patent is the cost of bringing the technology concerned to the market place. This requires the researcher or inventor to accurately estimate the stage of the technology with respect to market readiness to accept it. Some technologies are not patentable until they have been developed further and produced some promising results that fulfil a patent application. Researchers in this position will need more money to develop the products further. Industries are generally not willing to sponsor very early research with uncertain markets (Thursby and Thursby, 2000; Thursby et al., 2001; Thursby and Thursby, 2003; Markman et al., 2003; Shane, 2004; Markman et al., 2005a).

- **Characteristics of technologies.**

Bringing new technologies to market may require substantial investments. This is certainly true especially for biotechnology which requires specific test and trials drugs (Henderson et al., 1998; Mowery et al., 2001; Goldfarb and Henrekson, 2003). In this situation, universities have to build strategic partnerships with industries that are interested in seeing the technology patented. The industry should be able to gauge the market potential and the value of the technology. This is because industries have expertise in particular fields and experienced staff and may be able to see to the future of the technologies. In turn, they should be willing to sponsor specific research activities to bring the technology to the marketplace (Shane, 2002; Henderson et. al., 1998). These specific activities result in more patents and will bring more revenues, as they are more market specific.

Research has showed that patenting applications are very active in biotechnology and new drugs and less active in engineering. This is mainly because biotechnology and new drugs will result in new markets which are potentially huge, while new engineering technologies mainly deal with improvements, thus, have to contend with older technologies which may be cheaper in the market place (Thursby et al., 2001; Coupe, 2003; Saragossi, 2003).

Owen-Smith and Powell (2001) reported similar results in their studies between life science and physical science at EPU (Elite Private University) and BSU (Big State University) in US on their patenting activities. The decision to disclose the invention and whether to pursue a patent varies between life science and physical science. Life science inventions have larger and potential new markets and will gain high returns on IP. In contrast, physical science normally will enter established markets where established products already exist and this impedes the university's ability to gain revenue from IP. The effect is to reduce the incentive to patent the technology in physical sciences. Furthermore, according to Owen-Smith and Powell (2001), physical science research typically involves improvements on established process or products. Patents are only used to develop relationships with industry and as exchange to access to equipment or other opportunities. Thus, physical scientists are less concerned about patent royalties or finding the right licensee and so favour non-exclusive patent agreements.

In contrast, inventors in life science involved with technologies such as therapeutic or medical devices, view patents as tangible properties to be protected and sold. Life scientists also expect personal gains from patent royalties, and so are very protective of their patent when they seek rent. Universities, which are involved with life science research hope that one day they will come out with a 'big winner' invention that will give them a substantial return (Blair and Hitchen, 1998). This explains why the empirical evidence shows that most of the patents from universities are in the life sciences (Mowery et al., 2001; Mowery and Ziedonis, 2002; Mowery et al., 2004; Mowery, 2005; Stephan et al., 2006).

In the case of high technology industries, such as computers, semiconductor and aircraft industries, patent protection is not very effective. Companies tend to try to gain market share by increasing sales and giving a good service to stay ahead of competition (Mazzeloni and Nelson, 1998). For example, the majority of computer software inventions from Columbia University (83%) were never patented (Mowery et al., 2001). Industries with little R & D and without proprietary advances in technology also reported that patents were not effective for them (Mazzeloni and Nelson, 1998).

- **Maturity of technologies**

The stages of maturity of the technology will also influence the decision whether or not to patent. Some universities are not interested in filing the inventions when the technology is at very early stage, unless that technology attracts industry interest. Developing such technology further, may involve a huge cost and in the absence of support from industry, the technology may not be filed at international level. Technology that has attracted interest from industry because it gives them competitive advantage will encourage the inventor to patent the invention even though it is still at an embryonic level to protect it from competitors before they license the technology. For universities, these types of technologies will extract generous funding from industries or additional funding from existing sponsors. Universities will normally provide an exclusive license in order to give a monopoly to industry to exploit the patent successfully without fear of infringement from others (Mazzeloni and Nelson, 1998). The invention is easier to patent if it at an earlier stage, the inventor can find a sponsor who can fund the development research. If they are unable to do so, they might prefer to publish the results to gain publication reward from the university.

- **Commercial potential of technologies.**

Colyvas et al. (2002) found in some cases that industries used a technology before they patented it. In special cases, where the invention has high and urgent potential market value, some of industries 'booked' the technologies and developed it before they patented it even though the invention was still at the embryonic level. It is simply because it was profitable to do so. One example is biotechnology research tools for producing commercial protein, which were being used by industry before a patent was ever granted and even without the involvement of the TTO (Technology Transfer office).

However, not many companies are interested in highly advanced technology, on account of the high cost of bringing it to market and the slow initial return. Thus, new highly advanced technology, which is at a very early stage of development rarely gets patented (Mazzeloni and Nelson, 1998). Sometimes these technologies get special protection from the government for strategic reasons, such as aircraft and defence technologies.

Most university technologies are at the embryonic stage (Thursby and Thursby, 2000; Thursby et al., 2001; Thursby and Thursby, 2002; Jensen et al., 2003; Thursby and Thursby, 2004) and its potential value at the time TTOs or when inventors decided to patent (OECD, 2002) is unknown. Other technologies that are not attractive for patenting are those with a short life cycle, which require low initial investment and those that customers regard as of low value, such as plastic products (Paul, 2002).

- **Technology monopoly**

Large organisations patent their inventions in a particular field to gain monopoly power in that particular sector. It will normally aim for a broader scope of patent rather than a specific narrow one in order to block rival patents for related innovations and to prevent others from copying the inventions (Cohen et al., 2000; Shane, 2001; Blind, 2006). Monopoly of technologies gives the patent owner a substantial potential income, thus, recouping their R&D expenses and bringing more funds for further research.

Obtaining a monopoly for certain technologies may be positive for the companies or universities to conduct research in particular technologies. On the other hand, a patent monopoly will exclude others from that particular field with the consequence that it will slow down the development of that technology at the cost of society at large. Products from the monopoly may also be very expensive (Mazzeloni and Nelson, 1998). It also restricts future and alternative developments of inventions based on the same technology foundation. Other inventors who want to get involved within the same field will need cross-licensing or special permission, which could stifle creativity.

ii. **Internal influences**

- **Publish or Patent?**

Traditionally, the standing of an academic depends on the quality and the number of his/her publications, normally in refereed journals. In UK universities inventors prefer to publish rather than to patent (Decter et al., 2007) which might hinder the process of university commercialisation. Patent Legislation in the UK inhibits inventors from seeking patent protection if the invention has already been published. In which case the invention would be considered a prior art. The absence of patents reduces the chance of inventions to be exploited, especially in the biotechnology field. In the UK 90% of academics agreed that they were more focused on publishing to boost their research assessment exercise score rather than applying for patents for their research (Hughes, 2006). It was further reported that 26 % institutions have not, adopted a formal exploitation policy and 28 % have not prepared standard license agreements (Hughes, 2006). Agrawal and Henderson's (2002) study of two departments in MIT supports this view. It was noted that publication is a much more important activity than patenting for academic.

However, recent studies show contradictory findings. For example, Elfenbien (2005) studied inventions disclosures of more than 2000 technologies, invented by faculty members of Harvard University in US between 1974-2003. The results show that a larger number of publications are associated with a higher chance of licensing. Publications show that a strong academic reputation is a good predictor or wether or not a technology can be licensed. A further study by Markewic and DiMinin (2004) in the US using the NBER patent database in 1995 shows similar results. Data on patents and publications for all faculty members (inventors) were examined. The result indicates that publications and patents increase simultaneously, and papers which are published in the year of a patent application, were cited more heavily.

However, these studies have been conducted in the US, which is a different environment from the UK. In US the inventors have one-year grace period to publish their invention before seeking for patent protection. In the UK as mentioned earlier, once the invention is published, it cannot be patented and normally industry refuses to give funding for further development. With Bayh-Dole Act in the US and the devolution of the British Technology Group (BTG) monopoly, more universities have started to take a more active role in protecting their intellectual properties rights. Some academics feel there is a conflict of interest between their traditional function and the commercialisation effort in universities (Blair and Hitchen, 1998; Etzkowitz et al., 2000). In US universities, more than 70% of faculty members favour a policy of rewarding 'research credit' equivalent to rewards on publications (Lee., 1996). In the same survey 72% accepted a more user oriented applied research, and a strong majority of 64% support the university in expediting commercialisation of research by developing the necessary institutional infrastructures. Particularly in countries other than the US, commercialisation activity should be taken into account in the promotion exercise to avoid inventors publishing their findings (Tornatzky et al., 1999; Ndonzuau et al., 2002; Siegal et al., 2004).

- **The perception roles of the TTO by the inventors.**

Many universities in the US and Europe have established technology transfer offices (TTOs) with professional staffing to facilitate and speed-up the process of commercialisation of their technologies (Bower, 1992; Blair and Hitchen, 1998; Mowery et al., 2001; Mowery et al., 2002). Coupe (2003) reported that universities with TTOs have 45 percent more patents than equivalent universities without a TTO.

One of the roles of the TTO is to act as an intermediary between faculties and industries to commercialise research result. The TTO fosters and facilitates faculty to disclose their inventions, help them to patent and to protect their Intellectual Property rights (IPR) (Owen-Smith and Powell, 2001). The TTOs should play a proactive role, have an adequate number of experienced staffs to facilitate the faculty to identify the technologies that have potential commercial value, and guide the faculty in order to get their IP protected. In addition, the TTO works with venture capitalists, business angels and is a mentor for those who have the intention to form a spin -off company.

To fulfil these roles, it is a normal practice for the TTO to patent an invention before getting it to market. The process starts with the disclosure in the form of a patent specification through a Patent Agent to Patent Office. The role of the TTOs here is to give guidance and encouragement to the academic so that the process of disclosing the invention and patenting can be smooth (Mowery et al., 2001). The TTO should build strong relationships with researchers and continue to strengthen networking with the industry (Colyvas et al., 2002). If such relationships are built successfully, then more quality disclosures may get patented due to early identification of potential market and potential licensees (Mowery et al 2001; Owen-Smith and Powell 2001). Without that relationship, the probability of an invention to be licensed may be reduced. Alternatively, the invention might get patented but could not be licensed due to its low quality, as after the introduction of the Bayh-Dole Act in early 1980s (Henderson et al., 1998, Mowery et al., 2001, Mowery and Ziedonis, 2002).

Patent applications also depend on how universities or TTOs create supportive, effective and conducive environments that support faculty perceptions to the benefit of patenting and minimizing conflicts between basic science and commercial activities (Owen-Smith and Powell, 2001; Saragossi, 2003). According to Owen-Smith and Powell (2001), the faculty decision to disclose their invention when they get benefits is greater than the cost of interacting with the TTOs. This includes incentive, and 'hassles and difficulties' time dealing with TTOs. A TTO with a successful track record and has a good track record in patenting and licensing will encourage the faculty to disclose their inventions. The TTO encourages staff to patent when there is a company interested in licensing the technology at the beginning of the project.

- **Strategic reasons**

Universities also use patents for strategic reasons. As noted earlier, universities have changed their role to become more entrepreneurial (Etzkowitz et al., 2000; Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2002; Etzkowitz, 2003) thus, patents are perceived as an asset to the university that can be traded, making it important for universities to patent their intellectual properties to obtain rent. Furthermore, universities are competing against each other to gain funding from industries and government. Empirical evidence shows that increasing funding will see an increase in patent applications and vice versa (Coupe, 2003). Thus, patents are an increasingly important instrument for securing a position in joint efforts to conduct research that could generate knowledge, secure competitive advantages, enhance reputation, negotiate revenue from cross licensing, and performance of an organisation (Cohen et al., 2000; Blind et al., 2006).

- **University prestige**

The higher the number of patents that a university has indicates high R & D performance and gives a signal to the industry to conduct research with the university. Lee (1996) confirms this view. R & D expenditure and the institutional prestige of universities are correlated with the decisions of academics whether to patent their inventions or not. The higher the budget the higher R & D activities and this could lead to increase of inventions and patents (Coupe, 2003). The prestigious universities get more funding from governments as well as from industries (Binks et al., 2005).

According to Owen-Smith and Powell (2001) when high profile research is conducted, more academics will seek to protect their inventions. In reality, higher quality research is more likely to be contacted by industries and may result in the academic staff seeking to circumvent TTOs by engaging in informal consulting work with industry. Inventors are likely to circumvent the TTO when they are not satisfied with TTO offices (Owen-Smith and Powell, 2001; Siegal, et al., 2003; Audretsch, 2006) limiting disclosure to low quality inventions (Jensen and Thursby, 2003).

2.5. COMMERCIALISING STRATEGIES

Poole and Moore, (2002) defined commercialisation as the act or process by which intellectual property generated in public sector research institutes and institutes of higher education is taken to market or exploited within a commercial setting. It involves the outsourcing of R & D, consultancy and training, patent and license agreement and spin-off company formation. The process should generate value added in the economy and generate funds flow back to the university. Kneller (2001b) suggests the commercialisation process of academic inventions will come under one of the following arrangements, which normally involves transfer of IP rights or patent rights:

i. collaborative or sponsored research agreements to develop new information or technologies;

ii. licensing or assignments of pre-existing technologies; and
iii. formation of spin-off companies or start-up companies that are usually financed by venture capitalists

2.5.1 Licensing

Licensing is the traditional and most common method of commercialising a technology from university to industry (Siegal et al, 1999). A license is a contractual agreement between two parties, the holder of the right or licensor (the seller), and the licensee (the buyer), authorising the latter to use their right either exclusively or otherwise. The licensee will make payment to the licensor usually in the form of royalties. The right is thus, conferred temporarily to the licensee to exploit the invention. The right itself remains within the jurisdiction of the original licensor (Foltz and Penn, 1990).

In the context of technology transfer, Reamer et al. (2003) identifies two routes to the licensing or sale of intellectual property:

> *"Traditional licensing or sale-owner of technology transfers certain intellectual property rights to outside business in exchange for certain benefits, usually financial".*
>
> *"Spin-off-technology organisation licenses intellectual property to the in-house developer of the technology, and so enables the developer to found a new business".*

2.5.2 Spin-off definition

The term 'spin-off' is contested and inconsistent, often referring to any new, high technology or knowledge intensive company whose intellectual capital is originates from a university or public research institution. Some institutions refer to such companies as spin-offs, while others use the term campus companies, or university start-ups. Some authors consider the terms as having the same meaning (Blair and Hitchen, 1998; Steffensen et al., 1999) while other authors use the terms differently. Some definitions restrict the term to those firms where the intellectual property of university is formally transferred to the start-up firms (e.g. example Shane (2004), Pirnay et al. (2003) and Lockett et al. (2005). OECD (2001) defined spin-offs would be having one of the following characteristics:

i) Any new firm which includes a public sector or university employee as a founder.

ii) Any new firm which licences technology from a university or public research institute.

iii) Any new a firm in which a university or national laboratory has made an equity investment.

Smilor et al. (1990) defined spin-off companies in two ways:

a) the founder was a faculty member, staff member, or student who left the university to start a company or who started a company while still affiliated with the university,

b) a technology or technology based idea developed within the university.

A recent definition by Nicolaou and Birley (2003) defined an academic spin-off as the formation of a new company that involves the transfer of a core technology from an academic institution into the new company. Founding member(s) may include the inventor academic who may or may not be currently affiliated with the academic institution.

In addition, they also broadened the definition of university spin-off as:

- An orthodox spin-out involving both the academic inventor(s) and the technology spinning out from the institution.
- A hybrid spin-off which involves the technology spinning out and the academic(s) retaining his or her university position, but holding directorship, membership of the scientific advisory board or other part time position within the company.
- A technology spin-off which involves the technology spinning out but the academic maintaining no connection with the newly established firm. However, the possibility of the academic having equity in the company and/or offering advice on a consultancy basis is not discounted.

OECD countries (2003) adopted a broader definition: i) a new firm with whose start-up includes a substantial contribution of knowledge recently developed in a PRO (Public Research Organisation) and ii) this knowledge is protected by IPRs that are either licensed or transferred to the firm. This definition does not require the direct involvement in the spin-off firm or staff or former staff of PRO.

In this thesis the definition of a spin-off is adopted based on the broadened definition introduced by OECD (2003), which is;

> *"a new firm with whose start-up includes a substantial contribution of knowledge recently developed in a university and this knowledge is protected by IPRs that are either licensed or transferred to the firm. This definition does not require the direct involvement in the spin-off firm or staff or former staff of a university"*

- **The importance of spin-off**

As mentioned in Chapter 1, university spin-offs are important in producing cutting edge technologies from software to medical devices, communication equipments to biotechnology. Companies like Cirrus Logic, Genentech, Lycos, in the US (Shane, 2004), Connaught Laborotories, MacDonald Dettwiler, Develcon and SED Systems in Canada (Doutriaux and Barker, 1995) and TurboGenset from Imperial College in the UK are examples of successful spin-offs (Charles and Conway, 2001). Chiesa and Piccaluga (1998) pointed out that one important contribution of spin-off entrepreneurs is to take technologies/prototypes that are often shelved in research institution and apply them to industrial related issues. Stankiewicz (1994) contends that spin-offs should be viewed from a systematic standpoint as elements of a 'knowledge industry' and pointed out that spin-offs are a heterogeneous group of firms. He points out that what is usually spun-off from universities are not technologies as products but R & D and problem solving capabilities. He describes two modes of spin-off activity, where the application of this type of competency is a patent: consultancy and R & D contracting mode: technological assets-oriented mode, in which firms are exclusively 'concerned with the development of technologies which are subsequently commercialised, through spinning out of new firms, licensing, joint ventures or other types of alliances (Stankiewicz, 1994:102).

According to Shane (2004), university spin-offs are important in five ways: 1) they encourages economic development by producing innovative products that satisfy customer need; 2) generate significant economic value; 3) create jobs; 4) induce investment in university technologies; 5) and promote local economic development. In developed areas such as Boston, spin-off companies and other related activities contributed $7.4 billion to the regional economy and provide for about 50,000 university employees and 37,000 workers in related areas who emanated from 8 universities (Boston Report, 2003; Simha, 2005). In less successful areas such as Newcastle in North-East of England, and Twente in Netherlands (Benneworth and Charles, 2005), spin-offs also play a significant role to develop their local economic. In the Newcastle area, around 5,000 people are employed by university spin-off companies created in the past 20 years. The companies originated from the university in that area are conducting research with the university through joint and contract research projects. The University of Twente helped to rebuild the Twente economy after the decline in its textile industries. Spin-offs from the university have created 3000 jobs in the past 20 years (Boston Report, 2003).

2.5.3 A brief process of decision making on selection routes

The process of commercialisation begins with a faculty member reporting a discovery to the TTO office which she or he believes has commercial potential. The TTOs use information provided by the inventors to discuss the possibility for a patent and the exploitation of the inventions. Normally it ends with the decision to reject the proposal or proceed with a number of option: licensing to establish company, spin - off company, joint venture and an assignment (McAdam et al., 2004). The decision is often linked with funding availability. If licensing to an established company is decided, the license agreement will be signed with the TTO after a series of negotiations. Prior to negotiations, the informal contact would be initiated by inventors or through the TTO by formal contact. Most of the technologies are transferred to established companies through these mechanisms (Harmon et al., 1997).

If a spin-off company is chosen as the exploitation route, the TTOs along with the inventors will normally reconfigure the opportunities from their research to identify various applications of the inventions to finalise new ventures and the ideas. As Vohora et al., (2003) pointed out, the process of the development of spin-off companies go through five stages: 1) the research phase; 2) the opportunity framing phase; 3) pre-organisation phase; 4) the reorientation phase and 5) the sustainability phase. In order to develop, at each stage the spin-off company is faced with several critical junctures which relate to resources, capabilities and network ties. Four critical junctures are 1) opportunity recognition; 2) entrepreneurial commitment by a venture champion; 3) attaining credibility in the business environment; and 4) achieving sustainable returns within their perspectives markets. A firm is considered to be sustainable if it is not able to move to another stage within a certain period of time.

According to McAdam et al. (2004), the spin-off process or business building process, can be divided into two phases; pre business plan and post business plan. At pre-business plan stage, there is a need for concurrent technology development and prototype and business development. This requires mentoring, marketing, business management, team management and financial management associated with the technology aspects and business plan. In-depth business and management help is required for the post business plan period.

The important resources in forming a spin-off company are financing and the entrepreneur (Roberts and Malone, 1996). To overcome financial problems, Harmon et al. (1997) suggest that, the technology which was invented in the university lab can be sold to: 1) a venture capital company; 2) a private firm that initially developed the technology, but the firm seeks out the university to assist in the areas where it has needed expertise or; 3) a new company that is created to exploit the technology if funding is available.

Roberts and Malone (1996) and Shane (2002) identify four principal parties involved in the spin out process: the technology originator, the entrepreneur, the R & D organisation and the venture investor. The interaction between these parties varies and five different models for the above actors were proposed. The first model assumes independence between the four principal groups while the second describes the situation involving an entrepreneurial technologist. The technology originator has the role in providing the technology and the TTO role is to seek for licensees to find entrepreneur from within or mostly outsiders, which is regarded as technology push. The second model was the technology originator as an entrepreneur or a group of entrepreneurs. This model is claimed as the most successful model implemented by MIT and Stanford University and increases the business pull. The third model involves both an entrepreneurial inventor and an internal venture capital fund. The fourth scenario involves an internal venture capital fund but distinguishes between the inventor and the entrepreneur, while the fifth model assumes the provision of venture capital by the entrepreneur.

At the same time when the company is launched, seed money for product development is sought through the above models to transform the project to prototype stage or a genuine entrepreneurial project. The university or venture capitalist will decide who should lead the company: either the inventor if she/he committed full time in the company, a CEO appointed by venture capital firm or surrogate entrepreneurs appointed by the university.

The final stage sustainability involves the consolidation and strengthening of the economic value created by these firms (Vohora et al., 2003). The detailed process from the practical TTO point of view will be explained in Chapter 4.

2.5.4 Licensing vs spin-off

Empirical evidence shows that university spin-offs (USOs) play a crucial role in the development of their local economies. The firms are providing job opportunities and stimulating local economic development. However, some commentators suggest that their economic impact is exaggerated (e.g. Malecki, 1997, Lambert, 2003). Some academics prefer university to focus on consulting and traditional technology transfer activities (such as licensing and contract research) rather than forming spin-offs, which are risky and divert them from their traditional roles in the university. Some have argued that spin-offs and licensing activities have been skewed in favour of elite universities and particular regions but in general their job creation is not proven (Harmon et al., 1997).

However, there is considerable evidence that spin-off businesses benefit their local regions. The evidences are:

i) Creation of jobs for high tech workers, paying good wages, leading to job and wealth creation and promoting entrepreneurship (Olofsson and Wahlbin, 1993; Rogers et al., 2001; Etkowitz, 2001).
ii) Building technological and client knowledge in building new networks to access finance, sales, and marketing (Dahlstrand, 1999).

iii) Retain close relationship with the parent organisation, through equity holdings, incubators, technological transfers, recruitment and research collaborations (Dahlstrand, 1999; Bray and Lee, 2000; Shane, 2004).

iv) USO(s) are becoming sources of entrepreneurs whose technological entrepreneurship can transform the wider regional economy (Etkowitz, 2001).

v) Becoming sources of technological spillovers, which can promote and shape the emergence of regional technology cluster (Di Gregorio and Shane, 2003).

vi) Stimulate business support services and infrastructure, benefiting other start-ups (Lockett et al., 2003).

Empirical evidence suggests that the advantages of spin-off outweigh the disadvantages (Table 2.2). The advantage of licensing a patent to a spin-off company is that a university can control its technology development and its applications compared to licensing to outside firms. Exploitation of technology through spin-off companies will benefit the university and their students in the form of new and advanced knowledge. If the technology was to be licensed to other company, the development and its secret will not pass down easily to outsiders even though the technology was originally from university. Latest technology could be accessed easily (Science Council of Canada 1985, Blair and Hitchen, 1998) by students who may be do research for the companies. Students are likely to be more predisposed towards R& D and technological innovations as well as more exposed to university intellectual properties, in the form of patent and technology know-how (Blair, 1998). The university can control a licensee through equity, incubator facilities, and continuous research collaborations.

The disadvantage of spin-offs is that the company needs the full time commitment of the inventors to ensure company performs well and succeeds. Inventors have no need to play this role if patents are licensed to established companies. Spin-offs are risky because they are involved with the embryonic stage of technology (Thursby et al., 2001) and need a high commitment from academic staff. The commitment and involvement of the inventors are required in the process of spin-off formation and product development. Universities that do not allow their academic staff to be involved on a full time basis in their firms, suggest that surrogate entrepreneurs are used (Lockett et al., 2003). Firms could be managed by a surrogate entrepreneur (Radosevich, 1995; Franklin and Wright, 2000; Lockett et al., 2003b), or the inventor could be in the board of directors of either the 'technology spin-off' or the 'hybrid spin-off' and maintain their academic post as suggested by the Nicolaou and Birley (2003) model. This overcomes the brain drain of academics to industry.

Table 2.2: Pros and Cons of licensing to spin-off and to established company

Licensing to new Spin-off		Licensing to established company	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
University can control the technology that licensed.	Lack of technical skills and knowledge to narrow down the market.	Further development of the technology that initially invented from the university not benefited to university	University cannot control the technology
Continuous relationship with parent organisation	Need high commitments and need special skills of the inventors and TTOs	No special business skills require	The licensing companies may not be local, thus, any commercialisation would not benefit local economy
In certain circumstances, inventors may remain in the university and the spin-off company would employ surrogate entrepreneurs.	More commitment from the inventors. Inventors may leave universities. Department will loose good staffs when the inventors work full time in the company	Reduce staff time. Academics staff can focus to traditional roles: teaching and doing research. Academic staff remain in the university Return in the form of royalties	The inventors would not be explosed to entrepreneurial activities and experinces
Opportunity to local development. Job creations and multiplier effects	Needs more funding.	Funding provided by the firms	Industry focus more to applied research. Contradict with traditional roles to disseminate free knowledge.
Taking equity in spin-off give higher return compared to licensing to establish company	The company has its own plan of exit. Business cannot be inherited by next generation	Royalties.	Only get upfront money, if the technology fail.
Exploit technology that industry is unwilling to license. Technology might become a breakthrough in the future	High investment is needed.	Exploit technology that is in line with their business only	Refuse to license if the technology is too radical.

Another disadvantage of forming new spin-offs is that they require sufficient funding, technical and other resources such management and business skills

(Ndonzuau, 2002). Vohora et al. (2004) noted that two fundamental problems of spin-off are: i) spin-off is stemmed from non-commercial environment face of lack of resources to create viable venture; ii) possibility of conflicts with other stake holders, such as conflict with the objective of the university, venture management team, investors, and academic entrepreneurs.

However, the advantage of spin-off companies helps universities to exploit technology when licensees are difficult to find (Thorburn, 2000). University technologies are normally radical (Shane, 2001, 2004), 'ahead of the market' and difficult to convince industries to adopt. Spin-offs are the only solution to exploit this kind of technologies. Furthermore, a spin-off gets direct support from the parent organisations especially in the early years of formation (Perez and Sanchez, 2002). A strong support from the university will enable easier and convenient access to the latest technology and direct consultancy service from the university (Blair and Hitchen, 1998). Some universities give support to its spin-off activities, by giving a more tangible help such as lab instruments and staffs assistant (Steffensen et al., 1999). As a result of support from the parent organisation spin-offs may have low rate of bankruptcies even though in some cases they have slow growth (Steffensen et al., 1999).

Expected returns are greater in spin-off companies when a university takes equity in lieu of upfront fees. Compared to return from traditional licenses, a university will get a higher return when the company makes an initial public offering (IPO). Substantial returns of up to 10 times could be obtained from selling equity of start-up at Initial Public Offering (IPO) after a relatively short incubation period, compared to licensing for the same period. Bray, and Lee, (2000) argued that taking equity gives freedom to licensing managers do more flexible deals. The university could hold the value of the invention if in case the start-up or spin-off companies changed the application of the technology, or change to new patent. Taking equity even with a minimum of only 5% up to 15% will change relationships with companies.

Finally, inventors become a role model or a champion to other academic staffs and students to become involved in new venture (Roberts, 1991; Blair and Hitchen, 1998). However, past evidences shows the disadvantage of patents or technologies that were licensed out to overseas company is there will be no real local economic advantages. Although the university and the inventor get revenues and royalties from the licensed company, technology and production may occur in another region or country (Blair and Hitchen, 1998). Thus, the innovation does not create jobs or stimulate prosperity in the local community.

Most of the licenses are based on arm's length licensing, which involve codified knowledge rather than tacit knowledge (Shane, 2004). Thus, a high commitment of the inventors in the process is not required (Thursby and Thursby, 2004). Spin-off creation requires inventors to have entrepreneurial skills, a strong management team, and business experience to convince private investors to get the funding and succeed in the venture. These criteria do not play a central role in licensing to an established company. All the funding for the project development and identification of market are provided and undertaken by the industry. When the project is licensed to an establish company, the negotiations normally involve royalty payments and product development, whereas in spin-off creation it requires all aspects of business start-up and business relations. Thus, the advantage of licensing to an established firm is that academic staff can focus on their academic roles, stay with the university, and wait for royalty payments.

2.5.5 Outcomes of commercialisation

As mentioned earlier (Table 2.1), patenting activities in UK universities and US universities have increased in number over time. For example in UK universities, the number of granted patents was 438 in 2003 and increased to 441 in 2004. The total numbers of patents filing in the US were 13,280 in 2003 and increased to 13, 803 in 2004. However there is imbalance between the number of granted patents, the number of licenses executed, and the number that earned significant income to universities which is still small. Government expectations about what universities can earn from their third stream are not being met. Though the US universities are far ahead of their UK counterpart activities, the relative numbers of patents that are exploited compared to the granted patent from both countries are still small in number particularly in the UK universities. An NHS report cited in Lambert (2003) estimates that the average revenues from technology transfers at leading US and UK universities are 2.5 per cent of their research income. MIT's revenues are only 3 % of its research income. As mentioned in Chapter 1, an OECD survey (2002) reported that only 20% to 40% of patents are licensed, and only half of these earned incomes.

A recent AUTM survey (2004) reported that only 22.4% of the total 27, 322 active licenses earned income. Universities rely only on few licenses that bring substantial income to universities (Jensen and Thursby, 2001; Grafft and Heirman, 2002, OECD 2002, Binks, et al., 2005, Wright et al., 2006). For example in the US universities, gross licensing income increased more then five folds, from under $200 million in 1991, to over $1.2 billion in 2000 and further increased to USD1.385billion in 2004 (Grafft and Heirman, 2002; Pressman, 2004). Recent data in the UK universities, the total number of License, Options and Agreements (LOAs) and income, increased in 2004. In 2004, 66% of respondents had existing LOAs that yielded incomes and 34% of them did not receive any income (UNICO, 2004). This is because most universities are ineffective in their patenting and commercialisation management (Thursby and Thursby, 2002; Thursby and Kemp, 2002; Siegal et al., 2003; Chappel et al., 2005; Lockett et al., 2005). OECD (2002) suggests TTOs just randomly filed and licensed their patents. Other views are that the TTOs' decision to commercialise is based of self interests rather that public interests (Sampat, 2006).This view is specifically based on the objectives of many TTOs to license for cash, R & D capital, sponsorship of research or equity payments (Thursby et al., 2001, Markman et al., 2005).

Thus, the above discussion leads this thesis to develop the main research question of this study:

> ***"What explains why some of the university patents are exploited and others are not?"***

2.6. PREVIOUS RESEARCH

The literature review in this section attempts to study the reasons why some university patents are not exploited and for those that are exploited, why the universities decided to commercialise them either through licensing to established companies or to spin-off companies.

2.6.1 Reasons for non-commercialisation

The reasons why most university inventions have not demonstrated any commercial value have not been studied intensively in the literature review. Few studies are found which focus on why university technologies are not exploited (Thursby et al., 2001; Hsu and Bernstein 1997; Shane, 2001a; 2001b; 2004). A few studies also have been found indicating why industrial companies are unwilling to exploit university technologies and the reasons why university technologies are not exploited (Henderson et al., 1998; Mowery, 2002; Thursby and Thursby, 2003 Low and McMillan, 2004). The reasons are discussed below.

i. Characteristics of university technologies: no economic value

The main reasons which universities technologies from being exploited is that they did not show any commercial value, and were so embryonic that they demonstrated insufficient proof of concept (Trajtenberg et al., 1997;Hsu and Bernstein, 1997; Henderson et al., 1998; Hall et al., 2001, Thursby et al., 2001, Thursby and Thursby, 2002, Siegal et al., 2003). A study by Hsu and Bernstein (1997) used 14 cases from Harvard and MIT universities to examine what factors lead to the licensing of university technologies. It was found that five cases failed to be marketed or licensed because a technology was proved not to have commercial merit and three had insufficient proof of concept which caused them to fail to be licensed. In addition, the majority of inventions that were licensed to established companies failed due to inappropriate incentives to TTOs who were not able to deal with unfamiliar products and technologies. Lack of incentive does not inspire TTOs to try to understand the technologies further. This also leads the product from the advanced technologies to have a high failure rate and be shelved. From the industry side the study reported that the companies did not have complete information about the technology, suffered from the 'not invented here' syndrome and university technologies at embryonic stage caused them fail to take up the licence. From the same study, the interview results from TTOs, managers, licensees, inventors and people who declined to license the technology for spin-offs suggested that the main factor leading to success in this venture in order of importance are; entrepreneur effort, the value of size, the stage of the technologies and financing issues.

University technologies, which are not relevant to the line of business of a company, are in itself the reason why industrial companies refuse to license university patents (Thursby and Thursby, 2003; Shane, 2004). However, they use university knowledge through substantial sponsored research. This is because sponsored research only involves short-term contract work. A company can also collaborate with a university through consultancy work, using the university's lab facilities and the placement of students after they graduate (Thursby and Thursby, 2003).

Henderson et al. (1998), from their survey reported the importance or commercial potential of patents has declined as a result of the increase in patenting activities and the changing relationship between the universities and the private sector. The study gave evidence that half of the university inventions did not have commercial value. The study compared university assigned patents to 1% random sample of all US utility patents. It was reported that the importance and generality of university patents had declined though the number was increasing every year. The university patents were less cited compared to the mid 1980s. Henderson et al (1998) concluded that the importance, and hence the value of university patents decreased due to a very rapid increase in the number of low quality patents being granted to universities. However, a study done by Mowery and Ziedonis's (2002a) showed a finding contradicting with Henderson et al. (1998). It was reported that there was no decline in the importance and generality for two universities: University of California and Stanford University in patenting activities after 1980 and no change in the orientation of university research. However, the analysis of overall US universities is consistent with Henderson et al. (1998) suggests that patents issued after Bayh-Dole have reduced their generality and importance. Mowery and Ziedonis's (2002a) study should be read with caution because the survey used a smaller sample than Henderson et al. (1998). The latter used all citations to universities, but Mowery only used citations that had occurred within five years of the issue date. Many inexperienced universities adopted a random policy towards patenting after the implementation of Bayh-Dole Act (1980), which led to a reduction in the importance of university patenting in general (Mowery et al., 2002).

However, Owen-Smith and Powell (2003) reported that universities have learnt to patent quality inventions after studying patent citations in the life sciences field. Quality disclosures, strong networks, and the experience of TTOs in evaluating technologies give stable impact of patent citation in the life sciences.

ii. Barriers to licensing

Some of the university technologies have the opportunity to be licensed if funding is available for further development of the projects. The technologies are often presented at an early stage or at the proof of concept stage, with an uncertain market and needing more funding for development up to a commercially viable stage. However, government funding is limited and industrial companies refuse to fund technologies that have uncertain value, which is a barrier to university technology being accepted by industry. Furthermore, industry usually employs university technologies, which only involve product development but not core technologies. This is because industry has its internal R & D departments, which already focus on their core technologies (Thursby and Thursby, 2004). Details of these and other reasons inhibiting the exploitation of university patents will be discussed in Chapter 5. Research propositions also will be developed in Chapter 5.

2.6.2 Reasons for the choice of the commercialisation route

i. Motivation of the academic entrepreneur/the champion factor

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. An inventor in 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 their idea to existing companies. Who the academic entrepreneurs are and what their characteristics are in exploiting opportunities through the creation of a company or a licence to an established company will be discussed.

An academic entrepreneur, according to Samson and Gurdon (1990) cited in Franklin et al. (2000) is defined as;

> *"... an academic whose primary occupation prior to playing a role in a venture start-up, and possibly concurrent with that*

process, was that of a lecturer or researcher affiliated with a Higher Education Institute...".

Previous research suggests that university spin-off companies or new venture creations are founded by an inventor or entrepreneur who has certain psychological and motivational characteristics such as a disposition to act, is willing to take risks, energetic, willing to give full commitment to the venture and extrovert characteristics 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). Non-psychological factors such as level of education, family background, and previous work experience also play a crucial part in shaping inventors to be entrepreneurs.

The recent theory of entrepreneurship (Shane, 2000, 2003, 2004; Shane and Ventakaraman 2000) suggests that entrepreneurs are different from others because they not only have distinctive characteristics but they also have 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 productions and transform them 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 (Khistrom and Laffont's 1979 cited in Shane, 2000). These factors are discussed below:

- **Psychological factors**

Individuals who exploit opportunity have different motivation factors, which other people do not have. Shane (2004) pointed out that understanding the characteristics of the inventors who own the technologies is important to explain why one is inclined to spin-offs. The desire to bring technology into practice, a desire for wealth creation, and the desire for independence are the main motivation for entrepreneurs or academic inventors to create a spin-off company (Shapero, 1984; Smilor et al., 1990; Blair and Hitchen, 1998; Oakey, 2003; Shane, 2003; Shane, 2004).

Doutriaux and Dew's (1992) study of 26 entrepreneurs at 10 universities in Canada, also found that personal motivation and the reason to form a spin-off company have a direct effect on firm creation and the growth of companies. The analysis of personal characteristics gives three types of academic entrepreneur based on their reasons for forming a company: reluctant entrepreneurs, casual entrepreneurs and genuine entrepreneurs. Genuine entrepreneurs are eager to proceed with their potential technologies that may relate to a desire to see the inventions exploited as mentioned by Smilor (1990), Blair and Hitchen (1998), and Shane (2004). Reluctant entrepreneurs showed slower initial growth due to lack of industrial experience. Casual entrepreneurs showed continued low growth due to not being motivated by business measures of success.

- **Non-psychological factors**

Non-psychological factors include education, age, career experience, social position, social ties and vicarious learnings (learning the skills by observing others), which affect the decision to exploit an opportunity (Shane, 2003). All these factors make an individual different which affects their willingness to bear the risk to exploit opportunity (Venkataraman, 1997; Shane and Venkataraman, 2000). Shane (2004) further suggests that career-related factors such as career cycles, academic status, intellectual capital and entrepreneurial experience influence the creation of a university spin-off.

Empirical evidence shows that most of the high tech entrepreneurs had PhD qualifications (Roberts, 1991a; Blair and Hitchen, 1998). Research outcomes from PhD projects are transformed into product through forming a spin-off company (Roberts, 1991a; Blair and Hitchen, 1998). Most of these inventors-entrepreneurs are star scientists who have high human capital assets. Many biotechnology firms in the US are formed by star scientists (Zucker et al., 1998). The average age of the entrepreneur also influences the creation of spin-offs. The ideal age of the individuals or academics to start their own companies is between 28 and 39 years old (Roberts, 1991a; Lowe and Taylor, 1996; Blair and Hitchen, 1998; Colombo and Delmastro, 2003). Most of them have not yet achieved any promotion to professorial posts and are very energetic. Some of them have just started a family and have financial difficulties. The technologies that they have invented influence them to start the company as a solution to their financial problems.

Career experience is another factor influencing an individual to exploit an opportunity. Through career experience, people acquire information and develop the skills necessary to form a company (Jones-Evans, 1995; Blair and Hitchen, 1998; Klofsten and Jones-Evans, 2000; Shane and Khurana, 2003; Shane, 2004). Career experiences according by Shane (2003) comprise of general business experience, functional experience, industrial experience and start-up experience. These experiences reduce the uncertainty and increase the entrepreneur's anticipated profit (Shane and Khurana, 2001). Successful high-tech firms found that the entrepreneurs had acquired both technical and business acumen, industry related experience, managerial experience and tacit knowledge (Oakey et al., 1988; Gimmon, 2005). However, many academic entrepreneurs, who came from a non-commercial university background, have no commercial experience or industrial environment (Jones-Evans, 1995; Blair and Hitchen 1998; Klofsen and Evans; 2000).

Roberts and Peters (1981), Shapero (1984) and Roberts (1991a) discovered that family background could also influence individuals to become entrepreneurs. According to Roberts (1991a), the largest percentage of technical entrepreneurs came from those whose father was either a professional or a manager. Children from professional families would be more likely to become entrepreneurs compared to managers. This is because a professional is more independent in his work environment than a manager. A family of smaller size or a first-born son is more independent and tends to develop self-confidence. Roberts and Peters (1981) differentiated between ideas havers or inventors and idea exploiters. Besides the above criteria, idea exploiters would have been much more active in publication and patenting. Ideas havers people were more likely to work in varied environments and spend some time in consultation.

- **Experiences of the inventors that lead them to recognise opportunities**

There is very little material on how and who recognise opportunities to commercialise university technologies. Opportunity recognition is an important stage in evaluating the technological validity and performance of the venture in order to identify market applications and customer needs (Vohora et al., 2003; Wright et al., 2004; Shane and Venkataraman, 2000). Internal and external sources may help the university to recognise opportunities in the creation of university spin-offs (Lockett et al., 2003a). The sources are: academic inventors, the university commercial company (TTOs), potential surrogate entrepreneurs or some external private sector organisation (Franklin et al., 2001; Lockett et al., 2003a; Wright et al., 2004). However they always lack the technical skill and have their own agendas (Franklin et al., 2001). Normally academics and TTOs jointly recognise the opportunities, and define and target their exploitation. A university joint venture partnership with a corporation will also help inventors recognise opportunities. A company that has sponsored research or contract research with universities usually recognises opportunity, but normally intends to license the technology (Thursby et al., 2001;Colyvas et al., 2002; Thursby and Thursby, 2004).

As mentioned earlier, industrial experience enables academic inventors to recognise opportunity (Shane, 2000). Normally, opportunities are recognised by suitable 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 opportunity. In some cases opportunities are imprecisely or ambiguously targeted which in turn makes the technology impracticable (Vohora et al., 2003). The TTO and academics lack understanding of how best to maximise returns and create commercial value from the technologies that they patent (Vohora et al., 2003). As mentioned before, prior industrial experience is important to validate technology and enable entrepreneurs to recognise opportunities that other people do not (Shane and Venkataraman, 2000; Shane, 2000a; Shane, 2000b; Shane, 2004). Entrepreneurs are more likely to recognise and exploit opportunities when they identify more customer demand for the new product, more fully developed necessary technologies, greater managerial capability and greater stakeholder support (Choi and Shepherd, 2003).

Shane's (2000) study of eight entrepreneurs who had exploited technology from MIT confirms the importance of career experience which helped them to recognise opportunities. He argues that the ability of an entrepreneur to recognise the market value of a particular technological innovation is based on their ability to recognise the value of the invention in the market, which is based on previous experience they have had in solving customer problems in related market situations. The work of Shane (2000) and others has been synthesised by Park (2005). He suggests that opportunity recognition is a very complex, interactive process involving three main components; the founding entrepreneur, the knowledge and experience of the firm and the technology (Hsu and Bernstein, 1997; Shane and Stuart, 2002; Lockett et al., 2003a). Wright et al., (2004) suggest that corporate bodies could also help universities to recognise opportunity, but how to access them was not suggested by the authors.

These discussions show that previous industrial experience gives inventors the ability to recognise opportunities. The combination with the motivation factors (psychological and non-psychological factors) allows the inventors who have 'entrepreneurial characteristics' to influence them to exploit those opportunities either through spin-off creations or licensing to established companies. Those inventors who license their patents to established companies may not fulfil all the characteristics (psychological, non-psychological factors and ability to recognise opportunity) above and may prefer to be an employee as suggested by Khilstrom and Laffont (1979).

ii. Spin-off creation or licensing to established companies: the role of funding

The availability of fund to commercialise a newly patented technology is the main factor for the choice of the route for exploitation of that technology. The technology may require high investment in tooling or marketing thus excluding the university becoming the main palyer in the commercialisation efforts. However, an established company might be willing to invest in that technology thus licensing the patent from the university. The money for product development is normally borne by the licensee, and the university would receive monies lump sum up front fee, sponsorship for further research in the technology, and royalties if the technology is successfully commercialised.

As the available funding from a university is critical in the decision to form new spin-off compnies for commercialisation of iuniersity patents, the discussions in following sections are more focused on spin-off funding.

- **External funding**

For spin-off ventures, there is a need for sufficient financial resources from the beginning to fund R & D, then to launch the product and to cover operating costs and upgrading the product development (Willard and Cooper, 1985; Smith and Cooper, 1988; Lockett et al., 2002; Shane, 2004; Binks et al., 2005; Wright et al., 2006). The availability of finance is a key constraint to high tech firms or spin-offs to growth (Lockett et al., 2002; Osman, 2002; Binks et al., 2005; Wright et al., 2006).

Funding for spin-off companies may come from external resources such as venture capitalists, business angels, or government seed money. Shane (2002) listed several mechanisms providing entrepreneurial companies with capital to finance technology licensed by a university. First, some universities bring venture capitalists to university campuses or have venture capital funds. Second, some universities also use their TTOs as brokers to the venture capital community. Shane and Cable (2002) pointed out that MIT spin-off companies used its TTO to help them to gain access to venture capitalists and business angels. Third, some universities such as MIT invested its university endowments in their spin-off companies. Fourth, they have established programmes to fund further development of university inventions (Tornatzky, 1995).

New spin-off companies have difficulty in getting funding from external sources such as ventures capitalists or business angels at the seed, start-up and early growth stages (Mason and Harrison, 1998; Lockett et al., 2002; Vohora et al., 2004; Shane, 2004; Binks et al., 2005; Wright et al., 2006). Thus, there is a gap of funding between early stage, and late stage technology. Venture capitalists and industrial companies refuse to fund 'blue sky research' with an embryonic, uncertain market due to information asymmetry problem between inventors and investors (Shane and Di Gregorio, 2003; Shane, 2004; Strandburg, 2005). The technologies are uncertain if there is a doubt that they can be converted into saleable products or services (Shane, 2004). Furthermore, the high research and development costs in early years, and long lead time in bringing new high technology into the market make early stage technology based firms are very high risk (Thursby et al., 2001; Osman, 2002; Shane, 2004; Binks et al., 2005).

The study by Binks et al. (2005) gave several reason in declining order of importance for the fact that university spin-off companies are more risky than investing in other high tech companies; spin-offs require building a management team, require a longer investment time horizon, need close monitoring, require several rounds of funding, have higher variability of return, involve protracted pre-deal negotiations and focus on small elite universities. Five most important factors why investors reject university spin-off investment proposals are: the absence of a clear route to market for applications of the technology, overall quality of the proposals, size of the potential market, stage of development of the product and the number of rounds of follow on the investment required. The research also suggests that universities should concentrate more on quality new ventures. Venture capitalist firms prefer universities or TTOs to achieve proof of concept before submitting the proposal to them. A similar study of the supply side reported by Kakati (2003) was based on the views of 27 venture capitalists who have experienced both failure and success in high tech ventures. The quality of the entrepreneurs is the main reason investors invest in high tech ventures and this is followed by resource- based capability (managerial, technical, marketing and input sourcing) competitive strategy, product characteristics, market characteristics and financial criteria. The different between successful and non-successful ventures is that successful ventures develop multiple resource-based capabilities to back up multiple strategies and take into consideration the future risks and are not based solely on the development of new technology. Furthermore, financing spin-off companies in the UK universities by venture capitalist and private equity firms is considered as a niche activity compared with management buy-outs and buying in (Mason and Harrison, 2002; Binks et al., 2005; Wright et al., 2006). Venture capitalists in Europe are reluctant to invest in early stage high tech investment or university spin-offs (Lockett et al, 2002; Binks et al., 2005; Wright et al., 2006) compared with the US. They become late stage investors in funding university spin-off ventures (Di Gregorio and Shane, 2003; Binks et al., 2005; Wright et al., 2006) and the availability of venture capital shows little evidence of the influence of start-up activity in the UK particularly. Difficulties in valuing university technology prevent many venture capital firms from investing in the early stages in spin-off companies (Lambert, 2003; Binks et al., 2005; Wright et al., 2006; Nilsson et al., 2006). Most of the studies on funding looked at the supply side and focused on venture capitalists and what are the criteria used by them to evaluate the venture to obtain funding. On the demand side, TTOs considered that venture capital contributions for seed stage investment are important to develop technologies to proof the concept stage technologies (Wright et al., 2006). Venture capitalists are an important source of funding to help spin-offs at their early stage, however the problems mentioned earlier discourage venture capitalist from investing in spin-offs. To encourage investors TTOs should increase the capability and resources for evaluating the technology or new venture. In addition, entrepreneurs' quality and ability to bear risks and have multiple strategies are also important in getting funding from venture capitalists who, do not solely depend on technology developments (Wright et al., 2006).

Uncertainty and information asymmetry are other problems restricting the ability of the founder to obtain funding from private investors (Wright et al., 2004; Mason and Stark, 2004; Mustar et al., 2006). Information asymmetry creates problems in financing spin-offs. First, the inventors want to keep the secret of the invention as a competitive advantage and not all the information is disclosed to potential investors. Second, the inventors use that information to attract other resources from other investors. Third, information asymmetry creates the potential for adverse selection because it makes it difficult to distinguish talented entrepreneurs pursuing valuable opportunities from the reverse (Shane, 2004). To overcome asymmetric information and reduce adverse selection, due diligence is undertaken by venture capital companies (Mason and Stark, 2004; Binks, 2005; Wright et al., 2006). However, Binks et al. (2005) and Wright et al. (2006) reported that lack of technological knowledge in venture capital firms make due diligence difficult. Investment executives in venture capital firms have a lack of technological knowledge where only 14% were reported to have graduate qualifications in technology or managerial experience in technological areas.

Empirical evidence also reports that venture capital firms tend to make their investments locally so that they can monitor, interact and inspect their investments closely. Venture capitalists tend to develop networks within their local area so they can tie in the new ventures with customers, suppliers and other stake- holders. They can also give assistance when start-ups are close at hand. Sorenson and Stuart (2001) found that the probability of venture capitalists investing in start-up decreases with the geographical distances between the headquarters of the venture capital firms and the start-up firms. It was found that the rate of investment in companies 10 miles from a venture capitalist's headquarters is double compared with companies located 100 miles away. This is consistent with the findings of Lerner, (1995) and Mansfield and Lee (1996) that the chance of the venture capitalist backing a start-up company was doubled when the distance between their headquarters were within 5 miles compared to distances of up to 500 miles away. Mason and Harrison (2002) conclude that 'classic' venture capitals which has the potential to invest in high tech growth companies is still concentrated in London, South East England and Scotland. However, other studies show that the amount of formal venture capital available in particular location has no significant effect on university start-up activity (Zucker et al., 1998; Di Gregorio and Shane 2003; Lockett. et al., 2003).

Business angels are another alternative that is often overlooked by universities or inventors to fund spin-offs. Business angels also have problems in evaluating university technology. Mason and Harrison (1998) noted that business angels undertake their own independent evaluation which is more based on their business experience and knowledge of particular industries and markets than on formal due diligence. The management team, the growth potential and the uniqueness of the product or market are the main factors the angels take into account when evaluating an investment opportunity. An independent technology appraisal service as part of the due diligence system has been suggested to overcome problems of evaluation of early stage technology for angels prior to their investment decision (Mason and Harrison, 1998). Banks play a limited role in spin-offs in the UK and the US (Roberts, 1991a; European Commission, 2002). Banks are also reluctant to finance high technology based firms because they are not expert in evaluating radical technologies (Mason and Harrison, 1998).

- **Government funding**

Since external funding is difficult to obtain, the development of projects to proof of concept and prototype level for spin-off companies is normally achieved by self financing, government seed funds and bootstrapping strategies before they reach the stage at which they can attract private investors (Shane and Di Gregorio, 2003; Shane, 2004; Harrison et al., 2004; Toole and Czarnitzki, 2005; Binks et al., 2005; Wright et al., 2006). Government grants are important and mostly are used for new firms to develop the product to prototype levels (Shane, 2004). It allows the founders of university spin-offs to find a commercial use for their technologies (Shane, 2004), and reduce technical and market uncertainties surrounding their ideas. In addition, government funding increases the credibility and value of the high technology firms, thus helping to access venture capitalist funding and future acquisition (Toole and Czarnitzki, 2005).

However, Binks et al. (2005) and Wright et al. (2006) contended that there is no evidence that the University Challenge Fund (UCF) has attracted venture capital firms to invest in spin-off at the later stage in the UK universities. Mason and Harrison (2002) found similar findings that the new government regional venture capital funds are not effective in closing the regional finance gap. They suggest that international venture capital investment from elsewhere is important in the globalisation era. Toole and Czarnitzki (2005) quote similar findings that SBIR is the only important element for facilitating commercialisation but not a prevalent mechanism for commercialising university scientific research nor did it show a robust propensity for commercialising their research (Audretsch et al., 2006).

To facilitate commercialisation activity, governments have provided various grants. In the UK for example, government funding by the DTI (the University Challenge Fund or Proof of Concept Fund) (UCF) from the Scottish Executive is given to the universities and is available for companies to develop their technology to proof of concept level (Lambert review, 2003; Binks et al., 2005). In the UK UCF comprises 77% of public funding (Wright. et al., 2006). In the US most of the spin-offs obtained funding from the SBIR programmes (Small Business Research). Though the government provides these grants, they are not sufficient, and the universities only provide a small amount that can only cover patent cost and very early stage development of technology (Wright et al., 2006), thus, preventing spin-offs from further developing their technologies. Moreover, it is not clear whether government uses the same criteria as private investors to fund university spin-offs.

- **To overcome constraint with financial resources**

To overcome funding problems with spin-offs, it has been suggested that universities can work as a joint venture with corporate bodies to create a spin-off company. This is called as a Joint Venture spin-off (JVSO) (Wright et al., 2004). The partnership with JVSOs helps to overcome four critical junctures, which relate to the financial and capabilities problems as discussed before. The partnership gives a greater access to critical resources such as marketing, technology, raw materials, equipment, facilities, financial assets, managerial expertise and political influence. However, the study did not mention how the university could access the JVSOs and what criteria are required by JVSOs of their partners.

Spin-off companies can be divided into two main types: one has a potential global market and one is a life-style spin-off (Pirnay et al., 2003). Venture capital companies are unwilling to invest in life-style companies. Wright et al. (2006) suggests that high due diligence costs discourage investors from investing in smaller firms and this is called an 'equity gap', where formal venture capital is not available for projects below £500,000. Thus, Wright et al., (2006) suggest that smaller venture capital firms with public sector investment are needed to invest in the projects lower than that amount.

Partnership with private investors also can overcome seed funding problems in spin-off companies. Private investors also provide an important quality measure and should be used to decide which spin-offs to pursue. Lambert (2003) suggested that an earlier relationship with IP2IPO (Intellectual Property to Initial Public Offering) Company, a venture capitalist company, is a good example of attracting them to invest in early stage technology and reduce public seed finance. IP2IPO Company was recently reported to have partnerships with various universities such as Oxford, Southampton University, University College of London, and University of Yorks's Centre for Novel Agriculture products in commercialisation of their IPs.

For example, this company acquired 50% of the stake in one Oxford University spin-off until year 2015. IP2IPO Company also provides management support and expertise to aid commercialisation process of Ips through new spin-offs.

It is also suggested that universities should have their own funding ventures that operate as a venture capital company, for example, Qubis Ltd at Queen's University in Belfast (Leitch and Harrison, 2005) or ISIS Corporation at the University of Oxford (Smith and Ho, 2006). In addition, it is suggested that in the area in which venture capitalists are not active, strategic alliances with established firms help spin-off companies to overcome seed funding difficulties as well as developing other skills and capabilities (Carayannis et al., 2000). The University of Strathclyde has recently launched The Strathclyde Innovation Fund, which is managed by the Braveheart Investment Group. Other investors could include members of the Strathclyde 100; a group of successful entrepreneurs and business experts who have attended the university; the Bank of Scotland Corporate; and a number of institutional and private investors. The fund is available for investments in spin-off companies and other opportunities to commercialise intellectual properties. The fund will work in two ways:

i. Investment of equity into spin-out companies at the seed funding stage, and in subsequent funding rounds for companies in which the Fund has already invested.

ii. Funding early stage loans direct to the University in return for a right to a share in future income resulting from the funding, or a right to equity in a future spin-out which is set up to commercialise the intellectual property.

In summary, financial availability is a part of the decision by universities in licensing their patents to established firms or to spin-off companies. Not all inventions are suitable for spin-off creation. Shane (2004) gave the factors as the effectiveness of the patents, the stages of the technologies, the importance of the complementary assets, the age of and the type of industries, the TTOs and the policies implemented by the universities. These will be presented in more detail in later sections.

iii. The effect of research funding

Industry and government funding in the US and the UK as well in European countries increases every year (Gulbrandsen and Smeby, 2005). However, government funding is decreasing in proportion and inadequate for project development. Industry is willing to invest in university R&D for a variety of purposes: testing, conducting specific research that the firm is equipped with the instruments to carry our or future job placements for talented students (Roessner et al., 1998; Bozeman, 2000; Feller et al., 2002; Powers and McDougall, 2005), and some companies rely heavily on university based scientific research (McMillan et al., 2000). Even though industry funding increases, government funding still comprises the largest amount. The result of research output disclosed in the 1996 AUTM survey in the US, 62% of inventions disclosed resulted from federal funding and 19% came from industry funding (Thursby et al., 2001).

Empirical evidence showed that the different sources of research funding led to different opportunities of research exploitation. Industry funding is claimed to have a better chance of being exploited compared with government based funding. Universities with closer ties to industries exhibit more spin-off companies created (Roberts and Malone, 1996; Shane and Stuart, 2002; Shane and Cable, 2002; Shane, 2004; Powers and McDougall, 2005; O'Shea et al., 2005). Nevertheless, a study by Powers (2003) of 108 research institutions drawn from AUTM data survey for the period 1991-1998 found that both federal and industry funding have a strong influence on the number of patenting activities. However, there is no measurable effect on the number of licences produced or licensing income by the university. Industry may benefit from contractual agreements to conduct a study or a clinical trial and not via licence on a patented technology.

There is a long debate on the influence of industry-culture directed research in universities as industry based on applied and short term research (Lee., 1996; Shane, 2004; Gulbrandsen and Smeby, 2005). The work of Lee (1996) showed that there had been some resistance by faculty members to commercial activity because of the concern it would detract from the basic research. However, the view of more entrepreneurial academics, with strengthened academic-industry links through sponsored research, is beginning to encourage universities to be more entrepreneurial

(Etzkowitz, 1998). The work of Mansfield (1995) illustrated this phenomenon. His study has been conducted on 66 firms in seven major industries and a sample of 200 academics who had received government funding at the early stage of their research projects. At a later stage, they received industry funding and from the project, successful products were turned out. In addition, there are faculty links with industry through consultation work and contract research.

Further study by Powers and McDougall (2005) supports Mansfield's findings. They collected data from multiple archival sources on 120 institutions classified as research extensive and research-intensive universities in the Carnegie Classification System. They found that industrial R & D revenues were positively predictive of both the number of start-ups formed and the number of IPO licences. Furthermore, industry funding increased the number of spin-offs and other financial impacts, nevertheless the more important aspect of industrial R & D funding is to stimulate a culture of entrepreneurship within the university. If there is no link with industry, it has proved difficult to commercialise technology from a university. The work of Colyvas et al. (2002) supports this view. In one case out of 11 in their study, the technology was never transferred because there were no links between academics and industry.

Work experience within industry also showed that inventors or scientists have a better chance to gain industry funding and a greater number of patents and publications. Dietz and Bozeman (2005) support these views with their study of 1200 scientists and engineers. The study examined career patterns within the industrial, academic, and governmental sectors and their relationship with publication and patent productivity. The scientists and engineers were working at university-based research centres in the United States. They found that scientists who spent a substantial percentage of their time in industrial jobs received more funding from industry and achieved a higher rate of patent productivity but a lower rate of publications. In contrast, those who received federal funding had a higher rate of publication and a lower rate of patents.

Another survey done by Gulbrandsen and Smeby (2005), at four universities in Norway with the sample of 1967 assistant professors and professors confirms this view. The result shows significant relationships between research performance and industrial funding. Professors with industrial funding have more applied research but not development work. They collaborate more with other researchers both in academia and industry, and they report more publications as well as revealing entrepreneurial results and commercial results such as patents, establishment of new firms, and consulting arrangements. O'Shea et al. (2005) in their survey of 141 US universities, also found that industrial R&D funding had a greater tendency to produce spin-off companies. They also found that a greater proportion of federal funding for life science and computer science disciplines had a greater propensity for spin-off creation. However, Di Gregorio and Shane (2003) failed to find adequate support for the argument that industrial funding would lead to more spin-off activity.

Furthermore, Coupe (2003) in his study on "direct real effect" of academic research looked into the direct real economic effect of R&D expenditure using econometric techniques. Patent data in 1994 from 537 universities that have positive R&D expenditure in 1993 was used. The result showed that R&D expenditures significantly influenced the number of patents awarded to the universities as well as to industry.

In sum, the discussions above showed that different sources of funding have different types of productivity and routes of exploitation. However, industry funding shows greater chance of patent will be exploited.

iv. The roles of academic inventors

The role of academic inventors in commercialisation activities can be divided into two. The first is commitment to product development and the second is involvement in networking.

- **Commitment in product development**

The inventors' involvement to bring the product into the marketplace is crucial for both types of exploitation once disclosure has been made and the commercialisation route is chosen. Without the involvement of the inventors it is difficult for the product to be brought on to the market (Markman et al., 2005; Thursby and Thursby, 2004; Agrawal and Henderson, 2001; Colyvas et al., 2002; Jensen and Thursby, 2001; Thursby et al., 2001; Thursby and Thursby, 2002).

The level of inventors' involvement in product development depends on the stage of the technology, types of knowledge and the speed of the inventors' involvement (Thursby et al., and Thursby, 2003; Shane, 2004, Vohora et al., 2003; Markman et al., 2005; Lockett et al., 2005). The first variable is of technology. Early stage technologies with tacit knowledge require very high commitment from the inventors compared with the codified knowledge of later stage technology. Pirnay (2003) defines tacit knowledge as pieces of personal knowledge accumulated by an individual during his/her academic activities. This knowledge combines capability, expertise and experience which are closely associated with each individual and these cannot be bought but are only accessible through interactive learning and explicit co-operation. Thus, the involvement of the inventors from early on in the project is crucial. Codified knowledge is knowledge that is written down and enhances the performance of the companies because it is easily available or through training the context and the content can be understood (Hindle and Yencken, 2003). It appears in various forms such as a publication, an experimentation report, a computer programme, a technical artefact and equipment. It can be easily transferred, distributed and used but also imitated by others (Pirnay, 2003).

Usually spin-off formation involves tacit knowledge and early stage technology (Shane, 2004) and requires a high level of commitment from inventors. The transfer of tacit knowledge in early stage technologies needs the same high level of commitment from inventors (Thursby et al., 2001; Shane, 2004; Markman et al., 2005). This is confirmed in Thursby et al. (2001) study of 62 TTOs in US universities. This suggests that 71 % of licensed inventions required the inventors' co-operation for commercial success. The inventors' involvement is crucial as empirical evidence showed that more than 45% of the university technologies were either at proof of concept or at lab scale prototype level (37%) when the potential market was still unclear (Thursby et al., 2001; Thursby and Thursby, 2004). A survey done by Thursby and Thursby (2004) pointed out that more than half of the respondents licensed university technology for product development, 18% for platform technologies and 9% for process improvement. It was reported that companies used university technology for critical product development without delay. Failure of technology always relates to product development. Thus, faculty involvement is important because of their specialised knowledge and particularly because of the low absorptive capacity of firms. Besides the commitment in product development, firms formation process also involves accessing funding, doing market research, preparing business plan as well as networking which will be discussed in the next section (Birley, 2003; Vohora et al., 2003; Shane, 2004; Lockett and Wright, 2005).

If patents are licensed to an established company, the inventors' commitments only focus on product development. If late stage technology is licensed, the commitment is not as great as at early stage technologies (Thursby and Thursby, 2004; Markman et al., 2005). Thus, if the inventors are not willing to be involved with a very complicated process (Vohora et al., 2003, Birley, 2003) as described in spin-off formation, licensing to an established company is a more suitable route. According to Shane (2004), late stage technologies normally will be licensed to established companies. Later stage technologies are associated with higher quality inventions very near to market application that result in higher royalty payments compared with early stage technologies (Jensen et al., 2003; Thursby et al., 2001). However, according to Markman et al., (2005), in certain cases early stage technology is also licensed to established companies. Normally this type of licence includes sponsored research with running royalties and small upfront fees (Thursby and Thursby, 2004; Markman et al., 2005). Sponsored research is offered in lieu of a licence agreement and closely related with basic research conducted by the firms. Firms license the technologies more on the basis of personal contact between the firm and the university. The study only focuses on faculty involvement from the product development point of view. The link with the TTO and how to build links with industry is not included in the scope of the study. Most of the licensing studies looked at licensing output to determine the performance or productivity of the process, which particularly relates to TTOs in universities.

The second factor is the speed of the inventors' involvement. The ability of inventors to co-operate, recognise opportunities and involve themselves in product development at the discovery stage reduces the commercialisation time. Time is important in that commercialisation activities can be accelerated, if either the university or the inventor decides to license the project to an established company or to a spin-off company. There is a positive link between commercialisation time, licensing revenues and new firm creation. The inventors' co-operation at an early stage is more important than resources or capability of TTOs. 'Self ready selection' of inventors of the chosen route either to established or new venture companies decreases the commercialisation time (Markman et al., 2005).

In sum, the willingness of the inventors to be involved in product development as well other related activities, affects which route the technology will exploited. If the inventors are not interested in becoming involved in commercialisation activities but are only willing to be involved in product development, licencing to an established company is suitable. However, as noted, the willingness of the inventors to become involved in business formation, networking as well as technology development normally leads to spin-off creation. These types of inventors normally have an entrepreneurial background or awareness, which differs from that of inventors who prefer to license to an established company as discussed earlier (Section 2.6.2).

- **Involvement in networking**

Networking is important for both routes of commercialisation. Inventors' and TTOs' networking with the external and internal worlds are important in their effect on the chosen route of commercialisation. Networking here refers to: 1) networking with industries which will help to recognise the potential of a project and a potential licensee in the future; 2) networking with private investors, government bodies, potential customers and suppliers; 3) networking with parent organisations that will support early coaching of a business venture up to seed funding stage.

Networking can be done as early as the inventors are able, through formal and informal networking such as working as consultants to the companies, or embarking on joint research and sponsored research. Inventors who have strong informal networks with industry normally end up licensing their technologies to established companies. On the other hand inventors who do not have strong networks tend towards creating spin-offs to commercialise their patents (Audretsch et al., 2006).

- **Networking that leads licensing to an established company**

There is very limited literature, which reviews networking, or social ties in connection with licensing activities. Universities usually license to an established company when there is a personal contact with the companies, which has been established before the project finished (Thursby and Thursby 2000; Thursby et al., 2001; Colyvas et al., 2002; Jensen and Thursby, 2003: Thursby and Thursby, 2004; and Ausdretsch et al., 2006). Colyvas et al., (2002) used 11 patents as case studies at Columbia University and Stanford University. The study found that personal contact with industry, by locating academic staffs in industry gives awareness of the importance of university research to industry. This makes it easier for university inventions to be exploited. The study also found that one patent whose inventor did not have any contact with industry was not exploited. It was also contended that the technology transfer office only plays a marginal role in transferring university inventions. The TTOs' marketing activities are most important for technological areas where existing links between academia and industry are weak. The study only looked narrowly into the inventors' and TTOs' roles in building networking.

Jansen and Dillon's (2000) survey of 1140 licensees from six institutions supports the importance of inventors' personal contacts or informal contacts. The finding was contradicted with Colyvas et al. (2002) in their view of TTO roles. The studies concluded that inventors and licensing professionals were the best source of leads to licensees, with 56% of licensing leads coming from the inventors themselves and only 19% from TTOs. Inventors or faculty members have a long history of industrial contact through sponsored research and contracts, conferences, graduate students and consultancy agreements. All these studies solely focused on general licensing activities, and the discussion is more about the role of inventors and TTOs in finding licensees. The study also focuses on 'what would happen' after the inventors disclosed their invention rather than 'what happened' before the disclosure. In addition, no part of the study examined thoroughly the decision-making process of the chosen route.

Audretsch et al. (2006) did a survey of 146 scientists who received a National Cancer Institute Grant in the US. It was concluded that inventors who have strong social capital with industry end up licensing their inventions to established firms and inventors who are not very active in social networking ended-up with spin-off formation (in this case those who have not assigned their patent to TTOs, venture it out through spin-off). It was further contended that the inventors who had strong social capital, which is determined by publications and co-patents with industry, have a greater chance of their inventions being licensed by industry. For those scientists who are helped by the TTO, licensing to an established company is the most prevalent mode, and for those whom it was perceived were not helped by the TTO venture out is more important mode. The study by Audretsch et al.(2006) examined the situation from the actual scientists' point of view and not from the TTO's view. '

- **Networking in spin-off formation**

There are abundant literatures on networks, but only a few relate to spin-off formation. Having reviewed the literatures on spin-off formation, informal and formal networking is important at the pre start-up and start-up stage of spin-offs. 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, lead to wider networks, overcome information asymmetry problems, obtain resources below market price and endorsement of new product, sell the first product and link with customers and suppliers (Zhoa and Aram, 1995; Steffensen et al., 1999; Rappert et al., 1999; Rogers et al., 2001; Perez and Sanchez, 2002; Shane and Stuart, 2002; Meyer, 2003; Nicolaou and Birley, 2003b; Walter et al., 2005). Networking also helps the inventors to involve themselves in different types of spin-off either: orthodox spin-off, technological or hybrid spin-off (Nicolaou and Birley, 2003a). In other words, following Shane, (2004:235) firstly, social relationships reduce the likelihood of acting opportunistically towards others by leading people to consider social obligations, generosity, fairness, and equity in their dealings with others (Marsden, 1981; Granovetter, 1985; Uzzi, 1996). Secondly, social ties create an incentive to preserve that relationship for future interactions, by sanctions against those who violate implicit contracts (Gulati, 1995). Thirdly, social ties transfer information about people and opportunities (Burt, 1992). Fourthly, social ties lead people to make more positive judgements about others (Podolny, 1994; Stuart et al., 1999).

Shane and Cable (2002) have carried out a survey on 202 US venture capitalists and 50 high tech ventures in 1998, which focused on the demand and supply side. The study looked at the effects of social capital as a part of the investment decision to fund company formation at the early stage. The survey showed that direct ties and indirect ties have a strong and positive relationship to the probability of investment from financiers for the seed stage. Direct or indirect social ties could overcome the information asymmetry problem between inventors and investors. Social ties provide for investors with information about entrepreneurs that could influence the investors to invest at the seed stage. Shane and Stuart (2002) support this view in their survey of 134 MIT firms focused on a broader view of start-up endowment. The study indicated how start-up endowment, which includes social capital, human capital, technical assets and industry attractiveness influence performance of a start-up up to IPO stage. The survey pointed out that firms 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. Shane (2004) further asserts that inventors that have networks with the MIT's TTO have a better chance of obtaining funding.

In addition, Nicolaou and Birley (2003) theoretically examined the role of exoinstitutional and endoinstitutional individual network influences on the types of spin-offs that were formed. It was noted that networks facilitate spin-off formation by providing four benefits: a process of recognition of opportunities; access to resources; timing implications to market; a source of status and referrals. It was proposed that an academic's embeddedness in networking of ties either, exoinstitutional or endoinstitutional, influences the type of spin-off initiated; either orthodox spin-off, hybrid spin-off or technological spin-off. Exoinstitutional social networks led to orthodox spin-outs being formed which developed more entrepreneurial academic-entrepreneurs who worked full time in the firms. The inventors received greater social support from this type of network, had greater opportunities for generating radical technology through opportunity recognition support from social partners. An endoinstitutional social network confined to intradepartmental and interdepartmental areas was more likely to lead to hybrid and technological spin-outs. Only the technology will spin-out but the academic remains in the university for hybrid and technological spin-outs.

The above studies show that informal and formal networks are important for both routes of exploitation. Personal contact or informal networking through a long history normally leads to a company licensing a university patent. For spin-offs, the network empire must be broader in scope of contact beyond the companies. Personal contact or social ties of inventors-entrepreneurs with the external world provides them with greater access to funding. However, the problem with academic entrepreneurs is that they do not know how to build network before the firm creation.

- **Team formation**

New ventures can be exploited by a single entrepreneur or by a team of entrepreneurs (Shane, 2003). The entrepreneurs must determine how large the founding team should be (Shane, 2003). A venture team can bring together a complete knowledge of the areas relevant to the new venture (Roberts, 1991a; Roberts, 1991b; Cooper and Daily, 2000) and allow those who have previously worked together and who are able to communicate with and trust each other to come together (Cooper and Daily, 2000). Empirical evidence demonstrates that companies started by teams are more successful than those founded by individuals (Cooper et al., 1988; Shane, 2003).

Clarysee and Moray, (2004) has studied how a team was formed in a Spin-off Company, a Belgium University. The study has shown how the champion of the venture automatically evolves into the CEO position if the training is given and in this instance the current (external) CEO created problems both for management and the direction of the company. According to Clarysee and Moray (2004), an external CEO hired from outside at the start of the venture can create problems for the team. The CEO did not understand the technology very well and tried to develop the business in the direction he favoured, which diverted the company from its original target market. After a year of operation, one of the engineers from the entrepreneurial team was coached by the financiers and gained the knowledge needed to run the company instead of hiring a CEO. The professional manager is only needed when the company has gained revenues and is at breakeven.

v. Characteristics of technologies that lead to spin-off or licencing to an established company

The characteristics of university patents or technologies affect the route of exploitation, the patent being exploited either through spin-offs or through licensing to an established firm. The characteristics of patents exploited through spin-off and licensing to established companies according to Shane (2004) are shown in Table 2.3.

Table 2.3: The tcharacterics of technologies that lead to being licensed to spin-offs and established companies

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**

Markman et al. (2005) explained that there are four stages of technology development, resulting from a survey of TTOs: the early stage, proof of concept stage, reduction to practice stage and prototyping, formulation and compounding stage. Table 2.4 explains the detail of the stages. Early stage technologies are often linked with an uncertain market 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 (Thursby and Thursby 2001; Thursby and Thursby 2004; Shane, 2004).

Empirical research has shown that technologies from universities are difficult to license especially to established companies. These views confirm the survey of licensing offices at 62 universities in the US by Thursby et al. (2001) who noted that most of university technologies are at embryonic stage at the time they were

Table 2.4: Technology stages

Technology	Description
1. Early stage	An early stage technology may be an idea that may work should the idea be reduced to practice. This technology may be the crude extract of some plant or cell that seems have an in vitro effect. Neither the exact compound in the extract is known, nor has the exact mechanism of its effect been identified.
2. Proof of concept	An idea or new technology has been developed to the point that its shows signs of having the proposed effect. Similarly a few target compounds in a crude extract may have been identified, but the mechanism by which they act may not have been discovered yet.
3.Reduction to practice	At this stage, an experimental model of the idea has been replicated several times and the intended results have been reliably and repeatedly reproduced. The mechanism of the compounds may also have been identified and again, reliable result will have been reproduced.
4.Prototyping, formulation of compound	The new technology now can be constructed as reliable method of producing a given result and/or it can be predictably manipulated to produce design results. For instant a compound from a crude extract would have been either scale up to industrial scale; based on its identified action. The compound could be used to screen for inhibitors or be used as a diagnostic tool. At this stage, new technologies might be applied in new and different settings.

(Source: Markman et al., 2005).

licensed. Since the technologies are at embryonic stage, universities are likely to license their patents to small firms (Tornatzky et al., 1999; Thursby and Thursby, 2003; Shane, 2004). Shane (2001, 2002), Scott and Shane (2003) and Shane (2004) support this evidence that established companies prefer to exploit technologies that are at the late stages of development with only minor technological development required, which means less risks and promises quick returns. Large firms focus on core technologies and often outsource research and development to minimise risks. This leads universities to increasingly license their patents to small firms short on cash but are willing to take greater risks, especially in the biomedical industry (Tornatzky et al., 1999; Thursby et al., 2001; Laursen and Salter, 2004; Thursby and Thursby, 2004). A similar finding was reported from a survey of 300 industrial companies (Thursby and Thursby, 2003).

It was further reported that university inventions have a high failure rate: 42 % of industries indicated that university technologies have a higher failure rate compared with non-university technologies. A quarter of respondents reported that university technologies take a longer time than expected to produce up to prototype stage. 22% of respondents reported that university technologies are not relevant to the firms' line of business (Thursby and Thursby, 2003). Why are early stage technologies not attractive? The reasons are discussed below.

Uncertain value and focus to existing operations The commercial value of early stage technologies is difficult to see and they tend to lack proof of effectiveness. This undermines the ability to establish its value and makes it difficult to set a price. Furthermore, as noted earlier, existing companies are not interested in early stage and unproven technology. They prefer to license late stage technology that has been shown to have commercial potential and tend to focus on existing technologies to enhance returns (Shane, 2004). As a result, the entrepreneurs need to found firms to develop university technology into products or a service that they can sell to other firms. Following Shane (2004), the founders of one of the MIT software spin-off companies with experience in selling his basic technology to established firms commented:

> *"No one wants to buy ideas, a technology that's very vague. People want to buy something ready to go out of the box. When we got down to it, there was nothing for them really to buy. We had nothing that we could just say, here it is, other than this piece of paper that says its okay for you to develop this technology that no one wanted to spend the development money to do. No one would say yes to licensing until they could actually see the stuff working. They figured that it was our job to do the development and research on it, not theirs" (Shane, 2004:116).*

Product Development Expertise Established companies do not have the expertise to develop new technology and managers are not rewarded sufficiently for bearing the risks of technology development. Established companies find it more efficient to buy already developed technology rather than to develop the technology themselves (Shane, 2004). Hence, most established firms relinquish technology development to small firms and focus only on their core technologies (Tornatzky et al., 1999; Santoro and Chakrabatrti, 2002; Shane, 2004).

Ability to Capture Value Established companies refuse to invest large amounts of money in early stage technologies, which are difficult to value. On the other hand, inventors are unwilling to license early stage inventions to large firms and prefer to license to spin-off companies to capture more of the value of their inventions. As cited from Shane (2004:121) one of the MIT biotechnology companies founders commented on the difficulties of selling his ideas, that then led to him forming a company:

> *"...Was more of a concept than anything. It wasn't even clear why you'd want to patent something like that. It was more of a concept of how things worked. It wasn't a composition of matter patent. It was more of a way of proceeding. There was no technology to license. It was just ideas. It was our knowledge and insight. It's not that I had a specific gizmo that we developed as we started our own company. You see, I've started a bunch of companies and none of them were based on specific experiments or specific things being done in my lab. It was more general concepts that I was aware that you could bring to market...".*

Time horizon. Established companies do not like to license university technologies that have an unknown or long time horizon. They intend to license ready-made technology. Thus, spin-off companies are a common vehicle for commercialising early stage technologies that have long time horizons for further development (Shane, 2004). However, as Markman et al. (2003) and Thursby and Thursby (2004) mentioned before, established firms also license early stage technology but with a lower rate of royalty or they only pay upfront payment to develop the technology. This contradicts Shane's (2001a, 2001b, 2004) finding. Established firms licensing university technology at an early stage may be involved with non-core technologies (Tornazky 1999; Waugaman and Gray 1999; Santoro and Chakrabatrti 2002;Thursby and Thursby 2004; Laursen and Salter, 2004).

- **Scope of Patent.**

Many studies have been done to examine the effect of patent and patent scope on industrial innovation. However, not many studies focus on the scope of patent and links with the formation of spin-off firms. Only Lerner (1994), Shane (2001a), Shane (2001b) Shane and Nekar (2003) and Shane (2004) are involved in this aspect. Lerner (1994) defined patent scope as the number of international patent classes into which United State Patent Office (USPTO) assigned to the patent, which refers to technological space the patent covers or protects from infringement. Lerner linked scope with economic value of the patent. The higher the patent classes the higher the value of patent. Lerner (1994) cited in Shane (2001a: 211) gave evidence that venture capital backed-biotechnology firms with broader scope of patents, as measured by a count four digits international patent classes received higher valuation. Similar regression results reported by Shane (2001a: 216) of 1397 MIT patents found that the more radical the patent, the broader the patent scope and the more important of patent tend to exploit through spin-off formation. According to Shane (2001a, 2001b, 2004), technological opportunities with broader intellectual property protection are more commonly commercialised through company formation or spin-offs and the narrow scope patent will be licensed to established firms. New firms normally lack complementary assets such as good marketing and manufacturing systems (Teece, 1986), having a broad scope of patent or effective patent protection may provide competitive advantages in the industry in which the technology will be exploited. Shane (2001b) used the same sample to examine the factors determining firm formation from broader aspects involving technology regimes and environment. He found that the younger the age of technology, the market is too small and the more it will be exploited by spin-offs. Established firms are more attracted to larger markets. In addition, spin-off is suitable when the market is segmented. Furthermore, strong patent protection allows the entrepreneurs to enjoy the profits before competitors copy the new technologies. This is great incentive that leads to firm formation by the inventors. Thus, the more important the complementary assets in marketing and distribution are, the fewer the number of new firms who can exploit the inventions. Earlier studies by Lowe of the UK spin-off situation (1993) and Hsu and Bernstein (1997) supported Shane's (2001a; 2001b) conclusions.

Though the broad scope of the patent and radicalness of technologies, as claimed by Shane (2001a), are the reasons university inventors choose to form a company, the formation and survival of the company does not only depend on them. Other factors discussed earlier and the concentration of industries will influence the survival of the firm. Nerkar and Shane (2003) developed a model to study 128 MIT firms between 1980 and 1996. It was found that the use of technology and the scope of the patent only reduce the number of failures of new firms in the context of fragmented markets but not in concentrated industries. In concentrated industries, it is difficult for new firms to enter the market, in which established companies have the monopoly of market in terms of size, associated players, image and customers. All the three studies above (Shane 2001b, 2003, 2004) used MIT as a single sample and the result should be interpreted with caution.

Another way to understand scope of patent refers to the first claim granted through a patent. If the claim is broad, then the patent is broad and strong (Shane, 2004), which is the definition adopted in this study. A broader patent scope allows the company wider powers to block competitors from exploiting the technology that they licensed. Broader patent protection gives competitive advantage to new firms against their competitors and prevents appropriation. Furthermore, the strength of the patent's claim is normally determined by the broadness of the scope of the patents, which do not cover any specific physical embodiment of the technology (Shane, 2004). A broad patent scope also has no prior art and has a family patent[4]. A family patent means when a patent has another or a few subsequent patents from the first technology invented.

All the above studies only focus on the influence of the scope of patent and patent effectiveness that leads to firm formation, which focus more on the economic point of view. Thus, a more comprehensive study needs to be done to enhance the effectiveness of the process before those holding the patents decide which route to commercialisation would be appropriate.

- **Radicalness of technology**

Radical technologies are important for spin-off creation whilst single product extension or incremental invention is suitable to license to established companies (Shane 2001a; Shane 2001b; Shane, 2004). Radicalness is a measure of the number of patent classes cited outside of a patent's own patent class (Trajtenberg et al., 1997; Shane, 2001a; Shane, 2001b; Nerkar and Shane, 2003; Shane, 2004). The assignment

[4] Interview with TTO Director University of Strathclyde.

of a patent to a particular patent class by patent office indicates that the patent belongs to a particular technical field. When a patent cites previous patents in classes other than the one it is in, that pattern suggests that the invention has been based upon different technical paradigms from the one in which it is applied. A more straight forward definition of a radical technology, suggested by Shane (2004:15) is an invention that involves a step-change in the nature of the technology. This definition is applied in this thesis. Radical technology has a tendency to exploitation through licensing to spin-off companies because: 1) radical technologies cannibalise existing assets; 2) radical technologies undermine existing organisational competencies; 3) established firms tend to react to radical technologies with disbelief (Shane, 2004:105).

- **General purpose technologies**

General purpose technologies or inventions that have multipurpose applications tend to be exploited through spin-off companies because they offer multiple market applications and established companies only focus on their core technology and are not interested with multipurpose technologies (Thursby and Thursby, 2004; Shane, 2004). Thus, these types of technologies are difficult to license to established companies. Multiple market applications allow the founders to change the first application if it fails. Furthermore it allows the company to spread the risks and recover their costs across different market applications.

vi. Industries where spin-offs occur

Spin-offs are claimed to be more successful in certain industries compared with others. The most common industry for spin-off is biotechnology followed by computer software. Between 1986 and 1996 more than half MIT spin-offs were based on these sectors (Shane, 2004). This is confirmed by evidence from other countries such as the UK (Smith and Ho, 2006), Switzerland and France (Lowe, 1993; Olofsson and Wahlbin, 1993; Dahlstrand, 1997; Mustar, 1997). Following Ku cited in Shane (2004), it was noted that a life science such as the biotechnology industry has a commercialisation time horizon longer than physical science. Physical science has too short a life cycle, which it is difficult to find investors and firms find it difficult to gain enough profit to cover their costs. Many more experts in the biotechnology sector remain in universities compared with other sectors that employed by industries (Kenny, 1986). In the US and Japan most biotechnology firms were created by star scientists from universities especially after the discovery of DNA (Zucker et al., 1998; Zucker and Darby, 2001). These sectors also have effective patents, weak complementary assets, young age of technical field and the market is segmented as explained above. These characteristics lead to the setting up of firms (Lowe, 1993, Hsu and Bernstein, 1997; Shane, 2001b).

vii. The roles of TTO

How selective, supportive and effective are the roles of TTOs pursuing the commercialisation route chosen by a university depend on the level of investment that the university makes in its licensing office, the experience and capabilities of TTOs staff, how strong a network the TTO staff with other stakeholders in the university and what the objectives of the TTOs are (Shane, 2004:76).

- **TTOs resources**

Some universities support more spin-offs than licensing to established companies and other universities have reverse strategies. How supportive TTOs are in these commercialisation ventures always relates to the level of resources available (Shane, 2004), and how helpful the TTOs are (Audretsch et al., 2006). These factors are related to each other.

First is the availability of resources. Some universities invest a lot of money in their TTOs to promote spin-off companies. A company formation needs high investment. TTOs have to spend an additional amount to the Patent Agents, conduct market research and negotiate an exclusive licence, which takes more time. With these activities and given budget constraints, many universities lack sufficient staff to undertake the extra activities adequately and have lower rate of spin-off formation than others (Wright et al., 2002) and prefer to license to established companies. This is confirmed in the study done by Lockett et al., (2003b) in a survey of 57 respondents in the UK universities. New entrant universities prefer licensing to established firms due to a lack of clear strategies and resources. Moreover, most of the 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; Markman, 2005) which for them is risky and needs special expertise.

It was found that experienced universities are more successful in commercialisation activities in spin-offs because of the role of their TTOs. The TTOs who have more experience and network with external parties can link inventors with specific knowledge and access to expertise, which leads to spin-off formation. The second factor is whether inventors perceived TTOs as helpful or not which is based on the adequacy of their resources and their capability. It discourages inventors from disclosing their quality inventions if they perceive that the TTOs have inadequate resources and capabilities (Jensen et al., 2003). Some of the inventors approach established companies or attempt to form spin-offs by their own efforts (Siegal, 2006; Audretsch et al., 2006). A recent survey by Audretsch et al., (2006) of 146 scientists who received National Cancer Institute Grants confirms that inventors who were helped by TTOs mostly licensed their patents to established companies. On the other hand, those who perceived that they were not helped by their TTOs, exploited their inventions through entrepreneurial firms or spin-offs. TTOs were not very helpful to them in start-up activity. Some of them reported that the TTO discouraged them from forming a company. As one of the inventors comments;

> *"...I refuse to work with the TTO. They have destroyed many of my commercial work. I have given up on any sort of commercial enterprise with my TTO. I don't think any of my colleagues have attempted to commercialise anything here for the past six years..." (Audretsch et al., 2006:25).*

- **TTOs' expertise**

Spin-off formation requires additional resources and routines/capabilities beyond the skills and strategy required for licensing to an established company as explained earlier (Eisenhardt and Martin, 2000). Furthermore, to generate spin-off formation, TTOs need to have staff who are expert in evaluating markets, writing business plans, raising venture capital, assembling venture teams, obtaining space and equipment, and testing the products. This is confirmed by a survey that has been done by Lockett et al. (2003). It was found that universities that are more successful in spinning out companies had more experienced licensing officers in spin-off activity than other universities. Lockett and Wright (2005) confirm the importance of business development capabilities in spin-off formation after having conducted a survey and interviewed 48 TTOs in UK universities. The study compares both new spin-offs and existing spin-offs created with equity investment. Business development capabilities focus on: i) a clear process for conducting intellectual property evaluation and due diligence to ensure IPR is identified and fully evaluated before commercialisation could commence (Vohora et al., 2004); ii) an absolute requirement for clear policies, processes and routines for creating and developing university spin-outs. The creation of USO included legally protected intellectual properties and the managerial and marketing skills, premises and financial resources to enable spin-off to prosper and iii) enhancing experience and the expertise of TTO personnel.

It was found that spin-offs are both significant and positively associated with expenditure on intellectual property protection, the business development capabilities of technology transfer offices and the royalty regime as well as the stock of technologies of the university. The TTO staff has insufficient resources (TTO staff lack of skill in evaluate all field of technologies) and competencies to identify the most viable technologies. Training was proposed to develop expertise in TTO personnel to increase capabilities and skills for TTO staff. These skills are important determinants of university success in creating spin-off especially for externally backed spin-offs as well as licensing to an established company (Lockett et al., 2003; Siegal et al., 2004). This study supports Di Gregorio and Shane's (2003) work that the intellectual eminence of a university increases the number of university spin-offs. If a university lacks business development capabilities, licensing to established company is appropriate if there is a licensee because the process is more linear than spin-off creation. None of the studies focuses on the decision-making process on commercialisation routes.

- **TTOs' objectives**

The choice of the commercialisation route also depends on the objectives of the TTOs. According to Smailes and Cooper (2004) TTOs' desire can be divided into three objectives: to develop local economic development, to gain financial profit or to give benefit to society. In other words, Smailes and Cooper (2004) assert that internal and external factors drive universities engaged in commercialisation activities. Internal factors are the desire of universities to stimulate local economic development through job creation, to gain financial objectives, and give benefit to society through new discoveries such as new medicines etc. External drivers are expectation and encouragement from governments and their agencies and industrial requirements through sponsored research. If the objective is for local economy development and social benefit, spin-off formation in the local area will help boost job creation and employment. To gain a financial objective, the university will license the technology for maximum benefit. The key point according to Smailes and Cooper (2004) is that the exploitation route should be the one most likely to take the invention to the market place to achieve one of the objectives. The university that aims for financial gains requires policies and procedures that emphasise control, and should be very selective in the patenting process. It also requires investment in the cost of patenting.

On the other hand, if the university sees the exploitation mainly for the benefit of the local economy, ownership of IP will need to be clear with recognition for the inventors who will have to adopt a broader measure not solely based on financial return. Those universities having wider social benefit objectives should apply a more lenient policies and procedures, and provide more by way of resources. Leicth and Harrison (2005) also pointed out that at Queen's University in Belfast, the TTO's function is beyond the normal routine, which is to develop second order spin-off activities or to focus on regional economic development. The TTO's role is to assist by taking equity in spin-off companies that have been formed due to technologies developed in an existing spin-off company. Thus, their development of spin-offs is far ahead of their counterparts in the UK.

Markman et al. (2005) in their work detailing 128 interviews with TTO directors has pointed out that 72 % of universities in the US prefer licensing for cash because this strategy gives an immediate return and the universities are not required to become involved in risky ventures. The most minimal licensing strategy to be favoured by universities, which is not likely to be used, is a combination of early stage technology and licensing for equity. Siegal et al. (2003, 2004) reported similar results, that stakeholders' perceptions of UITT (University Industry Technology Transfer) outputs were different. TTO directors and universities administrators perceived their main output were licences and royalties, patents, and sponsored research. Managers and entrepreneurs considered licences, new products, profits and economic development as output. Finally, scientists identified product developments and licences as output. Different outputs leads to different emphasis on the commercialisation route chosen.

- **University culture**

University culture influences commercialisation activities in several ways. Some universities reinforce entrepreneurial activities, which encourages spin-offs. On the other hand, other universities provide subtle cultural hints which give a signal discouraging spin-offs activity (Shane, 2004). Though some universities are in favour of commercialisation activity, they are opposed to spin-offs and prefer universities only to license to establish firms. In these universities, licensing to established companies has been dominant as a traditional route of commercialisation. Some academic staff have negative views and oppose any commercialisation activities proposed by the universities or the government. In their minds, they are trained to be academics not businessmen. This is more prevalent with senior academic staff.

To encourage spin-offs, nurturing entrepreneurial culture among top management, academic staff, and all levels of staff is important in the first place to overcome these problems. Nurturing an entrepreneurial culture does not happen overnight. MIT started in the 1930s to create the 'culture' that became embedded and institutionalised among academic staff (Etzkowitz, 2002). The need for role models from the same organisation who can demonstrates their success in spin-off or licensing activities is very important to influence other academic staff. Previous history of success can be as a yardstick for others to involve themselves in this activity influencing others to follow the same track (Bercovitz et al., 2001).

- **Conclusion from previous research**

The summary of the literatures review is shown in Appendix B. Having reviewed the literatures on patents, licensing and spin-offs, which related to commercialisation activities, most of the studies examined on the aspects as follows:

1. Increase interest of scholars to study licensing and patenting activities. Nevertheless, for licensing activities most of the studies have been done in US universities and few studies on the UK universities have been found so far.
2. All licensing studies are focused on establishing companies rather than spin-off formation with the exception of Chukumba and Jensen (2005). However, the approach used by Chukumba and Jensen (2005) is based only on a theoretical study.
3. Most of the studies are based on theoretical and quantitative analysis. Few used a qualitative approach (see Appendixes B1, B2, and B3 in which important studies are summarised).
4. Most of the studies on licensing (spin-off and licensing to established companies) used AUTM survey data e.g. the studies by Thursby and Jensen (2001), Shane (2001a, 2001b).
5. Discussions focus on limited issues emphasised activities after patenting (i.e. the objectives of TTOs, characteristics of university technologies, efficiency and productivity of TTOs and the view of industrial companies on university technologies).
6. None of the studies, either of spin-offs or licensing, is based on the decision-making approach to commercialisation process. Reasons why

universities decide to commercialise through spin-off formation or licensing to an established company were hard to find. Only Shane (2004) focused on both areas in one of the chapters but did not examine them intensively.

7. None of the studies compares unexploited patents with exploited patents to examine the effectiveness of the process.
8. None of the studies examined intensively the process before a firm is created. Most studies looked at the factors after a firm is formed or after the patents are licensed.

Thus, this thesis is trying to fill gaps in the literatures. In this thesis, three types of patents[6] were used to try to understand and refine the decision-making process of the commercialisation routes decided upon by the university. In addition, the three types of patents comprising: patents that are unexploited, patents that are exploited through spin-off firms and patents that are exploited through established companies will be used to study the effectiveness of the patenting and commercialisation processes. Thus, this leads to sub research question: ***what are the features of exploited patents and unexploited patents?*** that lead them to be exploited or not exploited?

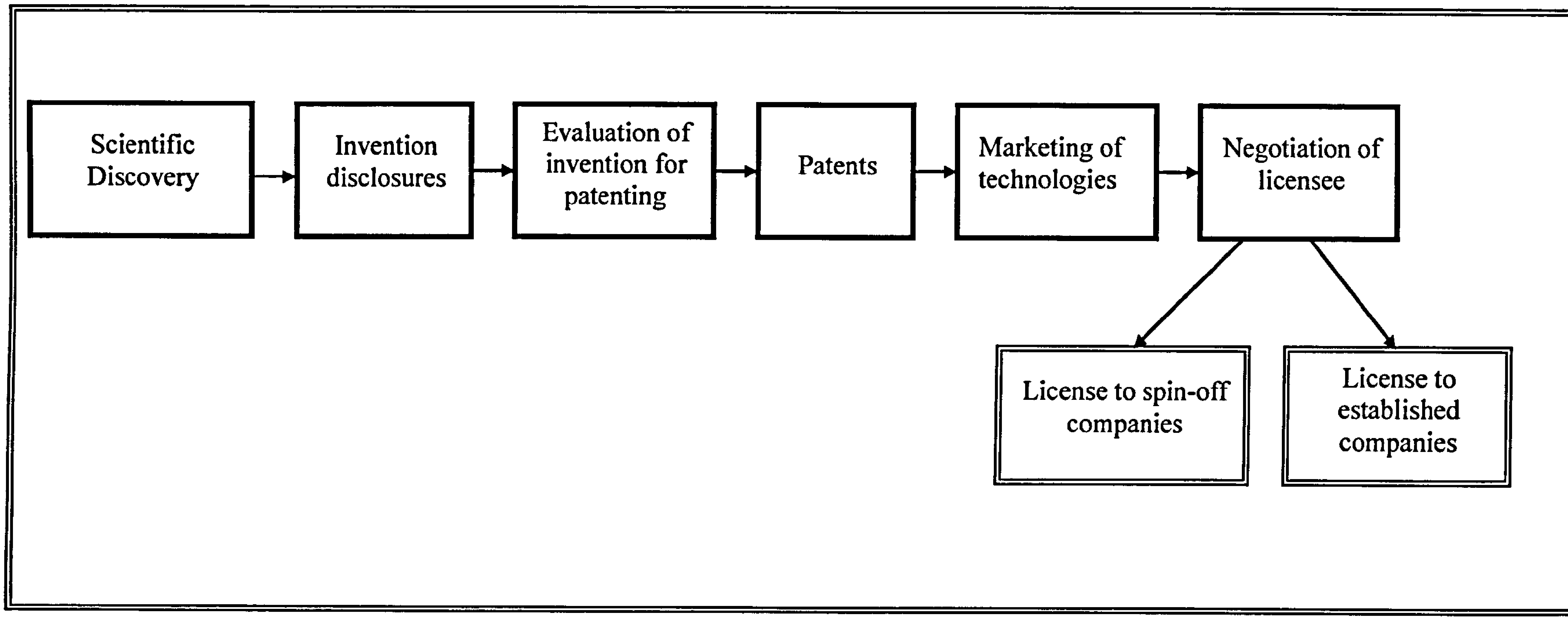
Having studied the literatures, the linear model of commercialisation is proposed below as depicted in Figure 2.2 below, which is based on Siegel et al. (2004) and Shane (2004) models (will be explained in Chapter 4). The propositions as Appendix A : (A1-A3) are proposed to answer the research questions and the objectives of the study.

2.7. CONCLUSION

Having studied the literature reviews on patenting, licensing and spin-off activities, and university technology transfer it was found that there is no comprehensive study on the decision-making process in commercialisation of university research, which focuses on institutional factors: starting from the

[6] The phrase 'three type of patents' is used to refer to unexploited patents and exploited patents, which includes patents that were licensed to spin-offs and patents that were licensed to established companies.

Figure 2.2: Linear model of the commercialisation process of university intellectual property



discovery of scientific knowledge to the decision-making by which route a patent should be exploited: licensing to an established company or to a spin-off company.

The studies that have been done so far are found to focus separately on the individual route of technology transfer from university: spin-off and licensing to an established company. Thus, this study is trying to fill the gap of knowledge in the university technology commercialisation process. The details of the process are studied from how the inventors decide to disclose their inventions up to the point when the route to commercialisation has been chosen. The institutional factors in this study will focus on: who recognise the opportunity, motivational factors and characteristics of the inventors, the characteristics of the technologies, the roles of the inventors, the roles of technology transfer office, the availability of research and spin-off funding, university culture and the university incentive and reward system as the factors to be studied in understanding the process.

To examine the effectiveness of the process of commercialising university intellectual properties, a comparison between exploited and unexploited patents will be conducted. Specifically the study seeks to understand how a university decides to patent the inventions for both type of patents and how decisions are made to exploit or not to exploit the patents. The study also tries to examine the factors that affect the decision-making for some patents being exploited through licensing to established companies while others are licensed to spin-off companies, and why some of patents were not exploited at all.

The next chapter will discuss what methodology is used to answer the research questions and the objectives of the study.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 RESEARCH PROCESS

Ghauri and Gronhaug (2002:8) explained that research is a systematic process, critically analysing issues or facts before making any decision about them. The gathering and analysing the data is a critical part of this process (Ghauri and Gronhaug, 2002). Figure 3.1 shows some generic steps that every researcher fulfils in order to find answers to questions or problems identified during the research process. In this chapter, the research design, data collection, and data analysis chosen in this study are discussed. Literature reviews, concept and models have been discussed in Chapters 1, and 2.

Williams and May (1996) assert that to 'research' means to seek answers that involve understanding and explanation, where the credibility of the outcome will rest heavily upon the conduct of the investigation. The process of research inquiry has to be carried out diligently, critically, objectively and logically with the aim of discovering new facts that will help us to deal with the problem situation (Sekaran, 1992:4).

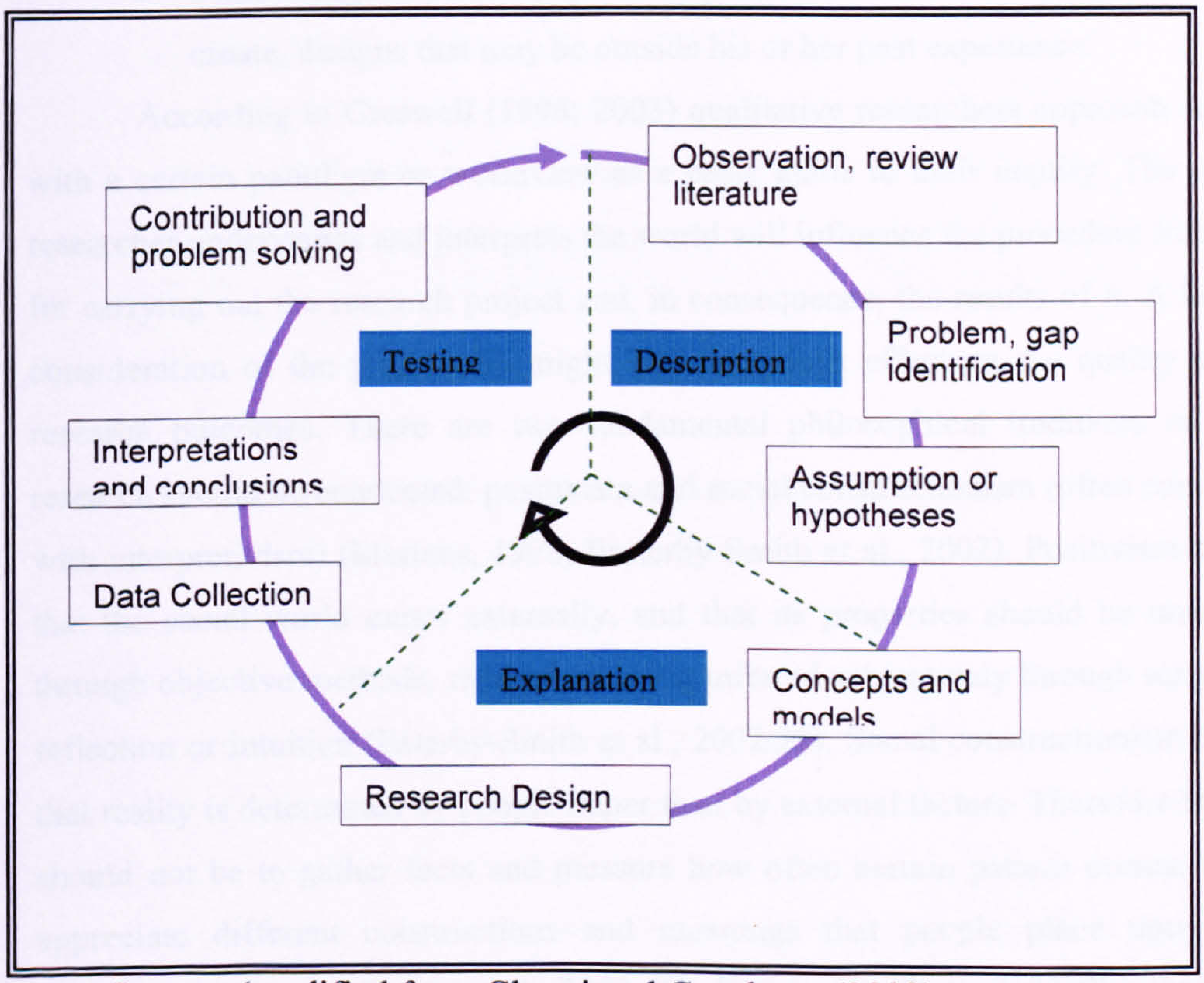
According to Easterby-Smith et al. (2002) research in management can be classified into three types: i) pure research that leads to theoretical developments, ii) applied research which is intended to lead to the solution of specific problems and iii) action research which is intended to have a direct and immediate impact on the problem being researched.

Preece (1994:18) gave a broader definition for the concept of research as follows:

> *"Research is conducted within a system of knowledge and that research should be probing or testing that system with the aim of increasing knowledge. The increase in knowledge*

may be something entirely new and original or, more commonly, it may consist of checking, testing, expanding and refining ideas, which are still provisional. In particular research should continually question the nature of knowledge itself, what it is and how it is known" (Preece, 1994: 18).

Figure 3. 1: The wheel of research.



Source: (modified from Ghauri and Gronhaug (2002).

From the definition, the question of what the nature of knowledge is and how it is known is commonly underpinned by a set of beliefs that define the researcher's worldview. This basic set of beliefs is known as a paradigm (Guba and Lincoln, 1994; Phillimore and Goodson, 2004), defined by some authors as the philosophicalassumptions. The stance of philosophical assumptions or knowledge claims undoubtedly comes with complex arguments against each other. Easterby-Smith et al. (2002) noted that the understanding of research inquiry can be divided into three approaches: i) qualitative approach - knowledge claims based primarily on a constructivist perspective, ii) quantitative approach which uses positivist/post positivist for developing knowledge, and iii) mixed methods approach which tends to be based on knowledge claims on pragmatic grounds. Easterby-Smith et al. (2002) gave three reasons why an understanding of paradigm or philosophical issues is very useful:

- it can help to clarify research designs
- a knowledge of philosophy can help the researcher recognise which designs will work and which will not.
- a knowledge of philosophy can help the researcher identify, and even create, designs that may be outside his or her past experience.

According to Creswell (1998; 2003) qualitative researchers approach studies with a certain paradigm or worldview as a basic guide to their inquiry. The way a researcher understands and interprets the world will influence the procedure followed for carrying out the research project and, in consequence, the results of it. A lack of consideration of the philosophy might have a serious effect on the quality of the research outcomes. There are two fundamental philosophical traditions on how research should be conducted: positivism and social constructionism (often combined with interpretivism) (Mertens, 1998; Easterby-Smith et al., 2002). Positivism claims that the social world exists externally, and that its properties should be measured through objective methods, rather than being inferred subjectively through sensation, reflection or intuition (Esterby-Smith et al., 2002:28). Social constructionism claims that reality is determined by people rather than by external factors. Therefore the aim should not be to gather facts and measure how often certain pattern occurs, but to appreciate different constructions and meanings that people place upon their experiences (Esterby-Smith et al., 2002:30). Esterby-Smith et al. (2002) contended that the focus should be on what people, individually and collectively, are thinking and feeling and attention should be paid to the ways they communicate with each other, whether verbally or non-verbally. One should therefore try to understand and explain why people have different experiences rather than search for external causes and external laws to explain their behaviour. The difference between positivism and constructivism is briefly showed in Table 3.1.

Some authors have divided an inquiry paradigm into three main elements: ontology, epistemology and methodology. The approach of the research or philosophical ideas is embedded in epistemology, ontology and methodology. The meanings of these terms are briefly explained below.

Table 3.1: Contrasting implications of positivism and social constructionism

	Positivism	Social Constructinism
The observer	Must be independent	Is part of what is being observed
Human interests	Should be irrelevant	Are the main drivers of science
Explanation	Must demonstrate causality	Aim to increase general understanding the situation
Research progresses through	Hypotheses and deductions	Gathering rich data from which ideas are induced
Concepts	Need to be operationalised so that they can be measured	Should incorporate stakeholder perspectives
Unit of analysis	Should be reduced to simplest terms	May include the complexity of whole situations
Generalisation through	Statistical probability	Theoretical abstraction
Sampling requires	Large numbers selected randomly	Small numbers of cases chosen for specific reasons

(Source: Esterby-Smith et al., 2002:30).

i) **Ontology**. This refers to the perception of the nature of social reality, or what researchers claim about knowledge (Creswell, 2003). Individuals involved in the research situation construct reality. In this study, the ontology of this research is subjective. The researcher views this world as subjective and there exist multiple realities, such as the realities of the researcher, those individuals being investigated, and those of the reader or audience interpreting a study. According to Bryman (2004:16) the central point of orientation is whether social entities can or should be considered objective entities that have a reality external to social actors, or whether they can and should be considered as social construction built from perceptions and actions of social actors. Bryman, (2004) referred to these as objectivism and constructionism. Objectivism is an ontology position that implies that social phenomena confront us as external facts that are beyond our reach or influence. In contrast, constructionism asserts that social phenomena and their meanings are continually being constructed by social actors.

ii) **Epistemology**. Epistemology considers the way knowledge is transmitted to other people or what is the relationship between the inquirers and what is known. Creswell (2003) claimed epistemology is how we know the knowledge.

The main epistemological stances in social science commonly are categorised into main camps: positivism and interpretivism (Bryman, 2004) as explained above. Some authors, as Easterby-Smith et al. (2002) claimed this to be a philosophical issue.

Positivism is an epistemological position that advocates the application of the methods of natural sciences to study social reality and beyond. It claims that it is possible to carry out independent, objective and value free social research because human behaviour is governed by laws and regularities (Snape and Spencer, 2003). Therefore the research methods used in this paradigm should be objective (value free). Researchers in this paradigm commonly deploy quantitative methods such as surveys or experiments. The main purpose of research is to generate hypotheses that can be tested.

Interpretivism or **constructionism** according to Esterby-Smith et al. (2002) is contrasted with positivism. It claims that laws and regularities do not govern social science, and natural science is not appropriate for social investigation. Therefore a researcher has to explore and understand the social world through the participants' and their own perspectives. Explanations can only be offered at the level of meaning rather than caution. Rather it seeks to produce descriptive analyses that emphasise deep, interpretive understanding of social phenomena. The interpretive paradigm thus, generally leads to the use of qualitative research methods that enable the researcher to gain understanding of the values, actions and concerns of the subjects under study. Interpretivists argue that it is possible to understand the subjective meaning of actions (grasping the actor's beliefs, desires, and so on), yet do so in an objective manner. Hence, interpretivists aim to reconstruct the self understanding (Verstehen) of actors engaged in particular actions (Schwandt, 1994).

iii) Methodology. According to Creswell (1998:77), methodology is how one conceptualises the entire research process. In other words it is how researchers collect knowledge about the world of reality (Phillimore and Goodson, 2004). Methodology sets rules and procedures to guide research so that the findings can be evaluated. Normally methodology is claimed to be research design, which includes how we conceptualise, theorise and make abstractions, and the techniques or methods for data gathering and analysis. Deduction is the process, which begins with theory and proceeds through hypothesis, data collection and testing the hypothesis. Quantitative method uses this approach (Creswell, 2003). This process guides the process of data collection so that they can be tested (Bryman, 2004:9). With the inductive stance, theory is the outcome of research. In other words, the process of induction involves drawing generalisable inferences out of observations (Bryman, 2004:9).

In practice, elements of induction and deduction are always present during the research process. It is impossible for a researcher to collect data without some explanatory model in mind which requires deductions (Veal, 1992). On the other hand induction is needed to develop hypotheses and theory. Moreover, qualitative research has also been used to test rather than to generate the theory (Bryman, 2004).

This study is attempting to understand the process of decision making in commercialising university technologies (patents). It focuses on institutional factors using interpretive epistemology, and socially constructed meanings (ontology) and sense making through informants. Social constructionism is adopted in this study because it can make a significant contribution to understand the process of commercialisation of university technologies. The research design of this study is based on Easterby-Smith et al. (2002) and Bryman (2004). (see Table 3.1).

3.1.1 Case studies

This study uses the case study as approach. Yin (2003:13) defined case studies as;

> *"An empirical inquiry that investigates a contemporary phenomena within its real life context, especially when the boundaries between phenomenon and context are not clearly evident. The case study inquiry copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to coverage in a triangulating fashion, and as another result benefits from the prior development of theoretical propositions to guide data collection and analysis".*

Stake (2000:437-438), pointed out that there are three types of case study.

i) The intrinsic case study, where the study is undertaken because the researcher wants a better understanding of this particular case.

ii) The instrumental case study, where a particular case is examined to give insight into an issue, or to refine a theory.

iii) The collective case study, where the instrumental case study is extended to cover several cases, to learn more about the phenomenon, population or general condition.

i) Aim of research

The use of case studies reflects the aims of the research. Yin and Eisenhardt (1989) agreed that case studies are appropriate when the aim is to provide description, test theory or generate theory, exploratory and explanatory.

As mentioned in Chapter 1 the aim of the research is to examine how and who are involved in the decision making process in the commercialisation of university technologies, specifically the selection of which discoveries to patent. This study involves detailed investigation of the commercialisation process and a strategy for carrying out the data collection and analysis processes (theory testing and refinement) (Yin and Eisenhardt, 1989). As highlighted by Hartley (1994:208) case study research *'consists of detailed investigation...with a view to providing an analysis of the context, in which the dynamics of the phenomenon need to be incorporated'*. Case studies are especially valuable to explore unique phenomenon, which are relatively new, and not well understood at the present as in this current study. The advantages are that it can gather extremely rich, detailed and in depth information (Berg, 2004) and studies the phenomenon in its natural setting. Case studies are able to recognise complexity and context and have a holistic focus, aiming to preserve and understand the wholeness and unity of the case (Punch, 2005:144).

Finally, case studies are a more comprehensive research strategy in this study as suggested by Yin (2003):

- they can cope with the technically distinctive situations in which there will be many more variables of interest than data points.
- they rely on multiple sources of evidence, which enables triangulation.

- they benefit from the prior development of theoretical propositions to guide data collection and analysis.

ii) Types of questions

The main argument for choosing case studies as a research strategy is the descriptive nature of the research (which does not require control of behavioural events but rather document them). The dominance of 'how' and exploratory 'what' requires an insight in what explains why some university patents are exploited and some are not exploited. In qualitative studies, the nature of research question often starts with a "how" or a "what", so that it will give initial general description what is going on (Yin, 1994; Miles and Huberman, 1994; Creswell, 1998; Patton, 2002). The 'what' question is justifiable for conducting exploratory studies, where the goal is to develop propositions for further inquiry.

Table 3.2: Relevant situation for different Research strategies

Strategy	Form of research question	Requires control over behavioural events?	Focuses on contemporary events?
Experiment	How, why	yes	yes
Survey	Who, what, where, how many, how much	no	yes
Archival analysis	Who, what, where, how many, how much	no	no
History	How, why	no	no
Case study	How, why, what	no	yes

(adopted from Yin (1994, 2000; 2003))

According to Yin (2000; 2003), research questions, which start with how and why, are likely to favour the use of case studies and explanatory study. Table 3.2 shows the five strategies for inquiry was proposed by Yin. They are experiment, survey, archival analysis, history and case study. Each type of strategy will be used based on three conditions; type of research questions as explained above; whether control over behavioural events is required (case studies do not have control of behavioural of event and are not like experiments); and, focus on contemporary events.

The exploitation of university technologies is interrelated with personal factors, the internal organisational factors and external environment. Basically it involves multiple factors and multiple actors. Thus, it could be concluded that the general research question "what explains why some patents were exploited and others were not" fits with the case study strategy.

iii) Focus on contemporary events and real life.

Case studies can also be used as an empirical inquiry tool to investigate a contemporary phenomenon in real life. But in this work the researcher also deliberately wanted to study the contextual conditions that are highly pertinent to the phenomenon of the process of the decision-making in the overall process of commercialisation of university technologies. The survey technique could also be used to study this contemporary phenomenon but its ability to investigate the context is limited.

Table 3.3: Strengths and weaknesses of the case study

Source of Evidence	Strengths	Weaknesses
Documentation	Stable-repeated review Unobtrusive-exists prior to case study Exact names etc. Broad coverage - extended time span	Retrievability-difficult Biased selectivity Reporting bias - reflects author bias Access -may be blocked
Archival Records	Same as above. Precise and quantitative	Same as above Privacy might inhibit access
Interviews	Targeted - focuses on case study topic Insightful-provides perceived causal inferences	Bias due to poor questions Response bias Incomplete recollection Reflexivity-interviewee expresses what interviewer wants to hear
Direct Observation	Reality-covers events in real time Contextual-covers event context	Time-consuming Selectivity-might miss facts Reflexivity-observer's presence might cause change Cost-observers need time
Participant Observation	Same as above. Insightful into interpersonal behaviour	Same as above Bias due to investigator's actions
Physical Artefacts	Insightful into cultural features Insightful into technical operations	Selectivity Availability

(Source: http: //www.arches.uga.edu~rtanis/casestudy3.htm. Dated 13/7/04)

The strength of the case study is its ability to deal with a full variety of evidence - documents, artefacts, interviews, and observations. Although there are multiple evidences that can be used in a case(s) studies, the six sources of evidences as suggested by Yin (2003) have strengths and weaknesses as depicted in Table 3.3.

Documentation and interviews were used as instruments to conduct the case in this study. The use of documentation gave the researcher the advantages of repeated views; the document can be read prior to engagements with the case. However, the disadvantage in this study is that not all documents were accessible which will be further explained in the limitations of the study.

Interviews which form the main instrument in this study, have the advantage that they focus on targeted case(s) of three types of patents. However, they have the disadvantage that the interviewees may express what the interviewer wants to hear.

3.1.2 The use of qualitative research in previous studies

Previous empirical studies on patent exploitation have been reviewed (Chapter 2). These studies only focused on the separate issues of licensing or spin-offs or were combined in a general study of licensing activities. None of the studies have focused comprehensively on the decision making process of patent commercialisation either to license the patents to established companies or to create spin-off companies. The methodologies used in previous empirical research in the area of the commercialisation of university technologies are listed in Appendix B. Most of the studies used quantitative approaches to study spin-off companies started since the early 1980s (Appendix B1). Only recent studies of spin-off formation, have adopted a qualitative approach using case study or interviews methods (see Appendix B2). For example, Leitch (2004), Wright et al. (2004) and Vohora et. al. (2003) all employed case study techniques to investigate the formation of spin-offs in the UK. However, there are not many licensing and patenting studies which have adopted a qualitative approach (see Appendix B3). Some qualitative studies only focus on one particular university. (e.g. Wallmark, 1997; Leitch, 2004; Nerkar and Shane, 2003; Shane and Stuart, 2002; Shane, 2001; and Shane, 2004). Even though these studies only focused on a single university, the universities chosen are active in commercialisation activities (e.g. MIT, Queen University in Belfast and Chalmers University in Sweden).

The majority of empirical studies have been principally conducted through the use of secondary data (mostly AUTM or other secondary data) (e.g. Shane, 2001; Dante Di Gregorio, 2003: O'Shea et al., 2005; Chukumba and Jensen; 2005); Chapple et al., 2005; Shane, 2002 and Henderson et al., 1998). Case studies have been used by Blair and Hitchen (1998); Leitch (2004); Wright et al. (2004); Vohora et al. (2003) and Siegal (2004) to study the licensing activities and the process of spin-off and its development. Three studies used longitudinal studies (e.g. Wallmark and Sjosten (1994), Perez and Sanchez (2002) and Leitch (2004).

3.2 RESEARCH DESIGN

According to Yin (2003), a research design is the logic that links the data to be collected and conclusion to be drawn to answer the initial questions of the study. A research design is a logical plan for getting from 'here to there', where 'here' is a set of questions and 'there' is a set of conclusion to be drawn about the research questions.

There are five components of a case study design as suggested by Yin (2003). They are:

a. a study question,
b. its proposition,
c. its unit of analysis, selecting the cases either single or multiple cases,
d. the data collection, and
e. how to analyse and interpret the data.

Component one was already explained in Chapter 2. Component number two will be discussed in every analysis chapters. The rest of this chapter will focus on what the unit of analysis is, data collection procedures and how the data is analysed as well as the limitations of the study.

3.2.1 Unit of analysis

Yin (1994; 2003) gives a general guide to the definition of the unit of analysis (or as a case) by stating that it is related to the way the initial research questions have been defined. Identification of the unit of analysis is an important element in order to determine the population, sample size and sampling strategy. This means that the primary focus of the data collection will be on what is happening to the unit of analysis in a setting and how the unit analysis is affected by the setting. Each unit of analysis implies a different kind of data collection, a different focus for analysis of the data, and a different level at which statements about findings and conclusions would be made (Patton 2000, Yin 1994). Patton (2000:229) stated that:

> *"The key issue in selecting and making decisions about the appropriate unit of analysis is to decide what it is you want to be able to say something about at the end of the study".*

In this study, from the research question that was identified, the patent is the unit of analysis. The aim is to find out what explains why some patents are exploited and why some of them are not. Who decides to patent a scientific discovery and how and why are the routes of exploitations chosen? Why is one particular route is chosen rather than the other one? So the main focus of the units of analysis are the patents and the subunit of analysis are the process of decision making by the actors involved.

3.2.2 The University of Strathclyde: a case-based approach

Every university has some similar and some different practices in the commercialisation process. The intention of this study is to use a case of a university in the UK to examine decision-making in the commercialisation process. The University of Strathclyde has been selected as the preferred case study for three main reasons. First, the University of Strathclyde has the highest number of granted patents in the UK universities (Times Higher 13/6/2003:9). Second, the requirements of the research require a focus on one particular case in order to explore, in depth, the commercialisation decision-making process. Third, the researcher is a PhD student in the University of Strathclyde; this enhances access to key individuals. The history and background of the university will be explained in Chapter 4 (Section 4.11).

The decision to choose the University of Strathclyde as a single case study is also based on the argument that qualitative inquiry typically focuses on relatively small samples and the sample can be selected objectively according to the aims of the research as stated in Chapter 1 (Patton, 2000). According to Yin (2003), a single case is chosen to determine whether a theory's propositions are correct, to test the existing proposition, and can contribute to knowledge and theory building. Similarly as suggested by (Scholz and Tietje, 2002:11) in choosing a single case design, a case may be considered unique, prototypical, salient or revelatory in the understanding of a phenomenon or problem. Multiple case studies are important when issues of generalisation are important (Yin, 2003). In terms of specific case study designs Yin (2003) distinguished four basic types; single and multiple case designs, which can either be holistic (single unit analysis) or embedded (multiple unit analysis). This is shown in Figure 3.2.

The single case design is justifiable to test existing theory. Multiple cases are often considered more convincing and are claimed to give more robust results. Yin (2003:47) considered multi cases as multiple experiments, of which the same study can be replicated but is more expensive and time consuming. This method allows for close correspondence between theory and data, a process which is desirable whereby the emergent theory is grounded in the data (Eisenhardt, 1989; Yin, 1994; Yin, 2003).

Figure 3. 2 Basic types of designs for case studies

	Single case designs	Multiple case designs
Holistic (single - unit analysis	Type 1	Type 3
Embedded (Multiple unit of analysis)	Type 2	Type 4

(Source: Yin, 2003: 40)

Multiple cases should be chosen carefully. There are three main types of cases (Punch, 2005): i) The intrinsic case study, in which the study is undertaken to get better understanding of the case. ii) The instrumental case study, where a particular case study is examined to refine a theory. iii) The collective case study, where the instrumental case study is extended to cover several cases to learn more about a phenomenon or population of the study. Bryman (2004) suggested that one approach to the selection of cases for a multiple study is based on extreme types such as successful and unsuccessful firms.

The approach in this study is Type 2 cases (according to Yin, 2003), that is embedded multiple units of analysis in a single case study, or type (iii), collective case study suggested by Punch (2005). To refine the efficiency of the decision making in the commercialisation process, as suggested by Bryman (2004), two types of patents, unexploited and exploited patents, were chosen as multiple cases within a single university.

3.2.3 Selecting the number of cases

Multiple cases (patents) were chosen in this study based on purposely sampling, sometimes called purposive or judgment sampling (Patton, 2002; Yin, 2003). In judgment sampling *"you decide the purpose you want informants to serve, and you go out to find some"* (Patton 2000:230). According to Ritchie and Lewis (2003), purposive sampling is also known as criterion based sampling, a key feature of which is that sample criteria are prescribed. Sample units are selected on the basis of known characteristics, which might be socio demographic or might relate to factors such as experience, behaviour, roles etc, which are relevant to the research topic. Units are chosen to represent and symbolise prescribed groups or characteristics and to reflect the diversity of the study population as fully as possible.

To answer the research questions in this study, three sub-samples (unexploited patents; patents that were exploited through licensing to spin-off companies and patents that were exploited through licensing to established companies) were purposely chosen. A total of 22 patents were selected, and divided into three sub samples; 10 patents were unexploited and 12 patents were exploited (patents that were licensed to spin-offs and licensed to established company). Out of

12 exploited patents, 6 patents were licensed to the established companies and 6 patents were licensed to the spin-off companies. Multiple cases were chosen to provide greater potential for generalisation than a single case.

In selecting cases in this study, there is no precise guide to the number of cases to be included. The decision is left to the researcher (Romano, 1989) and Eisenhardt (1989) recommended that the cases should be added until "theoretical saturation" is reached. Lincoln and Guba (1985:204) recommended sampling selection to the point of "redundancy". Similarly Patton (2000) does not suggest an exact number of cases as guideline for the researcher. Eisenhardt (1989:545) suggests between four to ten cases. From these recommendations, it was concluded that 22 cases would be sufficient.

3.2.4 Population size

According to the list of portfolio patents provided by Research and Consultancy Services (RCS), the University of Strathclyde had a total of 82 live and expired patents in the period of 1977-2003. Of that total, 11 patents were excluded (because 8 patents were licensed to bankrupted companies, and 3 patents were under contract research). This gives a revised total population of 71 patents. However, 28 patents could not be accessed, either because the inventors had left the university, had joined industry or had retired. That reduced the total of available patents to 43. Of this number, only 22 patents were studied. The inventors of the other 21 patents could not be interviewed because they were too busy, or refused to be interviewed because of the secrecy of the projects that involve license agreements. The participation rate is 51% (22 patents divided by 43 patents), after taking into account the non-response rate, which is considered a valid data collection as discussed above. The details of the population size and the sample size that were accessed are depicted in Figure 3.3.

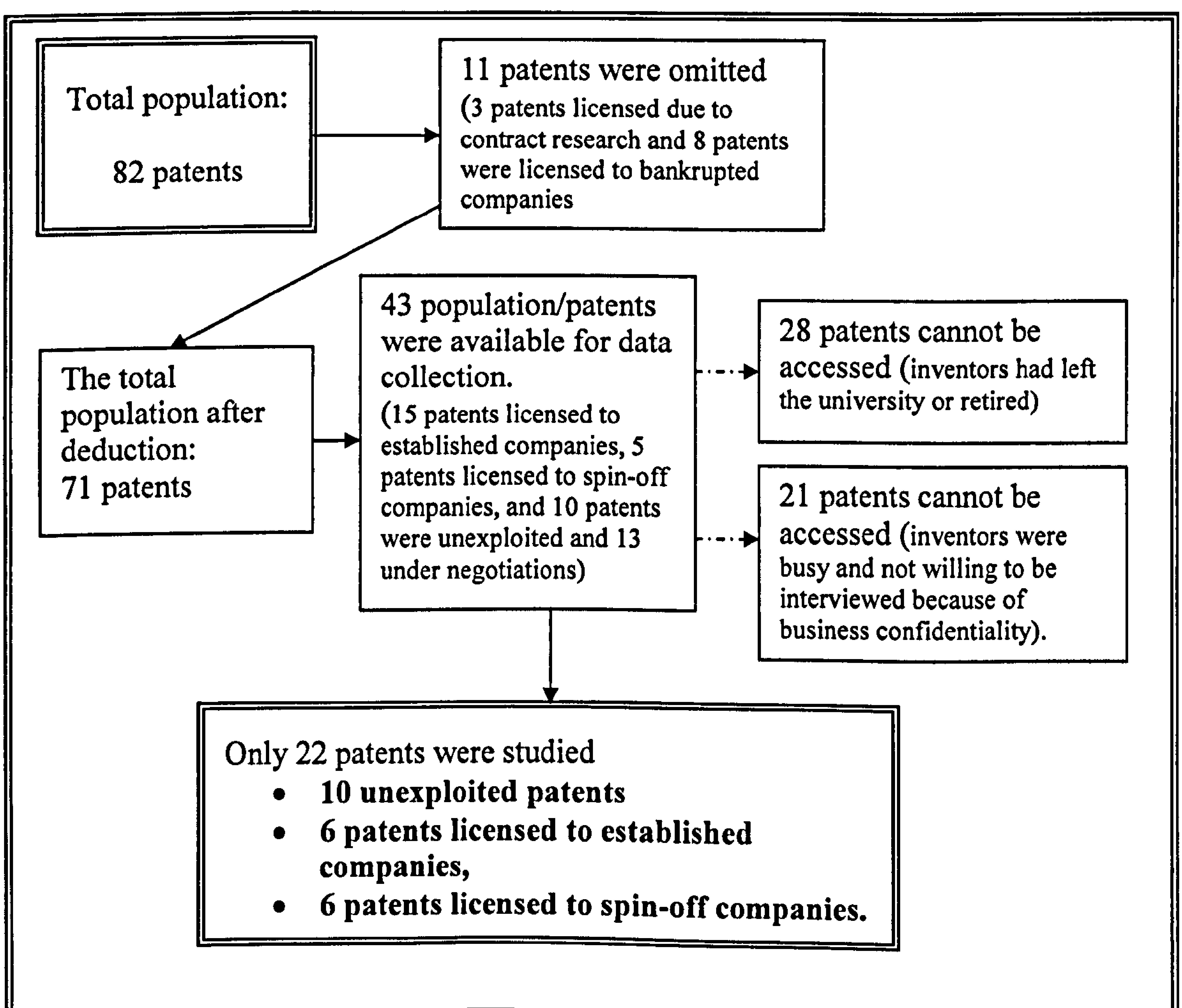
3.3 GETTING ACCESS

Creswell (1998) observed that it is often necessary to gain access to data via a gatekeeper. Establishing rapport with the gatekeeper is therefore extremely important before the data are collected. In this study the-gatekeepers were the Director of the

Research and Consultancy Services, whose approval was required before any information was made available, and an Intellectual Property Officer (IPR officer) who actually provided the patent information. The general processes of patenting and commercialisation activities of the University of Strathclyde were discussed using semi-structured questions at a preliminary meeting. This initial meeting helped to refine theoretical framework. Without practical experience, it is difficult for the researcher to grasp theoretical concepts presented in the literatures and translate them into useful constructs and definitions (Creswell, 1998).

Not all documents in the TTO office could be accessed. The documents that could be accessed were the granted patents list, patent publications, the granted individual patents (that were already published) and patents application (patents pending but the researcher was allowed to access the patent publications). Other written documents, information and regulations (if any) about the process were not accessible.

Figure 3. 3 Flowchart for sample selection



The IPR officer was briefed on the nature of the research and its objectives, and on the basis of this information identified the potential inventors to be interviewed based on the three types of patents (not commercialised, commercialised via spin-outs and commercialised through licensing). In reality, therefore, the selection of the inventors to be interviewed was controlled by the IPR officer not by the researcher, which may have led to unknown sample selection bias.

The researcher was not able to interview all the inventors. Some of the inventors left the university, joined industries and retired. Of those who were still in the university refused to be interviewed. The reasons were already explain in Section 3.2.1 (3) (population size). Those investors who agreed to the interview were very welcoming. However, the inventors were not willing to answer the questions that involved confidential issues, thus, limiting the discussion.

Even though the researcher tried to probe to get the answer to sensitive questions, some inventors-especially those who licensed their patents to the established companies-gave the answer '*I do not know*'. During the interview with the inventor-entrepreneurs, it was found that some of them were very secretive about certain issues such as funding and sensitive university policies.

3.4 METHOD OF DATA COLLECTION

3.4.1 Principles of data collection

Yin suggested (2003) three principles of data collections to increase the validity and reliability of the study.

i. Use multiple source of evidence.

A case study is much more convincing and accurate if it is based on different sources of information. Multiple methods tend to have greater validity and reliability than a single methodology approach (Yin, 1984; Yin, 1994; Denzin and Lincoln, 2000; Gillham, 2000; Yin, 2003). Patton (2002) identified four basic types of triangulation: i) data triangulation: the use of several data sources in a study; ii) investigator triangulation: the use of several different researchers or evaluators; iii) theory triangulation: the use of multiple perspectives to interpret single set of data;

and iv) methodological triangulation: the use of multiple methods to study a single problem or program.

In this study, the main data were collected through interviews, which will be discussed in the next section. In addition, documentation data (e.g. list of granted patent, granted patent publications and related internal records), websites (the university's UK websites, the RCS website and pamphlets and companies websites), email and secondary data (reports and newspaper cutting) were also used as triangulation methods of data collection. According to Yin (2003), the use of documentation is important for case studies to corroborate and augment evidence from other sources. Yin (2003) gives three reasons why documents are important: (i) in verifying the correct spellings and titles or names of organisations that have been mentioned in the interviews, (ii) they provide other specific details to corroborate information from other sources, and (iii) it is possible to make inferences from documents, for example, by observing information in the documents, new questions and networking within an organisation could be asked and accessed.

ii. Create a case study database

According to Yin (2003) any notes resulting from interview should be stored so that they can be retrieved and reviewed later on. In this study, responses from interviews (tapes that were transcribed and note taking) were used to develop a case study database (Vohora, et al, 2003), which included table shells to record data (Miles and Huberman, 1994). These tables outlined the data collection based on research questions and verified the same information was being collected for all cases in the same group of patent. In addition, other documents that were given by the interviewees were studied and kept in files for retrieval and review.

iii. Maintain a chain of evidence

This allows the researcher or other observers to trace back their evidence in any direction (such as to trace back the evidence from the conclusion to the research question or from the research question to the conclusion) of the case study. Maintaining a chain of evidence increases the reliability and the construct validity of the case study (Yin, 2003). In order to trace back the evidentiary process, the report itself must have sufficient citation and evidence to the database, questions and protocol. In this study, the interview was the main method of data collection. The following procedures have been taken before the data were collected.

- Identify a key informant for the university to be visited, the inventors and the founder of the company. Most of them were the main inventors in the research group. Thus, the information gathered was from the main source.
- The patent documents were studied before the interviews were conducted. By doing this, the researcher has better understanding of the inventions during the interview.
- All the documents given by the interviewees during the interviews were filed and studied.
- Interviews would have an open character (short question, long answers).
- Interviews were recorded and transcribed.
- Transcribed interviews were sent to informants for comment and feedback.

3.4.2 Interview as a technique for data collection

According to Patton (1980; 2002) the purpose of interviewing is to allow the researcher to enter to another person's perspective. As Patton (2002:341) noted:

> *"Qualitative interviewing begins with the assumption that the perspective of others is meaningful, knowable, and able to be made explicit. We interview to find out what is in and on someone else's mind, to gather their stories".*

According to Saunders et al. (2003), there are three types of interviews:

i) structured interviews: use questionnaires based on predetermine or standardise set of questions.

ii) semi-structure interviews: the researcher will have a list of themes and questions to be covered. In particular interviews some questions may omitted and additional questions may be required to explore the research questions and objective given.

iii) unstructured interviews: This is informal interview to explore in a particular area in depth. No predetermined questions are needed.

Bryman (2004) and Easterby-Smith et al. (2002), noted that there is a growing tendency for both semi-structured and unstructured interviewing to be referred collectively as in-depth interviews or as qualitative interviews. In-depth interviews are often an appropriate method in qualitative research (Warren, 2002). Saunders et al. (2003:248) pointed out that semi-structured and in-depth, or non-standardised, interviews are used in qualitative research in order not only to reveal and understand the 'what' and the 'how' but also to place more emphasis on exploring the 'why'. According to Robin (2002:59), various types of interviews may be used to gather information and assist each kind of study (see Table 3.4).

Table 3.4: Uses of different types of interview in each of the main research categories

	Exploratory	**Descriptive**	**Explanatory**
Structured		//	/
Semi-Structured	/		//
In depth	//		

(Sources: Saunders, 2003).Note: // = more frequent, / = less frequent.

In an exploratory study, semi-structured and in-depth interviews can be very helpful to find out what is happening and to seek new insights and may be used to understand relationships between variables. From the above discussions, it is clear that in-depth, semi structured interview is the appropriate approach in this study.

According to Easterby-Smith et al. (2002:87) in depth interviews are appropriate in five conditions, which all apply in this research:

i) When the purpose is to seek understanding of the constructs that the interviewee uses as a basis for his/her opinions and beliefs about a particular matter or situation.
ii) When the aim of the interview is to develop an understanding of the respondent's world.
iii) When the step-by step logic of a situation is not clear
iv) When the subject matter is highly confidential or commercially sensitive.

v) When the interviewee may be reluctant to be truthful other than in a one-to-one situation.

Patton (2002: 324-347) suggested three basic alternative approaches to open - ended interviews:

i) The informal conversional interview. This relies entirely on the spontaneous generation of questions in the natural flow of an interaction, often as part of ongoing participant observation fieldwork.
ii) The general interview guide approach. This involves outlining a set of issues that are to be explored with each respondent before interviewing begins, and serves as a basic checklist during the interview to make sure that all relevant topics are covered.
iii) The standardised open-ended interview. It consists of a set of questions carefully worded and arranged with the intention of taking each respondent through the same sequence and asking each respondent the same questions with essentially the same words.

3.4.3 Actual interviews

The discussion of the literatures in Chapter 2 and Section 3.2.1 identified the following, from the institutional perspective, as factors that affect the commercialisation of university technologies. They are the TTO directors, the inventors, venture capitalists, licensees, resources and capabilities of the TTOs, the inventor's networking and involvement, and the policies and organisational support provided by the universities concerned. To understand the process of decision-making within the university in the commercialisation of university technologies, interviews were conducted with the main actors involved. They are the TTO personnel, including the director, and the inventors.

A total of 32 interviews were conducted. The interviewees were divided into three main groups. The first group were with the director of the University of Strathclyde, Research and Consultancy Services (RCS) and three staff officers in charge of the commercialisation efforts. The second group was the six directors of TTOs from selected UK universities. The third group was the inventors from the University of Strathclyde whose scientific discoveries had been patented.

Interview guides were used with standardised open-ended questions (Appendix C) for each group (Appendix C1; C2; C3 and C4). All interviews were recorded and in addition, notes were taken.

Probing questions, which were not in the original interview guide, were used in all interviews to explore certain subjects in depth, and thus, allow inclusion of new areas or dimensions of inquiry that were not originally included or established in the original questionnaire guides. These probing questions, additional to the prepared interview guides, were suggested by Miles and Huberman (1994) and Patton (2002). Similarly, Easterby-Smith et al. (2002:93) have also pointed out that in case studies, probing questions can be useful as an interview technique to improve, or sharpen-up the interviewees' responses.

i. Interviews with Research and Consultancy Services (RCS) staffs

The first interview was conducted with the Director of Research and Consultancy Services (RCS) the University of Strathclyde in early 2004. After that, four more interviews were conducted with the Director, which spread over a period of four months. The main purpose of the interviews was to gain in depth views on patenting and commercialisation activities and practices at the University of Strathclyde, and to gain access to the patent data files. A further seven interviews took place with RCS staff officers during the study to gain a deeper understanding of the real process of patenting and commercialisation and to focus on specific issues.

ii. Interviews with the Directors of Technology Transfer Offices of selected universities

The literature reviews found no evidence of the process of patent commercialisation in the UK universities. In order to fill this gap, the Directors of six University Technology Transfer Offices were interviewed (excluding the University of Strathclyde)[7]. The details of the universities involved are shown in Table 3.5. The criteria for selecting the universities were as follows:

- links with either the first or the second supervisor of the author, increasing the access.

[7] Discussed separately in chapter 4

- They are active in technology transfer activities.
- To achieve a balanced view between the English universities and the Scottish universities in technology commercialisation activities.

The interview was mainly to get an understanding of the process of patenting and commercialisation in each university. The questions asked were mainly on how decision making on patenting and commercialisation activities were conducted.

Table 3. 5: The universities involved in the interview

Number	University	Key informant
1	University of Glasgow	The Director of the TTO
2	University College of London	The Assistant Director of the TTO
3	University of Warwick	The Director of TTO (Warwick Venture)
4	University of Edinburgh	The Director of TTO
5	Heriot-Watt University	The Assistant Director of TTO
6	University of Southampton	The Director of TTO

In the interviews there were also particular focus on funding, how patents have been exploited, how marketing has been undertaken, how the networking has been built-up, at what stage of the technologies that decisions were taken to apply for patent and to start commercialisation efforts, and the university's general policies on commercialisation activities. The differences and commonalities of the commercialisation practices between the universities are reported in Chapter 4.

iii. Interviews with the inventors in University of Strathclyde

The inventors were contacted through the 'PEGASUS' online staff directory based on the list given by the RCS's IPR officer. Letters were sent and followed up by emails and telephone calls. The first group of interviews were conducted with inventors whose patents were not exploited. Initially seven inventors were interviewed. Three more inventors were subsequently added. The second group of interviews were with the inventors whose patents were licensed to spin-off companies. Even though the University of Strathclyde has more than 30 spin-off companies, most of the companies are exploiting know-how rather than patents that were granted to the university. Only six companies were involved.

During these interviews, questions were asked about the background of the companies that their patents were licensed to, background of their inventions and how long it took for the technologies to be taken to the market place. Other questions were how the opportunities were recognised, why they decided to form a company, how the management team was formed during pre-set-up and after set-up periods, access to funding, the IPR policies that concerned them, exclusivity of the licenses, how the company initially found their customers or marketing, how they built networking, commitment and what are the university policies that were related to the commercialisation process which led to the this particular exploitation route.

The last group of the inventors were those whose patents have been licensed to established firms. More than half of them could not be interviewed because they had either left the university to join other companies, had retired, were too busy, or the projects were highly confidential. Only five inventors were willing to be interviewed. The questionnaires for this group was shorter compared to the other two groups since RCS played the major role in the process of licensing the patents to established firms. The interviews ranged from about forty-five minutes to two hours and all the interviews were recorded. Notes were also taken. The departments of the inventors are shown in Tables 3.6-3.8. The departments involves are Pure and Applied chemistry, various Engineering departments, Pharmaceutical Sciences, Computer Science, Bio engineering and Physics. All these departments are active with patenting and licensing activities.

Table 3.6: Unexploited patents and their departments

Num/Total	Inventors' departments	Technology invented
1	Education and computer	Producing a three dimensional image
1	Electrical and Electronic Engineering (EEE) department	Sensors and Micro-system
1	Centre for Photonics	Trying to produce blue LED[2].
1	Pure and applied Chemistry	To develop Sensors from black strip plastics.
1	Naval architecture and Marine Engineering.	Submersible craft
1	EEE	To develop novel gas separation..
1	EEE	Signal processing technology- FENN[3]
1	Pure and applied Chemistry	DNA
1	Pharmaceutical science	Vesicle formulation
1	Pure and applied chemistry	Tissue culture
Total = 10.		

[2] Light Emitting Diodes
[3] Functional expanded Neural Network

The total period taken to accomplish the data collection was more than one year, including interviews with the six TTO directors. The interviews started in January 2004 when the initial meeting was held with the RCS director of University of Strathclyde and the series of interviews were finished by the middle of June 2005.

Table 3.7: Exploited patents, licensed to spin-off companies

Num/total.	Inventors/department	Technology invented
1	Bio engineering	Activity monitor
1	Physics	Gas Sensor
1	Computer Science	Data Compression
1	Electric and Electrical Engineering.	GIS Monitor
1	Mechanical Engineering	3D imaging system
1	Pure and applied Chemistry	Hydrogel
Total = 6		

Table 3.8: Exploited patents licensed to established firms

Num/total	Department	Invention
2	Pure and applied Chemistry	DNA system
1	Pure and applied Chemistry	Cancer Drug
1	Pharmaceutical	Obesity drug
2	Bioengineering	Prosthetic Elbow Joint
Total = 6		

3.5 ANALYSING THE DATA

To analyse the interview transcripts, the software package Nvivo was used as an aid. The advantages and disadvantages of Nvivo are discussed below.

3.5.1 The advantages and disadvantages of Nvivo

The Nvivo software is an aid to analyse qualitative data but it cannot analyse the data in it self. The software only can be used to facilitate the analysis process (Silverman, 2000; Weitzman, 2002).

- **The advantages**

1. *Speed.* The use of the software package should save some time for the researcher especially when dealing with a large amount of qualitative data. It is able to do automated coding, to search, code and recode. These features encourage the researcher to conduct multiple searches that apply to particular questions. It can also quickly re-sort a database, and re-assign chunks of texts, which enables and encourages the researcher to revise the analysis many times

as suggested by Weitzman (2002). The researcher saved a lot of clerical work that would have been necessary with manual methods and was also able to draw conceptual maps that assisted the development of the consequent theoretical models (Seale, 2002).

2. *Analytic rigor.* The Nvivo software helps the researcher to undertake more rigorous analysis and helps in making the conclusions from the findings. By using the software, the computer coding forces a more careful and detailed reading of the interviews as suggested by Seale (2002:656). The software was also used to generate a listing of all the coded segments which allowed the researcher to code these into subcategories as suggested by Silverman (2000).

3. *Consistency.* The software helped the researcher with consistency. The software gives the researcher ability to compare a code or combinations of codes and enable the researcher to see the relationship of the codes. Thus, the researcher was able to easily review all the data to give a conceptual category or theme and decide whether the categories belong together. This feature was discussed by Weitzman (2002).

- **The disadvantages.**

1. *A narrow approach to analysis.* Using a software package as an aid might narrow down the analysis to more systematic coding. A researcher might miss the nuances and preferences of the language used by the actors, such as the choices of words, and the intonation the words were said (Silverman, 2002:163).

2. *Auto coding.* The 'auto coding' feature of the software may encourage the researcher to take shortcuts (Weitzman, 2002). The researcher may fail to check 'what passages' were actually coded in the auto-coding process. This may lead to premature theory building. The software in itself cannot do the coding and the analytical thinking for the researcher (Lewins and Silver, 2005).

These disadvantages and cautions which were raised by Weitzman (2002) and Lewins and Silver (2004) were taken seriously by the researcher when using the software package. Multiple runs were conducted and a final check was done with the original transcript.

3.5.2 Actual analysis

Qualitative analysis transforms data into findings, but no formula exists for that transformation (Patton, 2002: 432; Punch, 2005). However, guidance to conduct analysis is suggested by many authors. Miles and Huberman (1994: 10-11) suggested three main components of data analysis which interact with each other during the analysis: i) data reduction, ii) data display, and iii) drawing and verifying conclusions.

In this study, the Nvivo package was used to help data reduction, data displays through coding, re-coding, editing, storage, search and retrieval, data linking, and merging of categories together. The data were coded as explained below. Data reduction occurred continually throughout the analysis and became part of the analysis. Data displays included tables, charts and diagrams which were mainly part of the coding operation. The third part was developing propositions.

i) First level analysis

The first step in this study was transcribing the interviews. The audio tapes were played on a transcription machine. Each tape was labelled and Word files stored in pen drives and hard disk in rich text format. During the transcription of the data, the researcher was not overly concerned at the quality of grammar but more about the quality of the correct conveyance of meaning as close as possible to the style of language of the interviewees. This process took more than six months to complete. Almost 250 pages of transcripts were produced, typed using Microsoft Word software package. The transcripts were then sent to corresponding interviewees for validation. These files were then imported into the Nvivo software package. The entire files were named as 'PhD 324' project.

ii) Coding

In Nvivo, coding is a way of expressing thinking 'up' from the data by making nodes of the transcripts as suggested by Bazeley and Richards (2000). The

Table 3.9: A qualitative procedure

1.	**Code as soon as possible.** This is to avoid being swamped by the data
2.	**Read through your initial set of transcripts, field notes, documents etc.** without taking any notes or considering an interpretation; perhaps at the end jot down a few general notes about what struck you as especially interesting, important, or significant.
3.	**Do it again.** Read through your data again. But this time begin to make marginal notes about significant remarks or observations. Makes as many as possible. Initially, they will be very basic-perhaps key words used by respondents, names that you give in the data. When you this you are coding-generating an index of terms that will help you to interpret and theorise in relation to your data.
4.	**Review your codes.** Begins to review your codes, possibly in relations to your transcripts. Are you using two or more words or phrases to describe the same phenomenon? If so, remove one of them. Do some of your codes relate to concepts and categories in the existing literatures? If so, might it be sensible to use these instead? Is there some evidence that respondents believe that one thing tends to be associated with or caused by something else? If so, how do you characterise and therefore code these connections?
5.	**Consider more general theoretical ideas in relations to codes and data.** At this point you should be beginning to generate some general theoretical ideas about your data. Try to outline connections between concepts and categories you are developing. Consider in more detail how they relate to the existing literature. Develop hypotheses about the linkages you are making and go back to your data to see if they can be confirmed.
6.	**Remember that any one item or slice of data can and often be coded in more than one way.**
7.	**Do not worry about generating what seem to be too many codes.** At least in the early stages of your analysis; some will be fruitful and others will not-the important thin is to be as inventive and imaginative as possible; you can worry about tidying things up later.
8.	**Keep coding in perspective.** Do not equate coding with analysis. It is part of your analysis, albeit an important one. It is a mechanism for thinking about the meaning of your data and for reducting the vast amount of data that you are facing. You must still interpret your findings, which means attending to issues like the significant of your coded material for the lives of the people you are studying, forging interconnection between codes, and reflecting on the overall importance of your findings for the research questions and the research literature that have driven your data collection.

(Source ; Bryman 2004, pp 408-409)

researcher also applied Bryman's (2004:408) 8 steps of analysis procedures as shown in Table 3.9 and Dey's (1993) steps as shown in Table 3.10 for the analysis. Dey's steps are basically good practices in analytical data coding. These steps were done for the first five interviews to get the 'feel' of breaking down the data. Once that was achieved, the researcher then proceeded to code and analyse the whole data.

Table 3.10: Good practice in creating nodes

1.	Become thoroughly familiar with the data
2.	Always be sensitive to the context of the data
3.	Be flexible-extend, modify and discard nodes
4.	Consider connections and avoid needles overlaps
5.	Record the criteria on which coding decisions are to be made.
6.	Consider alternative ways of categorising and interpreting the data.

Source: Dey (1993)

As the data were being collected using semi-structured questionnaires, some of the codes were already in the researcher's mind. These codes were based on theoretical guidance, research questions or the phrases or ideas as suggested by Striling (2003).

The researcher used free coding, or open coding, as suggested by Strauss and Corbin (1998) and Bazeley and Richards (2000). The transcripts were read a few times before coding to identify and ensure the real concepts and the process of each case. The same procedure was done to each type of transcript for each type of case (22 patents) and the seven TTOs. During the open coding process, the data were broken down into discrete parts, closely examined, and compared to find similarities and differences.

New elements and new concepts emerged as more transcripts were coded. Interpretations or definitions of nodes were given as guidance to the researcher. A total of 143 codes or concepts were established based on the free coding. These codes included new emerging themes which were identified to stem from the unexploited patents data. Example of these codes were university-industry (U-I) gap such as: company copy the invention, not invented here (NIH) syndrome, and patent as strategic reasons or as an industrial secret. A sample of coded transcript of patent that was not exploited is shown in Appendix D. These basic codes or concepts, or axial coding according to Strauss and Corbin, (1990) are able to provide understanding or to provide new aspects that become major concerns to the aim of this research.

iii) Second level analysis

From the free nodes the researcher transformed the data to the node tree. The node tree is an important aspect of analysis, as it allowed modification of the initial results mentioned above. The reasons for having a node tree are to keeps things tidy; to represent taxonomy; to gain an overall view of the growing conceptual framework; to prevent node duplication; and to form the basis for using matrix searching (Gibbs, 2003:135). The node tree can be used for keeping similar nodes together under a shared parent. This requires two things: an appreciation of what the nodes have in common and the recognition of what node might be their parent. The understanding of the relationship between the groups of nodes and their common parent are the key aspect in building a node tree (Gibbs, 2003).

In this level of analysis the free nodes were clustered or categorised into ten major headings or selective codings as suggested 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.

These steps allowed the clustering of the coded themes into categories that shared similar or distinctive conceptual themes or new emerging themes. The 10 main themes and their 'children' are shown in Table 3.11. These themes were discussed in every finding chapter (Chapters 5, 6 and 7) and in the discussion chapter (Chapter 8).

Then the analysis went into another round of refinement. In this next stage, the 10 original themes were refined to seven themes. This stage of refinement is discussed in Chapter 9. The inventors' backgrounds, companies' backgrounds and patents were clustered into the stage of technology or backgrounds. These themes were refined to: stage of technology or technology background; opportunity recognition/industry experience, motivation; funding; inventors' roles; the TTO roles; and the University support and incentive.

Table 3.11: The ten major themes

Parent nodes	Children or siblings nodes
1. Inventor background	• Industry background • Qualification background
2. Company background	• The company formation • Surrogate entrepreneur or fulltime • The founding of management team
3. Stage of technology or background	• Research history • Application /potential commercialisation • Stage of the technologies or why not exploited • Industry refuse to exploit university technology
4. Patent	• Exclusive/ non-exclusive • Number of patent produced • Single or family patent • Who decide to patent • Strategic reasons or secret
5. Opportunity recognition	• Who is recognised the opportunity (Inventors, the TTO or industry) • Who is decided to commercialised
6. Motivation	• What are the trigger factors to commercialise the inventions. • Why spin-off or license to established company
7. Funding	• Research and spin-off funding • The amount and who funded the inventions (industry, government or charities bodies) • Funding problems (Bootstrap, personal saving and loan).
8. Inventors roles or involvement	• The time devote to develop the product • Networking (consultancy with industry, conference and publications)
9. The TTO(s) roles	• Networking with industry and faculty members • Skills and capabilities (do not have due diligence system, Do not have skills in evaluates all technologies field.
10. Incentive and reward/support/culture	• Taking equity by the University • Reward for commercialisation activities • Infrastructure and business coaching supports • Culture

- **Third level analysis (Interpretation of the data)**

After the data reduction through coding as explained above, further analysis of the data was done by looking into each case of the 22 patents, and then extending the analysis to cross case. Data display of the theoretical propositions (Miles and Herman, 1994), rival explanation(s) and explanation building (analytic induction[8]) techniques as suggested by Yin (2003) and Gibbs (2002), were used to support the analysis of each case and cross cases of the 22 patents and the TTOs. Quotations from the interviewees were used where appropriate to represent the findings. These themes were then systematically discussed in terms of logical understanding of decision making in the commercialisation process from the six universities, and in the two main types of unexploited and exploited patents.

- **Case by case analysis**

Within case analysis typically involves a detailed case study write-up for every case (22 cases). Eisenhardt (1989) contended that there is no standard format for this analysis, and it often involves pure descriptions to help researchers to get insight of the early analysis process. The main idea within case analysis is to become familiar with the particular data obtained in each case, and initiate sharing the first conclusions. An effective early conclusion of within case analysis will accelerate the cross case-comparisons.

In within case analysis, each of the cases is compared within its own group. The comparative method means that the researcher always attempts to find another case through which to test out a provisional proposition (Silverman, 2000). This involves going back and forth through the interview transcripts to compare the data from different transcripts and to repeated examples of the themes and sub themes (Miles and Huberman, 1994).

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[8] According to Jack (2001) Analytic Induction (AI) is a research logic used to collect data, develop analysis, and organise the presentation of research findings. Its formal objective is causal explanation. AI calls for the progressive redefinition of the phenomenon to be explained (the explanandum) and of explanatory factors (the explanans), such that a perfect (sometime called universal) relationship maintained. Initial cases are inspected to locate common factors and provisional explanations. As new cases are examined and initial hypotheses are contradicted, the explanation is reworked in one or both of two ways ..."

For example in the unexploited patent group, using search nodes, each of the cases is compared based on particular themes or all themes identified. An example for funding code for unexploited patent is given in Table 3.12. The data were analysed based on ***explanation building*** or ***analytic induction*** as suggested by Gibbs (2002), and the results displayed using tables.

Table 3.12: An example within case analysis for unexploited patent. Description of funding (research)

1.	Inventor A	"They give it to engineering department (Mechanical). Three quarters million dollars. This is one part of three projects"
2.	Inventor B	"some of this, funded by the Research Councils. Some funded by industries. Roughly we have 40-60% Research Council"
3.	Inventor C	"The person who did the research was a student. So the departmental student funded the research. So there was no involvement of industry at that time"

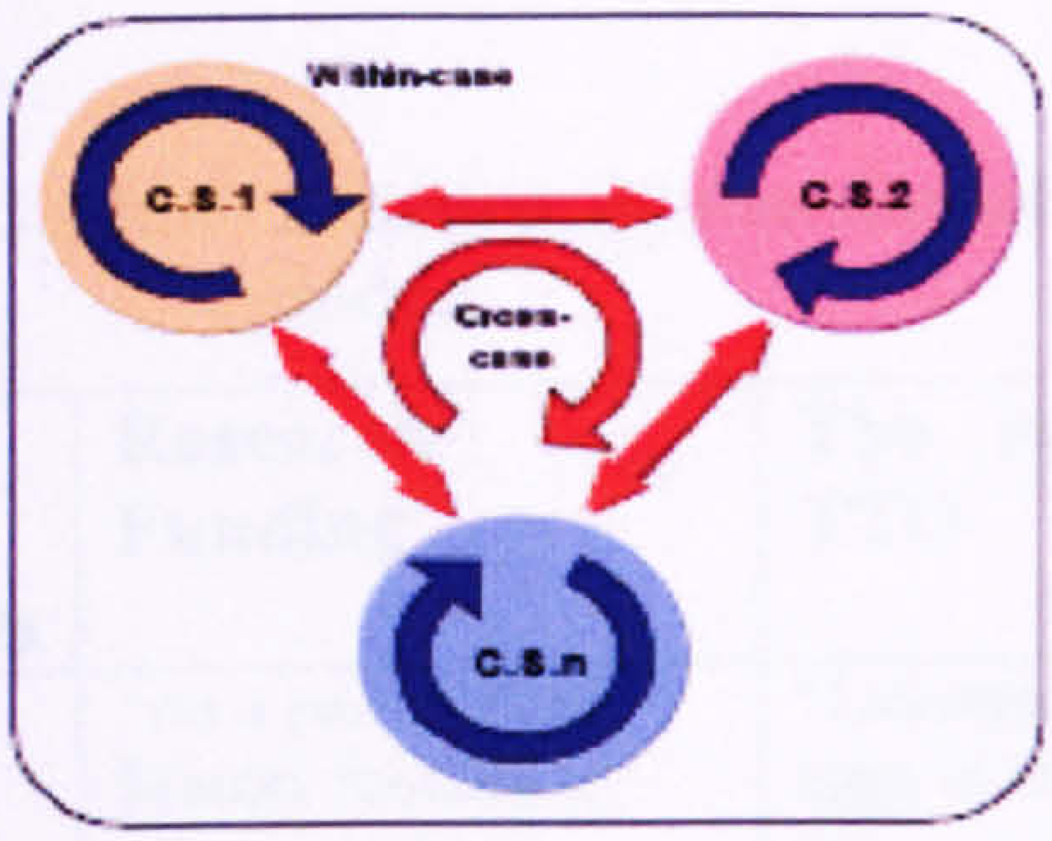
At this stage, the researcher entertained rival or other plausible explanations and referred back regularly to the research questions and the aim of the study as suggested by Gibbs (2002) and Yin (1994; 2003). This was found to be important to avoid drifting away from the main aims of this research. Any rival explanation that was found to be credible was tested with other cases in the data and to the literature reviews.

In the second stage ***tables*** and ***figures*** were displayed to give an easier and better understanding of the flow, location, and connection of events, and could lead to more causal explanations as suggested by Miles and Hurberman (1994). The theoretical propositions as shown in Appendix A, the earlier framework of commercialisation as depicted in Figure 2.2 and the rival explanation and analytic induction were used to integrate the data into a more coherent explanatory framework.

- **Cross case analysis**

The analysis was extended to cross cases, relying on the method suggested by Eisenhardt, (1989) and Miles and Huberman (1994). Figure 3.4 depicted how the data were analysed: C.S.1, C.S.2 and C.S.3 were referred to three type of patents respectively (unexploited patents, patents that were exploited through new spin-offs and patents that were exploited through established companies).

Figure 3. 4: Within case and cross case analysis



Source: (Monux, 2005)

The cross cases were done to corroborate the data from the three types of patents, and examine the similarities and differences between them. Cross cases comparison was undertaken by looking at the data in many divergent ways as suggested by Eisenhardt (1989). First, the patents data were searched using 'matrix intersection' according to the themes required. The passages that were coded from the themes were analysed using the same method (analytic induction or explanation building) as in the case-by-case analysis. Eisenhardt (1989) gave three strategies of analysing cross cases, two of which are relevant here. The first is to compare similar categories which were done by selecting the category dimensions and then looking for within-group similarities with inter-group differences. Secondly, pairs of cases were selected to list the similarities and differences between them. The idea behind the cross case analysis technique is aimed to force the researcher to seek for new insights and impressions that cannot be realised through an individual analysis of each case. This can lead to more understanding of the phenomena that were being studied.

As the study progressed to successive cases, the phenomena were inspected in sets to see whether they fall into cluster or groups that share certain patterns or configurations as suggested by Miles and Huberman (1994). These patterns or 'matrix intersections' were then presented in tabular formats. An example is shown in Table 3.13. In this table only three codes (research funding, the roles of the TTO and the stage of the technology or background of the technologies) which intersect with the three types of patents (A1, B1 and C1) are shown. These types of tables were then turned to straightforward finding tables which are shown in every finding chapter and Chapter 8 to facilitate reader understanding of the discussion of the findings.

Table 3.13: A matrix intersection of cross case analysis. An example the passages coded.

Types of patents	Research Funding	The roles of the TTO	Stage of the technologies or Technology background
A1	"As a part of Ford Motors funding to Mechanical Engineering Faculty"	"University has too many eggs in one basket at one time, and only a few of them will be commercialised"	"I can say it was at an embryonic level"
B1	"Funding has came from industry"	"The university has small investment and equity"	"This is a complete optics. ...and this is a 3D image, ...Our system can put in the desk"
C1	"Both projects were funded by Research Cancer Organisation and European Research Cancer"	" We approached companies, we had companies interviewed and when we started about licensing and after that it involved R & Cs."	".....was my PhD project. The development of this one was funded by ERC to use the one that we had developed"

3.6 GENERALISATION ISSUES

A common critique of case studies is that they provide little basis for scientific generalisation especially from a single case. However scholars are still debating the concept of generalisation. Yin (2003) contended that a case study is like an experiment, which is generalisable to theoretical propositions and not to population or universe. One way to generalise findings from a case study is to use multiple cases (Eisenhardt, 1989; Yin, 2003; Bryman, 2004). On the other Denzin (1983) pointed out that generalisation should not necessarily be the objective of all research projects, whether case studies or not. Punch (2005:146) pointed out that whether a case study could be generalised depends on two factors: the purpose and how the case is analysed. The first is by conceptualising rather than description and by developing propositions. The use of non-standardised interviewing could expose the study to the risk of producing biases in research findings.

Qualitative research cannot be generalised based on populations as in a quantitative study. It is rather based on analytical generalisations (Yin, 2003), and the factors and circumstances that shape and influence them can be inferred to the research population (Lewis and Ritchie, 2003: 269). New findings, categories and concepts could be generalised if the findings in a qualitative study could be internally validated (Lincoln and Guba, 1985).

In this study, the use of multiple cases (three types of patents) are more powerful than single case study (Yin, 2003:53), expands generalisation and strengthens external validity of the findings. Data triangulations were also achieved by other materials such as granted patent publications, websites, pamphlets, annual reports, articles and newspaper cuttings. The researcher also talked to other people who are involved in the same field of research. Based on all the above measures the findings, could be considered to have generalizability.

3.7 CONCLUSION

This chapter has discussed the methodology and the strategy of data collection and the data analysis in this research. Case study research strategy using a qualitative approach was employed in order to ensure deep insights into the phenomena that influence the process of commercialisation of university technologies which were the aim of the research, and to answer the research questions. Multiple cases from a single university in the United Kingdom, that is the University of Strathclyde, was chosen based on two main factors;

- it has the largest patent portfolio of all UK universities,
- the researcher is a PhD candidate in the university, which enabled easier access to the key informants to obtain the data.

These cases were divided into three sub categories; unexploited patents, patents exploited through spin-off companies and patents licensed to established companies. Inventors of each type of these patents were identified and interviewed based on information given by the TTO. This may have led to unknown sample selection bias.

The interviews were conducted with three main groups of subjects. The first interviews were conducted with the TTO staffs of the University of Strathclyde to get a deep understanding of the commercialisation process. The second group were TTO directors from six UK universities to understand their practices, and to see any differences if any with the one at the University of Strathclyde. The last group to be interviewed were the inventors the patented technologies as identified above.

The data were transcribed, and then analysed using a combination of methods. It was analysed on a case-by-case and cross-case basis as proposed by Eisenhardt (1989) and Miles and Huberman, (1994), and finally by relying on the analytic induction as proposed by Gibbs, (2002) and Yin (2003). NVivo software package was used as an aid to cluster each case into ten themes, and later reduced to seven main themes: motivation, opportunity recognition/industry experience, funding, characteristics of technology, inventor and the TTO roles, and the university support and incentives. These themes were used to organise the discussion.

The next chapter examines who are involved in the decision making process to patent and what are the decision criteria used by universities in the UK to help select the route of exploitation.

CHAPTER 4

THE COMMERCIALISATION PROCESS OF INTELLECTUAL PROPERTIES BY UNIVERSITIES

4.1 INTRODUCTION

The commercialisation of technology within universities is regarded as playing an increasingly important role to generate university income, in the creation of new businesses, and jobs. Despite the importance of commercialisation to universities as well as to local economic development, there is little systematic understanding of institutional practices in the commercialisation process. How universities get involved in the decision making and what are the decision criteria in the commercialisation process has not been studied intensively. In order to increase the effectiveness of the commercialisation process it is important to understand who are involved in the decision making and the criteria used, to transform the ideas from the laboratory into commercially viable products. This chapter examines who are involved in the decision making process from scientific discovery and what are the decision criteria used by universities in the UK to help select the route of exploitation. To understand the process in depth, interviews have been conducted with seven directors of technology transfer offices (TTO) from United Kingdom Universities[9]. In addition annual reports and university web sites were used to gather rich information on the process.

The discussion of the process will focus on institutional factors such as sources of funding for research and spin-off, how the decision to seek for patent protection is arrived at, how the decision as to which route to exploit is reached,

[9]. Interviews with TTO directors of University of Strathclyde, University of Southampton, University of Warwick, University College of London, Heriot-Watt University, University of Edinburgh and University of Glasgow

networking and the search for licensees, universities policies, ownership and overall management of IPR .The arrangement of this chapter starts with the understanding of the general commercialisation process followed by a section on the commercialisation process as practised by universities in the United Kingdom. The similarities and differences of the practices between the UK universities are highlighted. Lastly, a case study of the University of Strathclyde's commercialisation process is described.

4.2 GENERAL MODEL OF COMMERCIALISATION PROCESS

The general process of commercialisation starts from the scientific discoveries in the university labs. The inventors disclose the inventions to the TTO. The TTO evaluates the disclosures to determine if the inventions need to seek patent protection. The TTO, based on the information from the inventors, will evaluate the market potential for the inventions and how to exploit them. If there is a licensee for the inventions, global protection will be discussed depending on the market for the inventions. If there is still no taker after the filing date, TTO and the inventors will try to commercialise the invention up to the end of one year. After that period attempts to commercialise the inventions will be abandoned. Normally the decision to commercialise is either through a license with an established company or as a license to a spin-off company and is the result of a joint decision between TTOs and the inventors. This is also shown in Figure 2.2.

4.3 COMMERCIALISATION PROCESS FOR THE SELECTED UK UNIVERSITIES.

The commercialisation process in the UK universities is generally similar to the US universities. The latter have vast experience in technology transfer and have been involved with this activity for decades (Etzkowitz, 2002). However, there are some differences in practice due to the legal and regulatory systems, institutional practices and policies. The patent law in the UK recognises the first to file system rather than the first to invent system as used in the United States (see Chapter 2). That is the person that receives intellectual property protection is the first to file an application, regardless of whether she or he is the original inventor. For example, if X invents P, and Y later invents something essentially identical to P, but Y first files a patent application with the Patents Office, Y owns the rights under British law, whereas under the US law, X still has the right to file a patent that would supersede Y's patent application (Rubin et al., 2003).

In the UK, whenever inventors publish a description of the inventions, it destroys the ability to patent. In contrast, in the US universities would have a twelve-month period of grace after the patent application is submitted to publish articles about the invention. Patent law in the UK, therefore results in continuous tension between inventors and universities regarding patenting any new discovery or invention. Inventors insist on publishing and the TTO is trying to patent the invention as soon as possible, before a competitor does. However there is a conflict as the university requires time to gauge the potential of the technology, based on financial and market information before deciding to proceed with a patent application or not.

4.4 THE SOURCES OF FUNDING FOR RESEARCH

External funding provides the resources which enable universities to conduct research and development. This includes both government funding (Levie et al., 2003; Friedman and Silberman, 2003) and industry funding through contract research or sponsored research (Thursby et al., 2001; Siegal et al., 2003a). Research in the UK universities is typically funded by Research Councils and Funding Councils.

The government provides money to the universities through funding councils such as the Higher Education Funding Council for England (HEFCE), the Scottish Higher Education Funding Council (SHEFC), the Higher Education Funding Council of Wales (HEFCW) and the Department for Employment and Learning, Northern Ireland (DELNI) (Lambert, 2003).

A further source of research funding is the specialised research councils, who provide money mostly in the form of project grants. Examples of these councils are the Engineering and Physical Sciences Research Councils (EPSRC), the Medical Research Council (MRC), the Biotechnology and Biological Sciences Research

Council (BBSRC), and the Economic and Social Research Council (ESRC) (Lambert, 2003).

Funding from the Higher education and Innovation Fund in 2003/04 was £25,481,000 and increased to £64, 960,000 in 2004/05. Funding from council grants are also increasing. For example the EPSRC grant increased from £425,000,000 in 2003/04 to £490,000,000 in 2004/05 and Medical Research Council Grant increased from 409,932,000 to 414,799,000 in 2004/05 (DTI, 2005). Although this is quite impressive, investment in R&D in UK higher education is still behind compared to their counterparts in OECD countries. The UK Government spent only 0.75 percent of GDP in 2003 on R&D (OECD, 2005).

By no means, every university in the UK is engaged in commercialisation of intellectual property. Some commit significant amounts of effort towards it, allocating up to £750k a year, whereas others (8%) did not allocate any funding for the protection of their intellectual property (UNICO, 2004).

To encourage commercialisation activities through the formation of spin-off companies, the government provides other types of grant, such as University Challenge Funds, and the Scotland Proof of Concept Funds. These grants are actually seed money to fund a spin-off company and to further develop their inventions up to the prototype stage.

Sources of funding for the original research may determine the way the exploitation of the invention is managed. If industry funded the original research, which led to the invention, they may have the first right to license the technology. If the funding comes from the government, universities may exploit the invention by licensing it either to established firms, or to new spin-off companies. If the research indicates a potential market, industry will be interested and fund the original research project, particularly if the project is based on applied research. Universities have many experts in a particular field and will attract more funds from industry. It is also aware that technologies from universities are cheaper compared to other sources, such as private organisations[10].

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10 Interview with TTO Director of Edinburgh university- 2/9/04

4.5 THE INVENTION DISCLOSURES

The disclosure that has been submitted to TTO briefly describes the idea for the new discovery, technology or invention, on what platform it has been developed and so on. Other types of information included in a disclosure form typically are[11]:

i) Name of the inventors.

ii) Who funded the research that led to the inventions? Has there any publicationon the inventions?

iii) Potential commercial market.

iv) Companies that may be interested in licensing the discovery.

It is a normal practice among all the universities for the inventors to bring their inventions to the TTOs. This is because most of the TTOs do not have enough staff to scout for the inventions. Universities or TTOs also believe that the inventors should be highly enthusiastic if they want to see their inventions implemented. So it is normal for them to bring their inventions to the TTO, not the other way round[12]. Universities do not give any incentive for those who disclose their inventions to the TTO. Thursby et al. (2001) who found that only half of the inventions that have potential are disclosed to the TTO office. In some cases, a faculty may not realise the commercial potential of their ideas. However very often they are unwilling to disclose it to the TTO because they are afraid the application for a patent will delay their journal publications (Thursby et al., 2001).

The University of Southampton is proactive and is quite different from the other universities studied. The Centre for Enterprise and Innovation (CEI), at the University of Southampton, has a group of managers recruited from industry. These business managers will seek out a business partner, and identify opportunities and then draw up business plans. The CEI will then bring the resources required from within the CEI to implement the plan (Minshall and Wicksteed, 2005). In addition, it has an academic representative within every department and these representatives give specific briefings to the academics on patenting activities and the role and importance of patents to encourage academics to disclose their inventions. Courses

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11 Interview with an IPR officer University of Strathclyde- 2/5/04

12 Interviewed with TTO Director of Warwick University, University College of London and Strathclyde University.

are also given to the academics to familiarise them with the patenting activities and procedures.

4.6 HOW THE DECISION TO PATENT ARISES

The decision to patent and how they were arrived at are different among universities. The differences are due to the supportiveness and selectivity of the TTOs, who is involved in the patenting process, the resources available to them, and the skills and experience of the TTO's staff. Most of the universities, especially Warwick, University College London, Glasgow University and Southampton University, are selective on what types of inventions should be patented. Some of the TTO's Directors have full control over which invention is going to be filed for patent protection and which exploitation route to take, even though the views from academic inventors are always sought.

The inventions will be evaluated for potential applications and patent protection potential. At this level, the personnel who are involved in the decision to proceed, or otherwise, to patent application, and how to conduct market research differ between universities. Initially and generally, inventors and the TTOs' Directors or the TTO Director himself/herself will decide whether or not to patent the invention. For example, in the University of Edinburgh the discussion initially is between the inventors and the business development managers of the TTO. These people would decide whether the invention should be patented. They would also discuss the initial possible application and market for the invention.

Their decisions are then reported to the Director of the TTO and the Director will decide whether to patent the invention and whichever route to exploit it. On the other hand, at Heriot Watt University, inventors and board members will have a meeting together to decide, the board consists of six internal members and a few experts from outside[13]. At the University of Glasgow the Business Management team is involved at this stage. Their team is made up of nine members and one secretary. Some of the universities like the University of Strathclyde have a second meeting

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13 Interview with Mrs Jane Queenan. Manager Technology Research and Services Heriot-Watt University.

with committee members. The university has a small committee comprised of the TTO Director, IPR officer or the TTO's representative and a patent agent.

In the selection process, the University of Warwick has the most systematic system and is very selective with regard to the characteristics of the inventions that influence the decision to file for patent application or not. The University of Warwick also has a special and comprehensive evaluation form compared to other universities. It uses a scoring system to identify the market potential of the inventions. At Warwick, inventors that have inventions or ideas to disclose will contact the TTO. They are given a copy of COAP (Commercial Opportunity Appraisal Process). This system is used for managing commercial opportunities arising from research results. It is to ensure that all commercial opportunities are systematically recorded, so the opportunities are not lost if the inventors were to leave the university, which is quite common. It is also to ensure that the decisions to pursue or to drop the projects are made in an open, consultative manner, which can subsequently be properly justified. In the COAP scoring system, the opportunity has a priority score at all times. It also generates statistics, which help the progress of the project over time, benchmark the performance against other universities and finally report to the committee (see Appendix E). The Scoring system is based on a 10 dimensional rating scale:

i) Uniqueness of the technology
ii) Readiness of the technology for production
iii) Value of the market
iv) Anticipated profit margin
v) Intensity of competition in the market
vi) Competitive edged of the product or service
vii) Ease access to the market
viii) Customer conservatism
ix) Commitment of the team
x) Commercial experience of the team.

Each project should be scored from 5 (excellence) to 0 (very poor) on each dimension. Scores on each of the ten scales can be totalled and doubled, to give a score out of 100. If the marks scored were more than 56%, the invention will be filed for patent application. Basically, for all the universities the decision as to whether to file a patent application is generally based on at least three main questions, which are similar to US universities (CORG, 2000; Rootner, 2004). They are;

i) The inventions have prior art or not?

ii) Does the invention have commercial value to attract the commercial investments?

iii) Are there funds available within the institution or prospective licensee to pay for the patenting cost?

If the invention fulfils these criteria, universities will normally take positive steps to patent the inventions, even though at that time they have to make a difficult decision due to the uncertain market for the technology. Delaying the decision to patent will affect the publication and other competitors might be the first to file the invention for patent. If the inventor published a paper on the invention, the patent application can no longer be filed, as it is considered that the invention has a prior art. Some of the universities file the application as quickly as they can after having a meeting with the inventors or immediately after a board meeting. Prospective licensees are sought immediately after patent applications are filed.

Nevertheless, the University of Southampton and Warwick University for example, patent the inventions that really have potential value and only after thorough market research[14] has been done. The other universities totally rely on their inventors for market information on the invention. University of Southampton and Warwick University have done thorough market research and identified market size and value of the inventions, and identified who are the players in the field and their potential customers. Only inventions that have commercial value and need protection are patented. However, in some cases there were inventions that were not patented but they were licensed to companies and the university earned royalties. In such cases the university kept the technologies as a business secret. At Southampton University, an example of such a technology is the development methods of Auto–Sub, a remotely piloted underwater submarine that can be controlled from the surface. The submarine is able to collect several types of underwater data and is also capable of taking underwater photography. It has been designed for research under

14 Interview with Dr. Tony Raven the Director of TTO University Southampton on 9/9/04

Arctic ice. This particular technology was sold to Haliburton of the US without any patent protection[15].

4.7 FILING THE PATENT APLICATION

If the decision is made to file an application, the TTO engages a patent agent to work with the inventor (s) to write the patent application, file it with the UK Patent Office or their equivalent in other countries. The university will appoint a patent agent to help them prepare for the patent specification. Universities have a twelve month period to decide whether to patent at an international level or not. Within this period the university and the inventor try to get companies interested in the technology to make further developments and to cover the international patent cost up to Patent Cooperation Treaty (PCT). (The process of patenting was explained in Chapter 2).

Some universities require the faculty or the department involved, to share the patent cost. One example is the University of Southampton. Having been involved with sharing the patent costs, it is an obligation that the faculty will conduct market research before they seek patent application, and share the responsibility to market and further develop the invention. As the Southampton TTO Director said:

> *"... We share the cost of protection with the school concerned. The reason... we asked them to take part in the decision. They're going to take this seriously if they have to pay for it ..."*

To file a national patent in the UK as well as in the US would cost around USD10,000 or GBP5/6k[16] (Knight, 1996; Knight, 2001; Kneller, 2001a). Around 90 percent of this cost is attorneys' fees (Kneller, 2001a). Obtaining foreign patent protection will increase the cost substantially. In some countries, the number of claims and the total number of pages influence the cost. The cost varies according to the individual country especially when patent protection is filed in Japan. The costs increase due to the required translation of patent application documents (Knight, 1996; Knight, 2001).

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[15] Interview with the Director of TTO University Southampton on 9/9/04
[16] Interview with an IPR officer the University of Strathclyde

4.8 FINDING LICENSEES AND NETWORKING

Most of the universities start to find licensees immediately after the patent is filed. Several strategies are implemented. The strategies are similar to those in US universities. The strategies implemented and how licensees are chosen is explained below.

4.8.1 Licensing strategies

Most of the universities applied similar methods in their marketing strategies to find licensees. Involvement of the inventor from the beginning is important to the identification of the specific market for the invention. Usually, the university together with the inventor will identify the prospective licensees immediately after they file the patent. Universities use their web site, flyers, conferences and seminars to advertise technologies that are patented and available for licensing. On the web site, the general background and the applications of the technologies are explained. However, the web site does not work very well. The most effective strategy is to find all the active companies involved with particular technologies and approach them either by mail, email or telephone. A face-to-face meeting will then follow if the company is interested in the technologies. One of the TTO Directors commented;

> *"... all universities use the initial contact of academics to market their technologies. The TTO will assist them in negotiating contracts and contract agreements. The TTO will study what are the commercial values of the technologies and how much time they [need to] spend to bring the inventions to the market. The value of technology becomes higher when the period to produce is shortened. The product [would] become a market leader before other companies could introduce their products [using the same technologies] ..."*

The difficult stage is to find the companies that could be the potential licensees and who are willing to give support to the technology. Most of the licensees are from US companies. Companies in the United Kingdom are poor in R & D and are much less likely to support technologies from universities (Steil et al., 2002; Bower, 2003).[17] In addition universities target few potential licensees and tend to build long-term personal contacts in the industry. This personal contact is an

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[17]. Dr Toney Raven, Director of the TTO University of Southampton: CEI and Dr.Edeyrn William, Director of University of Warwick have made this point in interview.

effective way to attract companies to the universities' technologies (Kneller, 2000; Thursby et al., 2001; Colyvas et al., 2002; Thursby and Thursby ,2004).

At this stage, universities always have a problem convincing the prospective licensees of their technologies. Universities' technologies are unproven and normally need further investment before the product can really sell into a market. In addition, due to the technology being in its early stage, it is very high risk. Moreover some of the technologies have a market that is so broad, that it is difficult to identify which market to target. (Pressman, 1999:52) explains why marketing a university invention is so difficult:

> *"... University inventions are 'embryonic'. At the time a university is ready to hand over its inventions to industry, most have not even reached the prototype state, much less demonstrated manufacturing and practicality in the market. These inventions will require substantial investments in product market development, and many will never succeed. Thus, the task of the university is to find industrial licensees willing to make the high risk investment ..."*

Universities target worldwide markets for licensing, especially when licensed to established companies. The University of Southampton has an invention called infrared (IRed), which attracted interest from major companies around the world, especially Korean and Japanese. The same thing happened to the University of Strathclyde with its anti obesity drug, which was granted a patent in 1995/96. This patent attracted one Korean company to collaborate and to conduct further research into the drug and invest £1m.

4.8.2 Selecting and negotiating licences for specific fields

When more than one qualified licensee applies for an invention the University will consider co-licensees or may divide the licence by field of use. Some inventions cover multiple applications in a number of different fields. A biological invention, for example may have an application in research, in diagnostics, in vaccines and in therapeutics. A chemical synthesis method may have applications in agriculture, polymer synthesis, and in pharmaceuticals. In such cases different licensees will be given rights, upon negotiation, to exploit the technology in different fields. However, if the licensee is a multi-divisional company and is involved in businesses in all fields of the invention, and is willing to commit to product development in all fields, the licence granted may be a broad one.

On the other hand, if the company's business is limited to a single field, then a field of use may be specified in the licence, and the company's right to exploit the invention will be limited to that particular field. This will leave the technology or invention licensable to other companies working in other fields. This also allows the university to receive royalties from other company which might be better performs in exploiting that technology (Kneller, 2000).

4.8.3 Exclusive or non-exclusive within a field (or in all fields)

A licence granted by a university may be non-exclusive (licences may be granted to a number of companies) or exclusive (granted to one company only). Universities grant exclusive licences when the investment to develop the technology is high-risk. Exclusive licences are granted to permit licensees the right to develop the technology without fear of competitors. The patent also can be licensed exclusively, but limited to certain applications or methods of use of the technology, or limited to a certain geographical area or nations. Universities sometimes grant exclusive licences where the industry funded the research. The University of Southampton for example, gives exclusive licenses to Glaxo who funded research on pharmaceutical products.

Having granted non-exclusive licences, universities can license as many companies as they can. This could lead to a new invention or patented technology, which then could be exploited as broadly as they can and using multiple applications (COGR, 2000). However, royalty rates for non-exclusive licences are normally lower than the exclusive licence rates. The royalty rates for exclusive licences in the University of Edinburgh for instance are normally between fifteen and twenty percent of the turnover[18]of the product compared to between five to seven percent for non-exclusive licences.

If an exclusive licence is granted to a company, the university must monitor and ensure that the company works hard to develop the invention and not just shelve it. Some companies want to license the invention in order to prevent the invention

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[18] Interview with Dr Bob Smailes, Director of Edinburgh Research and Innovation Centre on 2/9/04

threatening an existing product. Diligence provisions are an important part of any negotiation with licensees. In these provisions the company is required to specify the number of people in the company assigned to develop the invention and the amount of funding it will commit. It must also specify the date when the prototype of the product will be completed, the date when the first product must be sold, and dates by when sales levels must be achieved. Diligence provisions are a mandatory contractual commitment. If these terms of the provision are not met, the university may cancel the licence or the university may make it non-exclusive, thereby regaining the option to grant licences to others (CORG, 2000).

4.8.4 Distribution of royalty income

The distribution of royalty incomes varies across universities. Revenues are generally distributed according to a formula that has been adopted by the university. Most of the universities implement sliding scales, with a higher share for the inventors in the early years of a licence when the royalty returns tend to be lower. The royalties will be distributed between inventors, inventors' faculty and to university general funds.

4.9 DECISION TO COMMERCIALISE: SPIN-OFF OR LICENSING

Academic staff aspirations and interests are considered when deciding the route for the exploitation of intellectual property[19]. There is a similar process in the US universities. Most of the universities have a discussion with the inventor as to which route they want for the exploitation of the invention. However in certain cases, the TTO Directors have the final say as to which route is to be exploited, such as Edinburgh, Southampton, Strathclyde and Warwick Universities.

Some universities preferred to license their intellectual properties to established companies rather than to form a university spin-off company, for example the University of Glasgow and Heriot-Watt University[20]. In the case of Heriot-Watt University, the reason is that, too many of their technologies have global

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[19] Interview with the TTO Director of Warwick University

[20] Interview with Mrs Jane Queenan. Manager Technology Research and Services Heriot-Watt University - 12/8/04

applications and are very technical. They prefer, as the best mechanism, licensing the technology to an existing company, that is already active in that field. Similarly the University of Glasgow prefers to exploits the technology by license to an established company because it is less risky. In 2003, fifteen inventions were licensed but only two spin-off companies were created from the University of Glasgow[21]. If the technology is at the late stage of development, the inventor will be encouraged to take the licensing route. Other universities license the invention to an established company, if the technology requires further development and the market is world wide like a drug discovery. Drugs need intensive investment and testing which involves a huge amount of money, with these types of inventions, the university usually licenses them to an established company.

Various factors influence the decision to form a spin-off company. According to a survey of TTOs directors by Minshall and Wickteed :(2005) the decision to form a spin-off company depends on the following factors:

- technologies are considered as platform technologies,
- the inventors are very keen to commercialise the technology themselves,
- when the idea needs to attract substantial investment to develop IP relating to the technology for subsequent licensing,
- when the technology is not readily licensable, and
- for a generic technology with many different applications.

However, based on the interviews with the TTO Directors for this study it is apparent that several more factors influence the universities decision to form a company. Many universities consider that if the technology is advanced or at a very early stage, has potential value, enough resources and no takers, then universities have to take the risk to form a company. The details factors are discussed below.

4.9.1 Academics commitment

Academics' aspirations and commitments are very important and the main factor considered in forming a company. At the first stage, universities consult with academic inventors as to which route to market they prefer to exploit the invention.

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[21] Interview with Director of TTO university of Glasgow on 27/9/04

Then the market analysis will be studied: who are the competitors, market accessibility, and the market size. Inventors are not necessarily equity members of the company and their involvement can be as a consultant to the spin-off company. Academic commitment is crucial if the licensing route is chosen when the technology is at an early stage. The contribution of inventors is also important when technologies are licensed to an established company. Without the academic's contribution and involvement, the chances of success for both exploitation routes are limited. As one of the TTO Directors reported:

> *"... The report comes to the Director of ERI[22] and that report makes recommendations as to whether we should protect, how we should protect and how to exploit the inventions. The technology exploitation route can be to set up a company, to license the technology through existing firms, or may be to take some contract research and to continue research with support from the existing companies. The decision as to which route to go forward, is basically decided by the Director. The decision always takes academics wishes into account because they have to work with us to exploit the technology...".*

Another TTO Director said:

> *"... The decision to form a spin-off company is made based upon discussion with academics and one of the university signatories. This is due to the cost involved in the formation of spin out company. We then quickly look for outside funding and investors. Sometimes academic staff can bring in investors and put their own money into the company..."*

4.9.2 When technology is radical, unique and has market potential.

Spin-off formation needs technologies that have made a significant advance in a scientific field and that will have significant economic value (Shane, 2004). The technology needs to be cutting edge and not to duplicate existing technology (Shane, 2004). Furthermore, the technology must be in demand and must expect more profit than alternative activities (Amit et al., 1995). Consistent with the literature reviews,

[22] The TTO of Edinburgh University is called Edinburgh Research and Innovation Centre, or ERI. It was formed in 1999. The main objectives of the centre are managing research and consultancy as well as provide services for technology transfer management to industry on behalf of the university

most of the TTOs Directors agreed that spin-off formation occurs when the technology is core and has major innovation. One TTO Director said;

> *"... if there is a core technology, and it represents a big jump in technology or is a revolutionary technology or will create major turbulence rather than an enhancement of an existing technology, then we look to form a spin-off company ..."*

Universities also consider setting-up a company, when the technology is at a very early stage and is unique with a potential value that can be transformed into a product. As Shane (2004) found, university spin-offs are an effective vehicle for commercialising uncertain and early stage technologies.

As a last resort where the technology is too advanced and has potential value, some universities will form a spin-off company even when there is no licensee interested in the inventions. For example, where the technology really has potential value, the University of Glasgow, will spin-off a company, even although no licensees are interested in the technology, or a licensee is difficult to find. Thursby et al., (2001) did a survey of 62 TTOs in US supported these findings. They found that established firms tend to license university inventions at the later stages. Small and newest spin-offs always invest in uncertain technology (Shane, 2002; Shane 2004). Lowe (2002) also found that most of the spin-offs companies at the University of California were founded because established firms were unwilling to license these technologies.

Another factor could be the geographical position of the market, which can lead to another reason for the creation of a spin-off, depending on whether the technology has a local or international market. A spin-off company is formed to turn the inventions into products and the company directly and indirectly will stimulate local economic development. If the market is outside the United Kingdom, licensing is preferred. However, the local population does not benefit from the development of the technology through job creation. Moreover, the type of technology and the cost incurred if the technology is further developed also has to be taken into account. After consultation has been carried out with the inventor, the university will study the amount of finance required to create the company. What is the cost to transform the product into the next stage; the time line involved to take the product to market; and whether or not the product is a single or multi products. Licensing to an established company is safer than taking the risk of forming a spin-off company where the costs to take the product to market are huge or it takes a long time to harvest [23]. A good example is the development of new drugs or compounds.

4.9.3 High expected level of return

Another consideration is the expected annual income from a spin-off company. One of the TTO Directors reported that the university would form a spin-off company when the expected income is more than USD100m per annum[24]. If the company's projection brings less than that, venture capitalists refuse to make any investment.

> *"... we do the technology review; for example the modification of a microprocessor. It is not sensible to set up a company to compete with Intel. We rather license to Intel. We carry out the technology review; we look at the industry; who are the competitors, market accessibility, and the size of the market. We are looking to build a company that at least gives turnover of USD100m per year. That is the target. If less than that, we will not form a company. We have to look for a unique market. ... If the company is not worth more than USD100m dollars, you cannot get investors ..."*

4.9.4 External factors

Economic factors are another consideration in forming a spin-off company. TTO directors of the University of Strathclyde and the University of Edinburgh both mentioned this objective. Government or local authorities require the development of their local economy. A university spin-off enhances economic growth by transforming the university technology into business opportunities. Forming spin-off companies will have multiplier effects, provide jobs to the local people and stimulate the local economy (Tornatzky, 2000; Pressman, 2002; Shane, 2004; Smailes and Cooper, 2004). However, if the university licenses the technology to international licensees, it will reduce the chances and opportunities to develop the local economy as mentioned before.

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23 The average for a spin-off company is seven years to get into the market – according to Southampton University TTO Director.

24 Interview with the Director of CEI Southampton University, Dr Tony Raven – 9/9/04

4.9.5 Exit strategy

Some of the universities form spin-off companies with the intention of selling the companies after the technology is mature enough or will maintain the equity in the company. This exit strategy will bring huge income to the university and the investors. The University of Southampton for example, has developed a company at a very early stage, and after the company and technology was developed, the university sold the company. Offshore Hyrocarbon Mapping (OHM) Limited, was set up in year 2002. The technology invented is used for oil exploration in deep water, using electrical measurement. On 11 March 2004, the company floated on London's Alternative Investment market (AIM). The company raised £10m at the floatation, while the market capitalisation of the company on admission was £49.3 million (CEI, 2004) Another example was Wolfson Microelectronics, which was spun out by the University of Edinburgh and floated on the main Stock Exchange at a value of £213 million[25]. However, during the interview neither of these universities was asked whether they have sold their shares in the companies.

4.9.6 Spin-offs funding

Universities need external funding to form a spin-off company. This funding comes either from government or industry. However since the patent's licence to spin-off companies is at an early stage, most of the funding for seed monies comes from the government. The UK Government has set-up the University Challenge Funds (UFC) to encourage universities to exploit research and fund the early stage of project commercialisation. Scottish Enterprise has set up proof of concept funds to support spin-off companies. Business Angels and venture capitalists are also important for start-up and early formation stage. For post start-up, the companies seek capitals for further growth from Venture Capital Companies or go to Initial Public Offering (IPO) (Figure 4.1).

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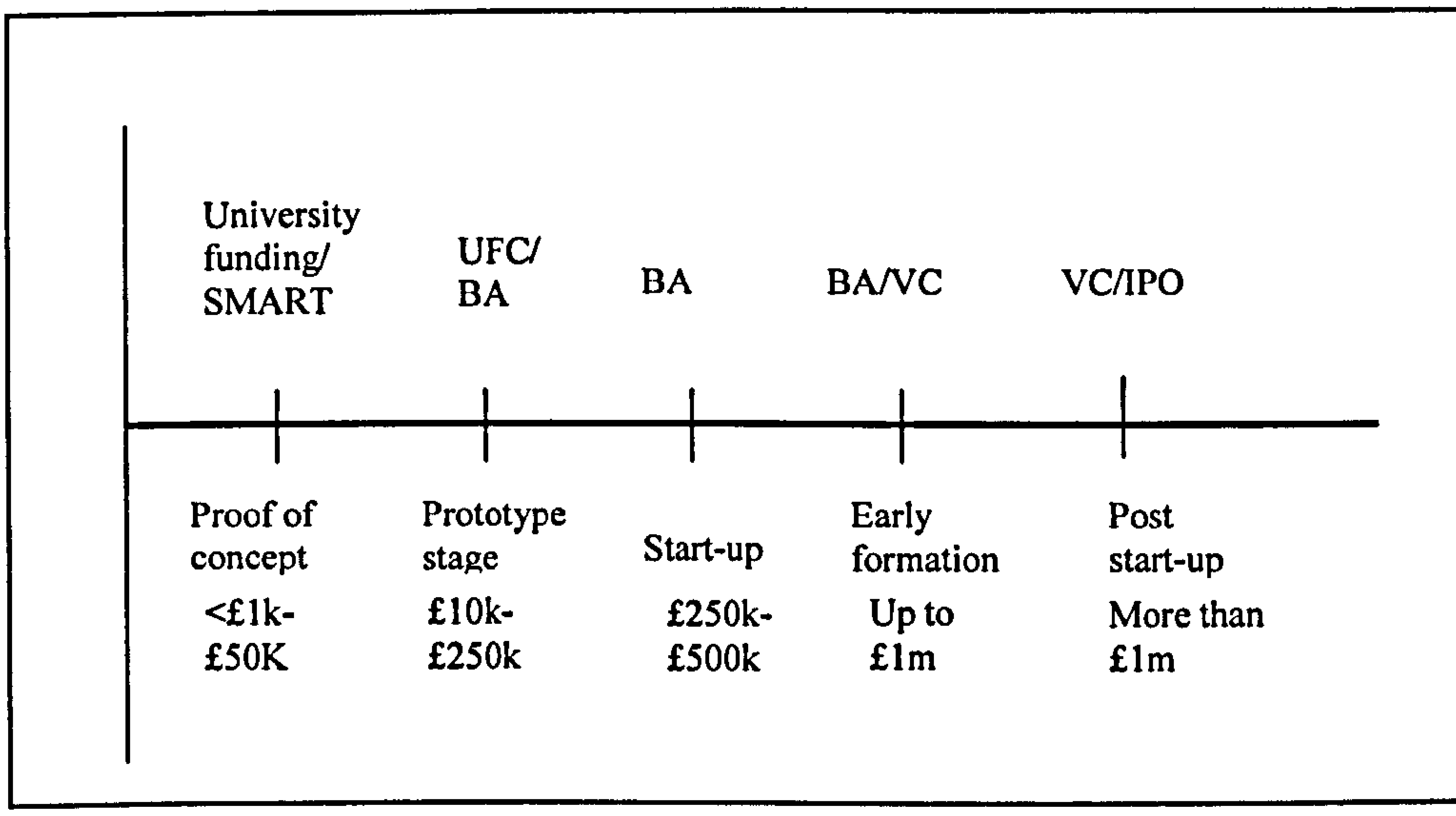
[25] Interview with University Edinburgh TTO Director

Figure 4. 1: Stages of funding in spin-off development



(Source: Discussion with the Supervisor and Business Advisor Scottish Institute for Enterprise).

The SMART scheme and UFC provides inventors with seed money to their inventions to prototype stage and to cover patent cost, business assessment, market research, and business plan development. The initial amount given is less than £50k for each new company. Universities normally provide £5k-£10k to the inventors for these activities as University College London, the University of Warwick and the University of Strathclyde. The University of Strathclyde has the commercial Development Fund which is controlled by BVG (Business Ventures Group). Any returns from spin-offs are invested straight to the fund.

University Challenge Funds (UFC) enabled most of the universities with the sources of seed money to fund spin-off companies. The amount is between £10k-£250k. For example, the University of Edinburgh has its own internally managed fund called the Integrated Company Development Scheme. The grant is given during the pre incubation stage. The total fund is £4m and each company receives a maximum of £75,000. The funding is given for the first-year and includes the cost of market survey, prototyping and additional lab works. The university takes 10% of equity per £50,000 investment in the case of the University of Edinburgh. Other universities take 10%-20% equity of the companies. Some universities applied jointly with other universities to bid for University Challenge Funding. For example, the University of Strathclyde and the University of Glasgow, have what is called the Synergy fund managed externally by Scottish Equity Parties. The University of Southampton, Bristol and Bath University have formed the SULIS fund which is also externally managed (Minshall and Wicksteed, 2005).

Further development of the product or additional investment is likely to require funding from venture capitalists and business angels if the companies fulfil their investment criteria. Certain characteristics of the technologies such as a clear route to market, size of potential market, strong management team, viable technology and level of patent protection are required by venture capitalists (UNEI report, 2004). Business angels and their network also provide the money for investment, typically in the range £50,000-£250,000. Venture capital firms fund university spin-offs at early formation with the amount up to £1m which is called venture capital series A. For further growth, venture capital series B and series C in which provide an amount of up to £5m and up to £10m subsequently.[26]

4.9.7 Networking

Informal and formal networks with individuals and organisations are important for spin-off formation (Birley, 1985).These networks link new firms to resources providers such as venture capitalists, business angels, banks, advisers as well as to potential customers. Shane and Cable (2002) pointed out that informal networks are an important means of accessing finance, thereby giving more chance to spin-off formation. Shane (2003) further suggests that the link to financiers give a better chance of founder access to a broader scope of networks such as suppliers, customers and other resources that a new firm requires.

For formal networks, universities that have built strong relationships with Venture Capitalists and Business Angels have an advantage in helping to narrow the market of the university invention. As one of the TTO assistant said:

> *"...We seldom go out to market the technology. We've marketed the technologies based on having a good relationship with financiers, which includes business angels and venture capitalists. VCs and Business angels help in narrowing the market. They will identify the potential market*

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[26] Business Advisor Scottish Institute for Enterprise at Hunter Centre for Entrepreneurship on 19/2/07.

before they invest in the company. ... The London Technology Network is a good channel to link the potential industry and the technology. It is very rare that the TTO goes to the general market ..."

In order to access sources of capital and future investors, universities have built external linkages. For example, the University of Strathclyde has strong links with Scottish Enterprise Glasgow. The University of Southampton has a different strategy. CEI has built strong links with a number of early stage investment funds, including SULIS (£9 million), WessexBio (£400,000) and IP2IPO (£5 million)[27] and runs its own presentation day annually in London. In 2003, the event was attended by over 40 early stage venture capitalists (Minshall and Wicksteed, 2005) to whom the inventors presented their business plans[28].

Universities have also developed specific mechanisms to build strong networks with industries. Some universities have links through particular mechanisms. The University of Warwick and Midland universities have access to Connect Midlands and universities in Scotland have access to Connect Scotland. These are designed to connect technology-based companies or inventors to potential financiers and investors. These organisations were established to achieve the main objectives of generating a network for entrepreneurs, drawing together people such as investors, business service providers and regional key players. Events, seminars and conferences aimed at investors are held to present the new ideas and the latest technologies from the companies and the universities and to build networks. Connect events are designed to add value to technology companies at different stages in the business and investment life cycle. The exchange of ideas, networking with peers, facilitating technology transfer opportunities, meeting potential non-execs/potential investors are some of the opportunities created by such events[29].

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[27] IP2IPO is a venture - capitalist company that helps to turn intellectual property developed in UK universities into companies that are structured for growth, ideally to the point where they can make an initial public offering on the stock market. It was founded in August 2001 and has direct stakes in 19 spin-off companies, three of them have already made initial public offerings. IP2IPO has provided initial funding and help some spin-off raise further rounds of funding. So far IP2IPO has a stake in seven Oxford University chemistry department spin-offs, University Southampton, King's College London, York University and University of Leeds (Luke, 2005).

[28] Interview with Dr.Tony Raven Director of CEI-9/9/04

[29] Interview with Dr EdeyrnWilliam Director of Warwick Venture.–22/7/04 and Dr.Andrew McNair, CEO Connect Scotland - 14/4/05

Beside external links or formal networks, most universities have internal links in order to support spin-off companies or to give access to sources of investment and other resources. Most of the universities have strong internal links with their own business schools or their Centre or Institute for Entrepreneurship (Minshall and Wicksteed, 2005), their Alumni and incubators. The Entrepreneurship Centres focus on entrepreneurship education that provides entrepreneurial awareness to students and faculty. Universities Alumni also give access to a broader network for new firm resources such as the Strathclyde 100 event in the University of Strathclyde that will be explained later in more detail in the University of Strathclyde case study.

Most universities also have links and investments in their incubators. The role of the incubator is to incubate spin-off companies until they are mature and ready to compete in the open market. The incubators provide common facilities for new firms with a lower market price than other places and management support services. Various studies have reported on the direct and indirect role of incubators in spin-off formation (Rogers et al., 2001; Phillips, 2002; Grimaldi and Grandi, 2003; Georghiou, 2003; Markman et al., 2005b; Siegal, 2006).

Some universities are now creating holding companies for their spin-offs such as Qubis Ltd in Queen's University in Ireland (Blair and Hitchen, 1998; Leitch, 2004; Leitch and Harrison, 2005). This specific company is a wholly owned subsidiary that invests in first order and second order spin-offs from the university. It was formed to commercialise research and development that has commercial potential and pull it through to the market. It is not only a support mechanism but is "doing business" by establishing business (Leitch 2004:8) and taking equity in them. In addition, the company provides incubation facilities, management support and help with running the company.

4.9.8 Ownership of IPR

Universities differ in terms of their practice of the ownership of IPR. The University of Strathclyde, the University of Glasgow and University College London retain their ownership of the intellectual property even though industry funds the research. At the University of Warwick, Heriot-Watt University and the University of Southampton, the IPR right is retained by industry if the industry funds the research. However, universities still earn the royalties paid by the licensees or the companies.

Whether the IPR is owned by industry or the universities there are advantages and disadvantages. One of the advantages of industry retaining the ownership is that they own the technologies. In addition the technologies or patents owned by investors or industries reduces the risk to investors and they can sell the patent if the venture fails (Levie et al., 2003). If the university retains the ownership of IPR, they can sell it to another party if the first licensee failed. Further development of the technology has a benefit to the university's student that they can learn new knowledge. The disadvantage is that the university does not have a final say in the development of the technology that was initially invented by them.

The University of Edinburgh, the University of Strathclyde and Glasgow University have different systems to other universities on student IPR. Undergraduate or postgraduate students can retain ownership of the IPR if the student does the research in the university. Most of the universities interviewed retain the ownership if a member of staff does the research, even though industry funded the research. Industry that funded the invention has the first option for license. Joint IPR between student and academic is allowed if the project is sponsored by industry. Strathclyde University so far, does not have any established system for students who are doing research in the university. According to the TTO Director, it is good practice if students that obliged to sign an IP agreement if the university funds the research. This will be explained in more detail in the case study in the next section.

4.10 COMMERCIALISATION PROCESS OF UNIVERSITY OF STRATHCLYDE: A CASE STUDY

The University of Strathclyde (hereafter called UOS) is chosen as a case study for this research exercise, and the details of the commercialisation process are explained below. Before that, the background of UOS and TTO: Research and Consultancy Services, are briefly explained.

4.10.1 Background of the University of Strathclyde (UOS)

The University of Strathclyde was established in 1796 with the name of Anderson's Institute and opened its first premises in High Street, Glasgow. It moved to George Street and developed rapidly in the nineteenth century. By the 1890s, Anderson's 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 and so the College merged with the Scottish College of Commerce, which offered a wide range of business and arts subjects. Shortly afterwards, in 1964, the enlarged Royal College was granted the Royal Charter and became the University of Strathclyde.

In 1993, the University merged with Jordanhill College of Education. Today, Strathclyde is the third largest university in Scotland. It has 67 buildings over 500 acres of land. It teaches over 20,000 students in five faculties: Arts & Social Sciences, Education, Engineering, Science and Strathclyde Business School. Taking account of distance learning, short courses and continuing professional development and evening courses, Strathclyde provides courses for over 50,000 people each year, making it the UK's largest provider of postgraduate and professional education (University Strathclyde website).

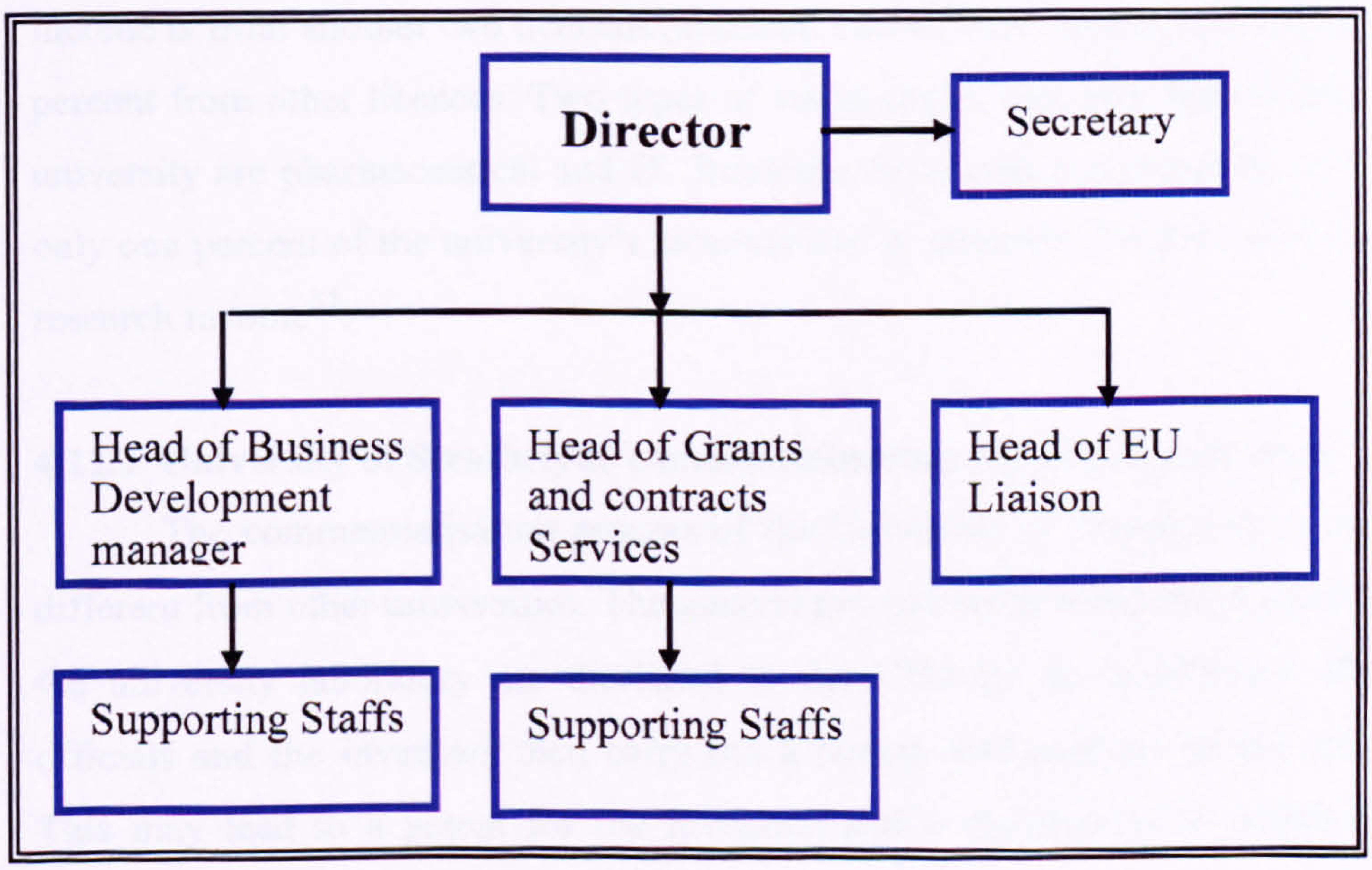
4.10.2 Background of Research and Consultancy Services (RCS)

Mr Hugh Thompson formed RCS in 1984, and became the first Director. RCS recently (2005) employs 25 staff in total. This comprises five administrative staff, 10 who are involved in contract and grant support, and 10 in business development. The latter 10 FTEs (full time equivalents) are responsible for the development of new research business as well as licensing and the spin-offs. On average there are approximately 3.5 FTEs working with spin-offs. The current Director, Dr David McBeath, administrates the centre and its primary role is to support research by University staff and its subsequent commercialisation. The Centre attracts outsiders and industries through marketing and contractual activities, and secures funding for various projects.

The main functions of the office are [30]:

i) To provide services to academic staff to help them market, obtain funding for, develop, and manage their research and research related activities.
ii) To negotiate and administer the contractual aspects of research contracts and grants, and to limit the risks to the University, arising from the contract, as they are always inherent in sponsored research.
iii) To identify, protect and commercialise the university's intellectual property arising from research.
iv) To assist with the formation of spin out companies, joint ventures, research institutes and other corporate and institutional bodies related to the University's research base.
v) To support services rendered and consultancy activities; and to implement the approved policies relating to such activities.

Figure 4.2: The Organisation Chart of Research and Consultancy Services University of Strathclyde



(Source: Research and Consultancy Services, 2005)

30 Research and Consultancy Brochure –The Research Resource, A portfolio of university expertise. (Research and Consultancy Unit, 2004)

To achieve these objectives the centre is divided into three main areas of activity each of which is managed by a manager (see organisation Chart, Figure 4.2). The three main activities are; Business Development Service (licensing and spin-off formation and IPR protection), Grants and Contracts Service and European Union Liaison.

4.11 PATENTING AND LICENSING ACTIVITIES

The University of Strathclyde has made 400 to 500 patents applications since the TTO was established 20 years ago. There are around 85 live patents, 25 percent of these are subject to license (excludes licensed to spin-offs). The University has 34 active spin-off companies in which it has an equity stake. Out of these only 5 companies exploit the university patents. The rest of the companies are exploiting know-how. Royalty income from licensing over the last five years is around £1.3-£1.4m per annum. None of the university's spin-off companies have generated income so far and only 10 percent of licences yield royalty income. The majority of licensing income comes from two licenses, Leucovorin to Wyth and Attacurium (for muscle relaxation) to Burroughs Wellcome and the Wellcome Foundation, which bring in around 70 percent of university licensing income. Another 20 percent of income is from another two licences (artificial elbow joints and Goniometers) and 10 percent from other licences. Two types of technologies that give high returns to the university are pharmaceutical and IT. Royalties from commercialisation activities is only one percent of the university's turnover and it generates 5-6 percent of the total research income[31].

4.11.1 University of Strathclyde commercialisation process: a case study

The commercialisation process of the University of Strathclyde is not much different from other universities. The general process starts when the inventions from the university laboratory are disclosed to the TTO by the academics. The TTO officials and the inventors then carry out a review and analysis of the inventions. This may lead to a patent for the invention and a decision as to which route to

[31] Interview with Dr David Mc Beth, Director of Research and Consultancy the University of Strathclyde on 17/2/04

commercialisation that is either to license it to an established company or to form a new spin-off company and license the patent to it. The detail of the process is explained below.

4.11.2 Research and spin-off funding

The University of Strathclyde obtains funding to conduct research from government bodies, charities, and industry. It has strong relations with these bodies and manages to obtain around 20-25 percent of the total awards in the whole Scotland and 10 percent of the total research funding. The University has a strong relations and skills in getting R & D collaboration and licences especially in the pharmaceutical area.

The University received around £15million per-annum from the Higher Education Funding Council (HECFE and Quality Research (QR) for conducting individual research projects. The amount of Quality Funding is based on the RAE exercise. On top of that, the University also has resources of £25million per annum. From that budget, 40-50% of funding comes from Research Council grants the majority of which is funded by the Engineering and Physical Sciences Research Councils (EPSRC). The rest is from other sources such as European Commission, Medical Research Charities, Industries, and schemes like Proof of Concept. The University also has a separate budget for the IP protection. The budget for 2005 is £180,000. This budget is controlled by the TTO.

The government provides the budget for spin-off formation through the University Challenge Fund or Proof of Concept Fund from Scottish Enterprise. The University of Strathclyde and The University of Glasgow have created a joint fund called the Synergy Fund, using the University Challenge Funds. This fund is used for further development or research projects in second round funding. The university has the initial budget for spin-off development. The amount is controlled by the Business Venture Group (BVG) and the amount received is around £100 000 - £200 000 per annum. The Proof of Concept Fund is managed by Scottish Enterprise to provide seed corn money to develop the product up to prototype stage for spin-offs companies.

4.11.3 Scientific discovery, invention disclosures and decision to patent

There are two main reasons why the UOS wants to patent its inventions. First, the protection of intellectual property (patents) will attract industry to carry out further research with the University. Initial protection could give the University the opportunity to test the market for the inventions. Universities in general find it difficult to narrow down the market in the case of early stage technology. However, the market can be narrowed down where an industry has expressed interest in a technology and the product fits within a particular field. The patent can also be a tool to test the academic standing, ability and quality of institutions in getting research funding.

Second, if the government has funded the research the University is required to patent the invention. The University is expected by the funding bodies to protect their intellectual property. Academics are free to use the intellectual property from their inventions because the University has ownership of the patent even though in certain cases industry funded the research. The problem of ownership of intellectual property normally arises when the University is doing collaborative research with industry. Industry might claim the ownership of the intellectual property, which will then restrict the ability of academic staff to pursue further research on the inventions. To avoid this, the University from the beginning applies for patent protection of the technology.

In order to patent, the University has to have a stock of invention disclosures. As the University does not have enough resources to scout for inventions, the TTO has to depend on the academic's own disclosures. Usually academic staff will approach the TTO if they have any invention to disclose (see disclosure form in Appendix F). Academics who think that they have worthwhile inventions will be given a checklist to determine the suitability of the invention for patent applications. So far, the office does not have any formal disclosure form.

The decision by the University to patent the invention is based on three factors. Firstly, the invention must fulfil the criteria to patent. It must has originality, be non obvious, have industrial application and no prior art. Secondly, the inventors must be enthusiastic and have an interest in commercialising it. Thirdly, it must be possible to indicate that the inventions have a potential market and that there is development funding available. Basically at this stage RCS tries to get initial protection once the inventions fulfil the criteria and prior to carrying out any market research.

The University has to make a very rough and general estimate of the commercial application and the market for the invention. A very quick decision has to be made at this stage and if appropriate try to file a patent at a minimum cost. If the University delays the patent filing, the consequence may be that other organisations patent a similar invention. Immediately after the patent is filed the real market research and search for licensees will be done. A prospective licensee prefers the invention to have basic protection. As the TTO Director said;

> *"...We try to have wide coverage ... stretching the ideas ... for initial protection. ... if there is seen to be something of a market for it ...and we normally try to protect it. We use the next twelve months as a period during which you have to firmly decide whether or not there is something here which is good for us ..."*
>
> *"...We can't possibly go into detailed [evaluation] ... because at this stage we recognise that an invention might be patentable. We probably know something like the overall market size, and maybe something about the current price or products or services that might compete with the inventions. So you have to make a very-very rough estimation at that stage ... as to what is the commercial potential. ..."*

If there is an invention to be disclosed, a first meeting will be arranged to determine whether the invention is patentable or not. The first meeting will involve academic staff and the IPR officer and will aim to get a preliminary view of the invention. If the result is promising, a meeting with a Patent Agent will follow. This meeting is to get the view of the Patent Agent and what the next steps should be for the inventors.

The next meeting will be arranged to prepare patent specification. This time the meeting involves the TTO Director, the IPR officer, a business development officer and the patent agent. At this meeting, the marketing officer, who has both knowledge of the market and a technical and business background, should be involved, and the future of the invention can be decided immediately. However the TTO officer does not have specific market expertise relating to the invention and the

University technologies cover a broad market and various fields. A Patent Agent will prepare patent specifications and will propose in which country(s) the patent should be filed. This will usually depend on which country (s) are chosen for the market of the invention.

4.11.4 Market research, finding licensees and networking

Immediately after the invention is filed by the TTO for patent application, the TTO staff will work with the inventors to identify the appropriate market and the market sector. At this stage the inventor's involvement to identify the market is crucial. The academic inventor is expected to know the basic market for the invention. Once the TTO and the inventor have a better idea of the market, they can start to approach companies and organisations that might be interested in the technology.

As the TTO does not have enough resources to carry out the market research, a marketing team is formed with members selected on their market knowledge and skills within the relevant market sector. At the University level, it has a team for market assessment and analysis called Pharmalinks. It is a joint organisation of the Universities of Strathclyde and the University of Glasgow and was created to develop inter-University biomedical research collaboration and increase the commercialisation of the two universities' pharmaceutically relevant research. The team gather the information about the potential market and evaluate the invention to proceed to PCT or abandon the invention. As mentioned earlier, last year this institute obtained £1million for a two years deal with Hyundai Pharmaceutical (a Korean company) for drug obesity research[32].

The Institute of Photonics concentrates on applied research and is a joint venture between the University of Strathclyde, Scottish Enterprise, and a number of companies. It is also an internal marketing research consultant to the University of Strathclyde. In addition, the TTO employs external consultants and technology brokers such as the British Technology Group (BTG) to find licensees. BTG will earn commissions if the technology is exploited. The group is a specialist in telecommunications and drugs. The TTO will employ external and internal

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[32] Interview with Prof. Brian L. Furman, the Dean of on 18/04/05and Dr David Mc Beath, Director of RCS on 17/4/04

consultants to conduct market research when Scottish Enterprise provides budgets of around £5,000 to £20,000. Conferences, and seminars are another means to find licensees.

The TTO Director said on marketing strategy;

> *"...there are three or four main ways how we will find licensees. One, obviously is through the contacts of the academic staff. Typically they have a lot of contacts and another way to find them [licensees] ... is by getting specific market research, which is done for us by consultants or whatever. They can sometimes find licensees for us on the basis of the knowledge of the market. The consultant may be internal as well. We have an organisation that I have mentioned before, Pharmalinks. Pharmalinks has specific responsibility to find out about the pharmaceutical market and is an internal organisation within the University. And the third way, to identify licensees or ultimate licensees, is to use technology brokers like BTG and people like that ..."*

In terms of networking, the TTO has an internal link with the Business Ventures Group (BVG) of the University Court. The membership of the group comprises of a few members of the University Court: RCS' Director and representative and a few other members appointed by the University.[33]. The function of this group is to approve all spin-offs and control a small but flexible Commercial Development Fund. The initial money comes annually from the University central budget and any return from spin out companies will be invested in that fund. The group disburses £150 000-£200 000 a year. It is primarily used for small investments in spin-offs, to meet exceptional patent costs and to cover the academic-inventors salaries whilst they seek funding to form a company.

The RCS also has links with the Hunter Centre for Entrepreneurship, which provides teaching in entrepreneurial education and organises business plan competitions amongst the students. These activities encourage entrepreneurial awareness among the University's staff and students and an understanding of the basic entrepreneurial process. In addition, RCS has good links with the Strathclyde University Incubator Limited, the University being one of the main four shareholders (along with Lloyds, Gresham House, and Scottish Enterprise). The incubator leases

[33] Interview with Dr Gay Wilson, University Secretary of BVG – 14/4/05

three floors of a University building and sub-leases this to 20-30 companies. The rental is below market price.

RCS and the Hunter Centre for Entrepreneurship also has link with Strathclyde 100. It is exists to involve successful alumni entrepreneurs in the process of mentoring, advising and supporting possible sources of funding in aspiring entrepreneurs. The aim is to build the culture of entrepreneurship at Strathclyde among students, staff and alumni. At a series of quarterly events, aspiring entrepreneurs (staff, students or alumni) present their ideas to an experienced audience drawn from commerce and industry, seeking help to take their business venture forward[34].

4.11.5 The process of patenting.

Immediately after the patent is filed, the Priority Date or the filing date is given. The Priority Date is important, as it is the effective date at which the invention is protected. After the filing date, the applicant has a twelve month period before any further action needs to be taken, and either proceeds to Patent Cooperation Treaty (PCT) or abandons the patent. Toward the end of this period, a series of alternatives, must be considered by the TTO either:

i) is UK protection sufficient?

ii) If not, then in which countries is protection required?

If it is decided that the invention is to be patented in the UK, the cost to patent is about £6,000 and the process will take twelve months. In the event that further development is required and confidentiality has to be maintained, it is possible to re-file the application claiming a new Priority Date. If the TTO decides to re-file the invention only in the UK, a further £200 will have to be paid.

If the TTO decides to apply for a world patent through the Patent Cooperation Treaty (PCT), another £6,000 of fees will be charged for preliminary application[35]. Normally the TTO will decide to file to PCT if there is a taker for the invention, or the invention is believed to have potential value. After eighteen months the invention will be published with the search report. The TTO will be asked after thirty months from the filing date, which are the countries in the world where they are going to file

[34] The University of Strathclyde website.
[35] Interview with IPR officer the university of Strathclyde.

the invention. They may decide to file individually in the Europe, Japan or US. Let's say the TTO wants to file individually in the US. The US Patent Office will do substantive searching and examining. The responses will be dealt with by the Patent Agent. If both sides agree with the claims, the patent will be granted. It will take another one or two years for the patent to be granted from the thirty months of filing date. Another fee of around £6,000-£8,000 has to be paid for the search and examination and renewal fees. If the invention is filed in Japan, the cost is more expensive due to the translation costs[36]. The University has to decide at which level the application is going to succeed, to spend more on the pursuit of commercialisation, further study of the market niche or abandon efforts on the inventions. In March 2005, the government fee for filing a UK Patent application was £30. The cost of drafting the initial application through a Patent Agent varies according to the complexity of the specification. Agents' fees for the preparation of a case of average complexity may be in the range of £700-£1400 (The Scottish Office, 2000).

4.11.6 Decision to license to existing companies or license to new spin-off companies

The TTO has meetings and discussions with the academic inventor to decide which is the best route to exploit the patent. The interest and academic enthusiasm as well as a viable business plan are crucial to the decision to either license the patent to existing companies or to form a new company. Basically the TTO tries to encourage inventors to license the invention to established companies. Spin-off formation is considered as a route of exploitation if the inventors show very high commitment and enthusiasm and the invention is proven to have a potential market and also that the RCS judge that the approach is sensible. If an academic inventor considers forming a spin-off company, the proposal will be forwarded to the Business Venture Group (BVG) to carry out the market study. If the invention is good, and has a viable business plan and opportunity, the BVG has normally approves the company formation, regardless of the size of the potential future pay out to the University.

[36] Interview with IPR officer the university of Strathclyde.

If there is a conflict between the inventors and the TTO as to which route to exploit, the final route of exploitation will be decided by the TTO Director and the Business Venture Group (BVG). The TTO Director said;

> *"...We're doing this ... as we work with the academics. We, the RCS always [try to help if] an academic staff member wants to form a spin-out. If the proposal seems credible, we will try to support them to do that. ... clearly we sometimes try to influence them ... ultimately we have to work on the basis [that] we are serving the commercialisation aspirations. We try to help them to move on. ... We normally try to encourage them to think about licensing because ... a spin-out is really not ... I don't think it is a very likely route to success, and we try as much as we can to encourage them to go down the licensing route. But if they want to go to spin-out route and there are some credibility in the proposal, we stick to the Business Venture Group. If the Business Venture Group turn [the proposal] down then we'll be back to licensing. If the Business Venture Group accept [the proposal] then of course we'll try to help them to form a company even though it wasn't advisable [from our initial opinion] to form a company ... that makes sense ... "*

Basically the University through BVG will judge the viability of the company on the following basis[37]:

i. The business plan must contain 2 years of financial projections for profit and loss account, balance sheet, and cash flow. These must demonstrate that the spinout company will not become insolvent or run out of cash at any stage of this 2 years period.
ii. The spinout company must be able to trade on an arms length, commercial basis, in its relationships with the University and with any other significant stakeholders.
iii. The spinout must have adequate insurance and premises.
iv. The management team for the spin out company must contain relevant commercial skills and experience.
v. The University will insist on the following conditions for the formation of a spinout company;

[37] Interview with RCS's Business development officer the University of Strathclyde.

vi. The University must have a right to appoint a non- Executive Director, though for the avoidance of doubt, this right will not automatically be exercised.

vii. The University must have the right to receive Board papers and the right to appoint an observer to attend Board Meetings.

viii. The spinout company must produce financial and management accounts on a timely basis and provide the University with copies.

Formation of a spinout company will be subject to agreement of an appropriate license/assignment agreement comprising of a commitment by the spin-out to meet ongoing patent costs and to pay royalties on a commercial basis. However the University may consider wholly or partially waiving the right to royalties if the founder/inventors all express a desire for the University to do so.

The TTO also takes into account the resources available and whether the stage of the technology has an important impact on the commercialisation route. However, academic interests will be given the priority. As the RCS Director said;

> *"....there are environmental considerations that affect agreements at very early stages. It is going to make it hard to form a spin-out company around that. But it is also hard to license, ... I think, without having done more development together with the company. So I won't say that [it is] necessarily the stage of technology has an impact on the chosen commercialisation route. I think the main factors that settle the choice of commercialisation route are the preference of inventors that I have already described and the market [that] the technology may address. ..."*

4.11.7 IPR ownership

The University of Strathclyde normally retains the ownership of the IPR unless the University has additional commercial agreement between licensees. The University will assign the IP to the company if the company fulfils certain criteria. The first consideration is that, assigning the license will not have a negative effect on the University research development. The second consideration is whether the company that is assigned the IP by the University has sufficient resources and competence to prosecute and maintain the IPR to avoid failure. The failure of the project affects the ownership as noted earlier.

For student's IPR, the University takes two considerations into account. If the student is funded by a University studentship then the student must assign her/his IPR to the University. In other words the student is treated as an employee. If the student is self-financing or funded in another way, the University does not have initial ownership of the IPR. In these circumstances the student will own the IPR. However, some of the funders of studentships make it a contractual condition that ownership may be assigned to the University or to the company. This is the case when the student is funded by the Research Councils.

If the University does not do anything, the student owns the IP, but the TTO tries to encourage supervisors or students to assign the IP to the University. The University will protect the IP and that will benefit the student. When the University protects the IP at the University's expense, the student will be treated as an employee. However this is not mandatory, although the TTO will encourage the student to do so.

4.11.8 Patenting and licensing strategy

University patents can be exploited either as a single patent or a group of patents (family patent). The University prefers to file a single patent with broad applications. This is because the University does not know what will be the final product of the invention. The University is using a very small budget to access market knowledge and try to find a way to file a patent as broad and as cheaply as it can. It is not common for the University to have many inventions that have a lot of patent associates with them. If the University has such inventions, the patent examiner will split it up into several applications.

The University will apply for a group of patents if the budget is available and if it is thought to be critical. Normally the budget to file a family patent is funded by the DTI. If the University does not have the budget for that purpose, the most critical commercial invention will be given the first priority. For example the University is now working with a number of companies in the area of Surface Enhanced Resonance Raman Scattering (SERRS) and has been granted seven patents in this area, which is the biggest University portfolio of a family patent. These patents are methods of application particularly in relation to DNA diagnostics. With these patents, the University prefers to keep some very basic patents, which described the very fundamental inventions. The application parts were granted separate patents.

These patents will be licensed non-exclusively to as many companies that can start using these methods. Some of these patents are more application-focussed patents, which the University wants to make available to a few limited licensees. By doing this, these particular companies will have a competitive advantage in that field and that particular application will be developed. The University will give more opportunities to licence to all players who might want to use that technology only when the basic technology has been adopted across more sectors. The University of Strathclyde granted an exclusive licenses to Wyeth the Luecovarin drug and Hyundai for and the obesity drug. For the case of SERRS, out of seven patents, two of them were licensed non-exclusively and two others were licensed exclusively for limited fields to the same company (Astra/Oxanica company). The TTO director said;

> *"...In that case we determine that we would prefer to keep some very basic patents which describe a very fundamental invention that we would license non-exclusively to companies. The reason for wishing to do this non-exclusively is to try to encourage as many companies as possible to start using this approach. And then some of the more application focussed patents, which we have we want to make them exclusive and issue a few limited licenses to these companies. So that some companies hopefully will develop particular applications for particular fields, which hopefully will give them some competitive advantages in these fields. But at the point when the basic technology comes to be adopted across more of the sectors we have the opportunity to give a more exclusive license to all the players who might want to use it".*

4.11.9 Process of licensing agreements

The University have two types of licensing agreements. The first one is the arms length license agreement, where the University licenses the IP straight to the company without any further assistance for research development from the University. The second type is the license agreement where the University has a relationship with the companies for research and development. In the latter case the University and the company initially try to reach the simplest terms of an agreement on commercial and IP terms. For further negotiation, a face-to-face meeting between the University and the company will be held. The University representatives comprise the RCS Director, other staff from RCS (IPR officer and Business Development officer) and the inventor. When the main terms of the deal have been agreed, a contact person from the University will work with the contact people in the company to produce a mutual agreement. The license negotiation process and signing of the contract will take three to four months. When the licence is signed, the University normally have a formal relationship with the company to monitor the company's development through to the launch of the product and will meet every six months.

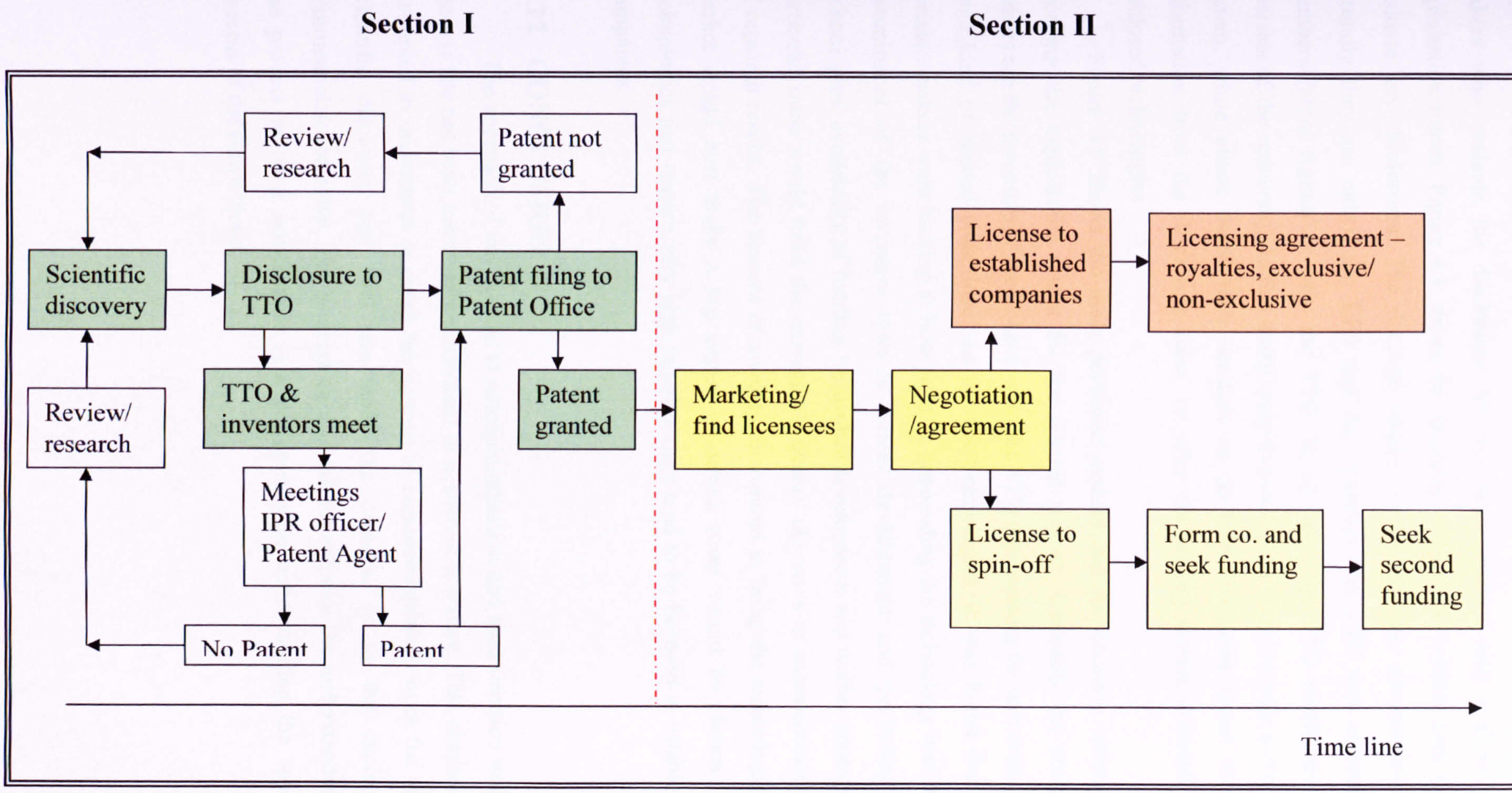
4.11.10 Commercialisation model

Having reviewed the literature and carried out interviews with the TTOs directors of the universities, the framework of commercialisation process as illustrated in Figure 4.3 is proposed. This proposal is an extension to the model adopted by Siegel et al. (2004) and Shane (2004) as shown in Figure 2.2. This new model is illustrated in detail in Figures 4.4 and 4.5, which focus on how the decision-making in patenting and the decision criteria are used to choose the commercialisation routes. This model integrates both theory from literatures and view from the TTOs collected in this study.

Figure 4.3 describes in more details the process of commercialisation in universities starting with the scientific discovery (Section 1) by the University's researchers in the laboratories normally whilst working on government research, charities or industry grants. Researchers are encouraged to file invention disclosures to the TTO. Inventors and the TTO officers then discuss the market applications and the commercial potential of the inventions. The TTO through a special committee must then decide to do market research for the inventions to identify market potential or the need to seek patent protection for them. The University should only patent those inventions that have market potential. If the inventions have industry partners who had sponsored the research, their views and interests are important in the decision to patent, as the sponsors of the research projects would normally be a licensor of the potential patent. Then a decision is made to either apply, or otherwise, for patent.

The next stage (Section 11) of the model shows those who are involved in the decision making to commercialise the invention. In some universities, the decision

Figure 4.3: Summary of the general model of commercialisation process based on literature reviews



makers who evaluate the disclosures are the same persons who evaluate the exploitation routes. Figure 4.4 shows the decision makers and criteria used to to evaluate any disclosures. The decision makers varies between universities but normally they are either, the TTO and the inventors, the TTO and committee members/Patent Agents or only the TTO. In all cases the TTO represents the intersets of the university. In this study, only University of Warwick uses a scoring system, while others based their decision on on basic judgment based on the information from the disclosure form, or after conducting market research for disclosed technologies.

Figure 4.5 shows the main deciosion makers and the decision criteria of choosing the exploitation routes for the granted patents. Generally the decision makers are the inventors of the technologies, the TTO representing the university and some kind of special committee. As for the technologies, it was found that the decision makers were looking at how good or outstanding the technology was, high commitment of the inventors towards further development and perfecting the technologies, availability of funding for further development and wether choosing a particular route would fulfil the university's overall objective in commercialisation of research results. The amount of investment required to bring the technologies to market would also make a big impact on which route would be chosen. The technologies that require very high initial outlays tend to be licensed to established companies.

4.12 CONCLUSION

The approach of universities to commercialisation and their decision making process has not been intensively scrutinised in academic literature. This chapter has attempted to understand in detail the process of commercialisation from the initial scientific discovery and who has made the decision as to the choice of commercialisation route. The findings of this chapter enhance the understanding of the process in other universities as a preliminary to understanding the specific process of the entire thesis.

Figure 4.4: The decision makers and criteria used to patent the inventions or disclosures (Section I)

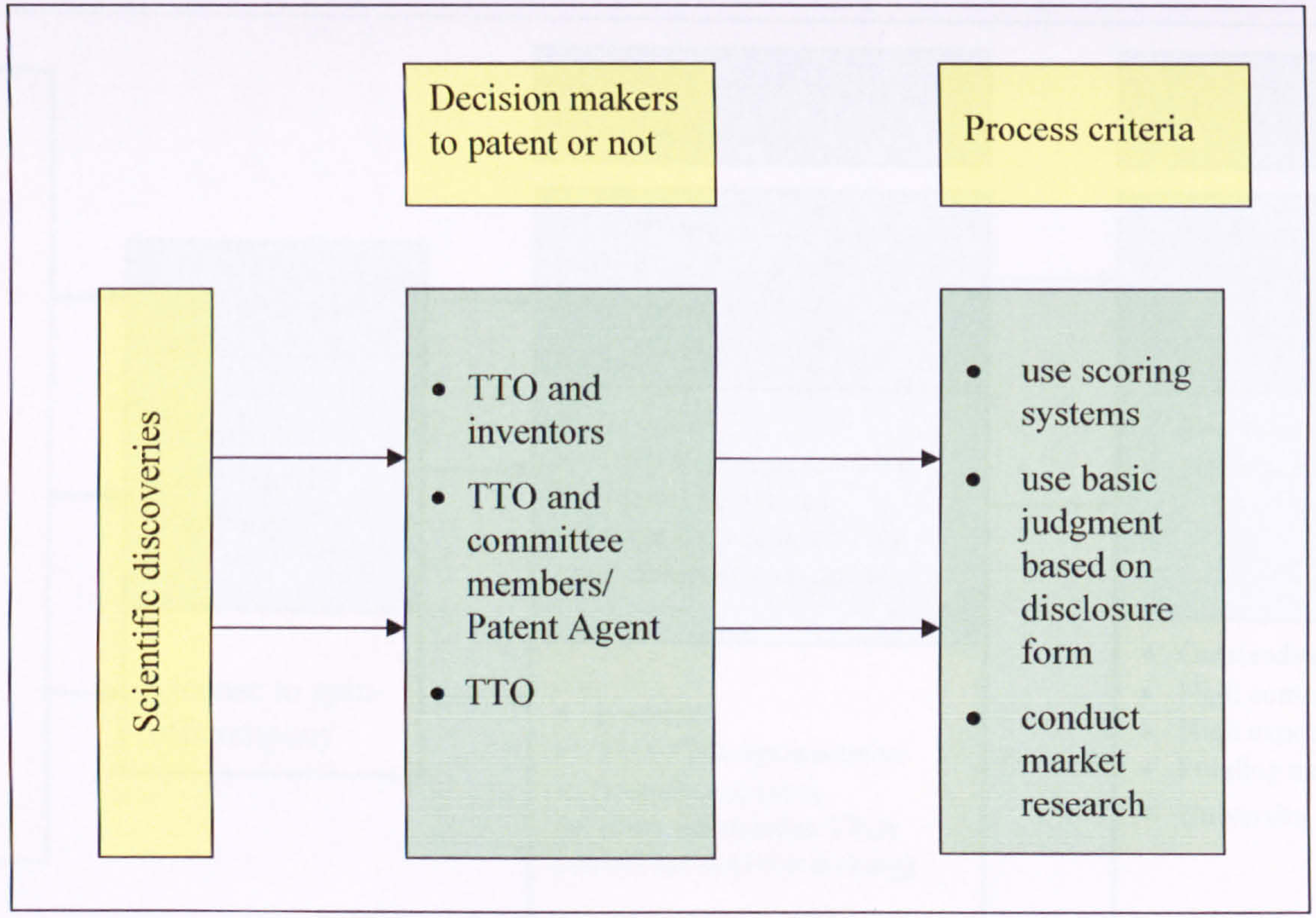
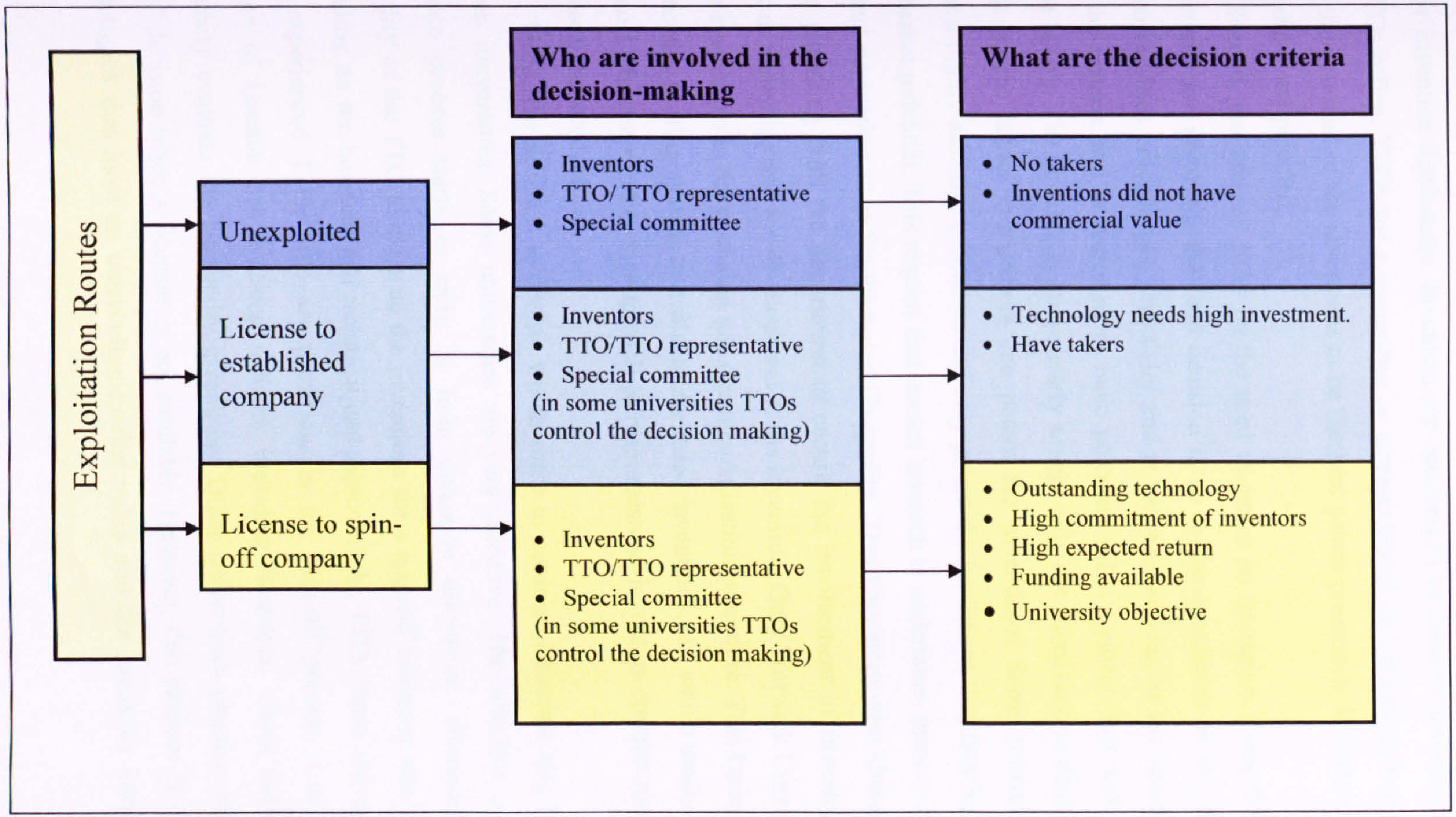


Figure 4.5: Decision makers and decision criteria used to exploit the patents (Section II)



The findings reveal that there are differences between universities in how they decide to patent and in the route to exploitation. First, none of the universities scout for invention disclosures. Inventors are encouraged to disclose inventions to their TTOs office. TTOs (or a committee or representative) and inventors together discuss the potential of the inventions to be filed for patent protection. However, not all inventions are patented.

Second, universities differ on the need to patent an invention. Even though the inventors are involved, the final decision is up to the committee or the TTO. Some universities practise low selectivity and is patented as long as the invention fulfils the criteria and is expected to have potential value ('patent first and find licensee later'). The licensee is immediately sought after the filing date as there is a need to patent before competitors can patent the inventions. Some universities practice a highly selective procedure and only patent the inventions that they believe have market potential. This request that market research is undertaken prior to filing for patent protection as at Southampton University. This University also shares the cost of patenting with the department to ensure the involvement of inventors or faculty in marketing and the development of the invention. Only Warwick University is very systematic in the patenting and commercialisation procedure. This University introduced a scoring system to evaluate disclosed inventions and which mechanism to exploit. However, other factors such as resources and inventors commitment are also taken into account.

Third, the decision to choose which route to commercialisation also varies between universities. Some universities are very selective. The selection or due diligence process starts as early as from invention disclosure. However, the capability of the TTO to evaluate the inventions for a spin-off company also varies depending on the business and technical experience of the TTO. Some universities have experienced TTOs who are proficient in the spin-off process. University College of London has a strong network including investors, which helps the University evaluate the University inventions. Other universities practise the 'last resort' decision when a licensee is not available. However, this practice is for the technologies that have an outstanding market value and the inventors have high motivation[38]. Other factors such as characteristics of technologies, resource availability, expected return at the certain value affect the decision making process.

Fourth, the decisions to award an exclusive or non-exclusive licence depend on the strength of the patents and the competence of the companies. All the universities practice the same procedures. Fifth, the ownership of the IPR varies between universities. Some universities retain their ownership such as the University of Strathclyde, the University of Glasgow and University College of London even though industry funds the research. On the other hand, the University of Warwick, Heriot-Watt University and the University Southampton the IPR is retained by the industry if industry funded the research.

Universities in England, have easy access to venture capitalist companies compared to Scottish universities. To attract venture capital companies they have various links and events to exhibit their technologies. The TTO Directors who have experience and background as entrepreneurs influence how they network and they employ different strategies in getting funding and building internal and external networking. Finally, all the universities confirm that commercialisation activities are not included in the universities promotional exercise.

In the next chapter, why the University decides not to commercialise some of its patents is explored. Inventors whose patents were not exploited were interviewed for their views on what are the features for this type of patent.

[38] The desire to see their inventions are being exploited and involve in product development, networking as well in the process of business formation during pre-start-up and post start-up period.

CHAPTER 5

WHY SOME UNIVERSITY PATENTS ARE NOT EXPLOITED?

5.1 INTRODUCTION

It has been established in Chapters 1 and 2 that the patenting process adopted by the universities is inefficient. Chapter 4 provides a detailed description of the commercialisation process as practised by various UK universities. It was found that universities share many common practices but there are certain differences in their approach to the commercialisation of technology. Patent filing and administration are expensive. Large patent portfolios that remain unexploited represent an opportunity cost as well as a sunk cost for universities. Unexploited patents do not have an impact on the economy either locally or globally. Budgets that are allocated to patent filing and administration could be used to the benefit of students and staff and upgrade other university teaching activities.

Various interrelated reasons were identified that explain why patents are not exploited. These include early stage technologies that have uncertain market value, technologies that is superseded by other advances in technologies, the broadness of the patents, a lack of skills, resources and networking of the TTO and a lack of networking and involvement of the inventors with industry.

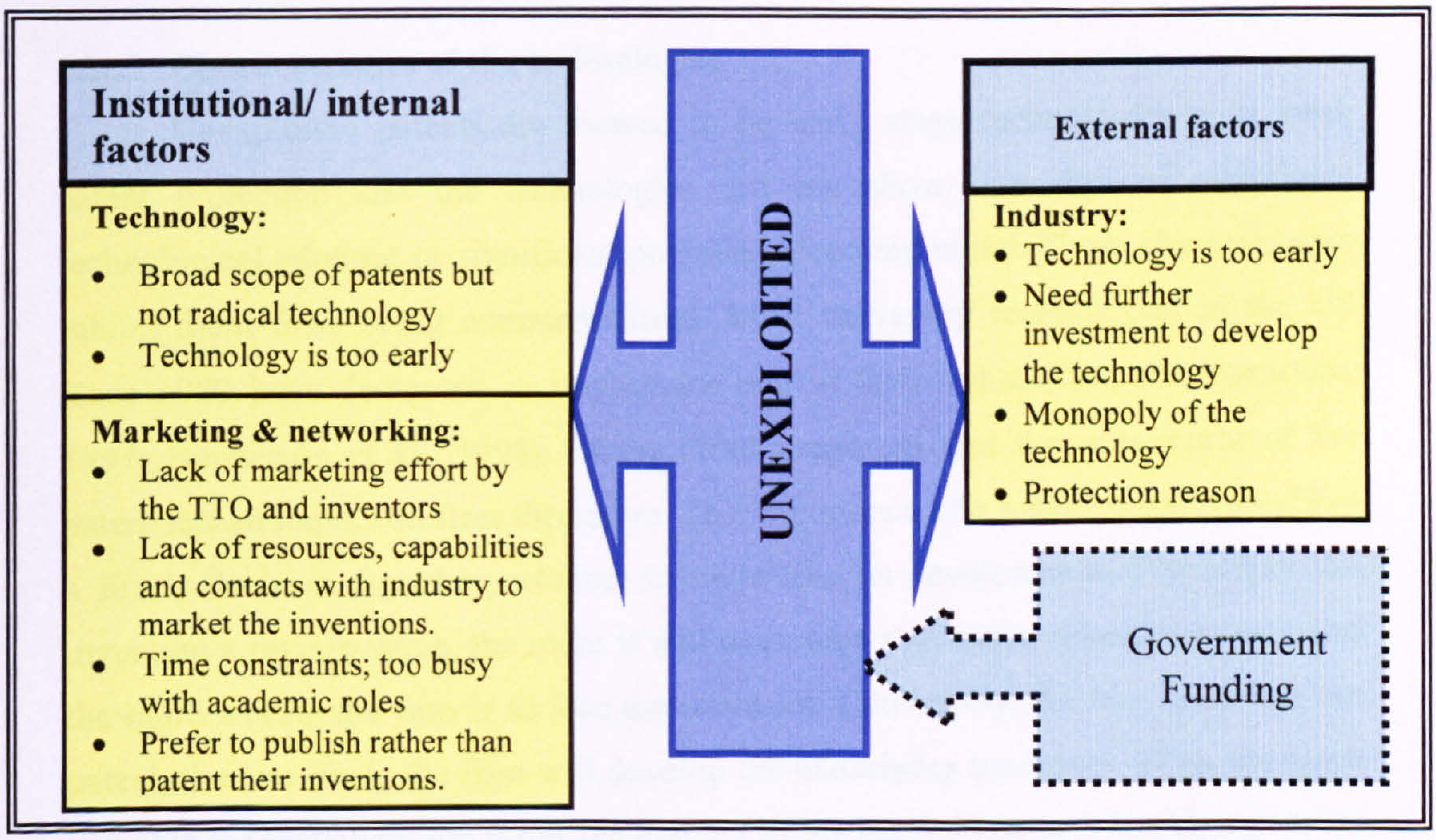
To overcome wastage of university resources, and reduce the number of unexploited patents the objective of this chapter is to examine patents that were not commercially exploited. The chapter explores the decision to seek patent protection and the characteristics of these patents, and seeks to identify which factors were most influential in their failure to be exploited.

5.2 LITERATURE REVIEW

Surprisingly, there is very little prior research which examines unexploited patents. Most of the research within the field of university commercialisation has looked at patents that have been commercialised. Thus, there is little prior guidance from the literature as to why patents are not exploited or what characteristics may be common to unexploited patents. The literature reviewed was based on 'indirect discussions' from papers that involve patents that have been commercialised.

The summary of the factors that inhibit patent exploitation is depicted in Figure 5.1. It can be concluded that factors that inhibit patent exploitation can be divided into institutional factors (characteristics of technology, lack of marketing and networking of TTOs and inventors, lack of TTOs resources) and external factors.

Figure 5 1: The factors that lead to patents not being exploited.



5.2.1 Motivation and opportunity recognition

As discussed in Chapter 2, the desire to see their inventions being exploited led most of the inventors to license their technologies either to spin-offs or to established companies. Their motivation was the desire to see their inventions developed into useful products and achieves commercial viability. Money was a secondary reason to license the inventions, which is consistent with studies done by

Shapero (1984), Olofson et al. (1987), Smilor et al. (1990), Blair and Hitchen (1998), Shane (2003, 2004) and Nilsson and Friden (2006). However, inventors who licensed their patents to established companies were risk averse and it suggests they were not interested in commercialisation activities. The inventors whose patents unexploited are also presumed to have 'need for achievement' personalities, and they considered commercial exploitation of their patents to be a symbol for success. This is one of the reasons why they patent their inventions. However, the inventors of this type of patent are not willing to go out to market their technologies to industry because of the technologies are at embryonic stage and they are too busy with their university workloads. The opportunities to exploit patents were limited and this was recognised by the inventors and the TTO. As Lockett et al. (2003; 2005) noted, TTOs are the first party who should recognise an opportunity before other external parties. However, in particular fields the skills of the TTO staff and of the inventors may not be enough to recognise opportunities.

5.2.2 Characteristics of the technologies

Unexploited patents are viewed to be early stage technologies with weak patent protection and the technologies did not show any sign of significant technological advance or significant potential economic value. These characteristics inhibit them from being commercialised. Most university technologies in the US since 1980 have decreased in importance and in their value (Hsu and Bernstein, 1997; Henderson et al., 1998). Shane (2001) reported that the importance of the patent has an impact on firm formation. The importance of a patent is likely to affect a firm's decision regarding whether to undertake its development. The higher the invention's private value, the more it will overcome the firm's opportunity cost and the more willing the firm is to face uncertainties. Conversely, the less important the patent, the less likely the firm will develop the underlying invention. Thus, the more valuable the invention, the fewer the number of unexploited patents remaining on the university's patent portfolio.

Hsu and Bernstein (1997) reported that unexploited technologies are due to insufficient maturity in the proof of concept, or a lack of apparent commercial value. Similar findings have been reported by Jensen and Thursby (2001), and Thursby and

Thursby (2000) (see section 2.6.1(i)). University technologies were claimed to be too basic and thus, are still far away from market applications (Strandburg, 2005) and so uncertain to succeed in the market (Shane, 2004).

5.2.3 Scope of patents

Shane (2001a, 2001b, 2004) suggests that industries prefer to exploit patents that have broad scope. On the other hand, if patents are too broad or too narrow, it is difficult for the inventors to identify the specific market that needs or wants to utilise the inventions. The recognition of the market is very important factor in the exploitation efforts of the patented inventions.

5.2.4 Research funding

Industry funding for research projects is claimed to increase the chance that patents will be exploited compared with government-funded research. Industry funding is easier to obtain when ties with industry exist and this normally leads patent exploitation. It also increases contract research, consulting, and publications, (Mansfield, 1995; Lee, 1996; Robert and Malone, 1996; Etzkowitz, 1998; Shane and Stuart, 2002; Shane and Cable, 2002; Coupe, 2003; Shane, 2004; O'Shea et al, 2005; Powers and McDougall, 2005; Gulbrandsen and Smeby, 2005).

Nevertheless, a study by Powers (2003) of 108 research institutions for the period of 1991-1998 suggested that federal and industry funding had a strong influence on the number of patents. However, he concluded that there was no measurable effect on the University's licensing income. This is because industry may only benefit from contractual agreements to conduct studies or clinical trials and not via licenses on a patented technology. Dietz and Bozeman (2005) gave evidence that those who received federal funding have a higher rate of publications and a lower rate of patents.

5.2.5 Inventor involvement in product development and networking

Product development is an important stage that needs both the inventor's involvement and commitment. A reduced commitment on the part of the inventors to bring their products to the market will lessen the prospect of exploitation of the inventions.

Networking by the inventor is an important influence and can increase the chances of patent exploitation. From the start of the research project networking with industry helps university researchers identify commercial opportunities for their projects. Less contact with industry leads to inventions not being exploited (Colyvas et al., 2002). Social ties, which include direct and indirect ties, also help inventors get funding for their projects. Inventions are easier to license, and spin-offs are easier to create, when inventors or TTOs have early relationships and network with industry. Colyvas et al. (2002) showed how important the role of the inventors are in getting the technologies licensed. Thursby et al. (2001) proposed that part of the reasons that patents are not exploited is because of less networking by the inventors. Indirect ties as a source of referral to investors will also help to reduce information asymmetry problems (as suggested by Nicolaou and Birley, 2003; Shane and Stuart, 2001; Shane and Cable, 2002) and reduce the chances of failure of the commercialisation efforts. Furthermore, some TTOs suggest inventors' networking is useful for marketing their inventions. The studies by Thursby and Thursby (2000; 2004) and Jansen and Dillon (2000) support this view. Thursby and Thursby (2004) found that personal contacts between companies' R&D staff and faculty staff were extremely important in identifying technologies to license. The closer the relationship, the increased likelihood that firms will license in lieu of sponsored research. Another study reported that the top ten universities in the UK have an external network that facilitates the process of spin-off formations (Lockett et al., 2003b).

5.2.6 The roles of Technology Transfer Offices

The main role of the TTOs is to accept any invention disclosures by academic staff, evaluate their impact and commercial potential. Then they have to decide whether to patent it or not. If they decided to patent, then they have to decide which route to use to commercialise the new invention or technology. This process was discussed in Chapter 2 and Chapter 4. Many TTOs have been found not to be too effective 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; Lockett et al., 2002; Markman et al., 2005b). When TTO officers have greater experience the number of spin-off formations are greater (Wright et al., 2002; Lockett et al., 2002). The role played by the TTO's staff is crucial to the success of the commercialisation effort for any new technology. Marketing efforts by TTOs are important to close the gap between academia and industry (Markman et. al., 2003; Colyvas et al., 2002). Markman et al. (2003) further suggested that TTO staff should be well rewarded monetarily to encourage their marketing efforts. Giving a higher salary to TTO personnel, Markman et al. (2003) argued, would have a significant positive impact on spin-off firm creation but would not necessarily improve licensing revenue.

5.2.7 Rewards and incentives

The world of academia is normally assessed by the quality and the number of publications produced by an academic. Commercialisation and entrepreneurial activities have so far been excluded from the performance evaluation of an academic researcher. The academic world is publication oriented. This acts as a barrier to activities by academics to exploit their research results (Ndonzuau et al., 2002).

There is a suggestion that academic inventors need more incentives and rewards for successful commercialisation efforts. Increased licensing royalties and commercialisation activities should be included in promotion exercises as they would encourage more patenting efforts and exploitation activities (Etzkowitz, 2000). Recognising these activities in promotion exercises in addition to refereed publications (Shane, 2004; Lambert, 2003; Siegel et al., 2003; Siegel et al., 2004) might, therefore, considerably encourage commercialisation activities. However, some researchers and inventors say that monetary rewards are not the main drivers towards commercialisation of their inventions (Blair 1998; Colyvas et al., 2002; Markman et al., 2003; Lockett et al., 2003; Shane, 2004; O'Shea et al., 2005). However, to encourage more commercialisation activities it is important to recognise those who have succeeded in licensing to established companies and those who have formed spin-off companies and remained in the University (the champions).

5.2.8 Conclusion

Having reviewed the literature, a set of propositions is put forward to answer the research questions and the objectives of the study. The propositions are shown in Table 5.1.

Table 5.1: The Propositions suggested for unexploited patents.

		Motivation and opportunity recognition
Unexploited patent	1A1	The desire to see their patent being exploited drives inventors to conduct their research.
	1A2	Limited networking with industry prevents the inventors and the TTO from recognising opportunities.
		Characteristics of the technologies/Scope of patent
	2A1	Early stage technologies with insufficient proof of concept generate patents that are not exploited.
	2A2	Patents are more likely to be exploited if their scope is broader
		Research Funding
	3A	The less industry funding for a research project, the less chance the resulting patents will be exploited.
		Inventors roles
	4A	The lower the commitment of the inventors to product development and networking, the less chance that the patents will be exploited
		TTO roles
	5A1	A systematic due diligence system by qualified and experienced TTO staff would reduce the number of unexploited patents.
	5A2	Extensive networking and marketing by a TTO staff, would increase the chances that patents in the TTO portfolio will be exploited.
		Incentive and reward
	6A	The lack of incentives and rewards would discourage academic inventors from exploiting their inventions

5.3 ANALYSIS

Interviews were undertaken with 10 inventors of patents which were not exploited. Table 5.2 shows the patent holders' job titles and backgrounds, their University departments, a brief description of their technologies and typical applications for their inventions, and the dates of the patent filings or patent grants. The inventors come from various departments. The oldest age of the patents is 30 years (that was granted in 1977) and the youngest is 3 years old after the date of filing or granted.

Table 5.2: Inventors of unexploited patents: their background and inventions

No.	Inventors info.	Dept.	Technology/ patent titles	The application of the inventions	Date of filing/ granted
1.	Inventor A, a lecturer and PhD holder. Head of Department A consultant to Irish 3D company and Scottish Enterprise	Faculty of education and computer science	Production of three dimensional images	1.Can produce large size images such as motor vehicles for advertising purposes. 2. Can be used to scan unborn babies. 3. For surgery- to produce three dimensional medical images	7/9/99
2.	Inventor B –a lecturer and a Professor Has a few patents. Active links with industry.	EEE[1]	Sensors and Micro-system	To detect presence of certain chemical compounds in transformer oil.	22/5/01
3.	Inventor C, a Head of Department and a PhD holder. Worked with industry.	Centre for Photonics	Is trying to produce blue LED[2].	Can be used in microscope and to check the back of the eyes.	27/02/01
4.	Inventor D - a Head of Department and a Professor. Used to license to established firm and a consultant to a few companies. Has 30 years experience in industry.	Pure and applied Chemistry	To develop Sensors from black strip plastics.	The sensor can be used to detect diabetes,	13/5/1992
5.	Inventor E- a Head of Department and a Professor. Used to be a consultant to companies. Had links with industries over a long period	Naval architecture and Marine Engineering	Submersible craft	The equipment can detect and repair the damage to deep sea rigs , replacing divers.	22/11/77
6.	Inventor F- a lecturer, PhD holder. Had one funding from industry.	Chemistry and process engineering	Developed novel gas separation. The nitrogen and oxygen can be separated using membrane, faster that existing technologies	The oxygen and nitrogen gases are useful in health and food industries. Aircraft cabin environment control. Nitrogen injection into aircraft fuel tanks	18/2/03
7.	Inventor F- a lecturer and a Professor. A Head of Department. Active in patenting. A new venture is being formed using a different patent.	EEE	Signal processing technology- FENN[3]	The technology is mainly used to analyse data and for prediction. It can be used by financial institutions, health services, and gambling businesses to increase productivity.	17/9/2002

1 Electric Electronic Engineering
2 Light Emitting Diodes
3 Functional Expanded Neural Network

8.	Senior Lecturer. Has links with other organisations to obtain funding, but not from industry	Immunology department, SIBU (Strath. Inst for Biomedical Science)	Vesicle formulation	Drug delivery formulation against parasite population	30/09/95
9.	Professor-lecturer. A Head of Department. Has a few patents. Another patent has been licensed and is bringing in a substantial amount of money to the University.	Pure and applied Chemistry	DNA Minor Groove Binding Compound	Therapy for anti bacteria/anti cancer drug. The component of analytical method for investigating property of DNA related to diagnostic tool for the determination of diseases.	24/12/2004
10.	Professor-lecturer and Head of Department.	Pure and applied Chemistry	Non-naturally occurring lipoprotein particle	i) a cell culture supplement ii) drug delivery agent	30/9/2003

5.3.1 Decision to patent

There was no consistency in the decision to patent. Three patent filings were initiated by the TTO (Patents 1, 3 and 4). The TTO and the inventors jointly initiated another three patents (Patents 8, 9, and 10). The inventors initiated two patents (Patents 2 and 7), and only two were initiated by industry (Patents 5 and 6) (Table 5.3). Whenever the TTO was the main decision maker, the decisions were based on information given by the inventors. Basically, the TTO tried to match the invention's characteristics to the requirements for patenting. One of the main factors in the decision was whether the inventions would generate income (interview with TTO). However, no proper market research was done by the TTO to verify that expectation.

Table 5.3: Decision to file for patent

Patents	Inventions	Decision to patent
1.	3D images	TTO
2.	Sensors & micro system	Inventors
3.	LED	TTO
4.	Black Strip Sensor	TTO
5.	Submersible	Industry
6.	Gas Membrane	Industry
7.	FENN	Inventors
8.	Vesicle Formulation	TTO & inventors
9.	DNA	TTO & inventors
10.	Non-natural Lipo-Protein	TTO & inventors

Industry would normally initiate the patent filing if the new inventions were the result of the research that they had fully or partially funded, and if they thought that the patents could be exploited in the future. They also requested patent applications to ensure their monopoly over those inventions (Mazzeloni and Nelson, 2002).

5.3.2 Inventors' backgrounds, motivations, and opportunity recognition.

The current average age of the inventors at the time of interview is 52 years. Most of the inventors have PhD qualifications and most were Heads of Department and Professors. Only two of them are Senior Lecturers. In seven cases (Patents 2, 3, 4, 5, 7, 9 and 10) the inventors had an industry background either as an employee or as a consultant. Their invention ideas could be said to have come from their consultancy jobs, as these helped them to identify opportunities in their research project and to narrow down the market. The inventor for Patent 9, for example, had 30 years experience in industry and the inventor for Patent 3 worked in industry before joining the University.

In all cases, the motivation to conduct research that leads to patenting the inventions was driven by the desire to see their inventions being exploited. Financial incentives were not the main factors that influenced the inventors to commercialise their inventions. As one of the inventors said:

> *"... it is quite nice to see ... what you have invented being sold. I get personal satisfaction, it drives me more than the financial rewards ...".*

The same view is shared by another inventor:

> *"...yes, we believed that we wanted to show the world that we can do a lot...At the back of your mind, you don't realise that. Yes it is the commercial success, it is nice that you will be financially rewarded but is not a driving force...".*

The inventors in this study were also unwilling to risk their time to network with industry, which may have resulted in the opportunity being difficult to recognise. Thus, the study supports propositions 1A1: *the desire to see their patent being exploited drives inventors to conduct their research and* 1A2: *limited networking with industry prevents the inventors and the TTO from recognising opportunities.*

5.4 REASONS WHY PATENTS WERE NOT EXPLOITED

There were several reasons why patents were typically not exploited (see Table 5.4 for a summary). All ten patents in this study were not exploited due to factors related to the technologies and their inventors. All the inventions were early stage technologies even though they were at proof of concept stage. Six inventors (Patents 1, 3, 6, 7, 9, and 10) reported that their patents were not mature enough and needed further developments (if funding is available at that time).

Table 5.4: Reasons why patents are not exploited

Patents	Inventions	Technology early stage/proof of concept	Used in conjunction with other	New Technology Superseded	Slow speed to market	Technology not reliable	Technology has changed	Broad scope of patent	Lack of time for marketing	Industry/organisation refused to invest /funding/ secrecy	Limited of time to develop product	Lack of funding	Promotion not counted	TTOS lack of resources	Protection reasons
1	3D images	√						√	√		√	√	√	√	
2	Sensors & micro system	√				√		√						√	
3	LED	√		√				√	√		√	√	√	√	
4	Black Strip sensor	√		√	√		√	√		√		√	√		√
5	Submer-sible	√		√	√		√	√		√			√		√
6	Gas Membrane	√				√			√	√	√		√	√	√
7	FENN	√						√	√		√		√	√	
8	Vesicle Formulatio n	√		√	√		√	√		√					
9	DNA	√	√					√							
10	Non-natural Lipo Protein	√						√	√		√			√	

Three patents (Patents 4, 5, and 8) were superseded by other technological advances, rendering them out of date. In the case of Patent 2 the technology was not reliable. For half of the patents the inventors did not have time to market their inventions (Patents 1, 3, 6, 7, and 10). The reasons are developed in more detail below:

1. Characteristics of the technology

- *Early stage technology*

The technologies for these unexploited patents were all at the very early stages or at proof of concept stage (Table 5.4). This supports the previous studies by Thursby et al. (2001), Shane (2004) and Markman et al. (2005). Most of the inventors reported that their patents were not attractive to industry if they are at very embryonic stage and need further development. This finding supports research proposition 2A1: *early stage technologies with insufficient proof of concept generate patents that are not exploited.*

One of the inventors claimed that his invention is an idea for the solution to the problem of getting blue light from an LED. Established firms wanted to 'see' the technology. The inventor commented:

> *"...That's the solution to that problem. It's ready to be built into something. What you got in this patent is ... a formula ... I want to get the light from there into there. And the patent is the formula in between to do that job. It's very much proof of concept. It's not a product. It's a solution to the problem [bringing the light from one point to another]. It's mature enough to patent, but is not mature enough to sell to the shop. There is a gap here ... This is only [a] physical proof of [a] concept ... ."*

The interviews also suggested that some of the patents need further development, which require the input of human, and monetary resources. The University has inadequate resources for these activities. The inventors also reported that they had limited time to network with industry, because of their teaching, research, postgraduate supervision and administration duties.

The inventors of the 3D image (Patent 1), FENN technology (Patent 7) and gas separation using thin membranes (Patent 6) also said that their inventions need further improvement. These three patents needed more funding for further development to prove that the technologies have potential use and could be brought to the market. Another inventor commented on his invention:

> *"... I can say it is at embryonic stage. If you put it all together in nice kits and put a nice button on it ... and made it more user friendly then anybody walking could use that ...".*

However, if the inventions did not have an economic value, were too basic or too far from the market, the inventions would not attract funders to finance further development, as previous research have suggested (Tranjtenberg, 1997; Thursby et al., 2001; Shane, 2004). For example in this study, in order to turn the technology behind Patent 6, (gas membrane) into a real product, further development work has to be done, which will require large monetary resources.

- *Scope of Patent*

All 10 inventors agreed that they were granted patents that were broad in scope. This does not support research proposition 2A2: *patents are more likely to be exploited if their scope is broader*

One of the reasons patents remain unexploited is because their scope is too broad. The broader the patent, the larger the technological space it covers, and therefore, the greater the array of potential applications that can be developed under its protection (for example patents number 1, 2, 3 and 6). These patents creating difficulties in narrowing down the application (as in the case of Patent 3).

An alternative explanation why research proposition 2A2 is not supported is that the scope of the patents may not have been as broad as the investors have suggested. This doubt arises because some inventors were wholly dependent on their patent agents who sought to make the patents as broad as possible. As one of the inventors said:

> *"... yes, in this case the Patent Agent tried to claim as broad (scope) as possible and the examiner may refuse grants to all the claims ... ".*

Another inventor commented:

> *"...I think it is a broad patent ... because when we write the claim, we tried to make it as broad as possible ... ".*

This is because inventions that are protected by broad scope patents make it difficult for others to copy. However, it cannot stop newer technologies that are developed independently from being introduced into the market. In this study, it seems that the scope of the patents granted was not as broad as claimed by the inventors, and other inventors could work round the patent coverage. For example (as discussed in Section 5.4), four new technologies had superseded those that were patented by the inventors. These were Patent 3 (blue LED), Patent 4 (black strip sensor), Patent 5 (submersible craft), and Patent 8 (vesicle formulation). These new technologies had become the market leaders in their respective fields. It is, therefore, difficult to contend that these four patents had a broad scope. If their patents had a broad scope, it would have been much harder for their competition to produce newer and superior technologies that superseded their original patented technologies.

In this study, the patents were not exploited through licensing to a new spin-off company or to established firms, though they were claimed by their inventors to fall into the broad scope category. This suggests that the scope of the patents is not the main factor that determines the chances of their being commercially exploited.

- *Superseded by new technology*

In four cases (Patents 3, 4, 5, and 8) the inventions had been superseded by new technologies in the market. As a result the inventions are now considered outdated. Because of this, industries stopped funding further research and development of these inventions. These inventions, at the time they were invented, were considered to have high potential. For example, Patent 8 provides good drug delivery using the blood system, and could be used to kill parasites, found in plink and the bone marrow. At the time the patent was filed, the system needed more trials to kill the parasites. Because of the time taken to produce a reliable product, the technologies were superseded. Inventors in universities are not full-time researchers. They are also involved in teaching and the supervision of research students. Thus, it takes longer to produce reliable products to bring to the market. In addition, the inventors did not have personal links with any industry in order to push their inventions and speed up the processes required to enter the market.

In the case of Patent 4, the patent application was filed only after the inventors realised that their inventions had been superseded. Although this means that the invention had no chance of being exploited, the patent would allow the inventors to have freedom to conduct further research in the same area and a subsequent patent in the same area was soon granted. The inventor commented on his invention:

> *"... It wasn't exploited, simply because industry decided they didn't want to fund it and pursue it. This patent was about the use of a conducting polymer as a sensor. While we were doing this work, they were highly efficient optical sensors. Because the sensors became efficient and reliable, that drove us to conduct further research at that time. This research was stopped because other technologies over took it. When we developed it, it was appropriate, a good idea, other technology came along and became more desirable. But to make sure we covered this, we actually filed the patent to get funding for developing further inventions ... ".*

Another reason that enabled competitors to come to the market was that the time was too long from patent filing to the production of a prototype. It is important to note that big corporations do have their own research programmes complete with infrastructure, support and funding, thus, they are nimble enough to enter the market with products to exploit any new technologies.

As one of the inventors commented:

> *"... there is no way that the University can do that [product and market research at the same level of resources as a corporation] because ... University research can't compete with the likes of Philips. It is the industry things ... you can just only keep trying and throw money at it. In 1996, I don't think the eight of us would have said '... in seven years time we would have devices 500 hundred times brighter ...' It'll take 30 years to get there. How could you ever believe that you could do that ... ".*

- ***Unreliable technology***

A technology that is not reliable has no commercial value, and so is unlikely to be commercially exploited. In this study, inventors of Patents 2 and 6 considered that they were not reliable. They were patented just to protect the idea behind the technologies but the technologies themselves would not be exploited in their current form. After further tests, Patent 2 could not be made more reliable. It was later abandoned. The inventor said:

> *"... we did [continue the] project internally;, after twelve months, the student finished the research. We concluded that it was not reliable enough. ... the fact is that if the technology*

is 100% reliable, then it would be worth commercialising. If the technology is only 25% reliable nobody would be interested in buying from you ...".

Patent 6 is not considered to be reliable unless industry is willing to fund it. However, as explained earlier, the technology is far from market ready and industry has stopped funding the project.

- ***Stand alone technology***

All technologies in this study reported were stand-alone technologies, which as suggested by Shane (2004) should be exploited through spin-off companies. However, the fact that they were not exploited suggests that this is not the only reason why they were not exploited.

2. Access to funding

In this study, industry funding only had a little effect on patent exploitations. Most of the research was funded by the government, through various government bodies such as Medical Research Councils, industry, external organisation (WHO), and various standing funds created by the government, industry or charities such as synergy funds and proof of concept funds. Most of the projects received funding from government sources. There are four cases (Patents 4, 5, 6 and 9) which received funding from industry, five patents (Patents 1, 2, 3, 7, and 10) from government funding and one from World Health Organisation (WHO) (Patent 8), none of which were exploited. Three projects were funded from more than one source (Patents 6, 9 and 10) (Table 5.5).

Four projects that were funded by industry only received first round funding from industry (Patents 4, 5, 6 and 9) even though one of the patents (Patents 9) may have had market potential. This is because, as mentioned earlier, Patents 4 and 5 were superseded by other more advanced technologies, and, therefore, industry stopped funding the projects. Patent 6 needed more money to further develop, as the technology is uncertain and far from market, and this need huge investment. Patent 9 involves a drug research project which industry prefers to fund at a later stage.

Of these patents only two (Patents 9 and 10), at the time of writing this thesis, are in the process of being exploited. During the interview, the inventor of Patent 9 reported that the invention would be exploited through licensing to an established company after various testings would have to be done to prove the reliability of the technology. For Patent 10, a company would be formed if testing were to prove that the technology is reliable. The inventor commented:

> *"... I could set up a company if venture capital gives me the money. We developed the technology for drug targeting in cancer chemotherapy ..."*

Table 5.5: Sources of funding for conducting research

Patents	Invention	EPSRC	Proof of Concept Fund	Synergy fund	Industry	External organisation (WHO)	Medical Councils	University funding	Total
1	3D imaging							√	1
2	Sensor and micro system	√							1
3	LED							√	1
4	Black Strip sensor				√				1
5	Submersible				√				1
6	Gas membrane	√			√				2
7	FENN							√	1
8	Vesicle formulation					√			1
9	DNA minor groove binding compound		√	√	√				3
10	NLP		√				√		2
	Total	2	2	1	4	1	1	3	14

Similarly with Patent 1 (3D imaging) and Patent 7 (FENN technology) it was believed that further research and development would lead to their inventions being exploited. They felt that their technologies were nearly ready for the market and only required final proof of product reliability. However, the required funding was hard to come by.

Another reason may be that industry sometimes tends to resist funding new technologies because they are 'disruptive' to their existing products. A good example is Patent 6 (gas membrane) gas separation functioning technology that had already been demonstrated, but further research was required on the mechanical strength of the membrane structure before it was acceptable to the market. However, once it was ready to be introduced into the market, the industry would need new investment to replace the old gas separation process with the new process.

Industry may be interested in funding early stage patents if the inventions have economic value. Economic value could be identified or narrowed down if personal contact with industry exists as early as possible (Colyvas et al., 2002). Early relationships with industry increases the chance that industry will get involved and help to develop the technologies at the early stages and also monitor the progress of the projects. This means that the direction of the research is 'guided' towards commercialisation and hence their chance of being exploited is higher.

Seven projects (Patents 1, 2, 3, 6, 7, 9, and 10) were funded by various government funds. Only Patent 9 received Proof of Concept and Synergy funding. These funds were given to develop the inventions to prototype level. As mentioned earlier the technologies are being testing and would be licensed to an established firm if the testing is successful. This supports previous studies by Powers (2003) and Mansfield (1995) that government funding of research projects leads to an increase in patenting activities but it does not lead to increases in licensing activities. Government funding is oriented towards basic research or curiosity study as suggested by Mansfield (1995) and Strandburg (2005), which does not require the researcher to identify commercial applications.

Rather, this form of funding is more likely to generate publications produced by the academics (Trajtenberg et al., 1997; Strandburg, 2005) as in the case of Patents 2, 6, 9 and 10. The overall findings show that both industry and government funding are important to conducting research projects for commercialisation activities. However, in this study industry funding failed to bring the projects they funded to the market place as already explained. This contradicts previous research (Mansfield, 1995; Robert and Malone, 1996; Etzkowitz, 1998; Cable, 2002; Coupe, 2003; Shane, 2004; Powers and McDougall, 2005; Gulbrandsen and Smeby, 2005), which suggested that industry funding would lead to greater exploitation of research results. The findings also do not support Research Proposition 3A: *the less industry funding for a research project, the less chance the resulting patents will be exploited.*

3. Inventors' involvement in product development and networking

University technologies have a higher potential to be exploited if their inventors were involved, or committed themselves to be to be involved in further developing the technologies. For this they need to retain their original sources of funding as well as to find new ones in order to develop their projects continuously, if they think the project have potential market. The researcher's existing network of social and business ties are crucial to seeking these new sources of funding. Half of the inventors (Patents 1, 3, 6, 7, and 10) commented that they were very busy with traditional academic duties and so did not have time to develop the technology and to build new and broader networks with industry (see Table 5.4).

The first reason is the technologies themselves. They are far from market application as discussed in Section 5.4. The technologies were really at embryonic stage (insufficient proof of concept, no economic value), difficult to prove their commercial potential, nor totally reliable or too advanced, which needs a lot of investment that industry refuses to invest in. Because of these factors, the inventors were unwilling to devote their time to be fully involved in the formative and developmental stages of the technologies and the potential products development. They also did not see the need to build networking. The inventors gave the 'easy reasons', which were related to their traditional academic duties thus, they did not have enough time to develop the technologies and build networks with industry.

The cause and effect here are actually interrelated which means that the technologies could not be exploited effectively, and this is consistent with Thursby et al. (2001), Colyvas et al. (2002), and Thursby and Thursby (2004). According to Thursby et al. (2001), and Colyvas et al. (2002) networking is crucial to further development of early stage technologies in order to gain continuous support and funding from either original or new sources.

Another time factor that inventors could not normally satisfy is the short development time required by investors. If the inventors could not set aside enough time for this crucial period in the product development, then it will be difficult to attract the funding essential for the exploitation of the technologies.

One of the inventors commented:

> *"...It's a metaphor. The tortoise and the hare were in the race. The hare is very fast. The tortoise is very slow. But the hare is reckless. The tortoise is methodical. The small methodical person often wins the prize. The rash, hasty person often fails ... I am the tortoise. I work slowly, and I'll do what I can and I am quite busy on a number of things. And ultimately this may come to something, but I'm not gonna drop everything else and kill myself over pursuing funding for this project. I've got a lot of things to do ... This patent hasn't ... as far as I know, hasn't aggressively been to the market. And I haven't been involved in any aggressive marketing ... "*

The second reason is time constraints, and some inventors did now know how to start to build up contacts with industry. Two of the inventors (Patents 1 and 7) in this study are of the opinion that there is a need for full-time marketing people in the research team to allow the rest of the team to concentrate on the research. Good personal contacts between inventors and industry can sometimes alleviate the requirements. As one of the inventor commented on the need for a full time marketing person:

> *"... I have nobody working 100% of his time on commercialisation. So you need somebody, that I could direct, supervise ... but all that person is doing is looking at commercialisation routes for that ...".*

The inventor of Patent 8 commented that she did not have any formal or informal contacts with industry. She contended that if there were people making good contacts for and networking her invention, the outcome would be that industry could help speed up the development of the product, its entry to the market, and could help overcome problems. The lack of industry contacts and lack of industry experience also hampers the inventors in the sense that they were unable to identify which industry to target. For example, the inventor of Patent 3 commented that the market was too broad for his technology and he did not know which industry to target at the outset.

On the other hand, the inventor for Patent 9 (using DNA to formulate anti-cancer drugs) has more than 30 years experience with industry. He also had previously licensed his Leucovarin drug to Wyeth and brought a substantial amount of money to the University. Because of previous contacts and experience, it could fairly be said that his technology (Patent 9) will be commercialised if the trials are successful and comply with the drug regulations of various countries.

All the above findings support the proposition Research Proposition 4A: *the lower the commitment of the inventors to product development and networking, the less chance that the patents will be exploited.*

The finding is consistent with the work of Thursby et al. (2001) and Colyvas et al.(2002) who pointed out that inventors involvement in product development and networking mean that it is more likely that the patents will be exploited and less effort in product development and networking leads to patents remaining unexploited. The finding also supports studies by Birley (1985) and Rappert et al. (1999) who suggested that these good contacts and networks increase the chances of a new technology being exploited

4. The role of the TTOs in decision to patent and to networking

As discussed in Section 5.2.6 the TTO needs a systematic due diligence system to apply to the patenting and commercialisation decision. This would enhance the effectiveness of the decision-making process, especially in selecting which inventions should be given a priority on patenting and commercialisation. Earlier, Table 5.3 showed that for more than half of the patents, the TTO had an important role in the decision to patent the inventions (the decision was either made by the TTO or a joint decision by the TTO and the inventors). However, for most of the patents the inventors commented that the TTO did not have a systematic commercialisation policy, which they saw as a part of the University not having a systematic due diligence system and overall commercialisation policy. As one of the inventors said:

> *"...Yes.. they don't have policies that are written some where.. there is no written policy that I know about. But we try (the University/the TTO) to encourage innovation and activities..."*

It is important that the TTO has adequate resources to bring the inventions into the market. In this study, the inventors for six patents (Patents 1, 2, 3, 6, 7, and 10) reported that in their opinion the TTO does not have enough resources to market their inventions. The TTO also lacks of knowledge in certain technology fields. A university needs market experts in many different technologies. In particular sectors the TTO's inadequate expertise may result in failure to exploit inventions. Two inventors suggested the need for a full-time marketing person to market their technologies. They also commented that the TTO was very slow in connecting them with potential licensees.

One of the inventors said:

> *"..I spoke to that marketing team quite a lot and spoke on this one as well. Only spoke, but nothing happened. No. It's slow .. it's slow .. the next time I speak, it starts [all over] again, nothing happened, .. ".*

The inadequate resources at the TTO is recognised by the director himself. He commented:

> *"... Within this office a few people may know one sector better than another but they aren't specialists. We have so many different types of inventions and technologies that come out. They [the TTO staffs] couldn't be expected to be experts in all fields ... ".*

However, the inventors conceded that the TTO was trying hard to help them. The office was supportive in trying to link them with a few companies, which could help find other links to market their inventions. The inventors of four patents (Patents 2, 6, 7 and 9) agreed that the TTO was very supportive and efficient in preparing patent specifications, and linking to patent agents. But in other aspects, especially in marketing their technologies, the TTO's help was much more limited.

The inventors of Patent 4 and Patent 5 whose original research was sponsored by industry gave another view of the process from research to the commercialisation of technologies. Their patents were granted during a period when there was little encouragement for commercialisation activities in comparison to now (Patent 5 was granted in 1977). At that time, as Lee (1996) contends, sponsored research was more important than other commercialisation activities such as the formation of start-up companies. Researchers were encouraged to get close to industry by doing consultancy and sponsored research to access funding (Thursby and Thursby, 2001; and Markman et al. 2005). These inventors, therefore, have a different priority from the TTO which targets cash incomes from licensing royalties than the formation of spin-off companies. In the formation of spin-offs one of the inventors commented:

> *"... the University is overplaying commercialisation activities. .. The success rate is small, small returns. And the University is playing a game without enough money in order to commercially exploit the know-how - except in selected areas. What we need is to get people to be aware of [our technologies] or [the University needs to be] close with outside industry. That's what I called commercialisation actually, not products."*

> *"... The best output from universities is people. The most income for the University is students coming. Now, commercialisation is [only] a tiny portion of it. When the outputs are good students, industries will bring the money to University research ...".*

The findings conclude that a lack of resources and skills in technology evaluation of the TTO staff led to support Research Proposition 5A1: *a systematic due diligence system by qualified and experienced TTO staff would reduce the number of unexploited patents.* The finding also supports Research Proposition 5A2: that, *extensive networking and marketing by a TTO, would increase the chances that patents in the TTO portfolio will be exploited.* This is consistent with the previous studies by Lockett et al. (2003), Wright et al. (2002), Shane (2004) and O'Shea et al. (2005).

5. Rewards and incentives

All the inventors agreed that the main factor they got involved in research projects was to see their inventions being utilised. Money is not the main factor. One of the inventors said;

> *"...it is quite nice to see what you have invented being sold. I personally would get satisfaction. You see, that is my idea .. all the way through .. it drives me more than [the prospect of] financial [returns] ...".*

Another inventor shared the same view;

> *"...Yes, we believe we want to show the world that there is a lot that we can do .., in the back of your mind, you don't realise that. Yes commercial success means that you will be financially rewarded quite nicely but it is not the driving force. The driving force is the belief that ... you can. No .. not money per se.."*

Other than the direct monetary incentives, six of the inventors (Patents 1, 3, 4, 5, 6, and 7) also said that commercialisation activities do not count towards promotion. For them, publications in refereed journals are more important than commercialisation activities. This suggests to a certain degree that peer recognition of their published work in journals is more important as suggested by previous studies (Tornatzky, 2000; Tornatzky, 2001; Lambert, 2003; Strandburg, 2005).

One inventor commented that he would prefer publishing his invention rather than patenting it. By publishing, everybody can access his knowledge faster than a patent. Patent protection needs a few years after filing to be granted. He commented that he could make money before the invention became popular. In this case, where commercial potential is very certain, quick entry into the market is more important than waiting for a patent to be granted before getting into the market.

One of the inventors said;

> *"... If I have new ideas, I may have to publish it, because I want to share my findings. I may package it in such a way that I can take advantage of its novelty – [I would have been] in the market for a year, before it became popular and common to everybody. Because, you know, other people are working on similar technology and could make an impact on the market [later on] ..."*

This finding does not support Research Proposition 6A: *the lack of incentives and rewards would discourage academic inventors from exploiting their inventions.* This is inconsistent with studies by Etzkowizt (2000); Lambert (2003) and Siegal et al. (2003; 2004). However, the finding is consistent with Locket et al. (2003; 2004) who found that monetary rewards were not a significant factor in the commercialisation of technology.

6. Patents for protection of inventions

Another reason for universities to patent their inventions is for strategic reasons to allow their academic staff to freely continue to conduct research in the field of the technologies that were patented.

The inventors of Patents 4, 5, and 6 claimed that the inventions were patented to protect the novel ideas. The research that resulted in Patents 4 and 5 was funded by industry. The inventors claimed that the industry asked the University to patent the invention to exclude others from the technologies. The industry involved tried to become the lead monopoly player in the market of that patent by obstructing other players through patent protection. They also hoped that better inventions would be generated from the initial patents through further research. One of the inventors commented:

> *"... You come up with a patent ... to protect the idea, to make sure no one else takes the idea ... but it does not mean it is the practical one. So out of that one you could develop more ideas, from which more patents [would] come out. You may have, for example, three or four patents related to that idea. The one that we make money [from] is not necessarily the one that you take up. And that's what happened in all cases. I'm watching that one company have 60 patents on different things. Out of that only two patents or three are making money ... But they protected it, so [that] no one else can take [up] the technology. So it's more for protection rather than a commercial role. If you are successful, you may earn money from someone else but not in everything. That is my understanding of how the patents work."*

> *" .. Patents are useful. ... they are to stop [other] people exploiting [our ideas]. At the same time it stops further development of new inventions and [unauthorised] utilisation [by other people] ..."*

Another inventor said;

> *"Patents are not only [for] making money, it gives protection [from] other people expanding the idea in the same field, and from one patent it will generate better ideas after that."*

> *"We actually benefit from the ideas being put in. The important thing to realise is that patents do not make money. As far as I am concerned this company has protected itself by its use of this. But on the other hand other people [are] interested in this technology and without infringing the patent ..."*

Reinforcing this point, another inventor commented that the University patented his technology for strategic reasons, and he commented that;

> *"I think it's a strategic patent, it's not really a commercialisation issue ..."*

7. Industry resistance

As mentioned earlier established companies sometimes resist new technologies unless the benefits of adopting those technologies are very clear. They refused to adopt 'disruptive' technologies that may jeopardise their existing production process. The inventor of Patent 8 had some experience of pushing her invention to giant pharmaceutical companies before it was superseded. The companies refused to license her technology saying that their main reason was the company could not commit to new investments.

One of the inventors, through his different patented inventions, had discovered how to produce photocopier toner through "clean environmental production". An established company rejected the invention saying that huge investment would have to be incurred. The technology was rejected even though the inventor had actually proven that the invention would give promising returns. The companies would also have had to invest in training their people to accept and operate this new technology. This inventor said;

> *" ... They have to commit and make new investments: large investment in machinery, and they have to increase the capacity and turnover to cover the new investment. If they do that, we're going to make big progress. So they invest in traditional process and didn't do our process. They filed our patent in a cabinet ... "*

Another reason why industry does not easily accept new technologies is that their staff members hold the not invented here 'syndrome' (Shane, 2004). Basically they do not want to be pioneers in adopting 'unknown' technologies. They dread the changes that the new technologies would bring and the need to re-train. Additionally, they were not very confident if the technologies came from universities. One of the inventors in this study said;

> *" ... 'Not Invented Here Syndrome (NIH)', always becomes a big challenge to universities' inventors. The industry did not appreciate and [usually] undervalue University technologies".*

This finding is consistent with Shane (2004) that the not invented here syndrome is one of the barriers for the exploitation of University technologies.

5.5 CONCLUSION

The chapter answers the question: what are the features that contribute to patents not being exploited. The findings are summarised in Figure 5.2. The reasons that influence patents being unexploited can be divided into five main factors: the technologies, the inventors, the TTO, University policy and the industry. First is the technology. All of the patents are in the early technology cycle, which means that their commercial viability is still uncertain and some of them have no commercial value, some have insufficient proof of concept, others were superseded by more advanced technologies, and the technologies are at the conceptual stage. Industry refuses to license these types of technologies.

Another technology-related reason is that all the patents claimed to have a broad scope. The broader technological space it covers, the larger the array of potential applications that can be developed under its protection. It is difficult to narrow down the applications, and there is a higher probability that some of these applications will actually remain unexploited.

The second factor that leads to the patents not being exploited are the characteristics or motivations of the inventors and the roles of the TTO. Most of the inventors claimed that they were busy with the academic workloads and did not have time to devote themselves to upgrade their inventions and build networks. This limits their ability to conduct research in line with business needs and keep up with leading- edge research knowledge from industry. Research was 'curiosity driven', and the results were unpredictable, which led to patents not being exploited.

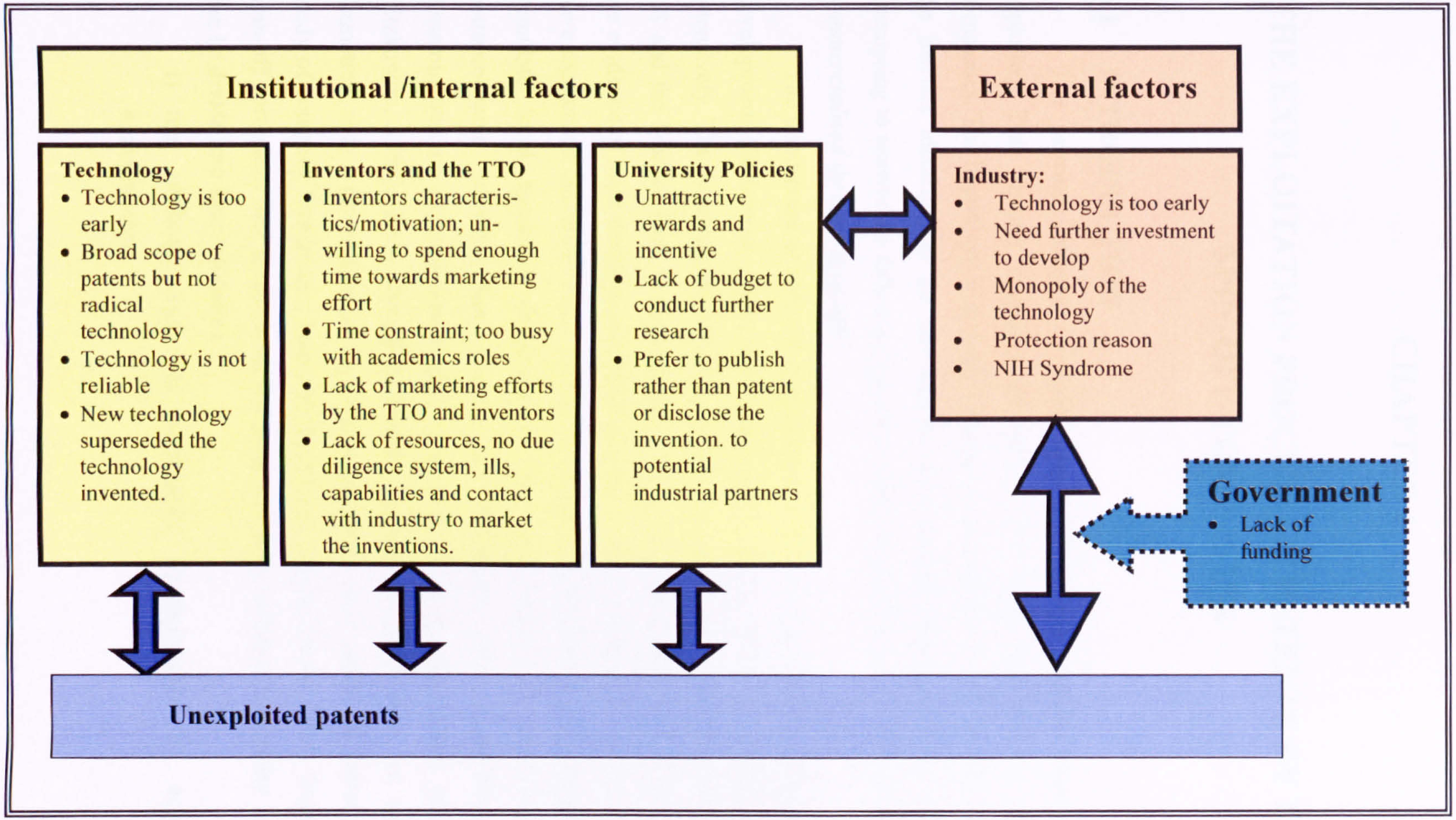
The third factor involves the TTO, and their lack of a specific selection system for patenting and commercialisation, along with their lack of expertise, insufficient skills in the relevant technology fields and lack of resources to market and network with industry. Deficiencies in the competency and skills the TTO required to evaluate the inventions, led to an increase in the number of unexploited patents. The absence of systematic due diligence means that the TTO is not be able to identify which inventions should be given priority in seeking patent protection and commercialisation.

The fourth factor is the University policy towards commercialisation activities, which involves incentives and rewards. Commercialisation activities are not rewarded unlike publication of papers in journals. This may mean that inventors are more likely to publish their knowledge in refereed journals to share the knowledge rather than patenting, which takes a longer period of time. Once articles are published, this limits the patented inventions that attract industry interests.

The fifth factor involves industry. Most industries refuse to license early stage technologies whose market values are uncertain, and technologies that is still far from the market. The "not invented here" syndrome is also a factor. It was found that the factors mentioned were interrelated.

For comparative purposes, the next chapter presents an analysis of patents that were commercialised by licensing to spin-off companies. This chapter examines the decision to patent and the features of the patents that are exploited by this route.

Figure 5.2: The findings of the study: factors leading to patents which are not exploited.



CHAPTER 6

THE EXPLOITATION PROCESS OF PATENTS BY THE SPIN-OFF COMPANIES

6.1 INTRODUCTION

The previous chapter identified that inhibit some patents from being exploited. This chapter examines the patents that were exploited by spin-off companies. The hypothesis is that these patents were commercially exploited because the barriers identified in the last chapter were absent. Specifically the study is attempting to answer the following question: *what are the features of patents that are commercialised through spin-offs?*

The importance of spin-off companies to stimulate and trigger local economic development (Etzkowitz, 2002; Etzkowitz, 2003; Shane, 2004) has been studied intensively. The development of local areas such as Route 128, Silicon Valley in the US and the Science Park in Cambridge in the UK (Oakey, 1995, Etzkowitz, 2003) are evidence of local development that has spun off from universities. Policy makers have recognised universities as a source of industrial innovation that can trigger and stimulate local economic development. The involvement of universities in entrepreneurial activities has changed the traditional role of teaching and dissemination of research knowledge towards a more entrepreneurial approach (Etzkowitz, 1998). Even though extensive research has been done on spin-off formation, only a few studies so far have used patents as an analytical factor in the study of company formation (Shane, 2001a; Shane, 2001b; Shane, 2004). Studies of spin-off formation that focus on determinant activities within a University context can be divide into four categories.

i) the attributes and the personality characteristics of academic entrepreneurs.

ii) the resources, endowments and capabilities of the University.
iii) the University structure and policies facilitating commercialisation.
iv) environmental factors influencing academic entrepreneurship. Other studies related spin-off contributions to economic development and their performance.

6.2 BACKGROUND OF LITERATURE REVIEWS

The literature review in Chapter 2, identified four factors that influence whether a patent is likely to be exploited through spin-off companies.

6.2.1 Individual characteristics, motivations and ability to recognise opportunities

There is substantial research on entrepreneurship which focuses on personal characteristics as a predictor of entrepreneurial activity (Roberts, 1991a) or champion to new ventures. Such personalities strive to achieve higher levels of financial success, self-achievements, the need for autonomy, are willing to take risks, energetic, have a disposition to act, and are more extrovert and independent than other individuals (McClelland, 1961; Stanworth and Curran, 1976; Khilstrom and Laffont, 1979; Shapero, 1984; Cooper, 1986; Doutriaux, 1987; Carter et al., 2003; Korunka et al., 2003; Shane, 2003; Shane, 2004). Roberts (1991a) study of the high technology entrepreneurs demonstrated that the factors that led entrepreneurs to form spin-off companies are outgoing characteristics; extrovert personalities; families with business background; independent, work experience; higher educations and skills; and dissatisfaction with existing job. As discussed in Chapter 2, the main factor is the desire to see their inventions being commercially exploited and key to achieving these are inventors who are highly motivated followed by wealth creation and independence (Smilor et al., 1990; Blair and Hitchen, 1998; Oakey, 2003; Shane, 2003; Shane, 2004).

Furthermore, the ability of individuals or TTOs to recognise opportunities influence company formations. The ability to recognise an opportunity is related to individual characteristics such as the ability to take risks; an optimistic personality; great awareness; and individuals that can recognise low opportunity costs that will lead the inventor-entrepreneurs to exploit those opportunities (Shane and Venkataraman, 2000). Prior knowledge and work experience also contribute to the application of specific skills and the recognition of future opportunities (Shane, 2000). Furthermore, Shane and Khurana (2003), who examined MIT-assigned inventions from 1980 to 1996, found that the career experiences of inventors significantly influenced the likelihood that their inventions will be commercialised through university spin-offs rather than licensed to established firms.

In addition greater knowledge of customer demands, more fully developed enabling technologies, greater managerial capability and greater stakeholder support (Choi and Shepherd, 2003) led to opportunities being exploited by spin-off. The ability to recognise an opportunity is not limited to the inventors themselves. In some cases, they have industrial experience, but do not have the ability to recognise an opportunity as discussed in Section 2.6.2. However, academics tend to have little prior market knowledge, lack of networks, and have no previous experience of professional investors or knowledge of what business model should be employed (Bower, 2003).

6.2.2 Organisational resources and capabilities

Spin-off ventures are different from other start-ups, because they develop out of a non-commercial environment. Thus, at their foundation these companies acquire different resources from other start-ups. The resources that are required at the launch period are: Characteristics of technologies, funding availability, a strong network, participation of the inventors in the product development, strong team formation, skills/capabilities of TTO, university reward and incentive system and external or environment factors. Different resources such as a strong patent at the founding period give a competitive advantage to high technology firms.

- ***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 tend to exploit ready-made technology (Shane, 2000; Shane and Khurana, 2003; Shane, 2001; Shane, 2004).

All the studies above, with the exception of Shane (2004), focus on limited constructs on patent scope and their importance using a quantitative approach. Shane (2004) gives a more comprehensive view on the factors that affect spin-off formation, which include entrepreneurs' characteristics and motivations, funding, characteristics of technologies and industries, university policies, and the role of TTOs. However, Shane focuses on only one University (MIT). Furthermore, all the above studies took their starting point as the start-up period and not the period before that. Therefore the above studies do not address the decision making process that is important to the examination of the effectiveness of spin-off creation.

Beside the above factors, University prestige, the history of a University's success, the impact of the faculty of Engineering and Science Department give an indication of the quality and variations of the spin-off activity among universities (Shane and Di Gregorio, 2003; Shane, 2004; O'Shea, et al., 2005, Powers and McDougall, 2005). The successful biotechnology firms in Japan and US were founded by star scientists (Zucker et al., 1998; Zucker and Darby, 2001). Shane and Di Gregorio (2003) found that some universities have more successful spin-off formations than others because of the intellectual eminence and quality of inventions. A university's prestige gives a sign of the quality research and inventors from the prestigious universities find it easier to get funding. In addition, equity investment and a low inventors' share of royalties increase the likelihood of company formation.

- ***Research funding***

The effect of industry funding can 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 funding which normally only leads 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 prevents free dissemination of their knowledge. The work of Lee (1996) showed that there has been some resistance by faculties to commercial activity as they are concerned that they will be diverted from basic research.

- *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 is uncertain market (Shane, 2004; Vohora et al, 2003, Binks et al., 2005; Wright et al., 2006). As mentioned in Chapter 2, for pre start-up and start-up stage, government funding, through various programmes, is crucial to the facilitation of a new venture as demonstrated by the SBIR programme 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 where a company can convince customers (Mansfield, 1995; Shane, 2003; Shane, 2004).

- *Networking and involvement of the inventors.*

Studies indicate that inventors with a strong network of social ties, either formal or informal, facilitate spin-off formation. These types of networks could link inventors to wide range of contact, including sources of funding (Shane and Stuart, 2002; Meyer, 2003). Friends, family, previous colleges, and previous employers are referred to as informal networks. Local community such as government agencies banks, private investors, and Chamber of Commerce or Small business Administration comprise a formal networks (Birley, 1985; Zhoa and Aram, 1995; Perez and Sanchez, 2002). These types of 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 work as a consultants before becoming the first buyer 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 investment from financiers. Shane and Stuart (2002) further examined why some universitiy start-ups are more successful than others. They 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 the network. This alleviates the information asymmetry problem (Shane, 2004; Shane and Daniel, 2002). Universities that have a strong network provide evidence of an increase in the number of spin-off compared to those who do not stress the advantage of networking (Shane and Cable; 2000; Lockett et al., 2003b; Shane, 2004).

Lockett et al. (2003b) reported that the top ten universities in the UK have an external network, and facilitate the process of spin-off formation. Nicolaou and Birley (2003) supported the view that internal and external individual networks influence the type of spin-offs formed. They proposed that an academic's embeddedness in a network of ties is exoinstitutional or endoinstitutional. The nature of these ties influences the type of spin-off they initiate, either as an orthodox spin-off, hybrid spin-off or technology spin-off.

Furthermore, according to Nicolaou and Birley (2003) networks facilitate organisational emergence by providing four benefits: opportunities recognition process; access to resources; timing implication to market; a source of status and referrals. Networks increase the opportunities recognition capabilities of the individual (Hills et al., 1997; Singh et al., 1999; Shane, 2000a; Elfring and Hulsink, 2003), the search for and decision to exploit opportunities (Venkataraman, 1997) and the access to information (Granovetter, 1985).

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 can be sustained. Vohora et al. (2003) proposed that (see Section 2.5.3) a spin-off company has to pass through five development stages and has to overcome four critical junctures related to resources and funding. Inventors' commitments are important because most of the university technologies are at an embryonic stage, which involve tacit knowledge (Thursby et al., 2001; Shane, 2004).

- ***Resources and capabilities of TTOs***

TTOs should have skilled and experienced officers, well versed with the legal aspects of patents and capable enough in exercising the due diligence in selecting which technologies to file for patents and choose the commercialisation route. TTOs also need to have a good link with the inventors and faculties, industry, private financiers, and this leads to a quality approach to inventions and could secure funding for spin-off formation.

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 chapter 2 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 perform poorly and are unsustainable (Lambert, 2003; Raven, 2006).

The TTOs skills and capabilities are associated with affecting the availability of resource (Lockett et al., 2003a; O'Shea, 2005). With resources, they are able to employ surrogate entrepreneurs or Patent Agents to evaluate disclosures before proceeding further (Franklin et al., 2001; Siegal et al., 2004). Lockett et al. (2003a) noted that the availability of resources (stock of technologies, and skilled staff), incentives and rewards, business development capabilities and the ability to access external finance and network building, were the main factors that facilitated the formation of spin-off companies. Lockett et al. (2003b) 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 venture as well as in R & D expenditure (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 perform in the decision making process.

Furthermore, to facilitate the commercialisation activity (Siegal et al., 2004), technology transfer office staff should be trained and equipped with knowledge, capabilities and skills in technology, business, and negotiations. Extra incentives should be given to TTO staff to encourage them to market the technology (Markman et al., 2003; Siegal et al., 2003b; Siegal et al., 2004).

6.2.3 University rewards and supports

Higher levels of commercialisation activities and high rates of spin-off activity are associated with a university culture that supports commercialisation activities. In contrast, university environments that do not encourage entrepreneurship will have less spin-off activity. Universities that support spin-off creation activities and have policies that include attractive reward systems, provide conducive environments for technology transfer. These universities also have flexible IPR policies (Rasmussen et al., 2005), positive role models (Blair and Hitchen, 1998) and have a strong mission or clear objectives towards commercialisation (Etzkowitz, 2002; Feldman and Desrochers, 2003; Lockett et al., 2003b; Lockett and Wright, 2005; Markman et al., 2005b). All these policies will encourage exploitation of inventions through company formations.

Taking equity in lieu of upfront payment (Bray and Lee, 2000; Feldman et al., 2002; Shane, 2004; Rasmussen et al., 2005) during the start-up period also increases spin-off formation. Equity gives more return to the university than does licensing to an established company when the spin-off company's traded at IPO. Other support such as incubators (Colombo and Delmastro, 2003; Grimaldi and Grandi, 2003) were demonstrated to facilitate spin-off formation.

University reward systems which take into account the commercialisation activities (not only based on publications) in the promotion exercise will encourage an entrepreneurial culture at the university that will lead to spin-off formation (Downes and Eadie, 1998; Franklin et al., 2001; Ndonzuau et al., 2002; Siegal et al., 2003b). Siegal et al. (2004) suggested that to facilitate a climate of entrepreneurship, university administrators should focus on five organisational and managerial factors; rewards system of university industry technology transfer activities, the TTO staffing policy, university policies to facilitate technology transfer, increasing the level of resource development and working to eliminate cultural and informational barriers in the UITT process. However, studies by Lockett et al. (2003a) and O'Shea et al. (2005) found that organisational incentives and rewards are not significant in spin-off formation. In addition, intellectual property rights (IPR) also are a major constraint to spin-off activity. No clear ownership of IPR in certain universities can deter the formation of a spin-off company (Argyres and Liebeskind, 1998). Lastly the support (Peters and Etzkowitz, 1990) and role models (Doutriaux and Dew, 1992), and behaviour at departmental level can have a stronger influence and effect on individual behaviour than the university's support for commercialisation activity.

6.2.4 External factors (environmental)

The effects of regional and legal factors and the government's national innovation schemes influence the creation of spin-off activity. Regional factors such as the industrial composition in the area surrounding the university can have an effect on spin-off activity as more customers, suppliers and potential employees will be present (Shane, 2004). However, Doutriaux (1991) reported that regional factors had the least influence on the creation of spin-offs in Canada.

On the other hand, in the US the introduction of the Bayh-Dole Act, 1980 facilitated commercialisation activities. In the US, universities and public research institutions are allowed ownership of their IP rights and they can license and make money from their IP (Etzkowitz, 2002). Although the effectiveness of the law has been debated by scholars, (Nelson, 1993; Henderson et al., 1998; Mowery et al., 2001; Shane, 2004) implicitly, it encouraged entrepreneurial awareness among academics. There was a similar situation in the UK, with the ending of the British Technology Group (BTG) monopoly, which in turn facilitated university spin-off activity (Hague and Oakley, 2000).

Furthermore, the government agencies can provide seed money for funding early spin-off activities. For example grants such as the University Challenge Fund for the UK universities and SMART Awards as mentioned in Chapter 2, can be given to successful innovations by Scottish Enterprise. These types of grants encourage spin-off activities.

6.2.5 Conclusion

In conclusion, spin-offs are most likely to occur in the following circumstances:

i) the presence of entrepreneurial academics;

ii) the existence of organisational resources (technology, funding, capability of TTOs, networking and commitment of the inventors);

iii) the policies and support of the university;

iv) the external environment (legal factors and support from government).

This chapter examines six companies that exploit patents from the University of Strathclyde. Are the above conditions found in these cases? To answer this question and the research questions in this study a set of propositions is set forth in Table 6.1.

Table 6. 1: Propositions for patents that were exploited through spin-off companies

	Propositions	Motivation and opportunity recognition
Patents licensed to new spin-off companies	**1B1**	The desire to see their patents being exploited, combined with the inventors' willingness to take a risk, the greater the chance that the patents will be exploited through spin-off formation.
	1B2	The more prior knowledge and industrial experience the inventors have, the more likely an opportunity will be recognised and lead to spin-off creation.
		Characteristics of the technologies/ scope of patent
	2B	Patents that involve early stage technology, are broad in scope, multipurpose and radical are more likely to be exploited through spin-off formation.
		Research Funding/spin-off funding
	3B1	The more projects funded by industry, the more likely spin-offs are created.
	3B2	Spin-off companies are likely to require external sources of funding to be created.
	4B	**Inventors roles**
		Inventors must be willing to be involved in product development, networking and other process, for a patent to be exploited through spin- off formation.
		TTO Roles
	5B	The creation of spin-off companies requires TTOs which are well resources and have skilss and capabilities.
		Incentive and reward
	6B	The creations of spin-offs require rewards given by the University.

6.3 COMPANIES PROFILE AND THE ENTREPRENEURS

The analysis starts with a profile of the companies and the background of the inventor-entrepreneurs.

6.3.1 Companies profile

Table 6.2 shows the companies' profile. All the companies are relatively new. Most 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. Only two of the companies were founded in the 1990s. Company D, was founded in 1995 and Company F was founded in 1999.

Company A was founded in 2003 by two people. They were University lecturers and the inventors of the technology. The company licensed the technology from the University based on exclusive rights, operating in the University's incubator and using the University's lab and facilities. It was planning to move out of the University incubator in May 2005. The company sells cutting edge technology; hardware computer products using high resolution, 3D display. The founder commented on the advantage of the system:

> *"... the advantage of our system is that you don't need to use glasses. The major disadvantage to using glasses is that you will get a headache, because the glasses use filters. Our systems are recreated without the use of glasses. Our system is very-very comfortable to use. They look like a normal monitor or any viewing devices but you see in 3D. The advantage of the system, is that they can be used as an ordinary computer and be put on the table ...".*

The company is targeting the market in geosciences for the gas and oil industry. Other markets include the medical sector to help scientists understand the neurological structure and geo-mapping for military and government applications. The founder-inventor of the company used to be a consultant with Ford Motors. He and his team had designed a 3D system for vehicle design, which replaced the clay models that had been used to advertise the Jaguar SK8. Work experience with Ford Motors gave him an advantage and helped him to develop the 3D visualisation systems hardware that the company is selling now.

Table 6.2: The companies' profile.

Company	Founded	Founders	Technolog y/patent	Filing date/granted	Application	Ownership /Exclusivit y 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	01/12/99 20/08/02 07/01/03	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 £3.5 m.University took 20% equity.

Company B, was started in the year 2001 with two founders and five employees, all of whom were university staff. Two of the founders worked full time in the company as the CEO and technical director, and the three of them worked part time. The company's office is located in the University's incubator. The company is developing and selling activity monitor devices that can monitor the daily activities of humans. This application can be used for clinical and personal applications. The clinical application is used for the management of a specific health disease whereas the personal application is used to monitor general health. The advantage of the technology is that it can give more accurate data than the existing technology. The University granted an exclusive license to the company. The founders had work experience within an industry that had designed a similar product. Two of the founders had experience in a Biomedical company.

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 the 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 to the company when it was formed. The patent maintenance fee has to be paid by the company. The company is selling gel material using a special membrane gel for indoor plants, and pots that can control the water level.

Company D was finally founded in 1995, even though the process of creating the company began in early 1991. During that time, the University had put little effort into encouraging spin-offs and the commercialisation of technology. One of the founders was a University lecturer 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. The company initially started in the University incubator from 1996 to 1998. However, working in the University incubator gave the feeling of being "the University's company" both for their clients and themselves and they decided to move out of the incubator after 1998. The main company office is now in the centre of Glasgow. The Managing Director described the situation at that time;

> *"... I think the difference here. When we did it in the early 90s, we were at Strathclyde University. At that time, the spin-off company was just a sort of a concept and was in its infancy. The local enterprise (Scottish Enterprise Glasgow (GDA Glasgow Development Agency which was the name at the time) was just waking up to the fact that yes, they could bring in companies from abroad to build big factories and so on but they will only last for 2 years and then they will be closed them down. These multi national companies just moved somewhere else because it is cheaper to build in other countries. It is only since the mid-90s that Scottish Enterprise or Britain in general realised that there is a lot of work done in Universities that could lead to commercial companies. When we were doing it in the early 90s (1991), we were leading the way in Strathclyde University ..."*

The company is now operating in a global market and is targeting new markets in the near future. The company is supplying monitoring equipment for gas insulated 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 this monitor. 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 buyer. Originally, the University had a share in the company with an investment of £10 000. The company bought back the share value 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 in 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 and which is as 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: defence, where kits can be used to sniff out chemical weapons; the security market for use in airports; the oil and gas industry where health and safety regulations demand rapid detection of noxious gases on oil rigs; and for medical diagnostics at the point of care, to pick-up early signs of illnesses. The device is the most effective and comprehensive method available for sensing dangerous drugs, explosives and hazardous compounds. At the moment, the company mainly targets the oil and gas industry.

Company F was founded in 1999 with four founders. The University gave an exclusive licence 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 the conjunction with voice system technology. Other services (video and camera) were requests to be provided by mobile phone providers in order to have 3G licenses. Orange funded the invention hoping to be awarded 3G licensed. At the end of the project, they were frustrated when Orange only did promotion on video for internal use rather than promote the technology they invented for mobile video compression. From that point, they left Orange and could see the opportunity that they could exploit. How they exploited these opportunities will be explained in the opportunities section.

6.3.2 Background of the entrepreneurs

Most of the entrepreneurs are technology originators and have hold PhDs (with the exception CEO of Company B) (Table 6.3). The companies came from various engineering and science backgrounds. The entrepreneurs were from engineering, computing, chemistry, physics and life science faculty. These fields have a significant impact on spin-off formations. They contribute to new innovatory discoveries, which lead to spin-off formation. Forming spin-off companies needs technical expertise that can be provided by a higher education institution as suggested by Oakey (1995).

Table 6.3: Background of the inventors-entrepreneurs[39]

Companies/Entrepreneur background	Age of the entrepreneur	Education background	Faculty	Field of research	Industry experience/funding
A	32	PhD in Applied optic in Mechanical Engineering	Mechanical Engineering	Applied optic in Mechanical Engineering	Consultant to Ford Motors. Obtained funding from Ford Motors.
B	43	Used to be a Research Fellow in Strathclyde University	B. engineering	B. engineering	Used European Union to fund a telemedicine project. Worked to design and deliver medical stimulator to mass manufacturer.
C	45	Used to be a Research Fellow in Strathclyde University and registered as PhD student	Chemistry	Hydro gel material	Patented a few patents from the same field and related fields.
D	47	PhD	Electric and Electronic 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

The current age range of these entrepreneurs is between 28 to 48 years old, similar to that suggested by McQueen and Wallmark (1982) and Roberts (1991a). After the age of 35, they already have a comfortable position in the University and it is difficult for them to leave the University and form a company. Most of them had work experience in industry. The technologies that they commercialised grew out of their experience in industry. This finding provides evidence that those inventors who had work experience in industry are more likely to form a spin-off company which

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

supports previous studies (Roberts and Hauptman, 1986; Roberts, 1991a; Shane, 2000a; Shane and Khurana, 2003).

One of the entrepreneurs said:

> *"...I worked with a company in Lanarkshire. I was in the University and I worked in industry. Then went back to University and back to industry again ..."*

Another entrepreneur used his idea and took forward the idea to build gas detection machines from when he worked with industry. He said;

> *"... I was working in the gas industry for a long time before that and knew that there were applications for the idea. Like defence for example through DERA. Before I did my PhD here, I was working at a national physical laboratory in London. We developed gas and drugs sensors".*

At the time the companies were founded, some of the entrepreneur-inventors remained in the University and worked as full time lecturers as well as part time in three of the companies (Companies B, D, and E). At least one of the founders worked full time in the company and ran the day-to-day management of the company during the founding period. Most of the companies started as a consultancy company or 'soft start-up' to support the business. During the start-up period, the companies can only support a limited numbers of staff. The advantage starting the business on a part time basis is that entrepreneurs have concurrent exposure to the needs of the new firms and other ideas that are current in his laboratory (Roberts, 1991a). Part time entrepreneurs gain an advantage by being involved in both and being engaged in more direct technology transfers. In the other three companies (Companies A, C, and F) the founder-inventors worked full time in the companies after they were founded as they believed that their products could easily penetrate the market. Two of these companies (Companies A and F) have multiple applications of their technologies and the target market is global. The technologies are near to the market stage (the development of the product had been done in the lab) even although when the companies were founded they only had prototypes. In addition, in Company F, the inventor had just finished his PhD, and it was therefore the right time for him to be full time in the company after he had finished studying.

6.3.3 Motivation

The findings demonstrated that the inventor-entrepreneurs spun-off from the University for a number of reasons (Table 6.4). Money is not the main factor that drove the inventors to exploit the opportunity. The main factor is the desire by the inventors to see their patents exploited (Companies B, D, E and F). This is consistent with the findings of Smilor (1990), Blair (1998), and Shane (2004). One of the inventors said:

> *"... I wouldn't say the money was the prime motivation factor. The prime motivation factor for me was a belief that the technology has actually a really good commercial capability and in fact I just want to see that it will be used. It's taken a lot of time inventing something, and it is nice to see it actually being used rather than gathering dust as some academic curiosity, and wanted to see it recognised and working ... that was the decision for me that was the motivating factor ... to see the technology being exploited and used and not just a collection of academic papers. ... I get satisfaction from making things work and I also get bored if it is just to do the same job over [a period of] time. I like new challenges. The challenge was to invent the technology and commercialise it".*

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. He commented:

> *"... At the point we applied for money, the intention ... was to own the company and exploit it. What happened was the Ford Motors Design Manager that we had had contact with, resigned from the company, approached the University and licensed the IP that we had developed under the POC (Proof of concept) budget and created the business. So from the side lines we saw, an individual give- up his job, earned hundred thousand a year, that was a good job, come to University and start the business, that was the experience ... that guy can do it why not us? ...".*

In only one case, the company that produces 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. Considering this as a push factor (Blair and Hitchen, 1998) he commented:

> *"... I had been working on the specific project on developing hydro gel and was working in a very insecure environment in this University. I was a contract member of staff. In 1999, I was involved with the Hunter Centre ... involved with the entrepreneurial subjects and had contact with Jonathan Levie. Jonathan contacted the research group and studied the potential commercialisation [opportunity identification] of the invention ..."*

Being highly motivated to see their invention being exploited does not happen without entrepreneurial characteristics as discussed in Chapter 2. 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, willingness to take risks, have an internal locus control are the factors that differentiate these inventors from others though these were not asked during the interviews.

The finding supports the previous studies and Research Proposition 1B1: *The desire to see their patents being exploited, combined with the inventors' willingness to take a risk, the greater the chance that the patents will be exploited through spin-off formation.*

6.3.4 Opportunity recognition and the trigger factors

The initial decision to exploit the opportunities of the patented inventions was initiated mainly by the inventors-entrepreneurs based on their work experience in industry. Potential customers and the Hunter Centre for Entrepreneurship also played important roles in the recognition of the opportunities. The identification of opportunities and the trigger factors are summarised in Table 6.4. The finding supports Research Proposition 1B2: *the more prior knowledge and industrial experience the inventors have, the more likely an opportunity will be recognised and lead to spin-off creation.*

Most of the entrepreneurs had enough knowledge about their patented technologies, what product to develop and what type of business they should be in. In all the cases the opportunities were evaluated and clarified before venture formation, Some of the companies (Companies B and F) used external consultants to carry out market research before going forward to Business Venture Group (BVG)

Table 6.4: Opportunity recognition and the trigger factors

Co.	Industry experience/ background	Potential of the technologies	Decision to patent	Opportunity	Decision to comer-cialise	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 plan 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 produce 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 defence 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 licence. -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

for 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. The entrepreneurs from Companies A and F had ideas for a few radical applications of their technologies, as the Technical Director of the company that produces the gas sensor system commented:

> *"...Oil and gas, followed by security, defence and medical diagnostics. Medical diagnostics is a longer project because not only do we have to develop the project ... it involves clinical trials in hospitals which take a long time and is not really worth our company's time, so what we will do on medical diagnostics is that we will partner a major player in that field. We develop the technology and support them in the selling of the technology ..."*

In the case of Company A, the entrepreneur used to be a consultant to Ford Motors. He received most of the funding from Ford Motors (less than £1m) to develop 3D vehicle design. The founders recognised the opportunity from the beginning when Ford Motors first consulted them. Prior working knowledge often leads the founders to start a company to make similar types of products or services to those of their former employers or their clients when they worked as consultants, which is consistent with studies by Shane (2003) and Heirman and Clarysse (2004). Entrepreneur B, CEO of the company that is selling activity recording and analysis devices, was the main player who recognised the opportunity to commercialise the invention after he was contacted by customers. The Hunter Centre for Entrepreneurship also helped the inventor to identify and exploit the opportunity. The founder had attended entrepreneurship courses in the 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 to exploit the opportunity was that one of founders was technical director of Biomedical Monitoring Ltd. The technical director's experience combined with the group's prior knowledge (monitor design and prior knowledge of market) helped them to exploit the opportunity:

> *"... we had people asking us to buy the technology. We had, we had published the works ...".*

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 the company was formed. A meeting with Head of the Hunter Centre for Entrepreneurship triggered that opportunity.

Company D supply 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 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. The Managing Director said:

> *"... When my colleague came to University and we got together, we discussed a complete monitoring system for a substation and there appear to be a commercial opportunity. There was no such system available anywhere else. The aim was that we supply this system to utilities worldwide ..."*

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 customer. Acceptance of the system by both of the established organisations made it easier for them to penetrate the worldwide utilities market.

The Managing Director said:

> *"...Through money from Scottish Power and National Grid and their system, basically upfront money from those 2 contracts, from ABB we get paid upfront money before we have absolutely done anything. We manage to create the system without taking out an overdraft or etc. Again, it is unusual for a spin-off company. We try to sell a lot of systems in order to build up good backing...".*

Inventor-entrepreneur 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 Hunter Centre for Entrepreneurship. Prior to his technical experience in gas sensors, 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, which 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 use in conjunction with mobile phone technology. This led the team to form the company and secure the first round funding. The CTO said:

> *"... When that was finished we left University with [an] interesting technology and with the experience from Orange. There was a market for it and it could be incorporated into products ..."*

The international standards requirement in mobile phone technology was the main reason the company changed its main target market from mobile phone to the security market. This also revealed that the company has a high quality multipurpose video compression technology.

6.4 CHARACTERISTICS OF SPIN-OFF PATENTS

Having identified the opportunity, motivation and characteristics of the inventor-entrepreneurs and the profile of the companies, the questions to be resolved are what are the features of patents, and who were involved in the decision to exploit the patent through a spin-off? The analysis starts with how the scientific discovery was started and identification of the opportunity, how the decision to patent and to exploit to spin-off was achieved.

6.4.1 Scientific discoveries

This study found that all of the inventor-entrepreneurs developed the technology while working at the University. Before the inventions were discovered and patented, the projects took place over a number of years in the University lab. These pre-founding efforts may give the start-up a competitive advantage over firms that start from scratch for example on account of tacit knowledge of technology that they can draw upon (Clarysee and Moray's, 2004). The idea to conduct research in the chosen areas were either based on the working experience of the inventor-entrepreneurs in the relevant industries or on scientific research that had taken place over a number of years in the University lab. Work experience with industry had enabled them to recognise the opportunities and to carry out further research in the area they were working on or while they pursued their PhD in the University as discussed in Section 6.3.4. One of the inventors said:

> *"... I studied here (University of Strathclyde), and I left and I worked for a while with a company in Edinburgh and that company was bought over by another company ... and I came back to do my PhD here ..."*

6.4.2 Decision to patent

The initial decision to patent was decided either by the research group, the TTO or by both the TTO and the research group. In three of the cases (Companies A, B and D) the decision to patent was decided by the research group, a further two cases (Companies C and F) by the TTO and in only one case (company E) was it decided by both parties; the TTO and the research group. One of the entrepreneurs said:

> *"...Myself and my colleague patented it. In fact, the technique itself wasn't patented because it came out of the research laboratory work. The CGB had at that time an open policy. You were able to publish the work. When my colleague worked in CGB, he published the work so the technique isn't patented but we did patent the system we designed through the University ..."*

Another entrepreneur said:

> *"... it actually came originally from R&C services [TTO] ... the original decision to patent actually came from the University itself..."*

Another inventor-entrepreneur reported that he decided to patent the invention before he applied to the Proof of Concept Fund, to avoid a public copy of his invention, which was one of the requirements of the grant. He commented;

> *"...Basically that is always the danger when you apply for Proof of Concept Fund, ... as soon as it works it was important to file for a patent ..."*

The inventor-entrepreneur from Company D commented that he needed to patent the invention to avoid a big company copying their invention:

> *"... We as a company have developed two different systems. For one of them we have a completely different patent and the other one we patented because we felt that that it was really the best way to stay ahead and stop people copying it. Particularly as there was a big company who had developed their own system and their technology was based on our system and we are only a small company ..."*

It is difficult to say whether the inventions that the TTO decided to patent have market potential. Most of the decisions to patent were a matter of judgement. The TTO tries to file, at a minimum cost, for a patent as soon as they think the invention has a potential value and after they have received the information from the inventors (interview with the TTO).

The findings demonstrated that in three cases (Companies A, B, and D) the inventors realised from the start of their research projects that their inventions had potential values to be exploited. They had industry background. The company whose technology was the only invention patented from joint decision by both parties (Company E), is now the fastest expanding company (based on the amount of funding it received). It may suggest that the decision to patent by both parties exists when the technology has global market potential and strong patent protection. All the inventor-entrepreneurs initiated the decision to exploit their patents through spin-off companies.

6.4.3 The criteria of technologies that are exploited through a spin-off company

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 technology at a very early stage, radical, multipurpose and with strong patent protection, 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.

i) Early stage technology

All the companies were based on early stage technologies when they were founded (Table 6.5). Only one company 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, had developed their products to prototype stage but they still needed improvement. Further development of the products was done as soon as the companies were founded. In these companies, the founders had work experiences with industry as consultants.

The study suggests that the experience of working with industry and the University gave the added advantage of a much quicker route to nearly mature technologies as suggested by Heirman and Clarysse (2004).

Interestingly, only one company had prototypes (Company C) and three of the cases found that they had only a 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.

Table 6.5: 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).

It seems that the lack of seed money or initial funding inhibits them from building prototypes. Prototypes were only built when the companies were incorporated and had received a certain amount of seed funding from government grants or from private investors. One entrepreneur explained:

> *"... When we founded the company, we developed the business plan and patent. The technology was developed with my supervisor at the University. There was a system ... but the company just has the business plan and patented the technology. So we have nothing here. We have to develop the project in commercial form ..."*

Even though the proof of concept idea convinces the potential buyer, they tend to 'see' the invention as proven at the stage of prototype level. As the founder of one company comments:

> *"... I would say proof of concept ... it needs a lot more development to be a product. They (venture capitalists) won't look at anything that's proof of concept. They don't want to put a lot of money in, taking it to the product stage ... but they all said ' if the product existed and if there is a good market for it'. ... the process was carried out when the company was formed ..."*

The finding is consistent with the previous research which has found that early stage technologies are difficult to license because the technologies are not proven, risky and investment is 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 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 license to established firms. One of the company CEOs commented:

> *"... we didn't have the product at that time. We just have the know-how. I don't believe that at that stage the technology will be easily license - because the product is unrefined. So we know that the concept is much better when refined. The know-how we have is stronger than the patent ..."*

Another CEO said:

> *"... you can't license like that. Proof of concept you need to go to other finished products that are working in the market.*

You need to demonstrate to the market. The best way to do that is to set-up a company, to take the product to the finishing stage. That gives credibility to the technology. If you license straight from University, the technology does not convince other people. Because the technology is at very early stage you cannot license it...Even if you wanted to license, it wouldn't be a good deal. You have to create value and after that you can license it ..."

One of the inventor-entrepreneurs had tried to license the technology but did not receive any response from the commercial sector. Forming a company is a solution to exploiting the technology. He said:

"...we had tried to patent the technology before and then had let the patent lag because there was no commercial interest. So, that's why we needed a company to exploit the patent ..."

ii) General purpose technology

The findings show that five companies (the exception is Company C) have broad application patents that were exploited and support Shane's (2001, 2004) findings. University spin-offs tend to exploit general-purpose technologies, or basic inventions with a broad application. Established companies are reluctant to exploit general-purpose technologies because they do not clearly demonstrate 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, with the total market estimation for medical diagnostics alone being valued at USD22 billion (Cascade Technologies, 2004). The Company Technical Director (CTO) said:

"... The markets are detection ... commercial detection are for exhaust measurement, environmental measurement, pollution as well as medical diagnostics where you can look for gas in the lungs ... so you can do the diagnostic. Or if you have kidney failure, or digestive problem, you can do many things ..."

General-purpose technologies 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 on all phone manufacturers prevented their technology from entering the market. The standard requires that all brands of mobile phones be able to receive and send calls, messages, and images to each other. However, the standard had already been accepted and approved before their technology, which is a lot better, appeared. 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. He commented:

> *" ...They did not change the standard ... the problem we had, the technology we developed was much better than the standard, but, did not conform to the standard. ... the company attended a number of standard meetings and lobbied quite hard, to try and get our technology to be adopted as part of the standard, and we got nowhere. We got nowhere because the hardware manufacturers who were the big players had already put huge amounts of money, to implement the standard ... "*

That was a very critical point and a very difficult time for the company after they had spent the first round funding of £1.4 million. 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. The CTO of the company commented:

> *"... So we targeted a second market that really gave us a little leeway on sales. Through 2002/03 we struggled looking at a number of different markets that were not really giving any serious returns. In 2003 we had to go for another round of funding".*

iii) Strong intellectual property protection and scope of patents

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 patent would not infringe other parties' patents and other parties could not copy their technologies.

These new spin-offs companies solely depend on their strong patent protection and broad scope of patents as competitive advantage (Shane, 2001b; Shane, 2004; Heirman and Clarysse, 2004) to access funding from external sources, when they founded the company. As one of the entrepreneur-inventors commented:

> *"... it is quite broad. It has 19 claims. We have to refine and split into two patents. But at the moment we've been advised by the Patent Attorney to go forward as it is ..."*

Another inventor commented:

> *"... it is a broad patent ... It has been suggested by the Patent Agent to claim it as broad as possible ..."*

iv) Radical technologies

All the cases reported their technologies have a big jump of technological development, in other words they are radical, which are difficult to license to established firms. The finding supports Shane's studies, (2001a; 2001b; 2004) suggest that the radicalness of technology increases the likelihood that it will be exploited by spin-off formation.

v) Summary

In summary, the findings reveal that the features of the patented technologies exploited by spin-offs are early stage, broad scope, radical and multipurpose, and confirm studies by Shane (2001a; 2001b; 2004) and Shane and Nerkar (2003). This finding supports Research Proposition 2B: *patents that involve early stage technology, are broad in scope, multipurpose and radical are more likely to be exploited through spin-off formation.*

6.5 FUNDING

6.5.1 Research funding

The findings show that both industry and government research funding contribute in equal importance to spin-off formation. Each source funded four spin-off companies (Table 6.6). In other words, each company received an average of 0.8 grants from each of these both sources.

Table 6.6: Details sources of funding for every company

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

Table 6.6 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 formation. The findings give partial supports to O' Shea et al. (2005), Wright el al. (2005) and Blumenthal et al. (1996) who suggested that the more research funding from industry, the more likely spin-offs will be formed. This finding partially supports Research Proposition 3B1: *the more projects funded by industry, the more likely spin-offs are created.* Government funding is important both for curiosity driven research as suggested by Strandburg (2005) and also for industrial funded research project at the later stage when the projects have shown sign of a potential market to result in spin-off creations.

6.5.2 Spin-off funding

The technology from university spin-off companies is based on leading edge and needs a huge amount of capital to develop. Universities cannot afford to fund such technologies and bring them to the market place. Thus, external funding is crucial to commercially develop those technologies. Without external funding spin-offs are difficult to form.

In this study, all cases received external funding from various sources. This included government grants, venture capitalist, private investors, personal savings and bank loans. The government grants are only given as seed money to develop patented technologies to the 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 such as Scottish Enterprise, Scottish Executive, and Synergy funds.

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 interview is company F[40]. It was also the company which received the most resource 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 on completion of his PhD. The company was funded by 3i venture capitalists with first round funding of £1.4m. Second round funding for market development was received from Aberdeen Asset Management (AAM) and Scottish Equity Partners with a total of £900,000.

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

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 only having a single application, nor does it involve future research that would be of 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. Company D received various funds from industry for the inventors to carry out research, but it did not receive any government funding for research at any period. The biggest funders were Scottish Power and the National Grid as was explained before.

The finding supports Research Proposition 3B2: *spin-off companies are likely to require external sources of funding to be created.*

6.5.3 Problems in obtaining funding

All of the companies had problems in getting external funding. All the companies took more than a year after they were founded to raise funding. All of the companies were therefore forced to up bootstrap funding during the start-up period. Company F reported that almost 95 percent of their time was devoted to finding funding. Referring to private investors and business angels the inventor said:

> *"...They come and promise so much and we had a few characters come in to value our technology and say " this is fantastic, yes we will do something. I can put money in your bank ... but the reality was that these people either had no money, or ... they were rich individuals but they were private investors, who very much had their own agenda ...".*

One of the reasons Company F had difficulties in accessing funding was because they did not have the knowledge and experience on how to access funding sources. The inventor commented:

> *"...The hurdle was really to identify sources of funding ... what they are looking for is a finished product. They won't look for something at proof of concept. They didn't want to put a lot of money in, taking it to product stage. That takes too much to produce. But they all said that if the product existed, there is a good market for it ... so that's partly from*

the basis of the view that there was a market but the alternative was to approach them when the company was formed ...".

Moreover, some investors purposely waited until the company was very desperate for additional capital. At that time the company value would be reduced, as the bargaining power of investors becomes stronger, so they can invest on terms and conditions that are more favourable to them.

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. Company B failed to find any commercial partner. They failed to convince investors that their technology had potential and could create a niche market. The commercial partners thought they could find this technology through other cheaper means, and were not willing to license or partner with them. This led them to create the company in order to make the technology as a standard. The founder of the company commented:

> *"... But we're not able to convince any other commercial partner. We won't even find the partner to license the technology. I think that special niche technologies are licensable. There are very small numbers of technologies that you can license. ... You have patents for particular drugs, for a particular process and then you see that that process or that drug is very important and then they will license it from you. But if you have a patent, where there is risk and there is another way of getting there perhaps it is cheaper for people to go the other way. They won't license it from you. But if you take your approach, you form a company and you make that approach the standard then there is more chance of licensing, perhaps ...".*

The findings are also consistent with previous studies that found the companies which obtained funding from industry through either consultation or contract research found it easier to obtain funding for further development of the project and for commercial exploitation (example are Companies A, D, and F) (Shane, 2004; O'Shea 2005). Previous success in funding through consultancy gives a signal to other parties in the further rounds of funding.

Two established corporations, Scottish Power and the National Grid, funded Company D. The technology they invented at that time was cutting edge and the target market was global. Company A received funding from Ford Motors and their technology is convincing: they won a Smart Award from Scottish Enterprise and are moving very fast to access first round funding.

In comparison Company C, which is selling plant gel, found it difficult to get early stage funding. The main reason might be that inventors felt that the company did not have growth potential. In addition, the company was limited as it was only selling one single technological application for indoor plants. This is common and there was in this case no market niche and no technological advancement for the investors. This company only obtained a little support from Scottish Enterprise in terms of identifying the market and they did not receive any funding from the University the reason for which was explained earlier:

> *"It is a difficult decision to make. We had to be dynamic and learn how to run the business. We had to use our own savings to run the company ...".*

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

6.6 THE ROLES OF THE INVENTORS

6.6.1 The roles of inventor-entrepreneurs in networking and product development

Having analysed the characteristics of the entrepreneurs that exploited the University patent through spin-off ventures, this section examines how far these characteristics influence the entrepreneurs' involvement in product development and networking in the set-up of the company.

- **Networking and links to funding**

As mentioned in chapter two, the involvement of inventor-entrepreneurs in networking is important to access funding and market knowledge in spin-off ventures. Formal and informal social ties through inventor-entrepreneurs personal contacts and presentation papers could operate as a referral to others to approve funding and reduce the information asymmetry problem (Colyvas et al., 2002; Shane and Cable, 2002; Shane and Stuart, 2002; Shane, 2004).

All of the inventors were very enthusiastic, energetic and hard working. One of the entrepreneurs said they spent almost 95 percent of their time looking for venture capital, working long hours, independently and copes with problems as they arose. One of the inventor-entrepreneurs commented:

> *"... We're presenting good things during conferences and exhibitions and we increase our networking with small or big companies like semiconductors ...'*

Prior to forming the company the inventor from Company D, had through his informal network, and consultation work enabled 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 or 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. 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 ...".*

- **Networking with the University**

The finding shows at the early stage of the company formation, networking with the parent University is important. The University can link the new founder with external investors and coaching them in their business plan development. At the later stage of company formation, links with parent University is less important because companies are more focused with customers and suppliers as suggested by Perez and Sanchez (2002). This was the experience of all the companies. Table 6.7 shows the link between the spin-off companies and the University and the facilities they used.

Five companies (Companies A, B, D, E and F) had strong ties with the University. Table 6.7 shows various types of ties between the companies and the University. These include the University holding some equity shares in the spin-off (exception being Company C), the companies exploiting patented technology owned by the universities (intangible resources), and the companies are given access to some University facilities.

Table 6.7: Link with the University and facilities provided.

Companies	Ownership of the patent	Equity	Universities facilities	Incubator	MSc/PhD student	Consulting from the University
A	√	√	√	√	√	
B	√	√	√	√	√	
C	x	x	x	x	x	
D*	x	x	x	x	x	
E	x	√	√	√	√	√
F*	√	√	x	x	x	

Note; i) * Company previously had incubated and used the University facilities before they were able to stand on their own feet
ii) x = did not use University facilities, √ = use University facilities

The companies can have MSc or PhD students conducting projects; and use of the University incubator. In the case of Company B, for example, when it was founded the development of the technology had already reached a mature stage and the link with the University was just to develop the company's name not for product innovation. CEO of the company commented;

> *"...There is a conflict of interest because we keep doing more research rather than more sales. We're not a research company; we're a selling company ... because we don't need product development and we need sales ...".*

Most of the companies used the incubator facilities, with the exception of Company C. Companies D and F have moved out from incubator, but still have a link with the University to support Masters and PhD students. After graduating these students become a source of skilled employees for the companies. Company D was created in 1995 and moved into the University incubator in 1996. The company has been expanding and has moved out to the town centre in order to convince customers it was not a University company. The same situation occurred with company F, which moved out of the incubator when it received its first round of funding.

However, the intellectual property is still owned by the University and the University has taken equity in the company.

Company E's founder has what Murray (2004) called a 'laboratory network' with his supervisor. The supervisor was appointed as a consultant to the company and also has a PhD student working for the company. As the Technical Director reported:

> *"...We have links with the University. I would say my supervisor is still at the University. One of them is a consultant for us and we also have a PhD student working with us. And otherwise the University has got equity in the company ...".*

The University assigned the right of the patent to Company C but did not take any equity investment. Close ties with the University give both advantages and disadvantages to the companies. The advantage of being in the University incubator is cheaper office space, the ability to share management facilities and close links with the University expertise as suggested by previous studies (Phillips, 2002; Colombo and Delmastro, 2003; Grimaldi and Grandi, 2003; Siegal, 2006). However, the downside of the companies' link with the University is that the customers and investors think that the companies depend too much on the University. The image of the companies as 'University Companies' may make it difficult for the companies to convince the clients and be able to move on and expand. This has already been commented on by an inventor-entrepreneur in Section 6.3.1.

- **Commitment of the inventors in product development**

The findings here are consistent with the previous studies reported that those universities that are more successful in spinning-off companies is explained by their inventors being willing to be involved in the process either as an advisor or working full time. In universities with less successful spin-off records most of the inventors lacked experience in company formation although they were very keen to be involved (Lockett et al., 2003b). In this study, all of the entrepreneur-inventors were involved in product development and work as full time staff in the companies (at least one inventor-entrepreneur working as full time for each company). Full time involvement of 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).

This finding supports Research Proposition 4B: *inventors must be willing to be involved in product development, networking and other process, for a patent to be exploited through spin- off formation.*

6.6.2 How the management team was formed

From the findings, the size of the team at the founding period varies amongst companies and depends on the technology cycle and who are the inventors and investors in the companies. Three of the companies, A, B, and D already had a team before the companies were founded. In half of the companies, (Companies B, D and F) at least one of the founders was working full time in the company and in the other cases they remained as a full time lecturer in the University.

Company D had two founders when the company was set up. One of the partners worked full time in the company, while the other founder still worked in the University until 2003 when he joined the company. In Company B, only one of the founders worked full time and was both CEO and champion of the venture. In this case, investors in this business did not seem to want to expand the management team. Company A had a team of four inventors when they were doing research in the lab. Only two of them joined the firm and worked full time in the company - one as the CEO. He had a clear idea of what type of person he needed in the management team. He commented:

> *"See ... it looks great if the four of us are going into business. But, if over the 12 or 24 months it has taken to develop this technology it has become apparent that the technology does not require the particular component that you were working on, then I am sorry but you can't be involved. So everyone is clear from the day one".*

Companies C, E, and F had investment from at least one type of investors either from private investor, venture capitalist or corporation. A private investor invested in Company C and became a majority shareholder, and then joined the company as the Managing Director. This strengthened the team, as the Managing Director was a qualified Horticulturist. A combination of high technical knowledge and business experience gave breadth to this team.

For company E, at the pre-start-up period, the inventor was the only employee in the company. He was both the champion of the venture and the CEO during the pre start-up period. After the company was incorporated in 2003, it employed a new CEO who was appointed by the Upstart Programme in order to secure funding from the investors. He had an accounting background and helped the company prepare and present the business plan to investors. In June 2003, one of his friends from National Research and Development joined the company and was appointed as Director of Research and Development. The company secured first round funding from investors in April 2004, nearly one year after the initial team and company was formed. The company then appointed a new company chairman in November 2004. The team of four members was very strong with a combination of technical, management and business backgrounds which is consistent with the recomendatins of previous studies (Shane, 2004; Clarysse and Moray, 2004; Mason and Stark, 2004; Binks et al., 2005). The founder knew the background of some of the members in the team and it was easy for them to work together and trust each other.

In Company F, at the pre start-up period, the team consisted of four inventors all whom were in the team when the company was incorporated in 1999. The team formation of this company was interesting and differed from the other cases. In 2001, the company secured funding from both the 3i Venture Capital Company and Scottish Equity Partners for a total amount of £1.4million. The team was led by a champion of the venture, who was the technical project manager before the spin-off formation. In 2001, after the company received funding from institutional investors, a new managing director was appointed by the venture capitalists. The company then started to employ a total of 16 employees. The new Managing Director did not understand the technology as well as the team and the company tried to develop in a new market direction but failed. The company was originally formed to sell video compression to the mobile phone company, but failed due to the standard implemented (as explained before). The team had to find a new market, and ended up with the security market in the US. The CTO of the company commented:

> *"...Basically they felt that they could not trust academics with that money. We don't have enough commercial sense. They wanted to put somebody in place that had commercial*

experience. The reality was a little different. Because we had a very clear idea of how the technology should be exploited. And when the individual came on board it was a problem for the organisation. When somebody comes in, they like to stamp their presence on the organisation. They like doing things their way. It is part of setting themselves up. Part of it was that he brought in a couple of individuals to deal with the marketing side and they came up with a plan that doesn't really fit with the direction that we thought the technology should take. The result was that, [we] actually we followed a number of blind alleys. Exploitation routes that really ending in nowhere ...".

In 2003, the investors realised that the company was not going in the right direction, and at the same time, the appointed Managing Director resigned. After that, a Board of Directors consisting of the original technical team effectively ran the company with the venture champion becoming the CTO (Chief of Technical Director) of the company. The CTO title was chosen because this title is better recognised in the US. The CTO said:

> *"...Shortly after that, towards the end 2003, the institutional investors lost confidence in the [appointed] managing director. They felt the company wasn't going in the direction that it should be going, and basically, he resigned. Since that point, the company has been run much more effectively by the board than by the ex-Managing Director. The board at the moment is basically the company chairman, and myself, and my title is CTO. Primarily that title has been chosen rather than[the title] technical director because it is recognised in [the] US ...".*

This case broadly supports the exploratory study that has been done by Clarysee and Moray (2004). However, there is also an important difference: the entrepreneurial team in Company F were "learning by doing" and there was no coaching system involved. The entrepreneurial team became the board of directors and managed the company until today without the investors' interference (no management position was chosen by the inventors). The team formation in Company F is therefore a very interesting case. It was proven that the academic inventors could manage the new technology venture if they were given a chance, aeven without any business coaching. The lesson for the venture capitalists is that not all appointed CEOs are good managers.

6.7 THE ROLE OF TTO

The TTO's role in facilitating commercialisation activities differed from case to case depending on when the ventures were set up. As mentioned earlier, the University became actively involved in commercialisation activities after 2000. Three factors influence why the University became active in this activity: 1) the government reduced the funding to public universities and forced them to find other sources of income such as the commercialisation of their research output; 2) financial support such as the University Challenge Funds, which are provided by the government to facilitate spin-off activity after year 2000; and 3) the different objectives and strategies of the technology transfer office.

The level of support given by the TTO to commercialisation could be divided into four phases: 1) absence of proactive spin-off policies (before 1990); 2) minimalist support and selectivity (1990-1995); 3) intermediate support and selectivity (1995-2000) and 4) comprehensive selectivity /support (since 2000).

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 at the Hunter Centre for Entrepreneurship, 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 technology transfer office. Company D was founded in 1995 and Company F in 1999. In this period the TTO may have implemented a policy of 'minimalist support and selectivity' and 'intermediate support and selectivity' (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 was only taking 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 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. The Managing Director of Company D commented:

> *"...then, through our efforts and lots of publications during that time, we went to exhibitions, talked to utilities and we had to educate the utilities on this technique. It wasn't something that can immediately be accepted. We have to sell the concept and then sell the technique. Because we were connecting a very sensitive electronics systems to their substations and that was seen as being impossible in such a high voltage environment. It (the trial system) didn't last, it always breaks down, so the whole concept has to go through a long period to build up credibility. That was about 1993-1995 ...".*

He added:

> *"... Other than taking shareholding in the company ... As I said before, the spin-off company was not well ... at that time...".*

Company F differed from the other spin-offs. The young inventor-entrepreneurs who formed the company only had technical knowledge and experience from Orange when they worked for them 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 the sectors. 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 and not surprisingly, the company took nearly one year from concept to start-up. The CTO said:

> *"... R&C services very much tries to bring big companies in to license the University technology but is not so good when it comes to spin-off companies. I think it is because of the skills and complexity around an understanding of the business model, ... because absolutely the simplest model is to license to a large pharmaceutical company and you just sit back. That's the idea. That actually is great. Our technology is very different, because they patented the technology it wasn't simply for anybody to just take and turn out. There is a lot of complexity involved. It's a lot more work required to ... actually to prove it, and the University finds it hard to grasp the techniques, it is not just simply a case of sitting back and waiting for money come in. A lot more work is required... it depends very much on the nature and complexity of the technology and the market size ...".*

This study supports previous studies (O'Shea et al., 2005; Lockett et al., 2003a; Wright et al., 2001; Wright et al., 2002). The limited support of the TTO in the creation of the spin-off of companies studied here would explained the low overall number of spin-off companies from the University, and therefore supports Research Proposition 5B: *the creation of spin-off companies requires TTOs which are well resourced and have adequate skills and capabilities.*

6.8 UNIVERSITY SUPPORTS

Taking equity in the company in lieu of up front fees encourages the formation of spin-offs (Bray and Lee, 2000). The University has taken equity in five companies (Companies A, B, D, E, and F) when the companies were founded. The University takes a minimum of 20% shareholding as trade off for investment in the company and to cover patent costs. The inventor-entrepreneurs of the gas sensor said:

> *"...I think taking equity is interesting because that allows the company to start with a small infrastructure. They do not need to buy everything as the University can provide that. But when the University takes equity or royalties from the liceninge of the IP the University is still the owner of the patent ..."*

All the companies except Company B used the University incubator during the founding period. Research suggest 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 establish 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. The reasons for moving out have already been mentioned in earlier chapter.

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. This does not support Research Proposition 6B*: the creation of spin-offs requires rewards given by the University.*

In terms of conflict between whether to publish or to patent, none of the inventor-entrepreneur had any problems. The University and patent agent were very efficient in the management to file a patent and were relatively fast at getting a filing date from the Patent Office. The TTO is expert at this and has very good IPR officers specially in charge of this process.

6.9 CONCLUSION

The question that this chapter addressed is *what are the features of patents that are commercialised through spin-offs?* 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 difficulty of getting seed funding, the right management team and marketing their technologies.

The spin-off formation process started once the opportunities created were recognised by their inventors and patent protection was sought. Opportunity recognition was undertaken 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 a spin-off company 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. Similar to the findings of Roberts (1991a) and Lockett and Wright (2005), the inventions in this study had been researched in labs, and had taken several years before they could be commercialised. The inventors were very highly motivated, and driven by the desire to see the their inventions being commercialised and utilised, even-though there was a long time horizon (Shapero, 1975; Shapero, 1984; Gartner, 1985; Roberts, 1991a; Oakey, 2003; Shane, 2003). Their entrepreneurial characteristics and leadership emerged during projects in the University labs (Etzkowitz, 2002), which are normally led by a group leader. A group leader is in general a person familiar with the invention and 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, as 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 done by Clarysse and Moray (2004) that an academic entrepreneur can be CEO of the company even though without a coaching system provided by the investors. The findings also support previous studies (Roberts, 1991a; Shane, 2003; Shane and Khurana, 2003; Shane, 2004; Dietz et al., 2005) that industrial experience of the entrepreneurs-inventors of the patents provides 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 new founders to external 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 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 at 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 the 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 links to venture capitalists, and were able to prepare their business plans, with coaching from the TTO.

Having examined the patents that were commercialised through the creation of spin-off companies, in the next chapter the other group of patents that were commercialsed through licensing to existing and established companies were considered.

CHAPTER 7

THE PROCESS OF EXPLOITATION THROUGH ESTABLISHED COMPANIES

7.1 INTRODUCTION

This chapter examines the features of patents that are exploited through licensing to established companies. Literature on licensing is scarce and mostly focused on the US licensing activities. Jensen et al. (2003) focused on how the disclosures and licensing process had been carried out. Thursby and Thursby (2002) examined who leads the university licensing activities. Thursby and Kemp (2002) looked at the growth and efficiency of university licensing activities and the practicea in US universities. Licensing practices in US universities have also been studied by Jensen and Thursby (2001). Thursby and Thursby (2003) on the other hand studied the views of industry about the characteristics of university technologies and Thursby and Thursby (2004) further examined the faculty's involvement in the industry-university relationships.

The objectives, characteristics and sources of university licensing have been studied by Thursby et al. (2001). Henderson et al. (1998) explored the importance and quality of university patents. Overall it could be said that most of the literature were the results of surveys on patenting and commercilisation activites, and as such quantitative approach was used. Very rarely the literature discusses the decision-making process employed when filing for patents, and then licensing those patents to established companies. The criteria used by the TTO to decide which patents should be license to established companies, or otherwise has not been comprehensively studied. The part of this study that looked into the patents that were lilcensed to established companies is discussed in detail below.

7.2 LITERATURE REVIEW

The literature review yielded a few main topics involving patents that were licensed to established companies. They were then studied in detail and the following sections are discussions on these main topics.

7.2.1 Motivation and who recognised the opportunity

As discussed in Chapter 2 most of the inventors who licensed their patents were motivated by the desire to see their inventions be developed and exploited to achieve commercial viability. Money was a secondary reason to license their inventions which is consistent with studies that was done by Shapero (1984), Olofson et al. (1987), Smilor et al. (1990), Blair and Hitchen (1998), Shane (2003, 2004) and (Nilsson et al., 2006). However, inventors who licensed their patents to established companies are risk averse, which suggests they are not interested in commercialisation activities.

It was also noted that recognition of opportunities was linked to the work experience of inventors with industry, through contact with friends, customers from the companies that the inventors worked with before or an industry researcher who had discussions with the inventors (Shane and Venkataraman, 2000; Shane, 2000a; Shane, 2004; Park, 2005; Shane, 2005). Lockett et al. (2003; 2005) noted that TTOs are the first party who should recognise an opportunity before other external parties. However, in the current study it is proposed that if it is industry that first recognised an opportunity, they will fund the project and are more likely to license the technologies.

7.2.2 Characteristics of university technologies

Most university technologies are at an early stage when they are licensed (Henderson et al., 1998; Jensen and Thursby, 2000; Jensen et al., 2003, and Shane, 2004). University technologies are uncertain and risky and the inventors' involvement is crucial in bringing the technologies to the marketplace (Thursby et al., 2001; Thursby and Thursby, 2002; and Thursby and Thursby, 2004). Thursby et al. (2001) reported that nearly half of the universities licensed their technologies at the proof of concept stage and only 12 per cent of the technologies were ready for practical use. Shane (2002) reported that because the patented technologies are at an early stage, they need further development to bring them to the market. Consequently, most are being licensed to small start-up companies.

Shane (2004) further suggests that the characteristics of university technology which is licensed to established companies involve narrow scope patents, incremental technology, and late stage technology. Established companies may refuse to license university technologies because they are early stage thus have uncertain market value, and the technologies not in line with their business (Thursby and Thursby, 2003). Industry tends to exploit late stage technologies, which represents less risk. Later stage technologies are usually ready or near ready to be marketed, which leads to greater royalties for the iniversities (Thursby and Thursby, 2001; Markman et al., 2005). Furthermore, because most university technologies are radical, they are not suitable for existing manufacturing processes (Shane, 2004).

7.2.3 Research funding

Previous studies suggest that research that is funded by industry has a greater chance of commercialisation than government-funded research (Mansfield, 1995; Shane, 2004; O'Shea et al., 2005; Powers and McDougall, 2005). However, industry only funds university research after the research has produced clear results or has shown proof that its outcomes have potential market. In such circumstances, industry would then license the technology (Mansfield, 1995). Thus, once the industry has come in, the potential of any resultant patents being commercially exploited is very high indeed. In other reports, it was concluded that government-funded research increased the number of publications but lowered the rate of patent applications (Powers, 2003; Dietz and Bozeman, 2005).

7.2.4 Inventors' involvement in product development and networking

Inventors' involvement in product development is more frequent when technologies are licensed at early stage. To induce inventors' participation in product development running royalties with small up-front fees is encouraged with a reduced inventor equity position in the firm. Small royalties are suggested when technologies are uncertain and sponsored research could be included in the licence agreement

(Thursby et al., 2001). Later stage technologies always receive larger amount of royalties compared with early stage technologies.

Inventors who have informal ties with industry through networking are more likely to have their inventions exploited. Ties with industry through 'industry-oriented research' give the inventors access to the latest knowledge about research in industry, which could help in identifying potential licensees. Early participation of inventors in recognising potential licensees increases the speed at which inventions enter the market (Markman et al., 2005).

In some cases, the inventors have claimed to market their inventions more effectively than TTOs through their personal contacts with co-researchers in industry. Colyvas et al. (2002) found that TTOs played a marginal part in the success of marketing university inventions. The inventors' involvement in networking and product development is important because the early stage of technologies involve tacit knowledge. The inventors are the people who know about their inventions and their involvement increases the success rate of bringing the product to market.

7.2.5 TTO networking and resources

The role of the TTOs is as an intermediary to bring university inventions to the marketplace. To perform this task, it is important for a university to have an adequate quality and stock of patents. It is crucial for TTOs to have skills in technology fields and capabilities to evaluate a project before the decision to patent or commercialise is reached (Lockett et al., 2003; Lockett et al., 2005). In other words, the use of a due diligence system may increase the chances that patents will be exploited.

TTOs also need to build linkages with industry. This is important in a situation when no previous relationship exists between inventors and industry (Colyvas et al., 2002). The chance of exploitation of the results of university research is greater when the university has ready built links with industry from the early stages of the research (Colyvas et al., 2002). The industry could identify and monitor research projects so that they can be tailored closer to market requirements. Thus, the project has a better chance of commercial exploitation.

The TTO should complement the efforts of academics, especially in initiating industry contacts, as academic inventors have other academic tasks to perform. In addition, sufficient monetary resources are crucial for TTOs to market and employ a patent agent to evaluate disclosures. As Siegal et al. (2003) states, an increase in the budget to pay for a Patent Agent will decrease the number of licensing agreements but increase the licensing opportunities.

Sufficient monetary and other resources should be allocated to the TTO to do its tasks and to employ good patent agents to evaluate disclosures and negotiate licensing contracts. Siegal et al. (2003) reported that spending more on good patent agents and lawyers reduces the number of licensing agreements but increases the licensing revenues, as lawyers are more meticulous and adopt tougher stances during negotiations.

Many TTOs in the US and in the UK are inefficient (Chapel et al., 2005; Thursby and Kemp, 2002) and are not productive. The absence of qualified people to evaluate disclosures in specialised fields like engineering, medical, pharmaceutical and life sciences hampers the TTOs' ability to commercialise any technologies in these fields. Even if they are not experts in the fields, they should have some basic technological knowledge. TTO staff also need to have marketing knowledge, business knowledge and negotiation skills to become effective marketers of the university technologies (Siegal et al., 2003).

Thus, to encourage efficiency and to encourage TTOs to become more involved in marketing the technologies and building linkages with the industry, incentives and rewards should be given to TTO staff and inventors (Jacobson et al., 2004; Siegal, 2006).

7.2.6 Rewards and incentives

Inventors do not feel that they are rewarded accordingly for engaging in commercialisation efforts, especially in licensing their technologies to established companies. It was suggested that most of them are not satisfied with the royalties received and try to gain quick revenue by other means. This is confirmed by Nilsson and Friden (2006) based on reports from inventors in three countries; the US, China, and Japan. Inventors seek to disseminate their ideas and breakthroughs with the end result measured according to their importance: publication; financial support for their research; access to testing, and lastly potential to license their discovery.

Table 7.1: The Propositions for patents that exploited through licensing to established companies.

	Propositions	Motivation and opportunity recognition
Patents that exploited through licensing to established companies	1C1	Inventors who have a desire to see their patents being exploited, but who are risk averse, are more likely to have their patents exploited through through licences to established companies.
	1C2	Where recognition of opportunities is by the company that funded the project, the more likely they will license the technology.
		Characteristics of the technologies/Scope of patent
	2C1	Established firms are more likely to license late stage technology than early stage.
	2C2	Established firms are more likely to license patents with narrow scope than ones with a broad scope.
	3C	**Research Funding**
		The more that research is funded by industry, the more chance that resulting patents will be exploited through licensing to established companies.
		Inventors roles
	4C1	The more that the interest of the inventors is confined to product development, the greater the chances the patents will be exploited through licensing to established companies.
	4C2	The more informal networking by the inventors, the more chance the patents will be exploited through licensing to established companies.
		TTO Roles
	5C	The more resources a TTO has and the more networking it does, the more chance of patents being exploited through licensing to established company.
	6C	**Incentive and reward**
		The more royalties that inventors receive, the more chance that patents will be exploited through licensing to established companies.

Inventors would normally receive royalties when their patents are licensed to established companies. However, the portions of royalties for the inventors differ between universities. These different royalty schemes may affect the motivations of inventors to license out their patents. Most universities use a sliding scale and practice different royalty schemes. This may affect the motivation of inventors to license out their patents. This is especially true when they license patents for early stage technologies rather than later stage ones where royalty rates increase (Thursby et al, 2001; Markman et al., 2005).

7.2.7 Suggestion of propositions

The discussions above which are based on the literatures leads to a set of Research Propositions as summarised in Table 7.1. This study attempted to prove or otherwise these propositions. As such, the interview questions were designed around these propositions.

7.3 BACKGROUND OF THE INVENTORS, THE TECHNOLOGIES AND THE ESTABLISHED COMPANIES

The TTO office reported there are 23 patents that were exploited through licensing to established firms. Eight patents could not be studied as the inventors had already left the University or transferred to industry. Of the remaining 15 patents only 5 inventors, who hold six patents amongst them, were willing to be interviewed.

The list of the licensees, the inventors' background, the granted patents and the technologies licensed are shown in Table 7.2 and Table 7.3. Table 7.2 shows that none of the companies that licensed the technologies from the University are local companies. Howmedica and Wyeth are US based companies. Orange, which originally licensed the technology from the university, has been bought over by Hutchison based in Hong Kong, and now Orange has been sold again to France Telecom. Oxonica was the company that originally licensed the technology from the University, but was bought by Astra, a large company from Sweden. The University gave exclusive rights of all six patents to these companies. By acquiring exclusive rights, the companies have the right to do further research and utilise the technologies in their products.

Table 7.3 shows that all the inventors had work experience in industry (with the exception of Inventor E). They had worked in industry before joining the

University, or were working as consultants for industry. Prior networking with industry provides information to the academics on the project to fulfil industrial needs.

One of the inventors said:

> *"... I have a lot of industrial connections because in all the research that we have done we have collaboration with industries. 80% of research that we have done has industry collaboration. I never work in industry ..."*

Table 7.2: Background of the companies, the patents and the technologies licensed.

Patent	Name of patents	Licensee	Technology applications	Date of patent filing/ grant	Ownership/ exclusivity of license
1.	Prosthetic Elbow Joint	Howmedica International	The invention relates to prosthetic elbow joint. The invention has the following advantages: the design follows the body shape, is easy to move and reduces the loss of bone.	10/9/76 (G)	Exclusive
2.	Electrical angular displacement sensor	Howmedica International	Relates to electrical sensor for measuring angular displacement. It is used for monitoring joint mobility in patients with ailments such as arthritis which produce abnormal joint movement.	25/7/89 (G)	Excusive
3	Nucleic acid sequence identification (4 patents were licensed)	Oxanica/Astra (Swedish company)	The system is called Chlamyde. The compound called Chlamyde system can test multiple diseases using body fluids	3/9/03 (G)	2 Exclusive 2 Non exclusive
4	Recognition system	Orange Company	Video compression.	7/1/03 (G)	Exclusive
5	Leucovorin-Optically Active Pteridine Derivatives	Wyeth Company	To cure certain type of cancer	8/1/03 (G) in US	Exclusive
6.	Agents for reducing weight	Hyundai, Korean, Company	Can cure diabetes at the same time as reducing weight	20/5/96 (G)	Exclusive

The findings show that 5 out of 6 patents licensed to these established companies came from the chemistry and bioengineering departments. Three were from the Chemistry Department, two from the Bioengineering Department and one from the Computer Science Department. None of the cases were from the Engineering Department.

Table 7.3: Inventors' background and industry experience

Inven-tors	Patent No.	Age	Education back-ground	Faculty/ depart-ments	Field of research	Industry experience/ contact	No. of previous/ subsequent patents*
A	1 2	55	PhD in Bio Engineering	Bio engineer-ing	Biomechanics and human function performance	Has industry experience	3
B	3	42	PhD in Chemistry	Chemistry	Produced compound that can detect multiple diseases using body fluids.	Has industry experience. Worked in drug company	8
C.	4	43	PhD in Computer Science	Computer Science	Video compression technology	Working as consultant to Orange	3
D.	5	57	PhD in Chemistry	Chemistry	DNA/cancer drug	Has huge industry experience	4*
E	6	56	PhD in Chemistry	Chemistry	Agents for reducing weight and diabetes	Has industry experience	1

Note: * Includes the number of patents in the sample for this study.

With the exception of Inventor E, all the inventors have more than one patent to their credit. Some technologies have multiple patents. Any 'subsequent' patents based on any new inventions or based on the original patents would be offered to be licensed to the same company as a family patent, or at least the company would have the first refusal rights.

Inventor A has three patents, of which two were exploited through an established company (Howmedica International) and one patent was exploited through a spin-off company in 1982. Inventor B has eight patents in a family, of which four are exploited through one company (Oxanica). Two licences are exclusive and the other two are non-exclusive. Inventor C has three patents, of which one has been exploited through a spin-off and one exploited through an established company (Orange). Inventor D has four patents, of which three have been licensed to an established company (Wyeth). Two of them are cases in this study. The other patent is yet to be exploited but licensing negotiation with an established company is ongoing. Lastly, Patent 6, a new patent, will be coming out in a near future derived from the first patent.

7.4 DECISION TO EXPLOIT THROUGH ESTABLISHED COMPANIES

The discussion in this section focuses on the decision to license patents to established companies and the personnel involved in the decision.

7.4.1 The discovery of scientific inventions

Generally, patents were obtained after years of study and as such the people involved are already well known in their industry. These researchers may already have prior patents either in the same field or some other related fields as their current patents. But at the point when the patents were granted the researchers knew that their technologies were still far away from the market, and might require another long period of hard work. All six patents resulted from research that has been worked on for many years in the University's laboratories. For example, the technology for reducing weight has been researched for five years in the laboratory. During the interview, the inventors were still looking for the right compound for the invention. Once the compound is ready, it will take another approximately seven to eight years to bring the invention to market after certain toxicological effects have been tested on humans. One of the inventors commented:

> *"...but to get ... into the market takes a long time; [first we need] to identify the compound that should be taken forward. ... If that stage had been identified, we have to go to formal toxicology screening, human trials ... and then into clinical trials. So, if we have the compound now, it will take maybe about, ... I could say, about seven to eight years [to reach] the market ...".*

Another inventor said;

> *"...to recognise commercial potential takes a very long time. ... the first stage was to get the rights to exclusivity. Eventually it was granted in both Europe and the US. It took seven or eight years before we got the patent granted".*

7.4.2 Motivation and who are the first to recognise the opportunity

- *Motivation*

All inventors in this group were mainly motivated by the desire to see their inventions developed and utilised. Only one inventor then reported financial consideration as the next reason for licensing the patent. Although they possessed some entrepreneurial characteristics such as the need for achievement, they were risk averse and were not interested in involving themselves in commercialising their technologies (Table 7.4).

Table 7.4: Motivation factors for inventors whose patents were licensed to established companies

	Patent No.	To see Patents exploited	Job not secure	Financial (to create wealth)	Not willing to take risk
License to established Company	1	√		√	√
	2	√		√	√
	3	√			√
	4	√			√
	5	√			√
	6	√			√

Inventor A of the Prosthetics Elbow said:

> *"... The biggest incentive is to get the device developed and be able to have it [utilised]. The first device allowed us to measure human movement. The second one where is to patent, license and commercialise for the inventors' financial return for a longer term ... ".*

Another inventor 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 who got the contract arranged."*

One of the inventors commented:

> *"...we don't actively try to commercialise at that stage. So RCS were doing marketing, they were trying to find somebody to take up the technology ...*
>
> *... Primarily at the start, it was all pushed and led by RCS. We were only interested in the technology. The University was interested in making money in this".*

Two inventors (Patent 4 and 6) initially were not interested in licensing their technologies. The inventors who licensed their technology to Orange were helped by the TTO to search for a licensee. This current finding is consistent with study by Lowe (1993) who reported that in a university, there are technology originators and technology harvesters. The inventors in this study could be categorised as technology originators and the TTO, SIDR (Strathclyde Institute for Drug) and Pharmalinks, as technology harvesters. The head of SIDR, for example, is a well-known person in industry and has strong contacts with them. Thus, it is easier for biotechnology and pharmaceutical inventions to link with industry. The role of the TTO is to identify which technology has potential value, link it with industry and try to exploit it. As Lockett et al. (2003a) suggested the TTO should recognise an opportunity better than the inventors and any external bodies.

The finding supports Research Proposition 1C1: *Inventors who have a desire to see their patents being exploited, but who are risk averse, are more likely to have their patents exploited through through licences to established companies.*

- ***Who are the first to recognise the opportunity***

Recognition of opportunities has resulted from the work experience of inventors with industries and through contact with friends. This finding is consistent with the studies done by Shane and Ventakaraman (2000), Shane (2001b), Shane (2003), Shane (2004), Park (2005) and Shane (2005). Inventors who discovered the opportunities through industrial work experience, especially through the companies' researchers are more likely to exploit these opportunities through licenses to established companies.

In all the six cases, the inventors indicated that they recognised the opportunities to conduct research in a particular area when they were working with industry, had discussions with friends, or with industry researchers. In other words, the recognition of research opportunities involved a combination of knowledge of industry and technologies. Inventor A recognised the opportunity when a surgeon from a hospital that had a problem with a patient came and had a discussion which led to the research and invention of the Prosthetic Elbow Joint. He said:

> *"...The prosthetic elbow is a joint research with Edinburgh Hospital and one of the inventors was a surgeon, Alexander Souter, the other was from Strathclyde University. ... So engineering [people] ... plus a medical person come together. The idea for the design [came from] a graduate project ... was a PhD project ... with the geonometer ... I had the idea sitting at my dining table during one night, coming here and asked the technician if they can do a certain*

procedure. He did and it worked. And we got a prototype built ...".

Their idea had interested the chief engineer of Howmedica. In addition, the surgeon also had networked with other companies to manufacture the product. The inventor said:

> *"...the chief engineer in the company shared the work together. We knew each other and he got the company [interested in the patent]. He got a good project from the company, but other surgeons also had networked with other manufacturers at that time, so that gave advantages ...".*

Another inventor of another patent explained:

> *"... the original thought of the invention [came] through discussions with the other inventor, Ian Smith. Ian and I were working [together] a lot during that time, when I was a Post Doc. We were working on the basic concepts, then we had a discussion with other two guys who were employed by Oxonica, and there was another guy, my industrial supervisor. And we found the idea for the technology ...".*

Inventor D recognised the opportunity when he found that the compound they had invented (Leucovorin) was sold in the market at high prices. The existing Leucovorin on the market at that time was only obtainable in large quantities from yeast at a cost of about $100 per kilogram but was sold for $10,000 per kilogram ($10 per milligram) - a mark-up of a hundred fold. The world market was believed at that time to be in excess of $100m. He explained:

> *"... The invention came because we had recognised in a group that the particular compound, which is a similar compound to the one they had invented, was sold at USD10 per mg. The market was believed to be in excess of USD100m. ... and we could produce at a lot lower cost. From this we saw [that] there were opportunities to commercialise [our product]. There was [also a] new science to be done because the practical method for obtaining this compound did not exist before."*

Inventor C, who invented video compression technology, explained how he started the project and how Orange and Acorn Computers were interested in funding the research project. The knowledge he had and the work experience with Orange motivated him to work with Orange when Orange initiated the funding for the project. He commented:

> *"...We came up with an idea to try applying Neural Network (NN) as a way of assisting the compression process ... to try to preserve enough information that would allow searches of the compression images. Didn't succeed in that ... but in the process came up with the new way of doing compression and this patent describes the compression process.*
>
> *The two patents are interlinked. This one fundamentally describes the way the compression process works and it was this patent that led to the exploitation by Hutchison, Orange and Acorn Computers. They funded the project to try to commercialise it and to take it to the working prototype stage."*

Orange was interested in funding the project in order to get a 3G licence. Through this system, all mobile phone manufacturers are compelled to have a system that could use more than just voice services. The University, through the RCS initiative, licensed the technology to Orange. The University and the inventors were hoping that Orange could produce mass-market quantities of video compression technology for external use. The University was also hoping that it would get royalties in return. Unfortunately, Orange was sold and the technology that was licensed to them was not exploited. This was because the new company that bought Orange had their own video compression technology. This led the inventors to form their own company to market the technology as explained in the previous chapter. The finding supports Research Proposition 1C2: *Where recognition of opportunities is by the company that funded the project, the more likely they will license the technology.*

7.4.3 Who was involved in the decision to patent/license

The same actors were involved in the decision to patent and to license. The decision makers in seeking patent protection which led to the group of patents being licensed to established companies could be divided into three categories, namely i) the research team and industry, or ii) jointly by the TTO and the inventors, or iii) the TTO alone. Generally, the findings showed that in half of the patents, the decision came from the TTO alone, one patent was decided by the TTO and the inventor and the remaining two patents was decided by the research team (industry and the University research groups). Table 7.5 shows the patented technologies, the respective initial decision makers to seek patent protection for the technologies, and the final licensees of the patents who were considered established companies in their respective markets.

Table 7.5: The decision makers to seek the patent protection/license.

Patents	Name of patents	Decision to patent/license	Established Company licensees
1	Prosthetic Elbow Joint	Research team & industry	Howmedica International
2	Electrical angular displacement sensor	Research team & industry	Howmedica International
3	Nucleic acid sequence identification	TTO and Inv	Oxanica/Astra (Swedish company)
4	Recognition system	TTO	Orange Company
5	Leucovorin-Optically Active Pteridine derivatives	TTO	Wyeth Company
6.	Agents for reducing weight	TTO	Hyundai, Korean Company

Note: TTO = Technology Transfer Office /Research and Consultancy Unit
Inv = Inventor(s)

In two cases, (Patents 1 and 2) the decision to seek patent protection and to license the inventions was made by the groups of inventors (industry and the University research groups). The industry partners in the research group became the licensees for these patents because the inventions resulted from their research works with the University's inventors. The markets for the above inventions were not very big and are confined to patients with fractured elbows. The licensee had more knowledge about the market than the TTO, thus, it was given exclusive license for that patent.

The decision to patent/license that was initiated by the TTO was made in three cases (Patents 4, 5 and 6). The TTO decided to patent these technologies because it recognised the potential market of the inventions. In addition, the findings showed that all the inventors were good scientists but they did not have any entrepreneurial background and were not interested in commercialising the inventions. Furthermore, two of the inventions were in the drug-based sector, which requires a lot more work before any products could be introduced to the market. The TTO also has very close relationship to SIDR, a body established by the University in 1988 (Clark, 1998) precisely to market any pharmaceutical discovery in the University (see Chapter 4). It was also possibly due to the qualification of the TTO

Director who has a chemistry background and therefore is more skilful at finding target companies and market in this sector to license the patents. One of the inventors said:

> *"... It was a group decision to go for patent protection ...".*

In the case of Patent 3, which was licensed to Oxanica, the decision to seek patent protection was an agreement involving the inventors, the TTO and the company. It was suggested that the company licensed a family patent from the University and the company covered the initial patent costs, because the patent cost would be very high if the University was trying to patent all of the four patents in the family at the international level. Patent protection for a family patent has to be applied separately for each patent even though it is treated as a family patent. One of the inventors from the group said:

> *"...The combination of the TTO, the inventors and the company ... when we were deciding that we want to protect it and [the rights would be] going to Oxonica Diagnostics. They [would] pay for that [patenting costs] initially. The University ... I don't think can pay for this ...".*

7.4.4 The stages of technologies and product development

The evidence from this study does not support Research Proposition 2C1 that *established firms are more likely to license late stage technology than early stage.* The finding of this study is consistent with previous studies (Thursby et al., 2001; Jensen and Thursby, 2001) who reported that most of the University technologies were at early stage at the time the University licensed them and needed inventors/involvement to bring them into the market. However, the finding does not fully support Shane's (2000, 2004) studies, who suggested that early stage technologies are normally licensed to small entrepreneurial companies or spin-off companies, and later stage technologies are licensed to established companies. In this study, most of the established companies licensed early stage technologies (Patents 1, 2, 3, 4, and 6) rather than the later stage technologies (Patent 5).

The early stage patents were at the proof of concept stage when they were licensed. This finding is consistent with Markman et al. (2005) who suggest that established companies tend to license both early and later stage technologies with different royalty payments or some amount of up-front fees.

Table 7.6: The stages of the technologies when licensed

Patents	Name of patents	Established Companies	Technology applications	Stage of the technologies
1	Prosthetic Elbow Joint	Howmedica International	The invention relates to prosthetic elbow joint. The invention has advantages in which the design follows the body shape, is easy to move and reduces the loss of bone.	Proof of concept
2	Electrical angular displacement sensor	Howmedica International	Relates to electrical sensor for measuring angular displacement. It is used for monitoring joint mobility in patients with ailments such as arthritis, which produce abnormal joint movement.	Proof of concept
3	Nucleic acid sequence identification	Oxanica/ Astra (Swedish company)	The system Called Chlamyde. The compound called Chlamydie system can test multiple diseases using body fluids	Lower than proof of concept
4	Recognition system	Orange Company	Video compression.	From proof of concept to prototype level
5	Leucovorin - Optically Active Pteridine Derivatives	Wyeth Company	To cure certain type of cancer	Prototype level
6	Agents for reducing body weight	Hyundai. Korean Company	Can cure diabetes and at the same time reduce weight	Proof of concept

Table 7.6 shows the stages of the technologies when the University licensed them. Only one invention was at the prototype stage at the time it was licensed and in this case the TTO initiated licensing efforts. All of the inventors were involved in further development of the inventions. This suggests that the full commitment of the inventors is crucial to bring the product into the market. Some up-front fees had been paid to the University to further develop the technologies. Thursby et al. (2001) suggested that for early stage technologies up-front payments such as sponsored further research would oblige the inventors to continue developing the technologies. A higher royalty payment will then be paid when the products go on the market.

Patent 4 (video compression system) was at the proof of concept stage when Orange funded the technology. Through that funding, the invention was developed to prototype level and was then licensed to Orange.

7.4.5 The scope of patents and multipurpose technologies

In this study, all of the established firms had exploited patents that had broad scope. Two patents (Patents 3 and 6) have multiple applications. Patent 3 can be used to test multiple diseases and patent 6 can cure diabetes and at the same time can reduce weight. Existing firms are unwilling to exploit multipurpose technologies because they do not see clear applications and they would also refuse to exploit technologies that do not fit their existing technologies and those which are likely to require huge investments. In other words, the characteristics of the technology is not a good discriminator of how a patent will be commercialised, which does not fully support Shane's (2001, 2004) findings. Therefore, Research Proposition 2C2: *established firms are more likely to license patents with narrow scope than ones with a broad scope* is not supported by evedence gathered in this study.

7.4.6 Research funding and further development

Previous studies showed that university research projects that are funded by industrial companies offer more opportunities for their results to be exploited than those funded by government (Lee., 1996; Shane, 2004; Dietz and Bozeman, 2005; O'Shea et al., 2005; Gulbrandsen and Smeby, 2005). This conclusion is supported by this study. Table 7.7 shows that five of the six patents were funded by industry (Patents 1, 2, 3, 4, and 6). However, most of the patents received more than two sources of funding to finish their projects. Two patents (Patents 4 and 5) were funded by the government on EPSRC studentships programme. Two other patents (Patents 1 and 2) received charity funding before being funded by industry. Industry funding is sought after the initial research indicated commercial value. In these cases, the companies then licensed the patents although the technologies were at the early stages, thus, requiring further development. Only one invention (Leucovarin) was at prototype stage when it was licensed.

Only two projects were totally funded by industry from the beginning of the project (Patent 3 and 6). For Patent 3, the inventor worked with the particular industry and was conducting the same project with the company's researcher.

Table 7.7: Funding for research projects and further developments of the inventions.

Patents	Name of patents	Established Companies	Technology applications	Funding for project
1.	Prosthetic Elbow Joint	Howmedica International	The invention relates to a prosthetic elbow joint. The invention has advantages in which the design follows the body shape, is easy to move and reduces the loss of bone.	1. Early project funded by Charity organisation (ERC) as inventor's PhD project. 2. The development project funded by Howmedica.
2	Electrical angular displacement sensor	Howmedica International	Relates to electrical sensor for measuring angular displacement. It is used for monitoring joint mobility in patients with ailments such as arthritis, which produce abnormal joint movement.	1. Early project funded by Charity organisation (ERC). 2. The development project funded by Howmedica.
3	Nucleic acid sequence identifi-cation	Oxanica/ Astra (Swedish company)	The system called Chlamyde. The compound called Chlamydie system can test multiple diseases using body fluids.	1. Oxonica funded the project. 2. The first company to license the technology
4	Recognition system	Orange Company	Video compression.	1. Early research funded by EPRSC as inventor's PhD project 2. Acorn Computers and Orange funded development to prototype level.
5	Leucovorin-Optically Active Pteridine derivatives	Wyeth Company	To cure certain type of cancer	1. PhD student project.(EPRSC) 2. Inventors' development project based on the initial project. 3. The WELLCOME company and American Cynamid. These companies were bought over by WYETH.
6.	Agents for reducing weight	Hyundai, Korean Company	Can cure diabetes and at the same time reduce weight	1. A PhD student project. 2. Originally funded by a British company. 3. Korean company continue funding. 4. The company licensed the patent

For Patent 6, a British company funded the project from the beginning and stopped in 1997 (inventor did not give the reason). Hyundai, a Korean Company, then funded the continuation of the project. The company then licensed the patent that was obtained for the inventions, which is still in its early stages and funded further development works.

Industry funded the five patents in situations where there were strong relations between the University (the TTO) and companies, and where there are personal contacts between the inventors and the company. The main reasons for this situation to develop are that the personnel involved in the research projects would be more aware of the market situations and thus, would direct the inventors towards fulfilling the market needs in their research efforts. From the perspective of the companies, they would fund research projects that they think would generate more tangible products. In contrast, government funds are more geared towards more fundamental and basic research.

This study qualifies the findings from previous research (Powers and McDougall, 2005; Dietz and Bozeman, 2005; Shane, 2004; Mansfield, 1995), which stated that industry funding is more likely to result in patents being commercially exploited. The evidence here indicates that other sources of funding are often important in the early stages of the research, with the industry often only funding the later stages, and this supports Research Proposition 3C: *the more that research is funded by industry, the more chance that resulting patents will be exploited through licensing to established companies.*

7.4.7 Investment cost and other factors

Most of the researchers said that their inventions would require huge investments to bring the products to the market. This makes such patents unsuitable for exploitation by new spin-off companies. This is linked to the fact that patented technologies were chemistry and biotechnology based. These industries require high levels of investments in development and testing costs. Complementary assets such as marketing and manufacturing in these types of industries also require high levels of investments (Teece 1987; Shane 2001a; 2001b; 2004; Shane and Nerkar 2003). These create high barriers to entry for new firms. One inventor said:

> *"We never ... We don't want to - too much money involved. We are going to start a company soon, but not for this technology".*

Another inventor said:

> *"... Prosthetic manufacturing base takes a huge amount of investment to set up, like the one we have here ... in the first year, ... this is going back in 1987, they spent about £250,000 for development costs alone ..."*

Another one said:

> *"... because in the Pharmaceutical industry the costs required for marketing and the back-up required to manufacture compounds is so large, it would be unreasonable to [internally] finance that. The right commercialisation route was royalties and licence and not the spin-out. We are talking about raising $100,000 million here ..."*

7.4.8 Inventors involvement in product development

As mentioned earlier in this chapter, inventors' involvement in product development is crucial to bring the product to the market. However, in all cases the inventors were only involved in the development of the products and were not interested in the commercialisation of the patents. Hence the current study supports Research Proposition 4C1: *the more that the interest of the inventors is confined to product development, the greater the chances the patents will be exploited through licensing to established companies*

7.4.9 Networking/who leads for licensing

This study shows that both informal and formal networking of the inventors and the TTO are important to market the patents. Interestingly, half of the patents (Patents 1, 2 and 3) were marketed through the informal contacts of the inventors and the licensees, and the other half (Patents 4, 5 and 6) through formal marketing by the TTO (see Table 7.8). 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). Therefore this finding partially support Research Proposition 4C2: *the more informal networking by the inventors, the more chance the patents will be exploited through licensing to established companies.*

In the case of Patents 1, 2, and 3 the inventors 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' engineers before hand. For example, in one case (Patent 2) the inventors and the licensee company were working in the same technology area. These pre-collaborations 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 customers' needs and the target markets were very clear from early on in their research.

The TTO initiated the search to seek patent protection and search for licensee for three patents (Patents 4, 5 and 7). There were two reasons: First, because of the stage of the technology. The technologies were at the later stage and have a clear target market. These attracted the company to invest in the technology. Second, the characteristics of the inventors: most of the inventors in this study were driven by the need to achieve something (McCleland, 1961), but were likely still to depend on the University for their careers (Birley 2003; Blair and Hitchen, 1998) and were risk averse. They were unwilling to take any risk and were aware that the technology needed huge investments so licensing them out was an alternative. This type of inventor prefers to stay in the University because they have comfortable and secure jobs (most of them are professors). Due to 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] ...".*

The same situation arose with Patent 3 (Nucleic acid sequence identification) where the University inventors and employees of Oxonica took the initiative to develop and license the technology. The inventor commented:

> *"I think the original thought of the invention arose through discussions with another inventor, Ian Smith. Ian and I were working a lot during that time when I was a Post Doc. We were working on the basic concept but then had a discussion*

with two other guys who were employed by Oxonica. There was another guy, my industrial supervisor and we worked out the idea of the technology ...".

7.4.10 The TTO networks and resources

The study revealed that the TTO does not have any formal links with the faculty members. The interaction is only one-way, with the inventors disclosing their inventions to the TTO. There is no proactive strategy from the TTO to go to the faculties to scrutinise the research projects that are underway.

The TTO occasionally gives talks to the academic staff to encourage them to patent their inventions. As mentioned in Chapters 4, 5, and 6 the TTO also does not have any systematic due diligence system to evaluate inventions after the disclosure, although the motivations and the opinions of the inventors are taken into account in choosing the route to commercialisation. This due diligence is required to assess which technologies should be given priority in the future commercialisation attempts.

Table 7.8: Actors involved in decision to license to established companies and finding the licensees

Patents	Name of patents	Established Companies	Technology applications	Who involved (initiated to license decision)
1	Prosthetic Elbow Joint	Howmedica International	The invention relates to prosthetic elbow joint. The invention has advantages in which the design follows the body shape, is easy to move and reduces the lossof bone.	Inventors and licensees
2	Electrical angular displacement sensor	Howmedica International	Relates to electrical sensor for measuring angular displacement. Used for monitoring joint mobility in patients with ailments such as arthritis which produce abnormal joint movement.	Inventors and licensees
3	Nucleic acid sequence identification	Oxonica/Astra (Swedish company)	The compound is called Chlamydie System which could test multiple diseases using body fluids	Inventors and company. TTO negotiates with the licensee.
4	Recognition system	Orange Company	Video compression.	TTO found the licensee
5	Leucovorin-Optically Active Pteridine Derivatives	Whyeth Company	To cure certain type of cancer	TTO and inventors .Inventors have wide experience with industry
6	Agents for	Hyundai,	Can cure diabetes and at the	TTO through SIDR and

	reducing body weight	Korean Company	same time reduce weight	Pharmalinks.

Table 7.8 summarise the involvement of personnel in the decisions to lilcense patents to established companies and the personnel involvement in finding licensees for the patents. In half of the cases, the TTO led the search to find licensees for the patents. The TTO is very active in marketing new technologies in biotechnology and pharmaceutical sectors because of the existence of SIDR and Pharmalinks, which links Strathclyde University to the University of Glasgow Biotechnology Research Group. Thus, more opportunities arise for technologies that resulted from research in these sectors (Patent 4, 5, and 6) to be exploited. SIDR and Pharmalinks have strong networking with industry. Generally, most of the University's patenta that were licensed are from these sectors.

One inventor expressed his satisfaction of the work of the TTO by saying:

"... Pharmalinks and R&C did all the negotiations ... ".

Most of the inventors are satisfied with the TTO office in helping them in patenting and licensing their technologies. The TTO also helped the inventors in negotiating and preparing agreements with the licensees. This finding is consistent with Audretsch et al. (2006) who reported inventors perceived that if they were helped by the TTOs it is more likely that patents would be exploited by means of licensing to established companies.

The finding suggests that in the 1990s the TTO targeted licensing to established companies rather than encouraging the creation of spin-off companies. The success story of Attracurium that was licensed in 1986 influenced this phenomenon. However, according to one of its inventors, the inventor's personal contact with the licensee contributed to the successful licensing of Attracurium. The TTO only became involved later in negotiating the license agreement. Another reason that could be envisaged is that creating, and managing spin-off companies need skills and capabilities, beyond the normal tasks in licensing to established companies (Lockett et al., 2003a). In licensing to established companies, after the companies had agreed to license the technology, the University just monitors the company and receives the royalties. One inventor-entrepreneur said:

> *"They weren't quite happy when we decided to form a spin-off company because they prefer other model - [that is] the company just paying [the royalty] money. That was what they achieved with Orange and I think they want to achieve that with other big companies ...".*

In contrast, for certain sectors such as engineering, the TTO has not played as active a part as in the case of the pharmaceutical and biotechnology sectors. A lack of knowledge in technical skills of the TTO staff in engineering sectors may inhibit licensing activities in this sector as recognised by the inventors and the Director of the TTO, as discussed in Chapters 4 and 5.

These findings are consistent with the studies done by Chappel et al. (2005), Shane (2004), Siegal et al. (2004), Lockett et al. (2003a) and Siegal et al. (2003). It also supports Research Proposition 5C*: the more resources a TTO has and the more networking it does, the more chance of patents being exploited through licensing to established companies.*

7.4.11 Royalty payments: university incentives and rewards

The University has only received royalties from three companies, which had licensed the technologies: companies that licensed Prosthethic Elbow, Geonometer and Lecouvarin technologies. For the first two, the life of the patent had expired and so the University does not receive any more royalties. For Lecouvarin the University is still receiving a substantial amount of royalties from the company, which has amounted to £6m so far. The royalties received reflects the fact that the inventions have been marketed successfully. In three cases, (Patents 3, 4 and 6) the inventions are at a very early stage and the University has only received up-front fees for further development of the inventions.

Every inventor has received a portion of the fees that has been agreed at the University level with a sliding rate if the amount of royalty increases. From the first stage of the royalties, the inventors and the University will get the same percentage, which is 50 % for the inventors and 50% for the University. When the revenue is increased, royalties to the University will increase to 60% and inventors get only 40%. The finding also reflects that the inventors of early stage technologies only receive the portion of up-front fees as their technologies were not utilised in any marketable products yet, and there are no royalties to collect. One of the inventors said:

> *"... the University had a revenue sharing agreement with the inventors. It is more University policy. When the invention is commercialised the University negotiates a revenue sharing agreement, which three of us share. The policy now in place is based on a sliding scale depending on the income. The first rate operates if there is not so much money, 50% to the inventor and 50% to the University ...".*

In the case of Leucovarin a new licensee has been found (Targent Inc.) who will market the drug in North America. This will give a new source of royalty to the University. The original licensing company (Wyeth) now uses another process to make the drug, so has stopped paying royalties to the University, and the company has given back the patent rights to the University after a few rounds of negotiations (Enterprise Matters, 2006).

All of the inventors agreed that commercialisation activities would not count towards University promotion. This statement is supported by interviews with TTO Directors of seven UK universities. All the Directors said that commercialisation activities were not counted in promotion considerations.

A TTO Director commented:

> *"I don't think that people seek commercialisation to get promotion. Younger scientists who have no job security look for exploitation rather than professors who have a secure place in the University ..."*

Although licensing and commercialisation activities are not counted in promotion exercises, the inventors still committed themselves to product development. This is linked to the non-monetary motivation factors that drive them to see their inventions developed and utilised in products useful to customers' needs. This finding is consistent with Lockett et al. (2003a, 2004) that there was no direct correlation on the effect of rewards and direct monetary incentives towards commercialisation of research results by academic inventors. Hence, the finding did not support Research Proposition 6C*: the more royalties that inventors receive, the more chance that patents will be exploited through licensing to established companies.* However, if there are incentives in promotion procedures, these might give a new impetus for academic inventors to be involved more actively in commercialisation and exploitation activities as suggested by Ndonzuau et al. (2002) and Tornatzky (2001).

7.5 CONCLUSION

It appears that the features of the patents that have been licensed to established companies possess certain characteristics as depicted in Figure 7.1. The findings contribute to the existing body of knowledge of commercialisation of university patents. The significant features of the patents that are exploited though licensing to established companies are as follows.

First, is the nature of the technologies themselves. Most of the patents that were licensed to established companies are broad in scope, early stage technologies, have commercial value and have had the commitment of their inventors in product development. This finding contradicts those from Shane's studies (2001, 2004), which suggested that licensing to established companies involves patents with a narrow scope and later stage technologies. Thus it can be said that established firms are interested in licensing early stage technologies, and license this type of patents with upfront fees, usually for exclusive rights to them. However, established firms also licensed later stage technologies (Markman et al., 2005). Licensing early stage technologies would normally come together with agreements for sponsorship for further research and licensing later stage technologies would result with greater royalties.

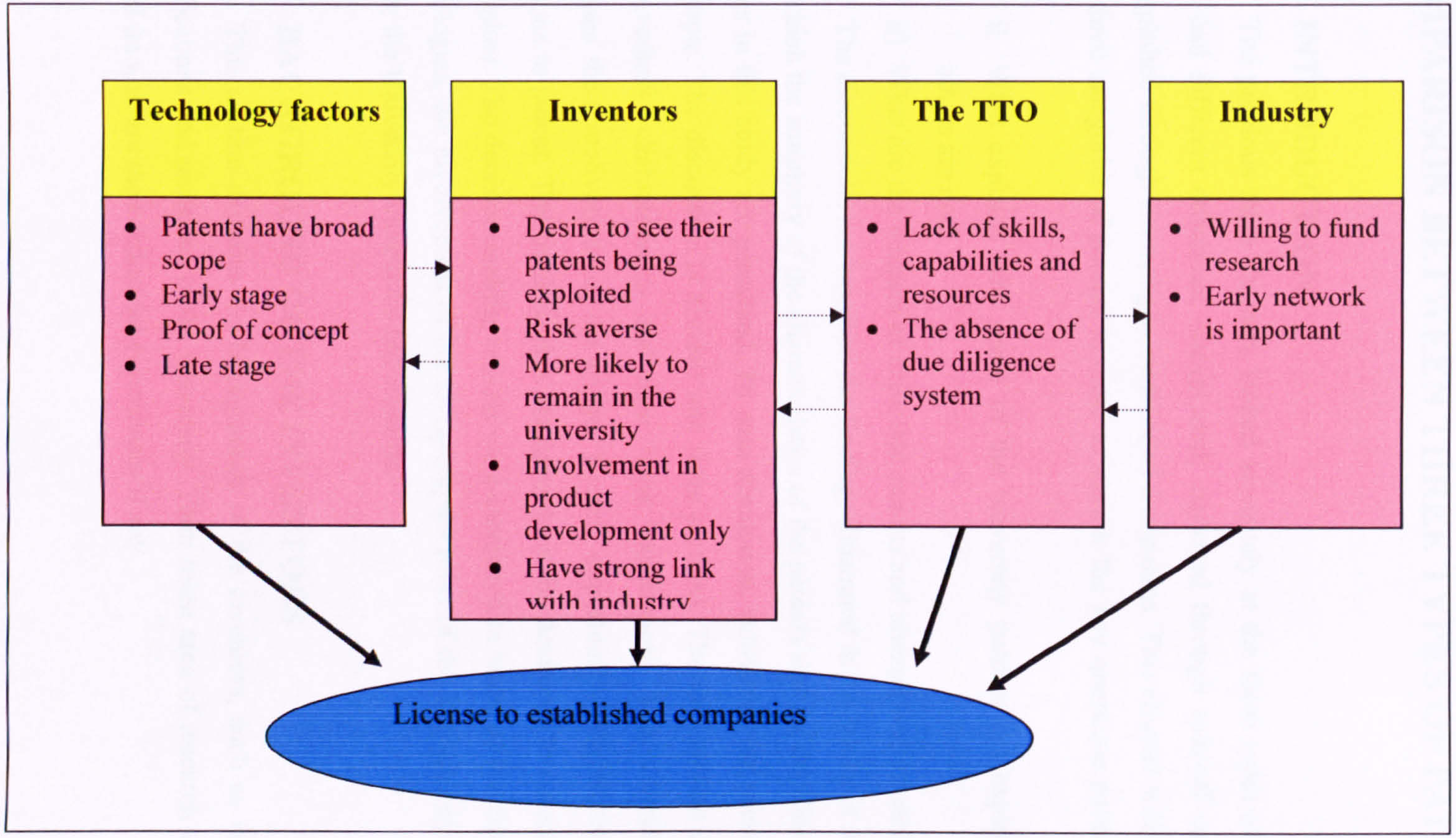
Second, is the inventors' factor. The inventors of of patent that are licensed to established companies are motivated by the desire to see their patents developed and utilised, and thus commercially exploited. But they are risk averse and intend to remain in the University. Most of them are professors and have comfortable positions in the University. All of them were committed to product development but mostly were not interested in involving themselves in commercialisation activities. Thus, the inventors' involvement in product development is crucial and supports previous research (Hsu and Bernstien, 1997; Thursby et al, 2001; Colyvas et al., 2002; Shane, 2004). The inventors also typically have strong links with industry either through work experience or consultation work, thus also helped in identifying and finding licensees.

The third factor is the TTO's role. The TTO's lack of skills in certain technology fields inhibits the chance of patents being licensed to established companies. The SIDR research centre and Pharmalinks gives patents from life sciences a greater chance to be exploited. In addition, the TTO Director has chemistry qualifications. Internal and external networking by the TTO or RCS with faculty and industry is also crucial to encourage young inventors to involve themselves in licensing activities. The TTO was able to identify opportunities in certain cases for those inventors who did not want to be involved in commercialising their invention. Thus, the TTO plays a role of technology harvester (Lowe, 1993) to bring the invention into the market. The findings also demonstrated that the TTO does not have any due diligence system to help with the process of selection of its disclosures for these types of patents or for exploiting the inventions.

The fourth factor is the involvement of industry. Formal and informal ties with industry are important to access funding for product development from industry. Industry will help inventors to identify opportunities and narrow down the market scope of the inventions, which leads to greater chances of exploitation. All the factors discussed are interrelated and interconnect with each other, as shown in Figure 7.1.

This and the previous two chapters have discussed the characteristics of three types of patents with different outcomes: those that were not commercially exploited, and those that were commercially exploited through licensing to spin-off companies and those that were commercially exploited through licensing to established companies. The next chapter undertakes a comparison of these three types of patents in order to explore what differences exist between them.

Figure 7.1: The features of patents that are licensed to established companies



CHAPTER 8

COMPARISON BETWEEN THREE TYPES OF PATENTS

8.1 INTRODUCTION

The previous three chapters looked separately at the three types of patents, which had different outcomes; unexploited, exploited through spin-off companies and exploited through licensing to established companies. This chapter will compare these three categories of patents in order to answer the key questions posed by this study;

i) What explains why some of the university patents are exploited and others are not?

ii) What are the features of exploited patents and unexploited patents?

The discussions are based on the findings illustrated in the tables in Appendix G in which the summary of the characteristics of the patents and the decision making process in this study are presented. To ease discussion, sub-tables are presented for each topic. The discussion is divided into three sections. The first section discusses the inventors' characteristics and their work experiences. The second section discusses their motivations or the trigger factors, opportunity recognition and the decisions to patent. The third section discusses how the decisions to commercialise were taken. The decision-making criteria were compared in terms of the types of the technologies, the involvement of the inventors, the roles of the Technology Transfer Office, the University incentives and rewards.

8.2 BACKGROUND OF THE INVENTORS

This section explores the backgrounds of the inventors, such as their ages, qualifications and positions in the university. Their main area of research were also looked into, so are their industrial experiences if any.

8.2.1 Age, qualification and position

Inventor-entrepreneurs are younger than both the inventors of uncommercialised patents and than whose patents were licensed to established companies. The average age at the time of interview of the inventors for the unexploited patents was 52 years, the same as the average age of those who licensed their patents to established companies. The inventors-entrepreneurs have an average age of 42. At the founding of their spin-off companies, their average age was 35 years. These average ages are consistent with studies by Roberts (1991a), and Wallmark and McQueen (1992). At this age, the inventors were still young, energetic and they were highly motivated.

All the inventors for unexploited and those patents that licensed to established companies have PhD qualifications and hold administrative post and very senior than inventor-entrepreneurs who were younger. Only two inventors from the spin-off companies hold Masters Degree (MSc) and four other have PhD degree.

Most of the inventors for unexploited patents were very senior and hold administrative posts in their departments as head of department. Two were senior lecturers and the others were professors, and most of them have worked in the University for more than 20 years and had experienced doing consultancy jobs for industry. Some preferred doing consultancy rather than getting involved in other ways of commercialising their knowledge.

Those inventors who licensed their patents to established companies are similar. They are professors, and their current average age is 52. They enjoyed stable positions and are comfortable with their posts. These types of inventors were risk-averse. Another reason is these inventors were senior staff, where at the time their patents were granted, the University (before the year 2000) was only encouraging licensing their inventions to established companies, rather than forming spin-offs. This group of inventors looked at spin-offs as a risky business which academic staff should not be involved with. This is the main reason why they sought to commercialise their research through licensing to established companies.

Most of the inventors whose patents were exploited through spin-off companies were young lecturers who considered their standard of living to be outside the comfort zone of the professors. For the young inventors, even though the main drive was to see their inventions being utilised, the secondary objective was to create wealth. Table 8.1 shows the inventors' age, education level, job positions and industry experience against their respective patents.

8.2.2 The origin of research

The majority of unexploited patents and patents that were commercialised through established companies, were from the Chemistry Department. However, patents that were commercialised through spin-off companies were from various departments. Of the unexploited patents, 4 out of 10 patents are from the Chemistry Department, which forms the majority. Two patents are from the EEE Department and one each from the Centre for Photonics, Education and Computer Science, Naval Architecture and Strathclyde Institute for Bio-Medical Unit (SIBU).

The chemistry Department leads with 4 patents out of 12 for exploited patents. Of these, 3 were licensed to established companies and one was licensed to a spin-off company. Patents that were licensed to spin-off companies were not only focused on life sciences or bioengineering as previous research has suggested (see Table 8.2) (Shane, 2004) but also includes patents from other departments. Similarly, with patents licensed to established companies, the Chemistry department supplied the majority of patents, not the bioengineering department. Bio-engineering accounted for only two patents licensed to established companies and one was from computer science.

8.2.3 Industrial experience

The majority of the inventors in this study (17 out of 21) have industry experience either as an employee or consultant. Of the 4 inventors who had no industry experience, 3 were inventors of unexploited patents, while the other one had managed to commercially exploit his patent by licensing it to an established company. The finding is consistent with previous studies (Shane and Venkataraman, 2000; Shane, 2000a; Shane, 2000b; Vohora et al., 2003; Shane, 2003; Shane and Khurana, 2003; Shane, 2004; Elfenbien, 2005).

Table 8.1: Background of the inventors

	Unexploited Patents										Exploited patents											
											License to spin-off company						License to establish company					
Patent Numbers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Age	52	50	47	62	59	44	52	46	55	56	35	43	45	47	28	43	55	55	45	43	55	60
Education	PhD	PhD	PhD	PhD	PhD	PhD	PhD	PhD	PhD	PhD	PhD	MSc	MSc	PhD	PhD	PhD	PhD	PhD	PhD	PhD	PhD	PhD
Position at the University	HD	HD	HD	HD	HD	SL	HD	SL	HD	HD	FT	FT	FT	FT	FT	FT	HD	HD	Prof	Entr	HD	HD
Industry experience	-	√	√	√	√	-	√	-	√	√	√	√	-	√	√	√	√	√	√	√	√	-

Note: HD = Head department, SL = Senior Lecture, FT = Full time; Prof = Professor; Entr = Entrepreneurs

Table 8.2: Types of patents and their inventors' department

	Patent Numbers	Departments
Unexploited patent n = 10	1.	Education and Computer
	2.	Electric and Electronic Engineering (EEE)
	3.	Centre for Photonics
	4.	Pure and Applied Chemistry
	5.	Naval architecture and Marine Engineering
	6.	Chemistry and Process Engineering
	7.	Electric and Electronic Engineering (EEE)
	8.	Immunology Dept, SIBU (Strath. Inst for Biomedical Science)
	9.	Pure and Applied Chemistry
	10.	Pure and Applied Chemistry
License to spin-off company n=6	11	Mechanical Engineering
	12	Bio Engineering
	13	Pure and Applied Chemistry
	14	Electric and Electronic Engineering (EEE)
	15	Physics
	16	Computer Science
License to establish company n=6	17	Bio Engineering*
	18	Bio Engineering*
	19	Pure and Applied Chemistry
	20	Computer Science
	21	Pure and Applied Chemistry
	22	Pure and Applied Chemistry

Note* = from one inventor

The finding showed that 70% of the patent holders whose patents were not exploited had prior industry experience. It is very tempting to disprove that industry experience would facilitate the commercialisation of patents. But looking more closely at these unexploited patents, it became clearer that the technology itself, even if it was patented, was not really ready for the market. The fact the patents are unexploited was more likely due to the technologies were immature, inefficient proof of concept and they were unreliable, as suggested by Hsu and Bernstein, (1997). The chance of the patents being unexploited increases, if the inventors hold administrative posts (such as Head of Departments and Deans). They would be busy with administrative works, which limits their time for efforts to commercialise their patents. These posts also attract career academics, as such of the 10 patents that are not exploited, 8 of them are heads of departments. Two of them had experiences of running spin-off companies using different but related technologies. Another one had just founded his company when this chapter was being written.

Conversely, for exploited patents, industry experience seems very important and led to the research results being exploited through both routes: spin-off and established company. Prior knowledge from industry will identify customer needs, manufacturing and sales needs to develop opportunities (Vohora et al., 2003). This finding is consistent with previous studies which suggest that inventors who had prior industry experience are more likely to form companies (Shane, 2000a; Shane, 2003; Shane and Khurana, 2003; Shane, 2004; Elfenbien, 2005) to exploit their inventions. In the case of the inventors that license their patents to established firms, their prior working experience in industry as consultants or employees helped them get contacts to license their technologies (Colyvas et al., 2002; Thursby and Thursby, 2000;Thursby and Thursby, 2001; Thursby et al., 2003).

8.3 MOTIVATION FACTORS OF THE INVENTORS

All the patent holders said that their main motivation for the commercial exploitation of their research was to see their inventions being used in products (Table 8.3). Thus, their desire for their research results to be useful is universal among the inventors interviewed. However, for each type of patent, the degree of motivation is somewhat different.

The inventors whose patents were licensed to established companies are professors or senior academics. As discussed above, they are quite averse to taking any risk especially involving any entrepreneurial activities that are required in the setting up and running of a spin-off company. Thus, they generally prefer their patents to be licensed to established companies as this does not require further effort on their part, except to support the licensees if required.

The inventors whose patents were licensed to spin-off companies have the highest desire level to see their inventions being adopted. This high motivation drives them to form companies to commercially exploit their technologies, as they believe that this route of exploitation is the best way to ensure the success of the technologies. This is the push factor as identified by Shane (2004). They also strongly believed that their technologies were ready for the market. They also seem to have personality traits that previous research identified to be pre-requisites for an entrepreneur: they have a high need for achievement, high locus of control, desire to be wealthy, risk taking, and desire for independence. This finding is also consistent with Shapero (1984), Blair and Hitchen (1998), and Shane (2004). Other motivations amongst inventors-entrepreneurs were to gain independence from the University, and to escape frustrations with the University, especially with its promotion system and bureaucracy. One inventor (Patent 13) was in contract employment at the University and so formed a spin-off company to gain independence (Shapero, 1984; Shane, 2003).

Table 8.3: Motivation factors of inventors for three types of patents

		Motivation factors			**Personality traits**	
Unexploited patents	Patents Number	i) To see Patents exploited	ii) Job not secure	iii) Financial (to create wealth)	Take the risk	Not willing to take risk
	1.	√				√
	2.	√				√
	3.	√				√
	4.	√				√
	5.	√				√
	6.	√				√
	7.	√				√
	8.	√				√
	9.	√			√	x
	10.	√			√	x
License to spin-off company	11	√		√	√	
	12	√		√	√	
	13	√	√		√	
	14	√			√	
	15	√			√	
	16	√			√	
License to establish company	17	√			√	
	18	√				√
	19	√				√
	20	√				√
	21	√				√
	22	√				√

All the inventors whose patents were not commercially exploited also wanted their technologies exploited. They considered commercial exploitation of their patents to be a symbol for success. They also have 'need for achievement' personalities. This is the prime reason they initially committed to conduct research project. However, these inventors were not willing to go out to market their technologies. They were too busy with administrative and academic works and not willing to invest their time for commercialisation activities. The fact that the technologies did not have potential markets may be one of the reason the inventors of this type of patent were not willing to risk their time to market their technologies.

The main difference between inventors who licensed their technologies to established companies and the ones who formed spin-off companies to exploit their technologies was the latter's willingness to take risks and make increased efforts in the ventures exploiting the technologies. The former are risk-averse and would prefer other parties to push their technologies into the market. Most of the inventors of unexploited patents were not willing to risk their time to be involved in commercialising activities.

8.4 OPPORTUNITY RECOGNITION

Inventors and industry played a dominant role initially recognising the opportunities for the exploited patents (Table 8.4). Industrial experienced played an important part in recognising the opportunity for both types of commercialised patents, especially for those licensed to spin-off companies. 'Industry pull' is also important (Rosenberg and Nelson, 1993). Industry played important roles in recognising the opportunities because it knows the market applications and the market size for the technologies. There is a demand for technologies where university inventions are near to industry applications.

The TTO did not contribute to the recognition of the opportunities in any patents that were licensed to spin-offs. However, it did play an important role for 2 technologies that were licensed to established companies (Patents 20 and 22). This is an obvious difference between the two types of patents. This finding, supports Colyvas et al. (2002) who reported that the role of TTOs is useful when marketing activities are most important for technological areas where existing links between academia and industry are weak. This study also shows that the companies that helped to recognise the opportunities for a patent, became licensees of that invention after they funded further work into the inventions.

The establishment of links between industry and researchers through prior work experience in the industry, either as employees or as consultants, helped them to know the market and recognise the opportunity. As such, the opportunities were recognised when the research projects were formulated or during the course of the research when results were analysed. If so, patent filing procedures were initiated for the technologies. Inventors of Patents 12, 14 and 16, which were licensed to Companies B, D and F respectively, were employed in the industry before joining the University; this supports findings by Shane (2000) and Shane and Khurana (2003).

Table 8.4: Opportunity recognition/trigger factors

Who recognised the opportunity				
	Patents Number	Inventors	TTO	Industry
License to spin-off company	11 (Co. A)	Inventors		Industry (Ford Motors)
	12 (Co. B)	Inventor/HCE		Industry
	13 (Co. C)	Inventors/HCE		-
	14 (Co. D)	Inventors		Scottish Power and National Grid
	15 (Co. E)	Inventor/HCE		Industry
	16 (Co. F)	Inventors		Industry (Orange Co.)
License to established company	17	Inventors		Industry's researcher
	18	Inventors		Industry's researcher
	19	Inventors		Industry's researcher
	20		TTO	Orange Company
	21	Inventors		Industry
	22	Inventors	TTO	

Note: NA = Not available, HCE = Hunter Centre for Entrepreneurship, TTO = Technology Transfer Office

In summary if the TTO or industry recognised the opportunity, the patent is more likely to be exploited through an established company via licensing. If it is the inventors who recognised the opportunity, then the patents are more likely to be exploited through spin-off formation.

8.5 RESEARCH FUNDING

The finding, consistent with other empirical studies, showed that research results from projects funded by the government are less likely to be exploited compared to projects funded by industry (Robert and Malone, 1996; Shane and Stuart, 2002; Shane and Cable, 2002; Shane, 2004; O'Shea et al., 2005; Powers and McDougall, 2005). Even though patents were granted for the research results funded by the government, the chances to exploit the patents are lesser compared to those resulting from research projects funded by industry. This in turn is likely to encourage license agreements and the setting up of spin-off companies as suggested by Powers (2003) and Gulbrandsen and Smeby, (2005).

Table 8.5 shows the distribution of sources of funds for the research projects in this study. The research projects were funded through various schemes such as EPSRC, Proof of Concept Fund (POC), Synergy Fund (SF) or University Challenge Fund (UCF) and University internal funding (UF). There are some projects that were funded by industry, charities, professional bodies and international bodies. Some of the projects were funded from multiple sources.

Table 8.5: Sources of research funding

Source of funding/ Types of patents	EPSRC	POC	SF/UCF	U.F	I	Other Organi-sations	Total
Unexploited patents (n =10)	2	2	1	3	4	2	14
Patents licensed to spin-off companies (n = 6)	4	0	0	0	4	0	8
Patents licensed to established companies (n = 6)	1	0	0	0	6	1	8
Total	7	2	1	3	14	3	30

Notes: EPSRC = Engineering and Physical Science Research Council, POC = Proof of Concept Fund, SF/UFC = Synergy Fund/University Challenge Fund, UF = University Funding, I = Industry, Other organisations = WHO, Medical Research.

The table shows that eight of the ten unexploited patents (80%) came from research projects that were funded by government-based money (from various funding schemes). Two patents came from projects funded from other organisations and 4 patents came from projects funded by industry. Three of these unexploited patents received more than one source of funding. The most prominent explanation why most of the research were funded by the government is that this type of funding is aimed at basic research which needs longer period of time to see exploitable results and even so would be difficult to commercialise (Strandburg, 2005). Some of the interviewees in this study who had unexploited patents suggested further funding to extend their research project might have helped bring results nearer to commercialisation.

There are 4 patents that were funded by industry and 2 patents funded from other organisations, which were not exploited. Two of the unexploited patents did receive further funding from the Proof of Concept Fund and one from the Synergy Fund to bring them closer to being viable projects. Two of these inventions are now under development and testing is being done before a final licensee is found. As noted earlier, one of them is being exploited through a spin-off company as this thesis is written.

Patents that were licensed to spin-off companies were divided equally between those funded by government and those funded by industry. Four projects were funded by the EPSRC and four others were funded by industry. In these cases funding from the government started the research, and industry provided further funding when the projects had commercial value for the end user. This supports empirical research by Powers and McDougall (2005), which concluded that research funding from both government and industry are important for spin-off formation. The findings also support previous research that inventors with close ties to industry are more likely to create spin-off companies (Robert and Malone, 1996; Shane and Stuart, 2002; Shane and Cable, 2002; Shane, 2004; O'Shea et al., 2005).

This study also highlights the importance of two giant companies (Scottish Power and National Grid) in helping the university to identify opportunities, markets and to become the first customers for the university's technologies (Wright et al., 2004; Shane, 2004). These companies have not licensed the technologies but used the University technologies not to strengthen and build their core competencies but to diversify their own technology development activities by accessing University knowledge through consultancies and funding research (Santoro and Chakrabatrti, 2002). For example, Company D was set-up by researchers who initially were involved in industry as consultants to Scottish Power and National Grid.

Industry funding led to six patents that were licensed to established companies. This finding suggests that industry may decide which project to fund based on: i) researchers having industry contacts; ii) inventions that tend to be based on applied research; iii) industry is involved with the project and licenses the invention. Most of the companies funded these projects at the early stage of the research, then licensed the patents resulting from that research. This also suggested that the industry has an eye for quality research projects (or R&D programmes) conducted by highly regarded researchers. These findings are consistent with studies by Colyvas et al. (2002), Mansfield and Lee (1996), and Gulbrandsen and Smeby (2005) who suggested that universities that undertake quality applied research would attract more research funding from industry.

The research leading to patents that are commercially exploited either by spin-off or licensing to an established company is more likely to have been funded by industry. However, both government and industry funding are important for spin-offs. Government funding is important for seed-stage money early in spin-off formation and industry funding is important at the later stage of product development. Unexploited patents are more likely to be based on research funded by non-industry sources, notably government.

8.6 DECISION TO PATENT

The decision to file for a patent for a newly disclosed technology normally involves the inventor, the TTO or the industry individually, although the decision could be made jointly by more than one of the parties mentioned (see Table 8.6).

Generally, the finding shows that the TTO took more active participation in the decision to seek patent protection in the case of unexploited patents. Of the 10 unexploited patents, three were decided by the TTO, three by the combined decisions of the inventors and the TTO, two by the inventors themselves and two by industry. In certain circumstances, the TTO and inventors influence each other in deciding to pursue the patents, but the industry decision became paramount if they funded the research project. On the other hand, inventors were more influential in the decisions for the patents that were licensed to spin-off companies.

The most significant difference for patents licensed to spin-off companies from the other two patent categories was that industry was not involved in the decisions. The inventors themselves decided to seek patent protection for three technologies, which were 50% of the cases. The TTO decided on two (33%) and both the TTO and the inventor decided on one patent.

Table 8.6: Decision to patent

	Unexploited Patents										Exploited patents											
											License to spin-off company						License to establish company					
Patent Numbers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Decision to patent	TTO	INV	TTO	TTO	I	I	INV	TTO & INV	TTO & INV	TTO & INV	INV	INV	TTO	INV	TTO & INV	TTO	RT	RT	TTO & INV	TTO	TTO	TTO
Decision route	NA	NA	NA	NA	NA	NA	NA	NA	INV& TTO	INV	INV	INV	INV	INV	INV	INV	RT & I	RT& I	RT& I	TTO	TTO & INV	TTO

Note: TTO= Technology Transfer Office; INV = Inventor; I = Industry, RT = Research Team; NA= not available

The patents that the University licensed to established companies showed a slightly different pattern. Half of the decisions (3 patents) to seek patent protection were made by the TTO, and another half by the research team and the industry partner.

The question here is on what basis did the TTO decided to seek patent protection for disclosed technologies in the first place? It has to be understood that patenting costs money but the potential benefits could be very rewarding. There are a few possibilities why universities patent new inventions, namely,

1) to gain financial benefit in the future (Cohen et al, 2000),
2) to help to obtain funding and/or continuation research funding (Coupe, 2003),
3) strategic reasons (Coupe, 2003),
4) to test the market for the invention [41],
5) to allow academics to continue with the research without competitions[42], and
6) to allow the University a better standing in collaboration with other organisation (Blind et al., 2006).

Basically, what is important is that the patent holders would be able to exclude others from their technologies, enabling them to control the usage of the technologies. Hence, the patent is considered a strategic asset to the patents holders.

Roberts and Peter (1981) suggested that once a patent is granted, the patented technology would create interest from industry and would show strong signs for exploitation, as the patent grant would make known the technology to the public. This is particularly true for good university inventions. Thus, to pursue all the intended benefits as outlined above, patent protection is very necessary indeed. In most cases patents become assets and bring competitive advantages to the University which could be utilised in future funding negotiations or in any venture to generate income (Mazeloni and Nelson, 1998; Cohen et al., 2000; Blind et al., 2006).

As discussed in Chapter 4, the University did not have any special due diligence system to analyse which technologies are to be given priority to be

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[41] interview with TTO Director the University of Strathclyde

[42] interview with the TTO Director the University of Strathclyde

patented, or on what basis they decided to seek patent protection for any disclosed technologies. The consequence of this practice is that the majority of the unexploited patented technologies in this study had insufficient proof of concept and some of them did not have commercial value. The patents also did not attract the attention of industry and the market after patents were granted as noted by the TTO Director at the outset. The absence of a due diligence system is one of the reasons why this type of patent is not unexploited.

The main reason why due diligence was not practiced by the TTO may have been because the main intention for the patenting efforts was to protect the University's inventions for strategic reasons to prevent others from copying the invention. All other benefits were considered to be incidental. That was why most of the decisions to patent the disclosed technologies were mainly based on the intuition of the personnel involved: TTO officers, the inventors and any parties involved with the funding of the research projects. This may be an explanation as to why many patents whose technologies were considered good for patenting by the TTO remain unexploited. But to be fair to the TTO, it should be noted that it is very difficult to predict the real potential market of any new invention (Shane, 2004). Moreover, if the technology is highly idiosyncratic, it is very difficult to identify its value and the potential market. Elfenbien (2005) commented:

> *"... technological information cannot generally be consumed directly, but only has value in its use. It may be highly idiosyncratic: there may be few (or no) potential entities for which the technology has any value ... a new technology can be difficult to describe and even more difficult to investigate. This may generate a particular severe problem in areas in which the science is immature".*

Elfenbien's comments concur with the actions of the TTO, thus, it is understandable that they do not conduct due diligence for new technology disclosures before seeking patent protection, unless the inventions clearly have market potential. This is likely to occur when the industry player, through its contacts with the inventors, has indicated its interests (as they did for spin-off companies).

Patents that were licensed to new spin-off companies differ from unexploited patents in that the decision to file for patents was mainly decided by the inventors themselves. The inventors generally recognised the opportunities in their inventions early on and before anybody else. The inventor for Patent 11 had the idea to form his own company at the start of his research project. This idea together with his high motivation (Shapero, 1984) steered his research towards technologies that could be used in saleable products, and hence he would be seeing his products used, which is the main motivation of many academic inventors in patenting.

Patents that were exploited through established companies again differed from the others in that 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 commercial activities involving their inventions. They were real scientists who saw their roles as doing research, having ideas or idea originators rather than idea exploiters (Roberts and Peter, 1981). Most of the inventors of patents that were licensed to established companies were not interested in involving themselves in commercialisation activities at all.

8.7 DECISION TO COMMERCIALISE: LICENSE TO SPIN-OFFS OR TO ESTABLISHED COMPANIES

The decision to patent that led to the 'intention to exploit' for unexploited patents mainly was decided by the TTO. The decisions on three patents were made by the TTO alone, and another three by the joint decision of the inventors and the TTO. This included two patents that have a potential to be exploited. The decision on the remaining two patents was made jointly by the industry and the inventors themselves. Half of the decisions to commercialise through licensing to established companies had been initiated by the TTO and the other half by the research teams or the inventors (Table 8.7).

This differed from the deciosion to exploit the patents through licensing to new spin-off companies. All of these decisions were initiated by the inventors. For patents that were licensed to new spin-off companies, different actors initiated the decision to patent and the decision to commercialisation. For nearly half of the inventions the TTO initiated patent protection. This may be because the inventors did not see the importance of their patent initially and had a lack of entrepreneurial awareness. However, they recognised the opportunity after their networks were strengthened with industry and other outside organisations. Hence all of the decisions to exploit the patents were decided by the inventors.

Table 8.7: Who were involved in the decisions of the route to commercialisation

The decision of the route to commercialise		
	Patent Number	The Lead Actors in Commercialisation Decision
Unexploited patents	1.	TTO
	2.	Inventors
	3.	TTO
	4.	TTO
	5.	Industry
	6.	Industry
	7.	Inventors
	8.	Inventors &TTO
	9.	Inventors &TTO
	10.	Inventors &TTO
License to spin-off companies	11 (Co. A)	Inventors
	12 (Co. B)	Inventors
	13 (Co. C)	Inventors
	14 (Co. D)	Inventors
	15 (Co. E)	Inventors
	16 (Co. F)	Inventors
License to established companies	17	Inventors & industry
	18	Inventors & industry
	19	Inventors & industry
	20	TTO
	21	TTO
	22	TTO

For patents that were licensed to established companies the TTO took the initiative if the inventors seemed not to be interested in the commercialisation of their patents. Similarly with unexploited patents, most of the inventors were involved with the research projects because of their interest and 'curiosity' rather than to commercialise. Thus, the TTO has to take the initiative to lead in the filing for patent protection, and the subsequent commercialisation efforts.

8.7.1 Early stage technology

The discussion on the stages of the technology here is based on Markman's stages of technology (see section 2.6.2 (5) page 72, Chapter 2) and Shane's (2004) characteristics of technology (see Table 8.8) that are exploited through spin-off companies or are licensed to existing companies.

Table 8.8: The nature of technologies exploited via spin-off companies and established companies.

Spin-off firm	Established firm
Radical	Incremental
Tacit	Codified
Early Stage	Late Stage
General purpose	Specific purpose
Significant customer value	Moderate customer value
Major technical advance	Minor technical advance
Strong IP protection	Weak IP protection

Source: Shane (2004:103)

Table 8.9: Number of stages of technology from different types of patents

Types of patents/stages of technology	Early stage technology	Proof of concept stage	Prototype stage	Total
Number of patent that not have been exploited	0	10	0	10
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**	**16**	**5**	**22**

Note*: Two on their way to prototypes

In this study, the majority of patents from all categories licensed were at proof of concept stage. It can be said that all the technologies (100%) of unexploited patents, half (50%) of the technologies that were licensed to spin-off companies and half (50%) of the technologies that were licensed to established companies were at proof of Concept stage (POC) (Tables 8.9 and 8.10). This supports Thursby et al. (2001) who reported that 75% of the technologies that were licensed were at proof of concept stage. Only 12% were ready for manufacturing and 8% were at the stage where manufacture was feasible immediately.

Table 8.10: Detail stages of technology for different type of patents

STAGE OF TECHNOLOGY	ES	POC	PTY
Unexploited patents			
Patent 1		√	
Patent 2		√	
Patent 3		√	
Patent 4		√	
Patent 5		√	
Patent 6		√	
Patent 7		√	
Patent 8		√	
Patent 9		√	
Patent 10		√	
Licensed to spin-off companies			
Patent 11			√
Patent 12		√	
Patent 13			√
Patent 14			√
Patent 15		√	
Patent 16		√	
Licensed to established companies			
Patent 17		√	
Patent 18		√	
Patent 19	√		
Patent 20			√
Patent 21			√
Patent 22		√	

Note: ES = Early stage; POC = Proof of concept; PTY = Prototype

Only two patents were at prototype level. They were exploited through established companies. Three patents that were licensed to spin-off companies were also at prototype stage (Table 8.10). Of these, one patent had finished its prototype stage and another two patents were being upgraded to prototype stage at the time the firms were being founded.

In the case of unexploited patents, why are these inventions were claimed to have been at proof of concept stage but were not exploited? Henderson et al. (1998), and Hsu and Berstein (1997) suggested that most of these technologies are of low quality with insufficient proof of concept: thus, they are not commercially viable (Trajtenberg, 1997). This is generally reflected in the unexploited technologies in this study. Table 8.11 shows the factors why patents were not exploited as extracted from Chapter 5. Though the inventors said that their technologies were at proof of concept stage, there was still 'insufficient proof' of that and hence most could not attract interest for commercialisation, the exception being Patents 9 and 10, which had shown market potential.

Table 8.11: Reasons patents are not exploited (as in Chapter 5)

Patents	Inventions	Technology early stage/proof of concept	Used conjunction with other	New technology superseded	Slow speed to market	Technology not reliable	Technology has changed	Broad scope of patent scope	Not involve in marketing/networking	Industry /organisation refused to invest /funding/	Limited Time to develop	Lack of funding	Promotion not counted	TTOs lack of resources	Protection reasons
1	3D images	√						√	√		√	√	√	√	
2	Sensors & micro system	√				√		√						√	
3	LED	√		√	√			√	√		√	√	√	√	
4	Black Strip sensor	√		√	√		√	√		√		√	√		√
5	Submersible	√		√	√		√	√		√			√		√
6	Gas Membrane	√				√		√	√	√	√		x	√	√
7	FENN	√						√	√		√		√	√	
8	Vesicle Formulation	√		√	√		√	√		√					
9	DNA	√						√							
10	Non-natural Lipo Protein	√	√					√	√		√			√	

As noted earlier for patents that were licensed to new spin-off companies, half of the patents were at the embryonic stage, thus the technologies are uncertain and need a huge investment for further development. University technologies that are at a very early stage of development and are unproven cannot be licensed easily to established firms. Such firms are more likely to exploit later stage technology. Shane

(2001a, 2004) said that proof of concept technologies are best exploited through firm formation and established firms are only willing to exploit later stage technologies.

However, this study found that the inventors who wanted to market their newly patented technologies have little seed money and initial funding to form spin-off companies with. This inhibits the inventors from building prototypes or other efforts to prove the commercial viability of their inventions. Respondents in this study further said that prototypes were only built when the companies had been incorporated and had received funding from sources that are designed to support the commercialisation process (mainly government).

According to Shane (2004), established firms tend to license late stage technologies. However, in this study established companies also exploited one early stage technology (Patent 19) and three were proof of concept stage technologies (Patents 17, 18 and 22). The possible explanation here is that the companies that adopted those technologies were already involved with the inventors from early on in their research projects as suggested by Markman et al. (2005) and Colyvas et al. (2002). Another reason why the University licensed this type of technologies to established firms is to conduct further research in collaboration with industry expertise.

Since the result is unknown but the technologies have shown proof of concept, the University only received low royalty payments, which is normally paid as a lump-sum payment until the invention enters the market. Markman et al. (2005) said that universities normally considered this type of 'licensing' as money for sponsored research but the company would be given first refusal rights for 'proper licensing' if the technologies come good later on. This was the case for the patents that were licensed to Oxonica, Wyeth and Hyundai.

Another reason why the TTO tries to license early stage or proof of concept stage technologies to established companies to have a long-term relationship with them. This relationship should ease the effort to secure future sponsorship or contract research, even though the money is not as much as the license for later stage technologies. According to Clark (1998), the University of Strathclyde has a long history and good working relationship with industry.

The amount of monies to be received by the University depended on the stage of the technologies licensed and the form of payment (cash, sponsored research or equity of the licensing companies). It would also be influenced by the aims and overall objectives of the University with regard to the commercialisation policy such as to support government innovation policy, to develop the regional economy or to purely generate cash for the University.

8.7.2 Multipurpose and radical technology with broad scope of patent

Multi-purpose technologies are technologies that could be used in different products. Radical technologies are new technologies that would bring major changes in the product range or which bring in newer standards, rather than small improvement to the same type of technologies. Examples include small portable music devices that have seen changes from Walkman tape players, to CD players to solid state ipods and MP3 players.

The inventors' categorisation of their technologies and patents are summarised in Table 8.12. This shows that all the inventors claimed that their patents have broad scope of protection. However, this may be an exaggeration as patent agents seek as broad coverage as possible for the patent. On the question of how radical are their technologies, two inventors from the unexploited group, six from those exploited to spin-off companies and two from those exploited to established companies said their technologies are radical.

Table 8.12: The scope of patents and nature of the technologies

Types of patents	Number of patents	Broad scope patents	Radical technologies	Multipurpose technologies
Unexploited patents	10	10	2	1
Licensed to spin-off	6	6	6	5
Licensed to established company	6	6	2	2
Total	**22**	**22**	**10**	**8**

One inventor from the unexploited group, five from those exploited to spin-off companies and two from those exploited to established companies said their technologies are multipurpose and thus, are useful in a range of contexts.

Shane (2001a, 2004) contends that it is best to commercially exploit patents that have radical and multi-purpose technologies through spin-off companies. This is reflected in this study as all six patents that were licensed to spin-off companies, claimed to be radical, and five claimed to be multi-purpose. At the other end of this spectrum only two of the ten unexploited patents were claimed by their inventors to be radical and only one was claimed to be multi-purpose. Unexploited patents also have broad scope but were not exploited for reasons associated with the technologies themselves (see Table 8.12). They had no economic value, were not radical and not multipurpose with the exception of Patents 9 and 10.

Shane (2004) suggested that a broad scope of patent could be defined by the first patent claim (first sentence) that does not cover any specific features to allow a spin-off to block its competitors exploiting the same technology (Shane, 2004), has strong family patents and no prior art[43].

A broad scope protects against competitors imitating their technology until the firm gains access to marketing and manufacturing assets (Shane, 2001b; 2003; 2004). All firms in this category outsource their products because their manufacturing system has not yet been established. Hence by having a broad scope of patent, competitors cannot invent around the technology, until the field of technology has developed, hence the patent is valid for a longer period (Levin et al., 1987).

Interestingly, it was found that Company C which licensed Patent 13, has a broad scope patent and radical technology but has only a single application of its technology using special gel for indoor plants. However, this patent is exploited through a spin-off company, which partially supports Shane's (2001a, 2004) findings. Maybe the inventors and the executives of the spin-off company that licensed that technology would find more usage for that technology in the future. Then it would be multi-purpose and thus fulfils shane's conclusion.

8.7.3 Cost of investment

After patents are granted normally more effort is required to bring the technology to the market. This effort requires more investment, the amount of which

[43] interview with the IPR officer University of Strathclyde.

depends on the maturity of the technology. In the pharmaceutical and drug industry there would be more testing stages to be done which would incur high costs before the drug or medicine is ready for the market. The cost of further development of the technology would normally determine the route of the exploitation of the patent. If the costs are high, the natural route is to license the technology to big established companies, whereas if the cost is not too substantial and the funding is available a new spin-off company could be formed to cemmercialise the technology.

Table 8.13: Patents and their industrial sectors

Patents and industries sectors		
	Patents Number	**Industries**
Unexploited patents	1.	Education and Computing
	2.	Electrical and Electronic Engineering
	3.	Photonics
	4.	Pure and applied Chemistry
	5.	Marine Engineering
	6.	Chemistry and Process Engineering
	7.	Electrical and Electronic Engineering
	8.	Biomedical Science
	9.	Pure and applied Chemistry
	10.	Pure and applied Chemistry
Licensed to spin-off companies	11 (Co. A)	Mechanical Engineering
	12 (Co. B)	B. Engineering
	13 (Co. C)	Pure and applied Chemistry
	14 (Co. D)	Electric and Electronic Engineering
	15 (Co. E)	Physics
	16 (Co. F)	Computer Science
Licensed to established companies	17	Bio engineering
	18	Bio engineering
	19	Pure and applied Chemistry
	20	Computer Science
	21	Pure and applied Chemistry
	22	Pure and applied Chemistry

Patents 9, 19, 21 and 22 (see Table 8.13) are new drug discoveries that need to undergo various tests and clinical trials before they could be brought to the market. These tests and trials, which are required by government regulations and international standards, involve very high costs and lengthy periods before marketing approval is granted. These patents are therefore more suitable to be commercialised by established companies that have a profit stream from their existing production. They also have their own structure to conduct testing and are familiar with the regulatory rules and procedures, which would be difficult for new firms. It should be noted that Patent 9 was being negotiated for licensing to an established company at the time of this survey.

8.7.4 Roles and capabilities of the Technology Transfer Office (TTO)

The main tasks of the TTO of a university are to facilitate, manage and becoming the agent for the transfer of technologies from the University to the market place. But the involvement of the TTO in the perception of the inventors varies from being very helpful to non-cooperative. A summary of perceptions among the 21 patent holders (22 patents) in this study is shown in Table 8.14.

The holders of the unexploited patents claimed not to have received enough help from the TTO to market their inventions. Half of the inventors of the patents that were exploited through spin-off companies, commented that they did not received much help in forming their companies while the other half claimed that the TTO was very supportive. In contrast, all the inventors whose patents were licensed to established companies claimed that the TTO was very supportive and helpful.

More than half of unexploited patents holders reported that the TTO did not have sufficient resources, skills and capabilities to help them market their patented technologies. This lack of resources, skills and knowledge of the TTO is recognised by the TTO Director himself. The University has research programmes covering a wide range of technologies. The TTO Director thought that it is impossible for the TTO staff to be experts in all fields of technologies. Hence it is difficult for the TTO to market all the University inventions. However, the comments from the inventors of the unexploited patent need to be interpreted with caution as the unexploited technologies were basically too early in the technology cycle with 'insufficient proof of the concepts' and thus, has debatable economic value. With the exceptions of Patents 9 and 10, the economic value of the unexploited patents was not very convincing.

The TTO Director further emphasised that the TTO would market technologies when they had gathered enough information from the inventors. To be convincing enough to the potential licensee or investors, the information should show enough proof of the viability of the patents and its technologies. The

Table 8.14: The involvement of the TTO in commercialisation process according to the inventors

	Unexploited Patents										Exploited patents											
											License to spin-off companies						License to established company					
Patent Num./TTO roles	1	2	3	4	5	6	7	8	9	10	11 (A)	12 (B)	13 (C)	14 (D)	15 (E)	16 (F)	17	18	19	20	21	22
Limited budget	√																					
Good in patent management		√							√													
Insufficient resources/skills			√	√		√	√			√												
No comments					√			√														
Full supports											√	√			√		√	√	√	√	√	√
Little supports													√	√		√						
Equity	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	√	√	√	√	√	√						
Coaching Bus; Plan	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	x	√	√	x	√	x						

Note: Full support = Inventors/entrepreneurs received all the supports/market and negotiation of agreements/ coaching of business plan from the TTO especially to form a company Little support = little support received by inventors/entrepreneurs, such as no business plan coaching, no encouragement to form a company, and no equity taken by the University. NA = Not available information from the patents holders was sometimes very sketchy and further clarification was required. This often needs further research, which may not be possible if the funding was already used up.

The inventors made the decision on the route to commercialisation in all patent cases that were licensed to spin-off companies and half of the patentcases that were licensed to established companies. The effect is to decrease the commercialisation time of the TTO (Markman et al., 2005). As mentioned in Section 6.7, of the inventors that formed new spin-offs, half 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. One of the reasons is prior 2000 the university focused their licensing efforts towards established companies.

Indeed before year 2000, there was no real push for the formation of technology spin-off companies in UK universities as a whole (Clark, 1998). Spin-off company formation activities in universities were in their infancy, mainly driven by 'entrepreneurial scientists' who had work experience with industry. The opportunities were commonly identified by their industry partners or clients for whom the inventors worked (Company C, D and Company F). In these cases, the new spin-off companies did not receive adequate support from the TTO. 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 is only capable of licensing patents to established firms but not capable enough in helping inventors exploit their patents by forming spin-off companies. Their belief that they were not given the necessary help was strengthened when they encountered various obstacles and challenges in the process to prove that the technology invented in a non-commercial environment is commercially viable as pointed by Vohora et al. (2003). This situation is consistent with the observation of Degroof and Roberts (2002; 2004) of 9 spin-off companies in Belgium.

Since 2000, the policy of the University changed towards giving more support towards spin-off formation activities. This was basically driven by changing government policies and availability of various funds to support the exploitation of new technologies from universities. Although more proactive policies were introduced, initially, individual motivation and initiatives were identified to be the main drivers for company formations. With the new policies, the TTO through the Hunter Centre for Entrepreneurship (HCE) provided entrepreneurial courses that coached inventors in the identification of opportunities, writing business plans, raising finance and networking with financiers and local business networks. Ventures were then financed with the help of seed funds that had been set up by the government. Thus, post-2000, companies like Companies A, B, and E, received more support from the TTO than older spin-offs.

The capability of the TTO to support spin-off has also increased since 2000. The TTO is now in the process of upgrading their staff and their policy guidelines, a process which was also noted by Lockett et al. (2003b; 2005) in other universities. In fact the TTO still does not have any 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[44] . Even so, if the due diligence system is set up, it requires quite an effort to bring the TTO staff involved 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 commercialisation skills that are required within the TTO are due diligence competency, analysis, legal, marketing, sales, science, and technical knowledge as suggested by Markman et al. (2003), and Lockett et al. (2003a; 2005). The TTO could have the right skills by training its people in these skills or bringing in experienced people by offering higher pay and/or some kind of rewards system (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 University's technology transfer and commercialisation rates as noted by Markman, et al. (2003).

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

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[44] Interview with Spin-off development Officer – Mr. Stuart McKenzie

commented that the TTO was very supportive, knowledgeable, highly skilled, highly capable, and were experts in negotiation skills. It was also noted that most of the patents that were licensed to established firms were in life sciences, such as patents on drugs and bioengineering. Hsu and Bernstein (1997), Etkowizt, (2002) and Mowery et al. (2002) noted that the majority of the exploited university inventions were from these fields. It should also be noted that in Glasgow, Strathclyde University has established two organisations - SIDR and Pharmalinks (joint venture with Glasgow University) - to market inventions in these fields. Therefore, it is not surprising that inventions in this field get more attention. The activities of these two organisations could explain the speed at which these patents were brought to the market.

There is 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 are 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 around marketing patented technologies to established companies. Efforts to license to spin-off companies and to established companies require different skills and capabilities.

The TTO aimed to get patents licensed by established companies and only if unsuccessful would they consider spin-off formation (Audretsch et al., 2006). This is because licensing to established companies gets the most cash as quickly as possible for the universities. Forming companies to license the patents requires the University to incur initial investment costs and extra efforts are required from the TTO, and the University will only get a financial return when the company is sold or has an IPO. 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. However, for spin-off formations, the TTO needs to be involved beyond the start-up stage (Lockett et al., 2003a; Lockett and Wright, 2005).

This is illustrated by Patent 10 whose technology was tested and was found to be very viable, but no licensee could be found. Finally, a decision was made to form a spin-off company to market products using the technology[45]. Similarly, Patent 16 that was initially licensed to, but was not exploited by, Orange was finally licensed to a new spin-off Company F.

Over and above all the considerations that are discussed, the TTO has to take account of the University's overall objectives and strategies for commercial exploitation of their patented technologies. Different licensing strategies are associated with different outcomes, such that universities that primarily seek R&D capital have lower commercial revenues and fewer spin-off formation activities. In this study the director of the University's TTO revealed that the main objective to the University is licensing for cash and sponsored research, though this is not mentioned in the University policy. This is understandable as this policy is the least risky. It was found that most universities have the same policy, such that spin-off formation would be efforts of last resort (Markman et al., 2005).

8.7.5 The roles of the inventors

Commercialisation of new patented technologies requires continued support from the original inventors, as being new technologies the original inventors are the people who understand them the most. These inventors are also most appropriate people to further develop the technologies. This study has shown that there are different levels of involvement of the inventors in the further development and/or commercialisation of their patented technologies. These different levels of involvement can be seen through their efforts in further development and networking. Networking here means how the inventors/entrepreneurs have built their commercial and professional linkages such as by presenting papers at conferences, publications, building contacts with parent universities and other universities, links with venture capitalists and industries, and private investors, local government agencies, and customers. Table 8.15 shows the number of inventors in this study that were involved in networking, product development, presentation of papers and license negotiations.

[45] Enterprise Matters, University of Strathclyde, issue, 2, May 26, 2006 and email answer from the TTO dated 6/10/06).

Table 8.15: The involvement of the TTO in commercialisation process according to the inventors

	Unexploited Patents										Exploited patents											
											License to spin-off companies						License to established company					
Patent Num./TTO roles	1	2	3	4	5	6	7	8	9	10	11 (A)	12 (B)	13 (C)	14 (D)	15 (E)	16 (F)	17	18	19	20	21	22
Limited budget	√																					
Good in patent management		√							√													
Insufficient resources/skills			√	√		√	√			√												
No comments					√			√														
Full supports											√	√			√		√	√	√	√	√	√
Little supports													√	√		√						
Equity	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	√	√	√	√	√	√						
Coaching Bus; Plan	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	x	√	√	x	√	x						

Note: Full support = Inventors/entrepreneurs received all the supports/market and negotiation of agreements/ coaching of business plan from the TTO especially to form a company Little support = little support received by inventors/entrepreneurs, such as no business plan coaching, no encouragement to form a company, and no equity taken by the University. NA = Not available

The data shows that more than half of inventors in the unexploited patents group (Patents 1, 3, 6, 7, and 10) did not get involved in any networking efforts. Only two were involved with product development and publications. They did not get involved because they accepted that their technologies were at an early stage such that they had no commercial value (Trajtenberg, 1997; Henderson et al., 1998). The inventor of Patent 3 said that his patent is just an idea to a solution while the inventor of Patent 7 only filed his patent as a strategic cover for his research project and said;

> *"It is a strategic move to cover a line of technologies that may or may not ultimately result in something that can be commercialised. ..."*

The notion of patenting to protect further research in particular technologies is supported by Strandburg (2005) who further said that many universities, with the help of governments through various funds (as discussed in Section 8.5.1), still encourage basic research or 'curiosity driven research'. These types of research sometimes result in technology breakthroughs, which lead to industrial innovations. In effect, these are really chance or incidental results that could be commercialised.

A few of the unexploited patents whose inventors had industry experience have commercial potential (Patents 9 and 10). The inventions had gone past the proof of concept stages, and the inventors were seeking more funds to continue testing.

In the case of Patent 9, the inventors had already exploited other patents before (the Leucovarin Patent). In fact, because of their experience they made sure that their new inventions were past the proof of concept point before seeking patent protections. This case showed a clear and distinct advantage for the inventors to have some industry experience, and the resulting patent has the potential to be exploited (Thursby et al., 2001; Colyvas et al., 2002).

In contrast, inventors whose patents were licensed to spin-off companies were fully involved in networking, product development, license negotiation and attended conferences (Table 8.16). In the case of spin-offs, the inventors' involvement in the wider business and industry networking, as well as product developments are essential. This is because forming a successful academic spin-off requires links and wider networks to transform the limited resources of the new company into products and services, and to exploit opportunities in the marketplace (Druilhe and Garnsey, 2001). The inventors used both direct and indirect social ties during their set up period (Shane and Cable, 2002). These networks give advantages for entrepreneurs to reduce information asymmetry (eg Company F) and to obtain funding.

Networking by inventor-academics also facilitates venture formation by providing four benefits namely, opportunity recognition process, access to resources, information and timing to market, and a source of status and referrals (Nicolaou and Birley, 2003).

Table: 8.16: Inventors involvement in the networking, product development and negotiations.

Types of patents	No. of inventors involved in networking	No. of inventors involved in product development	No. of inventors involved in license negotiations	Number of inventors involved in presentation of papers	Total
Unexploited patents n = 10	5	2	0	2	11
Licensed to spin-off n = 6	6	5	6	6	23
Licensed to established company = 6	4*	5	5	0	14
Total	15	12	11	8	48**

Note: * Inventors marketed their own inventions.

** Multiple responses possible

Through referrals, the academics involved in these companies received positive recommendations and evaluations at the right places. Inventors who network with industry increase their opportunity recognition capabilities, or are able to search for help to recognise opportunities, and increase access to information as suggested in previous research (Hills et al., 1997; Singh et al., 1999; Shane, 2000a; Elfring and Hulsink, 2003). The inventors of patent that was licensed to Company A had also established broader contact networks with established scientists, or cosmopolitan networks (Fiona, 2004).

The inventors of Patents 11, 14 and 16, which were licensed to spin-off Companies A, D and F respectively, used their network with the University to sponsor research students to work in their companies, employ other lecturers as consultants and to access laboratory and business incubator facilities. This relationship affects future firm performance. At post start-up stage, networking with customers, suppliers and other companies was done for product testing, outsourcing of supplies and manufacturing services, and acquiring supports for information services. The practices within the intra-university networks were also cited by Roberts (1991a), Dahlstrand (1997; 1999), and the practice of outsourcing from external networks was cited by Perez and Sanchez (2002).

Most of the inventors built their networks through presentation of technical papers at conferences and publications of technical papers in journals, before and after their patents were granted. Through these mechanisms, inventor-entrepreneurs get their customers and referrals (eg. Companies D and F). A large number of publications prior to granting of patents were associated with higher chances of the technology being licensed and exploited (Elfenbien, 2005). This is because professionals in the particular field read journals as part of their efforts to stay in touch with developments in their disciplines (Thursby and Thursby, 2004).

For patents that were licensed to established companies, more than half of the inventors (4 patents out of 6) were fully involved in networking with industries without the TTO help, which then led to industries licensing their patents. Here, personal contacts between the inventors and industries were important, and increased the chances of licensing and exploitation of their inventions by industry. Through personal contacts, the industry also would get to know the commitment of the inventors and their inventions before real licensing negotiations commence. This reduces adverse selection in the licensing of patents.

In regard to product development, all inventors whose patents were licensed to spin-off companies were involved in the product development as soon as the companies were incorporated and secured seed funding. All the inventor-entrepreneurs who formed spin-off companies in this study were involved on a full-time basis. This is expected, as their commitment was essential to the success of the spin-off companies, which in turn means the success of the efforts of commercialisation of the patented technologies. This is consistent with Shane (2004) and Toole and Czarnitzki (2005) who found that spin-off companies that licensed patents from universities performed better when there was full commitment of the inventors of the patented technologies in the companies. Zucker et al. (1998, 2001) reported that star scientists in biotechnology firms said that their scientific discoveries embody tacit knowledge that can only be communicated through 'bench-level' interaction by the original inventors.

In contract negotiations and agreements, all of the inventors of the licensed patents were involved, especially for spin-off companies. However, in the negotiation for licensing to established companies, the inventors' involvement was mainly only at the beginning of the negotiations. Only the TTO and the licensees were then involved in the follow on stages.

Almost all the inventors whose licensed their patents to established companies were involved in the development of products using their technologies, except for Patent 21 that is the Leucovarin technology, which was licensed at a late stage. All the other technologies in this study were licensed at an early stage. Thus, the involvement and commitment of the inventors to product development are crucial for the technical and commercial success of the product (Thursby et al., 2001).

In marketing the inventions, of all the exploited patents, two of which were licensed to established companies, were totally marketed by the TTO. The inventors, and the TTO were responsible lead for licensees. This was because their inventors were not interested in committing themselves to business activities. But the TTO recognised the potential of the technologies (video compression and weight reducing agent) and took the initiative to find licensees to further develop and commercially exploit them. This agrees with Lowe (1993), and Roberts and Peter (1981) who stated that in a university there are idea havers (academic inventors) and idea exploiters (academics who exploit the opportunities). The exploiters could also be the staff members of the TTO who could be able to recognise opportunities and encourage their exploitation, before other parties do (Lockett et al., 2003a).

The finding therefore partially supports previous research by Hsu and Bernstein (1997), Colyvas et al. (2002), Thursby et al. (2001) and Shane (2004) that personal contacts of the inventors tend to increase the chance of patents to be exploited. It could also be concluded from this finding that the level of commitment or involvement of the inventors, would determine the commercialisation route either to license to established companies or to form a new spin-off company.

8.7.6 University support systems

The University support systems are referred to the University taking up equity, royalty rates, the University's investment and incubators facilities for new spin-off companies. But, no equity was offered to the inventors whose patented technologies were licensed to established companies (Table 8.17).

- *Taking equity by the University*

Generally the University takes up 20% of equity, or higher if the venture is more risky [46] , in all the spin-off companies of the University, except in the case of Company C that licensed Patent 13. Table 8.17 shows the equity shares, royalties, the amount that the University invested in the spin-off companies and their use of incubators facilities.

Table 8.17: Equity, royalty and University investment in University spin-off at start-up.

Spin-off Company that licensed University IP	Equity by the University (%)	Royalty (%)*	University Investment	Incubators
A (Patent 11)	20	15	0	√
B (Patent 12)	20	0	20,000	√
C (Patent 13)	0	0	0	x
D (Patent 14)	20	0	-	√
E (Patent 15)	20	Confidential	Confidential	√
F (Patent 16)	20	5	0	√
Patents licensed to establish company	x	**Sliding scales**	x	x
Patent 17	x	√	x	x
Patent 18		√		
Patent 19		Lump sum		
Patent 20		Lump sum		
Patent 21		√		
Patent 22		Lump sum		

Note:* Royalties can be divided into two types: i) royalties that need to be paid to the University by a spin-off companies in the case the University takes the equity ii) Royalty paid by licensee to the inventors.

The University takes equity in its spin-off companies for a number of reasons. Most of the inventors in this study said that by taking equity the University is making

[46] interview with the spin-off development officer of the TTO of University of Strathclyde

a trade-off to cover its cost of patenting. The cost of patenting to cover international protection is high and pre-start-up firms could not afford that cost.

Thus, this cost is paid by the University, and in return the University was given equity in the spin-off companies. International patents are very important for companies intending to market their products internationally (eg Companies A, D, E and F). This is consistent with the Lockett and Wright's (2005) study which reported that the number of spin-out companies formed by universities is significantly positively associated with expenditure on intellectual property protection.

The equity is also given to the University in lieu of cash payments from the companies that licensed the University's patents. Basically, licensees should make a royalty payment or up-front fee to the University to exploit its intellectual property. Since the companies were new and lacked resources, equity is offered to the University based on the rate that both agreed.

Patent protection is a competitive advantage for new firms, before they gain access to their own marketing and manufacturing assets (Shane, 2004; 2001; Nerkar and Shane, 2003). Thus, if the University pays the patenting cost and in return takes up equity in the company to cover the costs, and any upfront payment, it encourages the inventors in spin-off formation (Feldman et al., 2002). The main return accrues when the company is sold or has an IPO (Bray and Lee, 2000). Normally, the company would want to reinvest its profits (if any).

Two spin-off companies also paid a royalty to the University even though the University took equity. For this type of royalty, the University also might consider wholly or partially waiving its rights to royalties if the founder/inventors all express the desire for the University to do so.[47] Company A that licensed Patent 11 pays 15% in royalties and Company F that licensed Patent 16 pays 5%, whereas the other companies did not have to pay any royalties. Company B that licensed Patent 12 was given special investment by the University of £20 000. However, these companies at the time of the interview did not pay any single pence to the University. This type of If the royalty payment is high it would discourage spin-off formations.

Licensing of university patents by established company would normally specify that royalties to the inventors would be based on a sliding scale. As the sales

47 Interview with Stuart Mackenzie the TTO spin-off development officer, university of Strathclyde.

increase, the percentage of royalties payable to the inventors is decreased. Any lump sum monies given to the University at the start of the licensing agreement would normally be used to sponsor further research and development of the patented technology. This is explained in Chapters 4 and 7. In this study none of the inventors whose patents were licensed to established companies commented on the policy of the distribution of royalties.

As a 'university spin-off' the companies were also entitled to receive other support from the University such as incubation facilities, business plan coaching, networking support and general advice. The University would also normally requests for an appointment of a university representative as non-executive director to the company board, thus, safeguarding the university's interests in the company, and hopefully strengthening its management.

- *Exclusivity of licenses and ownership of patent*

All licensing agreements in this study, except those that were licensed to Orange, a spin-off Company F and Oxanica (two patents), are exclusive licenses. The main disadvantage to the University of granting the exclusive rights of a patent is that only the licensee has that right to the technology and thus only one organisation to deal with.

In the case of ownership, half of the spin-off companies owned the IPR. For another half the IPR is still owned by the University or is jointly owned by the company and the University. For patents that were licensed to the established companies the University owns all the IPR. Thus, there is no dispute on who owns the rights to the inventions. Table 8.18 shows the patents that were licensed exclusively or non-exclusively and the ownership of the patents.

The main advantages of the ownership of IPR by the University are "to create consistency and prevent disputes between individuals" involved with the patents[48] The University would also have some flexibility to further license the patent after the exclusivity period runs out with the initial licensee if the licensee fails to exploit the license or it gave up the license prematurely. Furthermore, the University could

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[48]. The Times Higher Education Supplement - 25/11/2005, pg. 2, col. 2.

license to other parties if the first licensee fails to exploit the technology. This will benefit both the University and the inventors.

The disadvantage is that the research information in that particular field is not more freely available. Only a company that has exclusive rights has the monopoly power to further develop the patent without fear of its technology being imitated by other parties. This right is given to ensure that the company will be able to collect the rent from the IPR and can cover R&D costs within the period of the IPR rights.

Table 8.18: Exclusive/non-exclusive licensing and ownership of IPR of the patent

Patent licensed to spin-off companies	Exclusive	Non-exclusive	Company/University ownership
Patent 11	√	-	University
Patent 12	√	-	University
Patent 13	√	-	Company
Patent 14	√	-	Company
Patent 15	√	-	Company
Patent 16	√	√	University
Patent licensed to established companies			
Patent 17	√	-	University
Patent 18	√	-	University
Patent 19	√	√	University
Patent 20	√	√	University
Patent 21	√	-	University
Patent 22	√	-	University

- ***Rewards and incentives***

All the interviewees in this study said that the University did not take into account the commercialisation efforts by inventors in the University promotions and remuneration schemes. Internal university promotions are mainly based on the number of publications of articles in refereed and eminent journals. The system which is based on the number of refereed publications (Lambert, 2003) led to the difficulty for the University to recognise commercialisation activities as part of the criteria for promotion.

The interviewees did not give any comments on how the University rewards system affects their commercialisation activities even though the question was put to them from different angles. Maybe this was because it involves top down policies which are difficult for inventors to comment upon. As was mentioned before, most of the inventors whose patents have been exploited had expressed their desire to see their inventions utilised in useful products. This finding is consistent with Lockett et al. (2003a), Markman et al. (2003) and O'Shea et al. (2003) who reported that the availability of rewards and incentives are not significant in spin-off company formation.

The reason is that those who ventured out would normally leave the University (but some would stay) to give full commitment to their business and would not think about promotion exercises. However, attractive rewards and incentives may be effective to persuade some academics to consider licensing to established companies, and remain in the University as suggested by Siegal (2003a, 2003b, 2004). Thus, if commercialisation activities are recognised in the RAE exercise, as suggested by Lambert (2003), it may boost the quality of disclosures that may lead to more exploitation activities, and would also reduce the number of patents shelved or left unexploited.

8.7.7 Other support activities

The University supports inventors in spin-off company formations in many other ways. According to the TTO Director the University now has business incubation facilities, business coaching programmes and in some cases cash investment to invest as seed money in new ventures.

This study found that 5 out of 6 spin-off companies (the exception is Company C that licensed Patent 13) used incubation facilities when they were founded. Incubation facilities helped spin-off companies in the initial stages using the facilities available at the incubation centre. The incubator's management links the inventor with private investors or venture capitalists, industries, government bodies, customers and potential customers until they are mature enough to stand on their own feet. Companies A, D and F have 'graduated' from the incubator and are now growing and thriving. The University also allows its academics to act as consultants to private companies, especially to its own spin-off companies. The inventor-entrepreneurs suggested that the University needs to have a special start-up fund and to have bigger venture capitalists network so that any new patent grants could be communicated to the maximum number of potential financiers. They also suggested the necessity of the TTO helping them build better links and business networking with people sharing similar business interests. There is also a need for external parties to evaluate their business plans.

8.8 CONCLUSIONS FOR THE RESEARCH PROPOSITIONS

Based on the above discussions and propositions that have been proposed in each findings chapter, in this section the new propositions are proposed as in Appendix A4–A6. The new Research Propositions are proposed when the findings are not confirmed with the propositions that have suggested.

8.9 CONCLUSIONS

The commercialisation of university patents involves a complex decisions-making process immediately after their initial disclosures. The first of these is whether to patent the technologies. Then decisions have to be made whether to license the patent to an established company and let them do the hard work of commercialisation, or to let the academics form spin-off companies to commercialise the technologies themselves.

The study of the decision-making process was divided into three categories of patents in the University of Strathclyde. They are grouped into unexploited patents, patents that were licensed to spin-off companies and patents that were licensed to established companies. The study found that the decision-making process between the three categories of patents were very different. These differences are highlighted in every step of the commercialisation process.

The decision to commercialise the University patent depends on various factors. The main factor is opportunity recognition and the trigger factor, which showed that academics with industrial experience tend to have their patents commercially exploited. Other determining factors are the characteristics and motivations of the inventors, the roles of inventors, sources of funding, roles of the TTO in exploiting the opportunities, as well as rewards and incentive for the inventors.

The most significant difference between unexploited patents and the other two types of patents was in the initial decision to patent. For unexploited patents the decision to patent, which is assumed to lead to the decision to commercialise, was mainly taken by the TTO. By contrast, for the patents that were licensed to spin-off companies, the decision to patent was taken by either the inventors alone or together with the TTO, but the initial decision to commercialise was taken by the inventors. For patents that were licensed to established companies, the decision to patent and to commercialise was a joint decision between inventors, industry and the TTO.

Spin-off company formations to commercialise their patents by academics are more likely if they had industry work experience. If the academic had been involved with research sponsored by industry and had done consultancy work, then their patents would be more likely to be licensed to established companies.

The motivation levels of the inventors of the three categories of patents were varied. Inventors of unexploited patents claimed that they were busy with administrative and academic works which prevented them from networking with the outside world. However, this should be treated with caution as there are other interrelated factors that inhibited them from networking. Although they managed to get their technologies patented, many were too early as such their technologies are only proof of concept, immature, or with uncertain economic value. These were some of the factors that suggested to have de-motivated them.

Inventors that exploit their patents through spin-off companies generally have entrepreneurial characteristics, such as high motivation levels, really want to see their inventions exploited and are willing to take risks. They are willing to network with the outside world through attending conferences, linking with potential financiers and customers and committing themselves to product development. These characteristics were not prevalent in inventors that licensed their patents to established companies. Half of them were pure scientists that needed the TTO to push their patents to the market.

The features of the patents themselves will influence which route is the best to commercialise them. All the inventors in this study claimed their patents have broad scope. The differences between them are how radical and how multipurpose technologies are. Patents with broad scope, involving radical advances from the present technologies and which are multi-purpose in nature would be best exploited through new spin-off companies, as were the cases in this study. This finding supports Shane (2001a, 2001b, 2004). Patents that were licensed to established company are mostly not radical and are of single application only, and most of them are early stage technologies although they have broad scope, which partially supports Shane (2001a, 2001b, 2004) studies.

In this study 80% of the patents that were exploited were early stage technologies at the time they were licensed. This seems to contradict Shane (2004) who found that early stage technologies tend to be exploited through new spin-off companies. But it agrees with Markman et al. (2005) that patented early stage technologies would get the attention of established companies and would be licensed by them if the University continues development research, paying the sponsorship for the continued research, or a lump sum license fee. The final characteristics of the patents that seem to have influenced their commercialisation is the type of fund that academics receive from their research projects. If the research projects managed to get industry funding, there was a high possibility that the resulting patents would be exploited through established companies.

The conclusions and contributions of this study will be discussed in the next chapter. Limitation and future research also are highlighted.

CHAPTER 9

CONCLUSION

9.1 INTRODUCTION

The overall aims of this study were to examine what explains why some university patents are exploited and others are not, and what are the features of exploited patents and unexploited patents. To achieve these aims, the study particularly look into: i) how, why and who are the actors involved in the decisions to patent a new discovery and the exploitation routes chosen; ii) identify the factors that influence and/or hinder patent exploitation. The study also examined the effectiveness of commercialisation of university patents and the efficiency of its decision making process. To fulfil the objective of the study, two types of patents were examined: unexploited patents and exploited patents, of which some were commercialised through spin-offs formations and others were through licensing to established companies. The University of Strathclyde patent portfolio was used as a case study. To understand the commercialisation process in details, six TTOs of UK universities plus the TTO of the University of Strathclyde were interviewed.

9.2 THE RESEARCH QUESTION

Universities have important spill-over effects which benefit local and regional economic development. One of the key mechanism responsible for these spill-over effects is the patenting of scientific knowledge and licensing the patents either to spin-off or established companies. However the patenting system is inefficient, with unexploited patents representing a high proportion of granted patents (Nilsson et al., 2006). Moreover of those patents that have been exploited, very few generate income for the universities (Pressman, 2004; Geuna and Nesta, 2006). It is, therefore, essential that the process of university commercialisation, with focus on patents, be understood if the effectiveness of the whole activity is to be increased and the number of unexploited patents be reduced.

This chapter addresses the implication of the findings for the commercialisation process in the university. Specifically the findings suggest how University TTOs can improve their effectiveness in patenting by i) recognising what types of patents have a likelihood of being commercialised and ii) how to create a supportive environment in the university that facilitates the commercialisation of patents.

An understanding of patenting and licensing, including the existing process of exploitation, and the relevant literature was discussed in Chapters 2 and 4. The studies of licensing activities were mostly focused on the factors as to why companies licensed universities' technologies from the perspective of TTOs and industry, and the productivity and licensing objectives of the TTOs. Studies on spin-off activities have mostly analysed the individual and the organisation, with an emphasis on the post start-up period activities, describing factors such as the motivation and characteristics of the founders and the firms, and those influencing the formation and support activities and the performance of the company. None of the studies have focused on the whole process of commercialisation, particularly the institutional factors, which is the approach of this study. This study has been carried out to fill this gap. This study has specifically focused on answering the following research questions;

i) What is the explanation as to why some of the University patents are exploited while others are not?

ii) What are the features of exploited patents and unexploited patents?

Through answering the research questions above, this report has answered the two objectives of this study:

a) To identify, who are the actors involved, and how the decision-making process has been done with regard to patent selection and the patent exploitation process.

b) To identify the factors that influenced and hindered patent exploitation.

The conclusions of the study are discussed here in relation to the research questions above.

In term of the first objective, the process of commercialisation is started when the inventions are disclosed to the TTO office. The decision to disclose the inventions was decided by the inventors or the research group. The TTO did not scout out the inventors to get them to disclose their inventions and to scrutinise the inventions prior to the inventors disclosing the inventions. Thus, the inventors only disclosed any inventions that they thought were patentable. Some of the inventors preferred to publish rather than patent and derived their financial returns through consultancy work.

The decision to seek patent protections involved a combination of actors: from the inventors alone, to the TTO and the inventors, and in some cases the companies that funded the projects were also included in the decision-making. Both types of patents, the exploited and unexploited, demonstrated a specific pattern.

The inventors and the TTO play crucial parts in the decision to exploit the patents. Interestingly the decision to exploit the patents differed between patents that are licensed through spin-off companies and those patents that are licensed to established companies. All the decisions to exploit through spin-off formation were decided by the inventors. On the other hand, the decision to license the patents to established companies involved a combination of players. Either it was the decision of the inventors and the licensees, the inventors alone, the TTO alone, or the TTO and the inventors. The TTO office has played a proactive part and is an important actor in helping identify opportunities for the inventors with quality inventions, but who are not interested in commercialisation. With this type of inventor, the TTO would normally decide to license their patents to established companies.

The findings also revealed that the University does not have either a systematic approach or clear policies nor applies due diligence as to which patents should be given priority for seeking patent protection. A systematic selection process and clear policies might help reduce the number of unexploited patents. Most of the disclosures that fulfil the standard criteria will immediately be filed for UK patent protection at the minimum cost. International filing proceeds if licensees are identified. The decision to seek patent protection is based on information from the inventors or on information from the general disclosure form.

In answering the second objective of the study, seven major interlinked themes or factors have been identified which influence the decision whether to exploit the patents. These factors are:

i. Motivation factors and
ii. Opportunity recognition,
iii. The involvement of the inventors,
iv. The funding available,
v. The stages of the technology and the strength of the patents,
vi. The roles and capability of the TTO,
vii. The reward system.

The themes are integrated in three commercialisation models, which are presented in Figures 9.1, 9.2 and 9.3 (the models will be explained in Section 9.4).

9.2.1 Motivation, the opportunity recognition, and the involvement the inventors/ entrepreneurs.

The motivations of the inventors play a crucial role in the opportunity to exploit the patent, particularly those that were exploited through spin-off formations. The inventors' desire to see their inventions brought into practice being was an important factor in the exploitation of the inventions, supporting previous findings (Olofsson et al., 1987; Doutriaux, 1987; Blair and Hitchen, 1998; Shane, 2003; Shane, 2004). The desire to be rich was only a secondary reason (Blair and Hitchen, 1998).

Those who had worked in industry as consultants or as employees have a high desire to see their inventions commercialised and easily identified the opportunities (Venkataraman, 1997; Shane, 2000a; Shane, 2004; Park, 2005), and their industrial experience also helped them choose the exploitation routes.

For most of the unexploited patents, although the inventors did have industry experience, the main reasons why the patents were not exploited were due to particular characteristics of the technologies, and the limited value of the inventions (Guena and Nesta, 2006), or the absence of it (Trantenjberg et al., 1997; Henderson et al., 1998).

Nevertheless, the inventors' level of motivation[49] to see their inventions being exploited through licensing to established companies is lower than for those whose inventions were exploited through spin-off companies. They were not willing to take risks, and were not interested in being involved with the business. Thus, they preferred to license their patents to established companies rather than forming their own company. The type of technology that is incremental and single purpose needing huge investment, also contributes to the decision to license to established companies. Most of the inventors of patents that are licensed to established companies are professors who have been working for several years with the university and have a comfortable salary. This is in contrast to the inventors of patents that are licensed to spin-off companies, who are young, energetic and have not reached the comfort zone in their academic careers.

In contrast, for unexploited patents, most of the inventors demonstrated a very low desire to see their inventions being exploited, and claimed that they did not have time to do marketing and build networks with industry. Some of the inventors of these patents did not have the entrepreneurial awareness and business drive. A few of them mentioned that they 'did not want to be a millionaire'. For some other inventors they did not try to commercialise their technologies because they were not confident that their technologies were reliable and mature enough, or were already superseded by other technologies.

The inventors' role in building networks with industry and external bodies is critical to the commercialisation process. Personal contacts with industry was the crucial element that led both types of patents to be commercialised (Birley, 1985; Rapert et al., 1999; Jansen and Dillion, 1999; Thursby and Thursby, 2001;Colyvas et al., 2002, Jansen and Thrursby, 2003;Thursby and Thursby, 2004; Shane, 2004). Inventors' commitment to the project development was also crucial to bring the product to the market place. Again, the motivation of the inventors is linked to their desire to see their inventions being exploited.

[49] The inventors whose patents were exploited through spin-off formations, showed the highest desire to see their inventions being exploited, followed by those whose patents were licensed to established companies and the inventors whose patents were unexploited showed the lowest desire. This is reflected in their involvement in product development and networking.

The inventors whose patents were not exploited claimed that they did not have much time to market and network with industry, due to academic workloads and administrative works. Some of these inventors had actually marketed their technologies, but various factors had discouraged them from further efforts.

9.2.2 Funding for research and funding for spin-off ventures

Patents that are developed from research that is undertaken with industry funding are more likely to be exploited through the both spin-off and licensing to established companies. This finding is consistent with previous studies (Robert and Malone, 1996; Shane and Stuart, 2002; Shane and Cable, 2002; Shane, 2004; O'Shea et al, 2005; Powers and McDougall, 2005). Increased networking with industry by inventors and the TTO will increase the chances that the research output will be commercialised. The study also asserts that consultancy work by the inventors was an important factor to gain sources of research funding and also triggered inventors to exploit their patents. Five of the patents that were licensed to established companies and four patents that were licensed to form spin-off companies were based on industrial funding. Early research funding from industry gives a good sign that patents were more likely to be exploitable. However, this statement must be treated with caution for unexploited patents. Four of the unexploited patents received funding from industries but the technologies failed to enter the market. This is because the technologies were superseded by other advanced technologies and industry stopped the funding.

The willingness of venture capital companies to fund spin-off companies also varies. The "growth" spin-offs as suggested by the European Commission (2002) target the global market for their technologies and it is easier for leading-edge technologies to obtain funding compared to "life style" spin-offs where the technology only targets the local market and is more about supporting a comfortable living for the founders, or supporting job creation in the local area where the technology was developed. Two of the patents that were licensed to spin-offs demonstrated this problem.

9.2.3 The stages of the technologies and the strength of the patents

Generally, 80% of the technologies that were exploited in this study were at an embryonic stage when patent protections were sought. However, a few of them were at the prototype stage or even at the 'lab' stage. But all the unexploited patents were only at proof of concept stages.

Even though unexploited and exploited of patents are generally at early or embryonic stage, they differ in maturity and potential market. Most of unexploited patents were immature and had no potential market although two of them had potential if further testing was done. On the other hand, patents that are licensed to spin-off companies showed that the technologies were advanced, broad scope patents, multi-purpose and leading edge technologies 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 the patents that were licensed to Companies A, D and E, the technologies were considered as the 'first to market' technologies, available during the time the companies were launched. These technologies were considered as market pull technologies (Martyniuk et al., 2003) where the opportunities for funding and company expansion are great.

Nevertheless, most of the patents that are licensed to established companies are single application technologies, even although the inventors claimed that the patents were broad scope patents and the technologies were advanced technologies. This finding only partially supports Shane's (2001a; 2004) studies. Two of these patents were licensed to established companies at the proof of concept stage. Exclusive rights were given to the companies in order to allow them to exploit the technology to the maximum capacity.

9.2.4 The roles and the capabilities of the TTO

The TTO did not have either adequate skills or systematic due diligence process to evaluate all the invention disclosures. Lack of capabilities and skills in the selection process as to which inventions should be patented might lead the TTO to seek protection for low quality disclosures.

However, the TTO took a proactive role in identifying opportunities for some of the patents. The TTO took the initiative to commercialise patents where the inventor did not take an interest in any of the business activities. Half of the patents that were licensed to established companies resulted from the efforts of the TTO to find licensees. This finding is consistent with Lowe (1993), who suggests that in a University there are technology originators and technology harvesters. The TTO in this study are also considered as technology harvesters that recognise opportunities (Lockett et al., 2003a) This finding is also consistent with Audretsch et al., (2006) who found that for those scientists who were helped by the their TTOs, licensing is the most prevalent mode of commercialisation. On the other hand, those who choose the entrepreneurial route through breaking away are not helped by their TTOs.

The TTO has valuable knowledge and skills in negotiation of contract agreements. However, the TTO does not have sufficient resources and skills to market all the granted patents in all sectors. The TTO cannot be the expert in all sectors of research output. Thus, the roles and the initiative of the inventors are crucial in identifying the market before the TTO takes further action, which is difficult for young or inexperienced inventors, or where the patents are still at an early stage and need further development.

The patents that were licensed to spin-off companies before 2000, did not receive much support from the TTO. It was suggested that during that period the government did not offer any grants to encourage spin-off activities. Since 2000, the TTO has become more supportive in bridging between the inventors and private investors as suggested by Degroof and Roberts (2002; 2004). However, all the efforts to license patents to spin-off companies created since 2000 were initiated by the inventors rather than the TTO. For these patents, the evaluation system has been done based on the business plan that was forwarded to the BVG after being recommended by the TTO. Other systematic due diligence processes or scrutiny methods were not apparent in the selection process at the TTO level. The entrepreneurs' initiative and enthusiasm are considered as important criteria in this selection process.

The TTO also did not have any criteria for patents that are licensed to established companies. It was suggested that the TTO gives more priority to licensing inventions to established companies rather than to the formation of spin-offs, unless the inventors puts the initial efforts into forming a spin-off company or there are no licensees from established companies are interested in exploiting the patents.

9.2.5 The University's rewards and culture

Finally, the findings reveal that commercialisation activities are not taken into account with regard to promotion within the University. Most of the inventor-entrepreneurs mentioned that their involvement in licensing activity and the creation of new companies was driven by their wish to see their inventions being exploited rather than for monetary rewards. Monetary reward and the drive to be a millionaire is a secondary objective. Some inventors prefer to publish their research findings rather than to patent as a way of getting a quick return from their efforts. If the University could give special rewards to those inventors who disclose their inventions, it would change the landscape and culture of patenting and publication activities confirming Etzkowitz (1998); Siegal et al., (2003); Lach and Schankerman (2003); and Ndonzuau et al., (2002).

Academic culture is in contrast with business culture. It was found that some of the inventors are opposed to the involvement of academic staff in spin-off activities. They fear that there is a chance that they will leave the department once they are involved full-time in their business. They believe an academic is not trained to be an entrepreneur, as they were trained to be a teacher and a researcher (Geuna and Nesta, 2006), and are therefore they are anti spin-offs. Other alternatives to commercialisation such as consulting, sponsored research, research funding and their students working in the companies are thought to be more important and appropriate. Quality students give a signal to industry for future collaboration as a main output.

9.3 IMPLICATIONS OF THE STUDY

The implications of this study will benefit two groups. The first group is the researchers in this field of study, and the second is the practitioners or policy makers managing the university technologies and intellectual properties, in the form of patents.

9.3.1 Contributions to research

As explanatory, exploratory and descriptive research, this thesis provides an insight into the decision making process to patent a technology and those who were involved in the decision to exploit the University patents. The study has expanded the existing body of knowledge, particularly in its contribution to the literature on the commercialisation process of university patents.

This study contributes to the literature on the commercialisation of university patents especially giving an insight into every stage of the decision-making process. The study provided evidences that the decision-making process to commercialise university patents is a very complex process. It is portrayed in Figure 9.3.

The recognition of the opportunities and the concomitant decisions to patent and to choose the appropriate exploitation routes has been given less attention in the literatures. The identification of those who were involved in the opportunity recognitions and who decided on the commercialisation routes has expanded the literature debate on the commercialisation process of university patents from institutional perspectives. The study also sheds some light on why some of the university patents are not commercialised. These factors also have been given little attention in the university patenting activities literature.

The study has also hypothesised the influence of research funding on the commercialisation process. Results of research projects funded by the government tended not to be exploited. Indeed, some patents were taken out not for commercialisation reasons but to guard the university's lead in particular technologies. On the other hand, if the research were funded by industry, it would be highly likely that the resulting patents would be exploited through licensing to established companies. But if both the government and industry funded the research project, any resulting new technoliogies would be exploited through the formation of new spin-off companies.

This study found that early stage technologies, with broad scope patents, and of radical and multipurpose technologies have higher chances of being licensed to spin-off companies. In addition, both early and late stage technologies, incremental and multipurpose, and broad scope were licensed to established companies. These contradict Shane's (2001a; 2004) findings, which stated patents of late stage, incremental technologies with narrow scope of protection, are more likely to be licensed to established companies. This gives a new dimension in the body of knowledge for the commercialisation process of university patents.

The current study also confirmed previous studies (Birley, 1985; Thursby and Thursby, 2001; Colyvas, et al., 2002; European Commision, 2002; Shane and Stuart 2002; Thursby and Thursby, 2004; Shane, 2004; Nilsson et al., 2006; Audretsch et al., 2006) that a formal or informal networking by the inventors and the TTO is a crucial factor in patent exploitation. However, the finding suggests that an informal network is more important for patents to be exploited via established companies.

9.3.2 Contributions to practice/suggestions

Finally, suggestions are made to enhance the effectiveness of the University's commercialisation process. These proposals are based on the findings of the study, literature review, comments from inventors and interviewees, the TTO Directors of the seven universities and the views from experts and other scientists. The focus is on how to enable individual inventors and the TTOs to be more effective. Though the role of government is crucial in the University commercialisation process, the only suggestion that is put forward relates to the funding structure. Other government roles and activities were not included in this study.

The first set of proposals is to enhance the effectiveness of the patenting structure and the TTO roles in the commercialisation process. The second set of proposals is for the inventors or academics to increase the quality of patents and hence the chance that patents would be exploited.

A. Enhance the effectiveness of the TTO

To improve the effectiveness of the TTO in refining patenting and commercialisation activities and increase the chance of patents being exploited, the following factors are suggested. This study confirmed that the TTO lacked the skills and capabilities to evaluate the patents in all sectors of technologies as suggested by Lockett et al. (2003a).

i. Need to adopt a due diligence tools.

Low quality disclosures are the major barrier for universities in their bid to commercialise their technologies and lead to low quality patents or technologies. To reduce the wastage, sunk and opportunity costs of patenting, the TTO needs to have a due diligence system that can be applied to identify which technologies should be given priority to seek patent protection and appropriate commercialisation route. Even though it is difficult to judge and evaluate the embryonic technologies, a systematic system may help the TTO to compare and decide which technology has more potential. This will help the TTO patent only the inventions that have high potential value and a higher chance of commercialisation.

The TTO needs to patent the inventions that achieve maturity stage or to identify types of technologies suitable for patenting and those not suitable, thus, to be kept secret. This may help the TTO to identify a market and also could save unnecessary expenses by not patenting all the inventions, some of which might not exploited.

This suggests that the TTO has to be selective in determining which inventions should be patented. A scoring system is suggested for evaluating technology disclosures, based on the Warwick Ventures scoring systems[50] (Appendix E). This system is judged to be the best tools among the universities that were interviewed. The system is a good discriminator of patents that were commercialised and those that were not. This is proven, by testing the system to evaluate the data gathered from the interview cases. This work was carried out with the help of two PhD students, one with a background in mechanical engineering and the other in bioengineering. The data from the interviews and the patent documents was used to generate a score. Criteria 3, 4 and 9, were not asked directly during the interviews, however, the scoring for these criteria were drawn from other informations that were given in the patent documents.

The scoring system is mainly to evaluate the commercial potential of the technology. However, if the reason for applying for patent protection is other than commercial, such as for strategic reasons, future research or 'good feeling' of the inventions having market potential, then this scoring system is not appropriate, and

[50] Interview with Dr Ederyn William, the TTO Director of Warwick Ventures.

additional scoring system criteria are needed, which is not included in the scope of this study. This scoring system should be used to evaluate every aspect of the inventions; either the inventions should be patented, and either they are suitable for licensing to spin-off, or to existing companies as discussed in Chapter 4. However, subjective factors such as the inventors' intention and motivation should also be considered even though the resulting score is high.

The result of the testing is shown in Table 9.1. There is one important point to remember in order to test the data, namely that all the data were assumed to have been obtained before the patents were granted (assuming the granted patent documents as disclosure documents). Only two unexploited patents out of ten passed the average score (the pass score was also based on Warwick Ventures. The inventions that scored above 56% should proceed to patent filings). This tool therefore accurately identified eight of the 10 unexploited patents. These inventions should not have proceeded to patent protection filings, unless they were patented for a strategic reason. The question is, are all the eight inventions that were patented due to strategic reasons? The other types of patent all have scores above 56%. The highest individual score and average score is obtained by the spin-off inventions, of which four patents scored above 80%. It is followed by the patents that were licensed to established companies. None of these patents scored more than 80%.

However, from the findings, the Warwick system is missing some important dimensions, which influence the likelihood that a patent will be commercialised. Refinement of the University of Warwick scoring system could be made to increase the effectiveness of the selection process. It is suggested another three new dimensions be added under separate headings and two of the existing dimensions be modified. The suggested new dimensions are:

1. Who first recognised the opportunity. If the industry first recognised the opportunity, then the patent might better be exploited through licensing to established companies, rather than through spin-off companies.
2. The source(s) of funding for the research projects. An industry funding might point towards the closeness of the research team to industry. The industry connections might help the exploitation of the patent through the initial funders or their associates.

Table 9.1 Scoring results from the data (based on the Warwick Ventures scoring system)

Types of Patents	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6	Criteria 7	Criteria 8	Criteria 9	Criteria 10	Scores	Total score
Unexploited Patents												
1	2	3	2	3	3	3	3	1	2	0	22	44
2	2	1	0	0	0	0	0	0	0	0	3	6
3	2	3	3	2	4	1	2	1	2	3	23	46
4	4	3	2	3	2	3	1	1	2	2	23	46
5	4	3	2	3	3	4	3	1	3	2	28	56
6	4	5	3	3	1	4	2	1	2	0	25	50
7	4	3	2	3	3	3	3	1	3	1	26	52
8	4	3	2	2	2	1	1	1	2	0	18	36
9	5	3	4	3	5	3	1	1	3	0	28	56
10	3	3	2	2	2	3	3	0	0	0	18	36
											Average	42.80
License to Spin-off companies												
Co. A	4	5	3	5	5	4	3	5	2	4	40	80
Co. B	3	4	2	4	3	3	3	4	3	4	33	66
Co. C	2	5	3	4	3	3	3	5	3	1	32	64
Co. D	4	5	4	4	5	4	5	5	4	3	43	86
Co. E	4	3	4	4	5	5	5	4	4	4	42	84
Co. F	5	3	3	4	5	5	4	4	4	4	41	82
											Average	77.00
License to established companies												
1	3	3	2	4	4	4	3	2	4	4	33	66
2	3	3	2	4	4	4	3	2	4	4	33	66
3	5	2	3	4	5	5	3	2	4	3	36	72
4	4	3	3	4	3	3	3	2	4	3	32	64
5	4	4	3	4	5	5	4	2	4	4	39	78
6	4	2	3	4	5	5	3	1	4	1	32	64
											Average	68.33

3. The management experience of the inventor of running a business. Business management experience should also be given priority as commercial exploitation experience would be an advantage, which COAP already included in its scoring system. A person with more management experience could steer new spin-off into broader markets and networks.

For the two existing dimensions that should be modified, the first is the element of the uniqueness of the technology for the market. This study suggests that the scope of the patent and its potential utility (single or multipurpose) influences the likelihood of commercialisation. The second element is the readiness of the technology for commercialisation. Scoring on these two elements would help the TTO to decide the course of action after disclosures of any new technologies. These changes have been made to the original COAP system, which is now called the Warwick-Ismail Model (see Appendix H).

ii. Increasing the quality of inventions.

To increase the quality and the chances of exploitation of university patents, with the associated high royalty payments to the universities, the following suggestions are put forward;

- Increase formal and informal networks with industry. Informal networks are more prevalent in this finding. This can be done through the inventors' personal contacts as early as possible during the research project. Formal networking can be done through the TTO. Another suggestion by Lambert (2003) is that the universities should list inventors who are interested in becoming non-executive directors on company boards, and have them trained by industry. This may encourage more business people and corporate researchers to be involved in University research. The inventors may be given some relief from normal academics duties such as delivering lectures to students.
- Joint research funding. There are many options but an arrangement where the industry funds research projects and the University provides the skills and laboratory facilities is very ideal. There are quite a few projects in this study that employed this type of arrangement.

iii. Involvement of the TTO

A person with industrial experience and a business background should be employed and placed in every department to increase the efficiency level of the TTO and enable them to be specialised in most areas of research. Indirectly these people become the TTO specialist representative and report all the faculty's research and development as the opportunity arises. This person needs to build links with industry. In this University different types of sector are represented, which require a different type of knowledge and business model (Druilhe and Garnsey, 2005). Owen-Smith and Powell (2001) also assert that commercialisation within the life sciences and physical sciences is different and this reinforces the need for a special expertise in every sector.

The presence of a special representative at every department, decentralises the power of the TTO to department level creating a 'smaller size TTO' as contended by Chappel et al. (2001). This suggestion may increase the level of specialisation and effectiveness of the TTO. However, this might incur high costs. To reduce the cost, another approach is appointing existing academic staffs to be the 'departmental representatives' to the TTO.

iv. The TTOs and industry network

Some of the inventors of unexploited patents commented that they did not know which market to target and did not know who in industry should be contacted. To overcome these problems, one of the suggestions is that the TTO should contact the investors, venture capitalists, industries, and University spin-off companies and get inventors of unexploited patents to present their ideas to the delegates. This event not only demonstrates the strengths of the University patents portfolio to the potential licensee but could add value to the University especially after the company has been created. The TTO has to identify, which inventions have potential value and encourage the inventors to make a presentation of their projects, or the TTO has to make the initial contact with a follow-up by the inventors.

The study also would like to suggest that the University should set up a similar organisational body such as Phamarlink and SIDR for the engineering department. Such an organisational body is critical to engineering departments. The main function of this body is to market new University inventions. As the life science sector has a link with the University of Glasgow, the same strategy should be implemented with other universities for the engineering sector and physical sciences.

v. Research grant and seed funding for spin-off companies

Industry funding is an important element in the further development of technology. However, there is also a need for the government, through the TTO, to have a special fund to develop research further. This is especially the case where funding for a research project has been used up and industry is not willing to provide extra funding. This is not only to be used to develop proof of concept products for patents that can be licensed to established companies or spin-offs but also for high risk projects that have potential, but take longer to bring into market. Industry is unwilling to invest in this type of project.

- **For unexploited patents.** This proposal would enable some unexploited patents to have the chance to be exploited if the government through the TTO provides a special fund for further development of the inventions. The University needs to provide funding for high-risk projects as these tend to fall by the wayside (Lambert, 2003).
- **Spin-off funding.** The study found that two companies (B and C) had problems in getting first round funding, as they were considered to be 'life style' companies. Venture capital companies are unwilling to invest in firms that do not generate a certain level of return, and where the target market is not global. Thus, it was suggested that the TTO has to build links with smaller venture capital companies that are willing to invest as suggested by Wright et al. (2006) or create partnerships with specific investors as what the University of Southampton had done with IP Group. Partnership with such investors helps to speed-up patented technologies into the market, which is imperative for new companies in order to gain competitive advantage and become a market leader. A small venture capital company can assist with identification market and help the spin-off companies to focus within the identified market, as in the role taken

for University College of London by one particular venture capital company. The University has a strong relationship with this company and used the services of the company to narrow down market applications.

Another suggestion is that the University should set-up its own seed funding systems to help companies that are having problems in getting external funding. The initial funds might be obtained from the government central budget. A registered company on behalf of the University could manage the fund.

B. Inventors/academics pre-requisites to increase the chances of commercial exploitation of patents.

The following suggestions are aimed at academic-inventors to increase the number of quality of future patents that could be commercially exploited.

i. Involvement in product development.

The commitment of the inventors to the development of the project is one of the crucial factors to increasing the chance that patents are exploited. For those patents that were unexploited, inventors claimed that they did not have enough time to develop the product. The University could reduce the workload of the inventors who have potential commercial inventions and allow them to finish the development of the project until it is at the stage that it is acceptable for commercialisation. "Product development sabbatical or special leave" could be given to academics who need to pursue their research until the research has reached a viable stage to be commercialised.

ii. Networking with industry.

As noted in Section 9.2.4 besides the TTO having to build links with industry, the inventors' personal contacts and ability to network with industry is crucial for patents to be exploited. These links should be made as early in the academic career as possible (Colyvas et al., 2002; Thursby and Thursby, 2001; and Thursby and Thursby, 2004). From early links with industry, for example through consultation, contract research, sponsored research, and publications, the inventors will learn and gain the latest knowledge, recognise the possibility of conducting different research in the same area or see the opportunity in different applications. This would suggest that one of the criteria for the selection process in seeking patent protection must include this element.

iii. Increase consultation and sponsored research.

Most of the patents in this study were licensed either to established companies or to spin-off companies and began with the inventors' consultation work in industry. The Lambert report (2003) suggested that consultancy offers the chance for large companies to get to know researchers before deciding whether to set up larger research contracts. It may increase the volume of collaboration between industries and enhance the effectiveness of the commercialisation of technology. As Lambert (2003) reports, more than 50% of the licenses go to companies known by the academics. This would suggest that the University should particularly encourage young inventors or faculties to increase their involvement in consultancy work before other routes of exploitation are started.

iv. Entrepreneur Capabilities.

The findings of the study showed the importance of the founders' having business knowledge and pre-start-up knowledge. At the pre-start-up period, those founders who attended the entrepreneurship course offered by the Hunter Centre for Entrepreneurship (HCE) demonstrated fewer problems at start-up compared to those did not attend such courses (the course was not available in the University before 2000). McAdam et al. (2004) suggested that at the pre-business plan period, the mentoring process is crucial to help with business and management issues such as marketing, costing and developing an effective management team and how this interrelates with technology aspects. On the other hand, at the post-business plan period the companies required more in depth business and management help, beyond that of basic support and advice such as market penetration and segmentation, exporting, management decision making systems and structuring.

v. Overcome cultural barriers.

The findings reveal that a lack of motivation and entrepreneurial culture among inventor-academics, explains why some that the inventors are not interested in committing themselves to their inventions. The traditional roles of the University are still embedded in the minds of the academics, that they were trained to be an academic, not to be an entrepreneur.

Entrepreneurship courses offered by the Hunter Centre for Entrepreneurship can be used as a platform for the University to increase the entrepreneurial culture among inventor-academics. The findings showed that courses at the Hunter Centre for Entrepreneurship act as a trigger and help the inventors to recognise opportunities and provides preparation with start-up and business knowledge. These could speed-up the creation of companies.

The TTO has to identify and increase the exploitation opportunities at the faculty level, especially for those who have quality inventions but are not interested in being involved with commercialisation activities. It is important for the TTO to initiate the link with industry before the young inventors get involved. Thus, market and technical knowledge are an important element for the TTO staff.

vi. Increase publication.

The study showed that the inventors-entrepreneur of patents that are licensed to spin-offs, were active in presenting papers at conferences and seminars and publishing journal articles as a platform for marketing their technologies. This would suggest that inventors should increase the number of journals that publish their invention results, especially in referred journals after patents were granted to the inventors. It also suggests that there is no conflict between publishing and patenting. This also needs to be part of a scoring mechanism. This finding is consistent with Mohan and Roa (2005) and Fontana et al. (2006) who reported that industry use search and signalling strategies to identify R&D institutes. To identify partners for R&D 70% of industrial companies reported using published work and 67% using individual networks, this is through the inventors' personal contacts with industry.

vii. Rewards and incentives.

It was suggested that the university and the government should review the RAE evaluation system. Inventor-academics who are involved with business activities and bring back the money to the university should be rewarded by including this efforts in the promotion system. This will encourage the faculty and help promote the inventors' involvement in the commercialisation of technology and increase partnerships with industry. Thus, it would suggest that the evaluation criteria in commercialisation activities should be equated with inventor's published articles in refereed journals.

9.4 PROPOSED MODEL

This study has proposed a model that would increase patent exploitation either through reducing the number of unexploited patents, or increasing the number of quality exploited patents through licensing to new spin-offs or to established companies. The proposed general model is shown in Figure 9.1. There are five major stakeholders in the commercialisation process: the TTO, the inventors, industry, the government and the private investors. Each of the stakeholders has their own roles but are linked to each other to increase the effectiveness of the process. This finding suggests that the first stakeholder, the TTO should implement a scoring system/systematic selection process, have representatives at the faculty level, and increase internal and external networking. The TTO also needs to have funding for high-risk project or new start-up.

The second group of stakeholders are the academic-inventors. The inventors' involvement demonstrated an important factor to increase the exploitation of university patents. The involvement and commitment of the inventors such as in product developments and continuing research, will add value to the inventions. Other involvement such as consultancy work, networks with industry, publications and presentations of papers at conferences, attendance of entrepreneurial courses at the Hunter Centre for Entrepreneurship would increase the chance of patents exploitations. Restructuring the University reward system would surely attract inventors' involvement in the commercialisation of their patents.

The third stakeholder is the government. The government should consider the commercialisation activities in RAE evaluations, provide special funding for blue-sky research and seed funding for university spin-offs. The TTO and academic staff should have links with industry as early as possible[51] as the fourth stakeholder. The links could identify potential projects that should be undertaken by the inventors. Finally, networks with private investors or venture capitalists are crucial for spin-off creations. The network would also increase the chance of private investors as well as industry participating and playing their roles in helping the universities boost the local economy.

Figure 9.2 suggests how to increase effectiveness in the creation of University spin-offs in pre-start-up period. The factors are divided into internal and external factors. Internal factors are related to organisational factors, individual factors and technological factors. Each of these factors has been discussed earlier on in this chapter.

Figure 9.3 is the combination of the above two models (Figures 9.1 and 9.2) which represents the whole process of commercialisation. This model is a modification of the original linear model (Figure 2.2) that was proposed in Chapter 2 that was based on the literature reviews in the lights of the evidence obtained in this study. The model as shown in Figure 9.3 shows the complexity of the commercialisation process of university patents. To simplify the explanation, the model can be divided into two sections by the original linear model in the middle, which is not coloured. The coloured boxes are the proposals made as a result of the findings of the study. These boxes are placed in the upper section and the lower section of the model.

The explanation starts with early identification of opportunity recognition. The first stakeholder to identify the opportunities will influence the route for patent exploitation. If the TTO or industry identify and fund the inventions, it is more likely the patents will be commercialised through licensing to established companies. If the inventors have consultancy experiences with industry the more likely their inventions will be commercialised through spin-off creations. The actors who are involved in

[51] 'As early as possible' refers the link with industry that need to build by academic staffs in early days of their career.

Figure 9.1: Actors involved in the commercialisation process

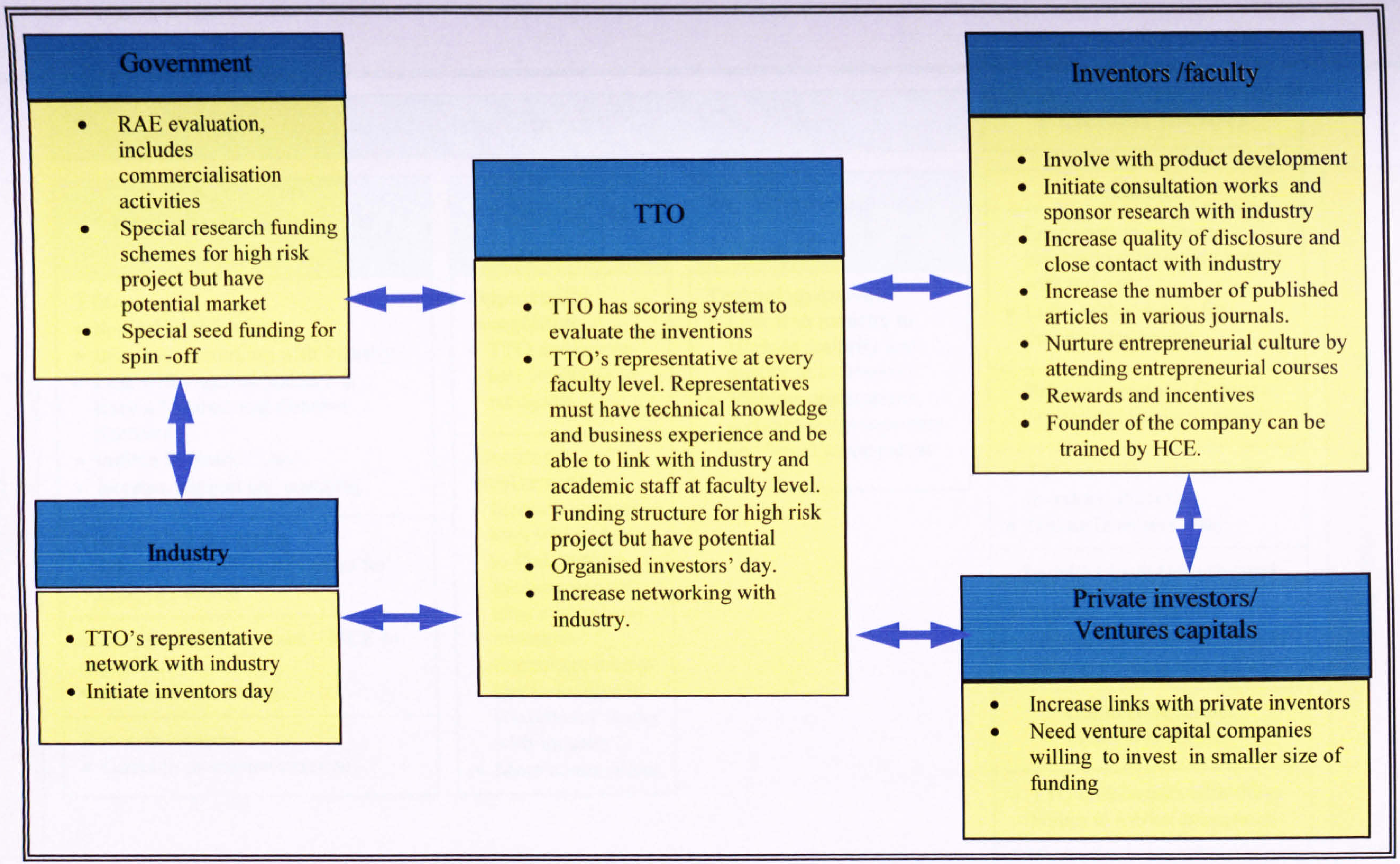

Figure 9. 2: Factors that influence the decision making to form a spin-off company

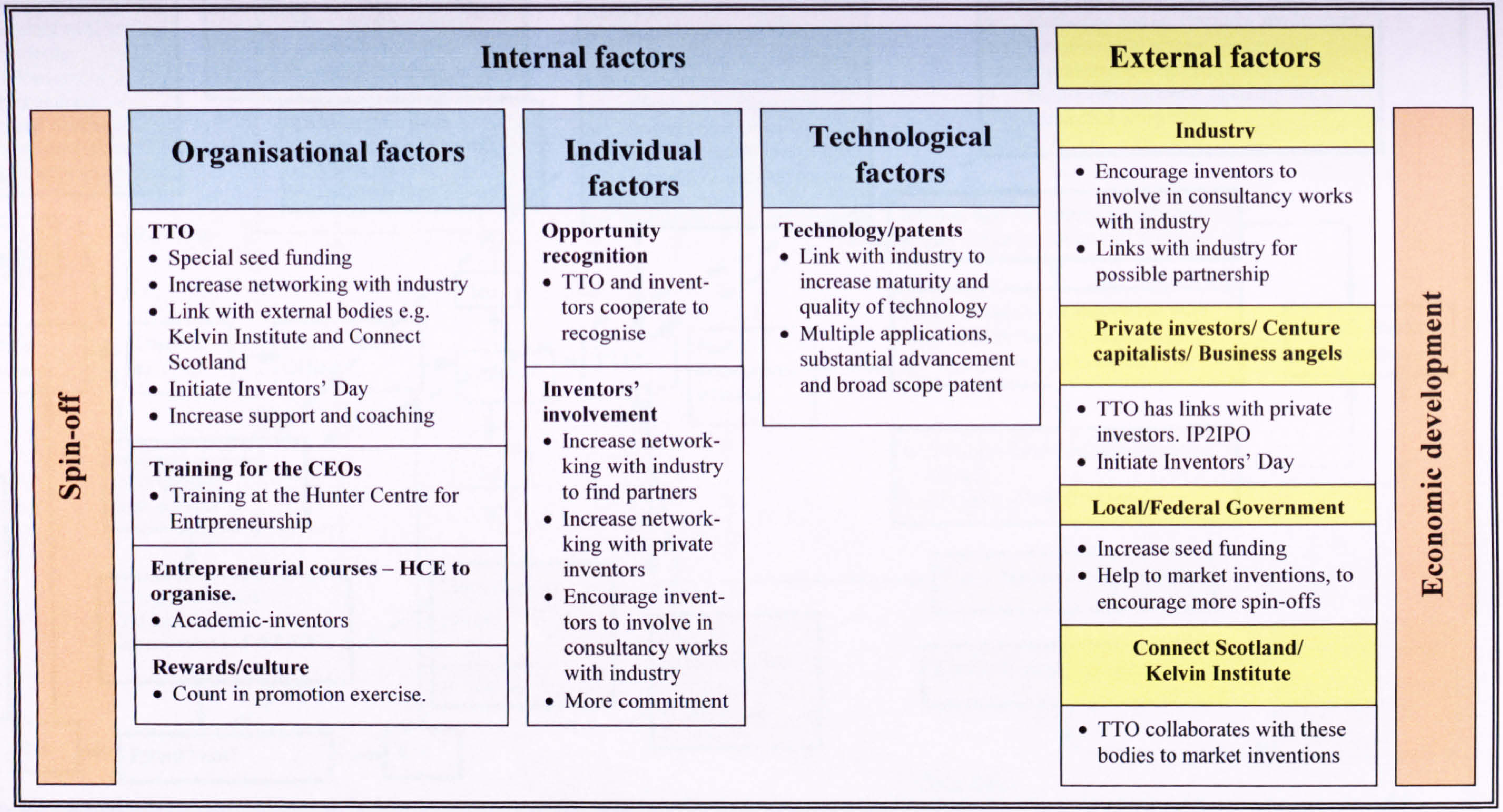

Figure 9.3: Suggested model of commercialisation process

the decision to patent or to commercialise either to license to spin-offs or to established companies at this stage are the TTO, the inventors or industry or the combination of any two actors. These are shown in two lower boxes in the model.

The model is followed by the suggestion to have a scoring system to select which technologies are filed for patents and to select the most appropriate commercialisation route. Having a scoring system would assist the TTO in selecting the inventions that really have market potential and in identifying the most appropriate route of exploitation. The motivation and industrial experience of the inventors, the stages and characteristics of technologies and scope of patents (early/later stage, broad scope/market size) and the willingness of the inventors to be involved are important criteria in influencing whether or not to patent and commercialise the inventions.

Patents of radical and multipurpose technologies with broad scopes, available funding, with the involvement of highly motivated inventors and highly skilled and capable TTO would be commercialised through new spin-off companies. However, patents of inventions that need high investment in product development, whose inventors are risk averse and the applications of the technologies are limited might be licensed to established companies.

Scoring system as an evaluation tool should be used at the point when the negotiation starts with the TTO, inventors and IPR or Patent Agent (as in Figure 9.3). If the market is still not clear during the earlier negotiation stages, the choice of routes for exploitation could be extended after the patents are granted. Thus, the inventors or the TTO still have a chance to identify the market while waiting for the patents to be granted. The strategies to choose the route of exploitation (in these cases either to form a spin-off or to license to established companies) are shown at both stages in the model.

In the middle of the model, it shows the networks that were built that led to patent commercialisation. Internal agents, such as Kelvin Institute and Connect Scotland, and external agents through the collaboration with other universities such as the University of Glasgow, local government and non-profit organisation would assist to identify the market for patents. The TTO staff and the inventors themselves could build network to market their patents through formal and informal contacts.

9.5 LIMITATIONS

This study has provided important insights into the decision making process of commercialisation of university patents. However, the study has a number of limitations. First, the study is based on a case study of the patents of one University, which may affect its generalisability. Second is the way the sample was accessed. 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 non-response bias. The study involved a case study and interviews with the inventors, inventor-entrepreneurs and with other key informants. Many inventors that licensed their patents to established companies refused to be interviewed as they feared the projects would be known by other parties. In addition, many of the inventors were too busy to be interviewed. Thus, the data are limited to those who were willing to be interviewed and not randomly selected.

Another limitation is that one individual in a company or a research group has provided the data. Although the respondents are comprised of inventor-entrepreneurs and heads of the research groups, who were responsible for the management and development of the firm and the projects, the possibility that a common response bias might have inflated the findings of this study cannot be ruled out.

9.6 RECOMMENDATIONS FOR FUTURE RESEARCH

The current research has revealed opportunities for further work. It would be of benefit to carry out a larger research study that would cover multiple cases from several universities. The study should not only be confined to patents, but should include other type intellectual properties such as registered designs and copyrights. Some universities enter the commercial world through selling expertise and know-how without publishing them. It would be interesting to study and to discover why and who made the decision not to patent or publish these secret inventions, what are the salient features of these technologies, and what are the factors 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 using this knowledge to reduce the waste within the University-patenting budget.

Future research could also be focused on individual themes. These themes include the motivation factors and the opportunity recognition by the inventors, how the research is funded, the involvement of the inventors, the TTO skills, capabilities and resources, and the role of incentive and reward systems influenced the decision to patent and the exploitation routes.

The study also could be replicated in developing countries such as Malaysia, which is the author's country. The result of the findings could enhance the understanding of the process. Are the problems of patents exploitation between the developed and developing countries similar or totally different results will occur? Thus, the suggestions to policy makers could be more meaningful tailored to each country, depending on their development status. Focus group interview technique may also be employed among the inventors from different types of patents. This may give slightly different view of the process when the inventors from different types of patent meet together. The 'real' problem of the decision to patent and the route of exploitation may be more transparent through the views from the 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 suggested studies should compare patents that are licensed to spin-off companies or established companies that went bankrupt, and a careful look into non-university start-up companies (companies created without university equity) would be valuable. The future research also could be done through mixed method of data collection. A combination of survey and interview methods would be suggested to get a bigger sample size and comprehensive views in understanding the process. The mixed method may give more comprehensive results but the research questions need to be changed according to the methods that would be adopted.

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APPENDIX A:

PROPOSITIONS SUGGESTED ACCORDING TO THE TYPES OF PATENTS

APPENDIX A1: PROPOSITIONS FOR UNEXPLOITED PATENTS

	Original Propositions	Motivation and opportunity recognition
Unex-ploited patent	1A1	The desire to see their patent being exploited drives inventors to conduct their research.
	1A2	Limited networking with industry prevents inventors and the TTO from recognising opportunities.
		Characteristics of the technologies/Scope of patent
	2A1	Early stage technologies with insufficient proof of concept generate patents that are not exploited.
	2A2	Patents are more likely to be exploited if their scope is broader
		Research Funding
	3A	The less industry funding for a research project, the less chance the resulting patents will be exploited.
		Inventors roles
	4A	The lower the commitment of the inventors to product development and networking, the less chance that the patents will be exploited
		TTO roles
	5A1	A systematic due diligence system by qualified and experienced TTO staff would reduce the number of unexploited patents.
	5A2	Extensive networking and marketing by a TTO, would increase the chances that patents in the TTO portfolio will be exploited.
		Incentive and reward
	6A	The lack of incentives and rewards would discourage academic inventors from exploiting their inventions.

APPENDIX A2: PROPOSITIONS FOR PATENTS THAT LICENSED TO SPIN-OFF COMPANIES

	Original Proposi-tions	**Motivation and opportunity recognition**
Patents licensed to new spin-off companies	**1B1**	The desire to see their patents being exploited combined with the inventors' willingness to take a risk, the greater the chance that the patents will be exploited through spin-off formation.
	1B2	The more prior knowledge and industrial experience the inventors have, the more likely an opportunity will be recognised and lead to spin-off creation.
		Characteristics of the technologies/ scope of patent
	2B	Patents that involve early stage technology, are broad in scope, multipurpose and radical are more likely to be exploited through spin-off formation.
		Research Funding/spin-off funding
	3B1	The more projects funded by industry, the more likely spin-offs are created.
	3B2	Spin-off companies are likely to require external sources of funding to be created.
		Inventors roles
	4B	Inventors must be willing to be involved in product development, networking and other process, for a patent to be exploited through spin- off formation
		TTO Roles
	5B	The creation of spin-off companies requires TTOs which are well resourced and have adequate skills and capabilities.
		Incentive and reward
	6B	The creation of spin-offs requires rewards given by the University

APPENDIX A3: PROPOSITIONS FOR PATENTS THAT WERE LICENSED TO ESTABLISHED COMPANIES

	Original Proposi-tions	**Motivation and opportunity recognition**
Patents exploited through licensing to established companies	1C1	Inventors who have a desire to see their patents being exploited, but who are risk averse, are more likely to have their patents exploited through through licences to established companies.
	1C2	Where recognition of opportunities is by the company that funded the project, the more likely they will license the technology..
		Characteristics of the technologies/Scope of patent
	2C1	Established firms are more likely to license late stage technology than early stage
	2C2	Established firms are more likely to license patents with narrow scope than ones with a broad scope
		Research Funding
	3C	The more that research is funded by industry, the more chance that resulting patents will be exploited through licensing to established companies.
		Inventors roles
	4C1	The more that the interest of the inventors is confined to product development, the greater the chances the patents will be exploited through licensing to established companies
	4C2	The more informal networking by the inventors, the more chance the patents will be exploited through licensing to established companies.
		TTO Roles
	5C	The more resources a TTO has and the more networking it does, the more chance of patents being exploited through licensing to established company.
		Incentive and reward
	6C	The more royalties that inventors receive, the more chance that patents will be exploited through licensing to established companies.

APPENDIX A4: NEW PROPOSITIONS FOR UNEXPLOITED PATENTS

	Original Propositions	Motivation and opportunity recognition	Confirm/not confirm	New proposition
Unexploited patent	1A1	The desire to see their patent being exploited drives inventors to conduct their research.	Proposition confirmed	
	1A2	Limited networking with industry prevents inventors and the TTO from recognising opportunities.	Proposition confirmed	
		Characteristics of the technologies/Scope of patent		
	2A1	Early stage technologies with insufficient proof of concept generate patents that are not exploited.	Proposition confirmed	
	2A2	Patents are more likely to be exploited if their scope is broader	Proposition not confirmed	Patents that are not exploited have too broad a scope.
		Research Funding		
	3A	The less industry funding for a research project, the less chance the resulting patents will be exploited.	Proposition not confirmed	Government usually funds unexploited patents. Industry only funded some projects at the beginning, and stopped if the projects were superseded. Projects that are needed substantial amount of money and a head from market also difficult to get funding from industry.

		Inventors roles		
	4A	The lower the commitment of the inventors to product development and networking, the less chance that the patents will be exploited	Proposition confirmed	
		TTO roles		
	5A1	A systematic due diligence system by qualified and experienced TTO staff would reduce the number of unexploited patents.	Proposition confirmed	
	5A2	Extensive networking and marketing by a TTO, would increase the chances that patents in the TTO portfolio will be exploited.	Proposition cinfirmed	
		Incentive and reward		
	6A	The lack of incentives and rewards discourage academic inventors from exploiting their inventions.	Proposition not confirmed	The amount of reward received by the inventors does not influence whether the patent was commercialised or not.

APPENDIX A5: NEW PROPOSITIONS FOR PATENTS THAT LICENSED TO SPIN-OFF COMPANIES

	Original Proposi-tions	Motivation and opportunity recognition	Confirm/not confirm	New proposition
Patents licensed to new spin-off companies	1B1	The desire to see their patents being exploited, combined with the inventors' willingness to take a risk, the greater the chance that the patents will be exploited through spin-off formation.	Proposition confirmed	
	1B2	The more prior knowledge and industrial experience the inventors have, the more likely an opportunity will be recognised and lead to spin-off creation.	Proposition confirmed	
		Characteristics of the technologies/ scope of patent		
	2B	Patents that involve early stage technology, are broad in scope, multipurpose and radical are more likely to be exploited through spin-off formation.	Proposition confirmed	
		Research Funding/spin-off funding		
	3B1	The more projects funded by industry, the more likely spin-offs are created.	Proposition partially supported	Both government and industry funding is required for spin-offs to be created.
	3B2	Spin-off companies are likely to require external sources of funding to be created.	Proposition confirmed	

		Inventors roles		
	4B	Inventors must be willing to be involved in product development, networking and other process, for a patent to be exploited through spin-off formation.	Proposition confirmed	
		TTO Roles		
	5B	The creation of spin-off companies requires TTOs which are well resourced and have adequate skills and capabilities.	Proposition confirmed	
		Incentive and reward		
	6B	The creation of spin-offs requires rewards given by the University.	Proposition confirmed	

APPENDIX A6: PROPOSITIONS FOR PATENTS THAT LICENSED TO ESTABLISHED COMPANIES

	Original Proposi-tions	**Motivation and opportunity recognition**	**Confirm/not confirm**	**New proposition**
Patents that exploited through licensing to established companies	**1C1**	Inventors who have a desire to see their patents being exploited, but who are risk averse, are more likely to have their patents exploited through through licences to established companies.	Proposition confirmed	
	1C2	Where the recognition of opportunities is by the company that funded the project, the more likely they will license the technology	Proposition confirmed	
		Characteristics of the technologies/Scope of patent		
	2C1	Established firms are more likely to license late stage technology than early stage	Proposition not confirmed	Both early and later stage patents are exploited through established companies.
	2C2	Established firms are more likely to license patents with narrow scope than ones with a broad scope	Proposition not confirmed	Patents that have broad scope, are more likely exploited through established company
	3C	**Research Funding**		
		The more that research is funded by industry, the more chance that resulting patents will be exploited through licensing to established companies.	Proposition confirmed	

		Inventors roles		
	4C1	The more that the interest of the inventors is confined to product development, the greater the chances the patents will be exploited through licensing to established companies	Proposition confirmed	
	4C2	The more informal networking by inventors, the higher the chances that patents will be exploited through licensing to established companies.	Proposition partially supported	Patents that have are exploited through established company require informal networking by the inventors or networking by the TTO.
		TTO Roles		
	5C	The more resources a TTO has and the more networking it does, the more chance of patents being exploited through licensing.	Proposition confirmed	
		Incentive and reward		
	6C	The more royalties that inventors receive, the more chance that patents will be exploited through licensing to established companies.	Proposition not confirmed	The amount of royalties received by the inventors does not influence whether the patent was commercialised through established company.

APPENDIX B:

SUMMARIES OF PREVIOUS STUDIES

APPENDIX B1: QUANTITATIVE METHOD USED IN THE RESEARCH OF SPIN-OFF COMPANIES

No.	Authors (year)	Emphasis /key result	Sample Size	Data Gathering Method	Data Analysis	Comments
1.	Franklin & Wright (2000)	**Topic**: University spin out companies: Academic and surrogate entrepreneur **Key result**: the advantage of surrogate and academic entrepreneur has been identified	57 universities	Postal questionnaire	Simple statistics; Mean and median	Focused to individual case
2.	Wall mark and Sjosten (1994)	**Topic**: Stability and turbulence among spin-off companies from Chalmers University **Key Result**: Spin of companies are too risk averse, too stable and static. To be competitive the companies have to market faster and expand at higher rate.	180 companies	Observation and survey	Longitudinal analysis	Too descriptive. No clear method has been described.
3.	Smilor et al (1990)	**Topic:** University spin out companies; technology start-ups from UT- Austin **Key result:** The factors enhance and inhibit the firm formation. Push factor are not playing significant influence in spin out Other factors such as the need for additional money is more important. University's role is important to idea and formation as well as development of spin out.	23 companies	Interview and survey	Simple statistic using percentage	Focus to one University and sample of spin-off company is quite small.

No.	Authors (year)	Emphasis /key result	Sample Size	Data Gathering Method	Data Analysis	Comments
4.	Lockett et al (2003)	**Topic**: Universities; strategies in the spinning out of high technology companies **Key result:** Universities that generate most spin-out have clear, well define spin-out strategies, strong expertise in entrepreneurship and established social network.	57 universities	Survey	Quantitative: Regression and correlation	The factors have been studied are related to institutional. The role of TTO is excluded in this study and why non-established companies prefer to license their invention is not clearly noted.
5.	Lockett, Vohora and Wright (2003)	**Topic:** Universities: Strategies in the spinning-out of high technology companies **Key Result:** The number of spin out created is associated with total research expenditure, the number of employees engaged in spin out activities and the development capabilities of TTO.	98 UK universities	Survey	Descriptive statistics and Kendall's Taub correlation	Did not explain what is external backup USOs. Either back-up by private or government venture capital.
6.	Chiesa and Piccaluga (2000)	**Topic**: Exploitation and diffusion of public research: the case of academic spin-off companies in Italy **Key result:** Push factors are the motivation to form a spin-off company. If the knowledge is tacit spin-off formation is suitable. Support from parent organisation is important. Italian model is different from US. Characteristics by low risk levels and modest growth rates. Italian entrepreneurs ready to accept failures and greater stability of life long employment offered by the University Entrepreneurship a good opportunity to achieve personal prestige and increase earnings and satisfaction but not force a way to have a job.	48 companies	Survey	Simple statistics: percentage and average	The sample size is too small for survey.

No.	Authors (year)	Emphasis /key result	Sample Size	Data Gathering Method	Data Analysis	Comments
7.	Nerkar and Shane (2003)	**Topic:** When do start-ups that exploit patented academic knowledge survive? **Key result:** Radicalness of the new and patent scope increase the probability of survival more in fragmented industries than in concentrated sectors effectiveness of technology strategies of new firms appears to depend on industry conditions technology	128 firms that exploited MIT technologies	Data observation and examination	Regression	Focus only one University
8.	Shane (2001)	**Topic:** Technology Regimes and firm Formation **Key result:** Radical technology tends to be exploited by spin-offs and incremental technology by licensed them to established company	1 397 patents From MIT	Patents observation and examination	Regression	Focus only one University
9.	Shane and Stuart (2002)	**Topic:** Organisational Endowments and the performance of University start-ups **Key result:** Start-up's endowments (technical assets, human capital, social ties, strong patent protection, has positive effect with the performance of start-ups.	134 firms	Survey and interview	Regression	Focus only one University
10.	Dante Di Gregorio (2003)	**Topic:** Why do some universities generate more start-up than others? **Key result:** Intellectual eminence, equity investment and low inventor share of royalties increase the rate of firm formation. No evidence that Capital market constraint limit the firm formation. Failed to find link between industry funding and firm formation.	101 universities	Survey. AUTM data	Regression analysis	Different University policies generate different rate of start-up.
11.	Power, et al (2005)	**Topic:** University start-up formation and technology licensing with firms that go public: a resource-based view of academic entrepreneurship **Key result:** The age of TTO, the availability of VC, R & D funding and the importance to work with faculty leaders to commercialise research products.	120 universities	Survey	Binomial regression	Networking as important element is not mentioned in the study

No.	Authors (year)	Emphasis /key result	Sample Size	Data Gathering Method	Data Analysis	Comments
12.	O'Shea, Allen, and Arnaud (2005)	**Topic:** Entrepreneurial orientation, technology transfer and University performance **Key result:** A University's previous success in technology transfer is a key determinant of its rate of start-up formation.	141 universities	Survey. AUTM data	Binomial regression/econometric	Other constructs are similar with other studies but element history is included. Similar with Di Gregorio approach. But using different name for constructs. Extended sophisticated econometric developed by Blundell used to measure history
13.	Chukumba and Jensen (2005)	**Topic:** University invention, Entrepreneurship, and start-ups **Key result:** Quality University and age of TTO influence the rate of spin- off activities.	110 universities	AUTM survey data	Regression	The same approach like O'Shea and Di Gregorio and Shane.
14.	Chapple, Lockett, Siegal and Wright (2005)	**Topic:** Assessing the relative performance of UK University technology transfer offices: parametric and non-parametric evidence. **Key Result:** UK TTOs exhibit decreasing returns to scale and low levels of absolute efficiency; Organisational and environmental factors have considerable explanatory power.	122 Universities	Survey- data from NUBS/ UNICO	Stochastic frontier estimation (SFE) and data envelopment analysis.	Different analysis were used to measure the effectiveness of TTOs.
15.	Lockett and Wright (2004)	**Topic:** Resources, Capabilities, Risk Capital and the Creation of University Spin out Companies **Key result:** A University's rate of start-up formation is positively associated with its expenditure on intellectual property protection, the business development capabilities, of its TTO, and the extent to which its royalty distribution formula favors faculty members.	48 universities	Survey	Regression	Sample is too small for survey and suggested interview should be support with interview.

No.	Authors (year)	Emphasis /key result	Sample Size	Data Gathering Method	Data Analysis	Comments
16.	Moray and Clarysse (2005)	**Topic:** Institutional change and resource endowments to science based entrepreneurial firms. **Key result:** PRIs may take different strategies to spinning out ventures: low selective, supportive and incubator.	23 spin-off companies from Inter University Micro Electronic Centre (IMEC)	Study archival data	Mix quantitative and qualitative/longitudinal studies	Only focus one centre
17.	Shane,S. (2001)	**Topic:** Technological opportunities and firm formation, **Key result:** Patent that broader scope, and radical technologies tend to exploit through spin-off formation.	MIT University patents 1397	MIT Patents examined in 1980-1996.	Statistical analysis/ regressions	One University
18	Shane and Cable (2002)	**Topic:** Network ties, reputation, and the financing of new ventures **Key result:** Direct and indirect ties are strongly and positively related with selection of ventures to fund through a process of information transfer, overcoming Information asymmetry problem. Direct ties superseded information from indirect source.	202 US seed stage venture capitalist in 1998 and 50 high tech ventures.	Survey	Statistical analysis	Only focused to seed investment and VC only
19.	Shane and Khurana (2003)	**Topic** Bringing individuals back in: the effect of career experiences on new firm founding. **Key result:** Inventors career experiences are more likely the inventions are commercialised thru firm formation. Drugs patents, academic highest ranking more to firm formation. Radical patent, career experience and radical technology do not predict licensing to establish firm.	1397 MIT patents between 1980-1996.	Longitudinal data of patent from MIT 1980-1996.	Statistical analysis	One University
20.	Markman et al. (2005)	**Topic:** Innovation speed, transferring University technology to market. **Key result:** Three key determinants of time to market: TTO resources, competency in identifying licensees, and participation of faculty. Shorter commercialisation time increase the number of licensing and venture creation.	91 UTTOs	AUTM survey, authors interview	Regression analysis/qualitative	Focus on TTO and academic involvement

No.	Authors (year)	Emphasis /key result	Sample Size	Data Gathering Method	Data Analysis	Comments
21.	Markman et al (2005)	**Topic:** Entrepreneurship and University-based technology transfer **Key result:** The most attractive combinations technology stage and licensing strategy for new venture creation -early stage technology and licensing for equity-are least likely o favored by the University	128 TTOs directors interviewed	AUTM survey, authors survey/linear regression analysis	Linear regression analysis	TTOs and University start –up
22.	Markman et al (2003)	**Topic:** University Technology Transfer on the Transaction Between Strategy , Structure , Pay and the Link to Licensing Revenue and Firm Creation. **Key result:** formation are positively correlated with TTO wages; uncorrelated or even negatively correlated with royalty payments to faculty members.		AUTM survey, authors survey	Linear regression analysis	TTOs and University start –up
23.	Franklin et al (2001)	Academic and surrogate entrepreneurs in University spin out companies. **Key result:** Combination of academic and surrogate entrepreneurs should employ to success in spin-off.		Authors quantitative survey of UK TTOs	Linear regression analysis	TTOs and University start –up

APPENDIX B2: SUMMARY OF QUALITATIVE METHOD USED IN RESEARCH OF SPIN-OFF COMPANIES

No.	Authors (year)	Emphasis/key results	Sample Size	Data Gathering Method	Data Analysis	Comments
1.	Leitch and Harrison (2005)	**Topic**: Maximizing the potential of University spin- out **Key result:** TTO (QUBIS) involvement in second order spin out company. The role of TTO is more wider to regional economic development and commercialisation University based research.	QUBIS companies (3 companies)	Case study	Qualitative/ longitudinal	Focus only for one University
2.	Harmon et al (1997)	**Topic:** Mapping the University technology transfer process **Key Result:** More than 80% of technologies transferred were based on relationship rather than advertising. Established firm did minimal role of formal searching of technology. No evidence technology transfer as major source of job creation. Do not have immediate impact of job creation or new business creation. For small or entrepreneurial firms-also provides most minimal level of job creation or economic impact.	36 companies	Interviews	Qualitative	Does University of Minnesota active in TT?
3.	Carayannis et al (1998)	**Topic**: High-Technology spin-offs from government R & D laboratories and research universities **Key result:** The new definition of spin-off is proposed. Entrepreneur and technology are the key issues in defining spin-off companies. Are they should transfer from the same parent organisation or either one from deferent source.	7 co. 3 R & D gov. labs. in new Mexico and 2 gov8. labs. in Tsukuba Science City, 2 from unis. in Tokyo.	Case study	Qualitative	The study has been done in the US and Japanese unis. gave broader view on the definition of spin-offs. Unis. In New Mexico and Japan has numerous technologies but difficult to transfer.

No.	Authors (year)	Emphasis/key results	Sample Size	Data Gathering Method	Data Analysis	Comments
4.	Wright et al (2004)	**Topic**: The Formation of High–Tech Spin-outs: The role of Joint Ventures and Venture Capital Investors **Key result:** Creating a spin out company as a joint venture with industry partners may be one way to overcome the lack of resources and capabilities and faster route to commercialise the technology	4 spin out companies with 36 interviews.	Inductive case study	Qualitative-interviews	Need to be tested to larger sample.
5.	Siegal et al., (2004)	**Topic**: Towards a model of the effective transfer of scientific knowledge from academicians to practitioners: qualitative evidence from the commercialisation of University technologies **Key Result:** Cultural and informational barriers among three-stake holders; academic, administrator and entrepreneurs. Staffing compensation and reward systems inhibit commercialisation of University IP.	55 interviews	Open ended questionnaires	Inductive and content analysis	Funding for R & D and start-up is not discussed as one construct. Funding also can inhibit UITT..
6.	Vohora, Wright and Lockett (2003)	**Topic**: Critical junctures in the development of University high tech spin out companies. **Key result:** USOs go through a number of different phases of activity in their development. Each venture must pass through each stage before progressing to the next phases. The venture faces four different critical junctures in resources, capabilities and sustainability	9 spin out companies	Semi structured questionnaires/ case study	Qualitative/inductive	The normal problem faces spin-off companies pre start-up and after start-up and during sustainability period. but called as critical junctures.

No.	Authors (year)	Emphasis/key results	Sample Size	Data Gathering Method	Data Analysis	Comments
7.	Perez and Sanchez (2002)	**Topic**: Development of University spin-offs; early dynamics of technology transfer and networking **Key result**:. Early networking with external world is started with consulting and contract R & D. some of them have the products at very beginning of the business and do consulting later Parent company is important customer during early years and decrease after the firms established.	10 companies	Case study: Structured interviews	Longitudinal analysis	Focus on development and networking with parent organisation.
8.	Shane,S.(2000)	**Topic**: University technology transfer to entrepreneurial companies. **Key result**:. To study the nature of collaboration between University-entrepreneurial firm based on four dimension: industry-sponsored contract research, consulting, licensing of technology and University involvement in technology development and commercialisation. The different between the two firms are given.		Review of published and un-publish papers.	Review of published and un-publish papers.	Only synthesis of literature reviews for start-up and licensing activity.
9.	Siegel and Phan (2004)	**Topic:** Analysing the effectiveness of University TT. **Key result:** Institutional and organisational practise both play important role to enhance effectiveness in TT. Increase skills in TTOs, design rewards systems, provide training for faculty members/graduate/post graduate. Business School need to play active roles.	Review and synthesise the literature.	Review and synthesise the literature on institutions and agents engaged in commercialisation of IP	Theoretical	Theoretical

No.	Authors (year)	Emphasis/key results	Sample Size	Data Gathering Method	Data Analysis	Comments
10.	Thursby and Thursby (2005)	**Topic:** Pros and cons of faculty participation in licensing. **Key result:** The growth of disclosure, patent and license are from central administration. Need faculty involvement The output of technology transfer is different between stake holders; central administration and inventors/faculty. TTO and central administration are prefer royalty while inventors prefer sponsored research that impediment to TT. To overcome impediment- sufficient incentive. Since University technologies are embryonic, royalties and equity may not provide strong incentive. Suggest milestone payment as regard to technical milestone.	NSF and AUTM survey. Cited survey from 112 industry, TTOs of 62 universities and 3,342 faculty scientists in six major universities.	Review of previous papers Three stages of production process from 1994-1998 is examined.	Review of previous papers.	Theoretical
11.	Ndonzuau et al (2002)	**Topic:** A stage model of academic spin-off creation **Key result:** To identify the stages of spin-of process	15 unis. (TTOs) - founders, incubator managers	Interviews	Qualitative	Who are involved to exploit through spin-off is excluded from the scope of the study.
12.	Nicolaou,N.; Birley Sue (2003)	**Topic:** Social networks in organizational emergence: the University spin-out phenomenon **Key result:** Internal and external network influence the types of spin-out performed.		Theory paper	Theory paper	Theory paper

APPENDIX B3: QUANTITATIVE AND QUALITATIVE METHODS USED IN LICENSING AND PATENTING OF UNIVERSITY TECHNOLOGIES RESEARCH

No.	Authors (year)	Emphasis/key results	Sample Size	Data Gathering Method	Data Analysis	Comments
1.	Colyvas et al., (2002)	**Topic:** How University inventions get into practice **Key Result:** University technologies are embryonic. Involvement of inventor and TTO in networking is crucial to bring the technology to market place. Link TTO with academia and industry is weak. This is the first study to examine the intellectual property rights that being transfer to industry.	11 patents or cases from two universities (Columbia and Stanford University)	Interviews	Case study	Spin-off formation also is not mentioned in the study.
2.	Sine et al (2002)	**Topic:** The halo effect and technology licensing: The influence of institutional prestige on the licensing of University Inventions **Key result:** Past performance increase the performance of licensing activity	102 universities	Data observations	Regression	Similar study with DiGregoria and Shane and O'Shea. Faculty quality and history play significant roles in licensing activities.
3.	Thursby and Thursby (2004)	**Topic:** Are faculty critical? Their role in University-industry licensing **Key result:** Sponsored research in lieu of licensing is closely related to the amount of basic research conducted by firms. The use of faculty	112 business units that licensed invention from universities	Surveys	Descriptive statistic and Econometric model	Focus only the role of faculty and inventors in technology transfer

No.	Authors (year)	Emphasis/key results	Sample Size	Data Gathering Method	Data Analysis	Comments
4.	Thursby and Thursby (2001)	**Topic**: Industry/University licensing: characteristics, concerns and issues from the perspective of the buyer **Key Result:** Industry do not license University technology because: early stage technology, not relevant with firms' business. Firm license from University due to change of University receptivity. Faculty moving toward applied research. Faculty/inventors involvement contact with industry is important.	300 respondents (112 directors business who active in license University technology and 118 who did not active).	Survey	Simple statistics: percentage	The types of technologies that industries exploited are not mentioned.
5.	Shane (2002)	**Topic:** Selling University technology: patterns from MIT **Key Result:** University are more to license when patents are effective. Effective patent usually University patent it to non-inventor. When patent is effective license it back to inventors increase license termination and reduces the likelihood of commercialisation.	1397 patents from MIT	Records observation	Regression	What measure patent Effectiveness of the Univ Single University.
6.	Wallmark (1997)	**Topic**: Inventions and patents at universities: the case of Chalmers University of Technology **Key result:** Patented invention has increase in Chalmers University. Professor the highest number disclosed the invention, 50 % of patents exploited through spin-off and the other half exploited through established companies. The companies contributed to employment for new graduates from University.	400 patents	Questionnaire	Quantitative and qualitative	One University

No.	Authors (year)	Emphasis/key results	Sample Size	Data Gathering Method	Data Analysis	Comments
7.	Jensen and Thursby (2001)	**Topic:** Proofs and prototypes for sale: The licensing of University inventions. **Key result:** Most of the University license at embryonic stage. Inventors' involvement is important. Ties the inventor s with royalties or equity are important to commercialise the technology. Ties the inventor with royalties and equity is important in commercialisation activity	62 universities	Survey	Theorem modelling and percentage	Does not study inventors who start their own company
8.	Henderson et al (1998)	**Topic:** Universities as a source of technology: A detailed analysis of University patenting 1965-1988 **Key Result:** The increase of rate patenting is higher than the increase of importance and generality of patent.	53,663 univ. patents granted and cited and 61,682 US random samples (granted between 1965-1992)	Survey	Correlation	Only focus on patenting
9.	Siegal et al., (2003)	**Topic:** Assessing the impact of organisational practices on the relative productivity of University technology transfer offices; an exploratory study **Key result:** TTO activity is constant return to scale. Environmental and organisational factors (rewards systems, compensation and cultures, barriers between universities and firms) explain some of the variation in performance.	55 interviews	Interviews	Qualitative and quantitative (Frontier Analysis)	Not mention specifically spin-off as one of the output.

No.	Authors (year)	Emphasis/key results	Sample Size	Data Gathering Method	Data Analysis	Comments
10.	Thursby et al (2001)	**Topic:** Objectives, characteristics and outcomes of University licensing: A survey of major US universities **Key result:** More license are executed at universities with large TTOs and medical schools. Royalties receive larger when technology at final stage and quality of faculty is high. License agreement will be included sponsored research when technology is at an early development	135 universities	Survey	Regression	Focus also to TTO licensing objective and licensing outcome.
11.	Siegal et al (2003)	**Topic:** Assessing the impact of organisational practices on the relative productivity of University technology transfer offices: an exploratory study. **Key Result:** TTO activity is considered constant return in scale. Environmental and organisational factors explain some of the variation in performance. Most critical organisational factors are faculty rewards systems, TTO staffing, and cultural barriers between universities and firms.	55 interviews	Interviews and survey	Content analysis and DEA (data envelopment analysis) and SFE (Stochastic frontier estimation	Environmental and institutional factors are not focus on funding.
12.	Smith and Powell (2001)	**Topic:** To patent or not: faculty decisions and institutional success at technology transfer **Key result:** Faculty patent the invention when they find benefit is more than the disbenefit. Redtape dealings with TTO considered as disbenefit.	Two universities and two departments	Case study	Interview/qualitative	Only two universities and two departments.

No.	Authors (year)	Emphasis/key results	Sample Size	Data Gathering Method	Data Analysis	Comments
13.	Siegal et al.(2003a)	**Topic:** Assessing the impact of organisational practices on the relative productivity of University technology transfer office; an exploratory study. **Key result:** To look the effectiveness of TTO and to foster the links with industry. They look whether universities get more patents per dollar spent on R & D, once they establish TTO. TTOs exhibit constant returns to scale with respects to the number of licenses: Increasing returns to scale with respect to licensing revenue; organisational and environmental factors have considerable explanatory power. This represents inefficiency. Land grant universities are more efficient in TT; higher royalties shares for faculty members are associated with greater licensing income	Interviews with 5 universities. Consists of 80 research one universities	AUTM data. NSF, and US. census Data,	TFP of University licensing stochastic frontier. Qualitative and quantitative method	Only focus on two outputs; licensing agreement and royalties. More factors influence UITT ie VC, TT policies
14.	Friedman and Silberman (2002)	**Topic:** Do incentives, management and locations matter? **Key result:** Higher royalty share for faculty members are associated with greater licensing income. Inventor involvement related to amount of royalty income received. Quality research relates to invention disclosure and increase license executed. License executed is function to income to inventors, experience TTO, supporting mission, royalty income	US research universities	AUTM, NSF, Milken Institute "Tech Pole Data" 1997-1999	Regression Analysis systems Equations estimation	Focus more to output of technology transfer. In order to get better output, quality input (disclosure) is important). Thus, royalty to inventors has positive impact on inventors involvement.

No.	Authors (year)	Emphasis/key results	Sample Size	Data Gathering Method	Data Analysis	Comments
15.	Bercovitz, Feldman, Feller, and Burton (2001)	**Topic:** Organisational structure as a determine of academic patent and licensing behavior; and exploratory study of Duke, Johns Hopkins, & Pennsylvania State University. **Key result:** Differences in structures may be related to TT programme.	Duke, Johns Hopkins, and Penn State universities	Case studies, interviews	Qualitative/quantitative	Only focus on organisational structure
16.	Thursby and Kemp (2002)	**Topic:** Growth and productive efficiency of University intellectual property licensing. To seek the level of productivity of universities and the factors related to the levels of changes in that productivity. Faculty quality and the number of TTO staff has a positive impact on various technology transfer outputs. Bioengineering and engineering are efficient but not physical sciences	112 sample	AUTM/NSF, NRC	Qualitative and quantitative analysis (Data Envelopment Analysis –DEA and logit regressions)	Only study the efficiency of input /output that can be quantified. The efficiency process before disclosure and decision to commercialise is not highlighted. Not included spin-off activity
17.	Thursby and Thursby (2002)	**Topic:** Who is selling the ivory tower? sources of growth in University licensing **Key result:** Growth in University Licensing and patenting can be attributed to an increase in the willingness of University administrators to patent and license, as well as outsourcing of R & D by firms but not to a shift towards more applied research. Negative in TFP growth is due to increase in disclosures and patent application but decrease in commercial appeal.	64 US universities and survey business during 1994-1998 and 1993-1997	AUTM and authors' own survey data.	Data envelopment analysis	Focus on growth or activity after patenting

No.	Authors (year)	Emphasis/key results	Sample Size	Data Gathering Method	Data Analysis	Comments
18.	Thursby and Thursby (2003)	**Topic:** Industry /University licensing Characteristics, concerns and issues from the perspective of the buyer **Key result:** industry not licensed University technology because of technology at an early stage, rarely license due to ownership. Time lag to market longer than expected Inventors failed to deliver know-how and not cooperate for further development Why industry do license from University?: For development of product or process without delay. Industry finds personal contact and faculty contact are important	300 business	AUTM data survey. Using universities licensing between 1994-1998	Regression	Only focus to characteristics of University technologies and view from industries of the technologies. The process of licensing is not included in the study.
19.	Jensen et al. (2003)	**Topic:** Disclosure and licensing of University inventions: the best we can do with the s**t we get to work with. **Key result:** Royalties of income is lower for University with lower quality inventions. More successful TTO encourage later stage inventions to disclose. TTO and administration look to royalties rather than sponsored research as academic do. Include sponsor research if invention have quality and probability of success the inventor received a zero share of these funds. Higher academic ranking disclose at POC.	62 US universities	Survey	Sub game/ Theoretical	Theoretical

No.	Authors (year)	Emphasis/key results	Sample Size	Data Gathering Method	Data Analysis	Comments
20.	Chukumba and Jensen (2005)	**Topic:** University invention, entrepreneurship, and start-ups. **Key result::** Start-ups are more likely to choose if the opportunity cost of development and commercialisation is lower or if opportunity cost of searching for a partner among established firms is higher. Universities with higher quality faculty are more likely to license their inventions to either start-ups or established firms. Faculty of engineering is most important to commercialisation to start-up /licensed to the established company. Older TTO choose more start-up.	110 universities, 40 private universities, 67 universities with medical schools 31 universities that received the largest venture capital investment.	The study uses data from the AUTM surveys for 1993-2002. National Venture Capital Association year book 2004 and 1993 National Research Council of PhD granting institution.	Regressions and statistical analysis	Theoretical model for both types of commercialisation; start-up and licensing to established company. Decision to choose spin-off more to economic point of view rather than institutional aspects. Quality term is more broader context to inventors quality, graduate, quality engineering faculty and quality faculty of natural science

APPENDIX C: INTERVIEW GUIDES

APPENDIX C1: WHY PATENTS ARE NOT EXPLOITED

The main theme	Main questions	Control questions (as a guide to interviewer)
Background of the invention	1. What area of research are you involved in? 2. Could you give a general description of your patented invention? 3. When was research started 4. Who funded the invention? 5. Did the funders have any expectation regarding commercial exploitation 6. Who were named in the patent application as the inventors? 7. Who decided to make the patent application? 8. What was your role in the decision to commercialise? 9. Who else was involved in the decision to commercialise? 10. Have you previously patented any of your research results? If so, how similar was it to this patent? 11. What are the factors that have driven you to commercialise the invention? 12. What incentives did the University offer?	Who initiated the invention -industry or the inventor? Name of the patent Industry or government? If industry what were the criteria (i e invention has applied & commercial value) (Names of each person: University / Outsiders) Money, reward and incentives
Technology Patents	13. Could you describe the actual and potential application of the patented technology. 14. How ready is the technology to be introduced to the market. 15. Can the invention stand alone or does it have to be used in conjunction with other technologies? If the latter are these technologies patented and who owns them? 16. Could you judge how narrow or how broad is the scope of your patent? 17. If yes, why? If no why not?	Embryonic? Proof of concept? Prototype?
Exploitation Funding Networking University policies	18. How was the invention marketed? What was your role in the marketing? 19. How did you think the patent would be exploited? 20. Who did you think might be interested in exploiting the patent? 21. Why do you think the patent has not been exploited? 22. Do you think that funding from government and industry will increase the number of patented technologies and increase the chance to exploit them? 23. Do you think inventors that network with industry at a very early stage will enhance the commercial value of the invented technology, easier to exploit, and to get funding from industry? 24. What kind of support do you think the University should give to encourage commercialisation of the invention?	- Failure of RCS to market it - Failures of RCS to encourage faculty to emphasise research in line with industry needs. - Inventors motivation
Interest	25. What interest has there been in the patent? Who have you talked to about it? What have you said to them about it? Why did this not lead to commercialisation?	
Other factors	26. Are there other things that could have been done to promote the commercialisation, and by whom?	i.e Internal (University? Faculty?) and external (Government, industry, VCs)

APPENDIX C2: THE COMMERCIALISATION PROCESS OF PATENTS THAT ARE EXPLOITED THROUGH SPIN-OFF (THE COMPANY IS SET-UP BY THE INVENTOR(S))

Themes	Main questions	Control questions (as guide to interviewer)
Background of the company	1. When was the company started? How many employees do you have? 2 What are the products that your company is selling?	
Background of the invention	3. What is the area of research in which you are involved? 4. Could you give a general description of your patented invention? 5. Who was/were named in the patent application as the inventors? 6. How long did your research take up to the stage you recognised the potential /opportunity to patent or commercialise it. 7. Who decided to apply for patent application? 8. Who recognised the opportunity to commercialise the invention? 9. If you were using a surrogate entrepreneur, did you have any problem in delegating responsibility for the management or product development? 10. Who was involved in the commercialisation decision? 11. Have you previously patented any of your research results? If so, how close was it to this patent? 12. What are the factors which drove you to commercialise the invention through a spin-off company? Why not just license it? 13. What incentives did the University offer? 14. Who funded the research development, which led to the invention?	Who initiated the invention-industry or the inventor? (Name of each person: from within University / Outsiders) TTO/inventor/industry/ entrepreneur Money, reward and incentive, equity by the University?
Technology/patent	15. Please describe the actual and potential applications of the patented technology. 16. How ready is the technology to be introduced to the market? 17. How did you develop the technology, who funded it until prototype stage? 18. Can the invention stand-alone or does it have to be used in conjunction with other technologies? If the latter are these technologies patented and who owns them? 19. Who evaluated the technology and how was it determined if it really worked and had market potential? Have you done market research? 20. Did you have any problems in evaluating the technology for suitable applications? 21. If the technology was at an early stage, how did you develop the technology up to prototype stage? How many patents that have you created to bring the technology up to its current stage of development? Who owns them?	Embryonic? Proof of concept? Prototype?

Management team	22. Could you judge how broad is the scope of your patent? Is your patent considered radical technology 22. Who had the ownership of the patent when the business was started? Did you have any problem in getting ownership? 23. How did University show their interest in your company? 24. Could you tell me who is in your management team? 25. Did you identify who was product champion? What is his/her role? 26. Did you have any management problems in starting the business and how did you solve them? 27. What are the problems and what strategies has the company developed to overcome them?	Scope of the patent- broad or narrow patent Partnership with industry or VCs? Was the new technology produced accidentally If the inventor is the champion, does his role involve driving forward the ideas, looking for business plan coaching, putting the team together, business and product development/ international networking and selling i.e. Entrepreneurial skills, entrepreneurial role models, lack of business experience
Exploitation/marketing/ customer Developing business plan Funding Networking/linkages University policies	28. How did you initially market your product? 29. How did you identify and gain access to your customers? What is your role in this process? 30. Who were involved in developing the business plan? 31. What problems arose when you developed the business plan? 32. What sources of funding have you used? 33. How many stages of funding did you obtain 34. Why do you think you were successful in raising finance? 35. What are the difficulties you had in raising funding? 36. Did you bootstrap the company funding? 37. Did you have any network or contacts with industry before you set-up the business? Who was the key person you had contact with? 38. Do you think existing networks helped assisted the exploitation of your technology, and made it easy to get funding from industry? 39. What kind of University support do you think would have facilitated the commercialisation of your invention? 40. What is the impact on the company's performance if you still have links with the University? 41. Do you think that without the link with the University company performance is better? 42. Do you think that the University taking equity in spin-off firms will increase the number of spin-offs?	Government/industry/VC/BA? What are the basic problems? What were the reasons given for not getting funding
Interest	43. Before the company was set up, what interest was there in the patent? Who did you talk to about it? What did you say about it to them? Why did this lead to spin-off formation?	
Other factors	44. What other factors or challenges arose during pre start-up stage 45. Are there other things that could have been done to promote commercialisation through spin-off activity, and by whom?	Management, technology, finance, etc i.e Internal (University? Faculty?) and external (Government, industry, VCs)

APPENDIX C3: THE COMMERCIALISATION PROCESS OF PATENTS THAT ARE EXPLOITED THROUGH LICENSE TO THE COMPANIES

Themes	Main questions	Control questions (as a guide to interviewer)
Background of the inventor Background of the invention and licensees Interest	1. Could you tell me about your education and industry experience if you have any? 2. What is the area of research for the technology that you patented and licensed 3. How is/are your patent(s) being exploited? 4. Could you give a general description of the patented invention(s) that you licensed? 5. How was the invention initiated? 6. How long did your research take up to the stage you recognised the potential /opportunity to patent or commercialise it. 7. Who decided to apply for the patent? How did the decision to patent arise? 8. Have you previously patented any of your research results? If so, how close was it to this patent? 9. Who recognised the opportunity to commercialise the invention? 9. Before you licensed the technology, what interest was there in the patent? Who did you talk to about it? What did you talk to them about? Why did this lead to it being licensed to an established company?	What type of company did you license the invention to? Could you name the company and where is the company located? Licensed to established or small firms Overseas or local company Who initiated the invention - industry or the inventor? TTO/inventor/industry/surrogate entrepreneur
Exploitation/marketing/customer Research Funding Networking/linkages Decision to commercialise	11.How did you initially market your product and find licensees? 12.Did R & Cs help you in the commercialisation process? 13.Who were (was) involved in marketing it to find licensees 14.How did you identify that your product had market potential? What was your role in this process? 15.Who funded the research and development, which led to the commercialisation? 16.Did you have any network or contact with industry before you licensed the technology? Who was the key person you had contact with? 17.Do you think existing networks helped assist the exploitation of your technology, and made it easier to get funding from industry? 18.What are the factors which drove you to commercialise the invention through licensing it to an established company? Why did you not form a spin-off company? 19.What incentives were there from the University when you commercialised (licensed) the patents?	

IPR Exclusive/nonexclusive Assigning IPR	20. After the patent was licensed, who owned the IPR? 21. How did the University decide to license your invention: exclusive or non exclusive? if exclusive under what condition (s)? 22. Did the University assign the IP to the co.? Why did the University assign it? What are the conditions and how did these affect the University research? 23. Did you or the University have any difficulties when negotiating the license? 24. Did the company give any incentives for you to be involved in further development of the invention if they needed it? 25. Did the University and the inventor try to find other licensees? 26. Could you judge how broad is the scope of your patent? Is your patent considered radical technology	
Royalties/incentive	27. Does the company pay royalties to the inventor and to the University?	Could you tell me how many percent and how much?
University policies	28. How do you think that the University could help in facilitating commercialisation activities through licensing/spin-off?	Might RCS be needed to stimulate contact with industries and have stronger link with them? Or create entrepreneurial awareness among academics on how important it is to exploit patents and to increase economic value. Or give day release for academics to be involved in research and commercialisation activities

APPENDIX C4: QUESTIONS TO TTOS

Main theme	Main questions	Control questions (as a guide to interviewer)
TTO Background/patents	1. How long has your TTO been in operation? 2. What activities does your Technology Transfer Office get involved in? 3. How many staff do you have? 4. Could you explain the process of patenting at your University and who are involved in the decision making process, as to whether to patent the invention. 5. What is the role of your TTO in getting invention disclosures and patenting and who makes the decision to exploit the inventions and how are the potential market opportunities recognised? 6. How many patents does your University have now and how many have been licensed? 7. What are the criteria used by the TTO when deciding whether to exploit the invention through licensing it to existing companies? Is it ever assigned to another organisation? If so under what circumstances?	Who decides to exploit thru licensing to spin-off or to existing companies. How does the TTO interact with departments? Does the department have a person who directly reports to the TTO? How many of them were licensed to spin-off companies?
Funding	8. Did industry fund any of the inventions, which have been patented by your University? Which technologies? Why did they fund the research and on what basis? Was it due to the technology's market potential? 9. How have spin-off companies been funded? How were they set-up? Was it a joint venture with the University and a VC? Can you give the names of the companies?	Industry or government? Through contract research/ sponsored research or sharing the patent cost? How many of them had been set up by academic staff, by the University or as a joint venture with VC or industry ?
Exploitation/licensing to established company	10. Could you describe how you recruit companies who might be interested in the invention? 11. Could you describe the licensing strategy that you employ? 12. What types of patent do companies prefer to exploit? A single patent or a group of patents? 13. Does industry prefer broad patents to narrow patents for exploitation? Which routes of exploitation are pursued and in what circumstances? Form spin-off or license to existing companies? 14. How long was the research funded? Were the industrial partner's facilities used for any of the research or was it all undertaken within the University? 15. What happened to the invention after it was funded? Did the industrial partner buy/license the invention? 16. How do you measure the potential commercial viability of a new technology? 17. Who makes the decision to license it to existing companies or to spin-off companies	

Patents & Motivations	18. What drives academic staff to disclose their invention and continue to commercialise it? What are the personal and professional motivations?	▪ Royalties ▪ Rewards/promotion ▪ Peer group recognition
Inst. Policies & support	19. Do University policies support and encourage academic staffs to disclose their inventions? And if so, how? 20. What incentives are given by the University to encourage staff to commercialise opportunities?	▪ supportive culture ▪ reward system ▪ equity & royalties
Networking	21. How does networking that is undertaken by the TTO or academic staff with industry players, increase the chances of exploiting the invention? 22. How does networking that is done by TTO or academic staffs with industries increase the chances to exploit the invention?	▪ ▪ Formal and informal relationship ▪ Which route is more likely to improve the chances of exploitation? Spin-off or license to existing companies?
Marketing	23. Does the TTO market the University's invention, and if so, how? 24. Does the inventors get involved with this process? 25. How are the royalties distributed between the inventors, the central University services (including the TTO) and the department in which the inventors are based? 26. What are the challenges faced by the TTO when commercialising University inventions? How does your TTO address these challenges?	Internal or external problem?

APPENDIX D: A SAMPLE CODING OF UNEXPLOITED PATENT.

Interviewee: □ Prof Uttamchandani
Department:□EEE
Venue:□Room 372
Date:□□22/6/04-
Time:□□1.10 pm 2.00pm

Patent name:□furfuraldehyde detector and method of manufacture
Filing date:□13/1/98
Granted date:□22/5/01
Technology usage: to test transformer oil.

K:□ As I mentioned in my letter, my research in on commercialisation process of intellectual property. So… I will study on patents that exploited and patents that not exploited. I am also going to study perspective inventors why patents are not exploited.
U:□OK…no problem
K:□So….can you explain to me what is the area of your research that you involved? [technology]
U:□Yes… my area of research is in. Sensors and Microsystems.
K:□So...eem.. Who is initiated your research? you yourself or industry initiate it?
U:□No. it was … it was .a discussion .that we had with one of my other colleague, with one of my other academic colleague and he had been reading some papers and from these papers it became [aware] that they will looking for that particular types of sensor, which is not available in the .. in the simple form. So, we decided, OK we have the sensor that is not available. Lets try it to do some research to investigate weather we can solve this problems. The problem it was not directly by industry. The problem was put on us, it was by just talking to some people and reading the literature and find out weather certain sensors weather available or not. [research]
K:□So.. could you give general description of your patented invention. The name of the patent I have ..I am not a technical background.. so if you can explain in …
U:□Yeah.. I do not know weather the technical description will be relevant…anyway...This is the patent...we had invented the materials that can detects present of certain chemical compounds in transformer oil. Transformer are used at electricity supply industry as you know. Transformer gives us power to our houses. Inside transformers normally have an oil which keeps transformer at low temperature. But sometimes this oil get contaminated with certain chemicals, ok. And we wanted to find out weather we can detect this chemical inside the this oil. That is the subject of the patent. And the chemical is call furfuraldehyde. The chemical is trying to detect, and we have built the detector which is the sensor, which is capable of detecting this particular chemical compound. Once this chemical compound .the concentration of the chemical compound rises in the transformer, it mean there is some technical problem in the transformer. That is the subject of the patent. [advantage of technology, commercial potential, technology.]
K:□Do you remember when this research is started?
U:□I don't remember, it may be about four years ago , perhaps…When was the patent filed?
K;□13/1/98
U:□So, it will be before that, say six months before that. Six to nine months before that. So ..that will be what? 1997
K: □1998?
U;□so six months before that, so around 1997. something like that [period]
K;□Who funded your invention

U:The person who did the research is was the student. So the research was funded by departmental student. So there was no involvement of industry at that time. This departmental studentship. One of our student who investigated this materials.
K:Do you think that if industry funded the invention, they have expectation that this invention has commercial value.
U;Yes, we think so, that the reason we took it, that the reason we did the work, because we thought that if we could achieve the right technical performance, than there will be some chance to make some further development and further commercialisation rather research. …Actually I gave you incorrect answer to one of the … I trying to remember.. this was seven years ago. I don't remember all the works. I think you asked me who funded the research.. part of the research was funded by the EPSRC. OK I know remember..
K:How much the grant that you got?
U:Say 120k, something like that. And when EPSRC contract cama to end, than we got a student to continue the work as studentship. So the work was conducted both as research grant, EPSRC and was followed by studentship, UK student. Now I remember.
K:Who decide to make the patent application? R …C?
U:I think, the academic staffs, my self and the other academic staff who was involved in this project. We though t there is something novel in this. We went to R …C people to explain to them what was our achievement.
K:So did you remember the name of the academic staffs?
U;Yes, professor Farish, he was the other academic staff.
K:Who is Robert Blue?
U;Robert Blue who was the person employed on the research contract through EPSRC. He was a researchers.
K;So you your self and this professor decide to patent the invention?
U:Yes.
K:What is your role in commercialisation the invention?
U:What you meant by….it hasn't been commercialised.
K:Let say .. this patent going to commercialise? What is your role to commercialise if the invention is at the stage to commercialise?
U;I cant predict that answer… so can commercialise in so many ways.. you can commercialise by setting up a company…by licensing he technology…so many different ways of commercialising. In each way you commercialise the technology you have different role. If you are commercialising by making a start up the company, and your role is one of the founder of the company. If your role is to commercialise by licensing that your role is may be to cooperate with the company try to improve the technology. So the role is different depending on which particular way you forward. Depend on the mechanism you used. We didn't reach that stage.

K;Have you patented any of your research result?
U;I am sure I do, I am not remember.. you can get it from R …C.
K;I was close t this invention?
U:No, completely different. This not related to any previous patents.
K;let say, you have the invention to commercialise, what are the factors drive you to commercialise the invention?
U;We did not commercialise the invention, because the technology is not good enough to make it worth while to commercialise it. The idea was a

who funded-amount
product development, commercial potential
who funded-amount
who funded-amount
decision to patent
inventor-research
decision to patent
commercialisation decision
commercialisation decision
other patents or inventions
technology is too early-poc, not exploited patent, stage of technology, technology is not realistic.

novel idea. The idea was patentable. But is one thing to have a good idea. This is something to take this good idea and make it into something that is very easy to commercialise and so, we did a lot of investigation, and discovered that technology was not reliable enough to make a suitable for commercialisation. So we put a lot of… so this how we .. we got a post graduate student. As I told you we got a studentship for the purpose …to make the technology more reliable and we spent almost twelve month on research to that, but at the end we concluded that, the technology was not sufficiently reliable, that some company that come to us and exploit this idea.

K:□What is the stage of the technology now, is still not reliable?

U:□I don't know. It was seven years ago. I haven't look the problem. We spent one year to see the technology is reliable or not. It was possible to make it reliable.

K:□one year research for PhD student?

U:□No...no it was a master student. Master level by research. We ask the student to work for twelth months and he spent his time to work, but we concluded that is was not just reliable enough to try to commercialise. We have to put much more effort and much more finances to try to improve this ideas. But we did not have funding and industries were not interested to give us funding, because it was not sufficiently reliable. So we concluded the best thing is to stop the work.

K:□Could you please describe the potential application of this technology?

U:□The potential application of the technology to monitor electrical transformers,, from the point of view of safety. That is the application. It was to make a sensor that can increase the safety of the transformer (transformer safety). That is the actual application.

K:□So.. the technology is not ready yet to bring to the market?

U:□No.. the technology was abandon seven years ago.

K:□Can we say that at the time the technology is at the proof of concept?

U:□Yes, at the time is at the proof of concept. We...we.. had some ideas that could work. But once we explore it more and more, it became clear that it was meet …the…the.. it was not reliable enough to use. Because at the end of the day, people want some technology has completely reliable, OK. Its not reliable than they were not interested.

K:□So may be this technology can stand alone if it is reliable or may it can be used conjunction with other technology?

U:□I don't know. I think it can be stand alone technology. You can make simple business out of it. You can make small business out of it. It could be used as stand alone technology.

K:□So.. if technology is reliable you can form a spin off company?

U:□Yes.. yes ..potentially. its was suitable for small spin out company. It was suitable for exploitation.

K:□Do you think that the radicalness of technology will be exploited trough spin off company rather than license it out to established company?

U:□That the though question. I cannot tell you whether it radical enough … I don't agree with you … radical invention can become suitable for spin out company. At the end of the day is not the invention. The inventor. The inventor makes the radical invention, but, is not really interested in spin off company. Some one else has to make spin off company. Not inventor. I don't think that you can say that. Because the invention is radical and can be formed a spin out company. It is down to individual. If I make a radical invection, but I don't care about spin out company. I don't want to be involve with the company.

K:□You are not interested in business?

U:□Exactly. Was that invention radical? I think the invention is quite

stage of technology, technology is too early-poc, not exploited patent.

technology is not realistic

stage of technology

product development

who funded-amount

potential applications and market

technology is too early-poc

stand alone technology

why spin off-cost

original which why the patent was granted. To certainly inventors
_certainly had some novel ideas. Which make it suitable to make a patent
award.
K:□So_how do you know whether this is broad patent or not.
U:□I think is a broad patent.. ..because when we write the claim. We
tried to make it as broad as possible. But I haven't read this document
for_nearly seven years. So I don't remember. I haven't read the document
although you have sent me a copy. I have to read the whole document. I
think we targeted to be broad patent as possible. Because that the
general ideas that you have to make it as broad as possible.
K:□So...when you said it broad, why you said it broad?
U:□Because we tried to look other application, which is not in
transformer area. So we try to take this technology and see if we can
find some other application for it, which not necessarily related to
transformer. That is why I think we claim more broad application.
Although the original motivation for the work was connected to
transformer safety, but we took the advise of patent agent and try to see
the worth the areas which we could broaden the application.
K;□When you claim is as broad, you can block the competitor to copy your
invention?
U;□That was the ideas
K;□So_it quite difficult to ask this question_ because you said just now,
you never market the invention_we abandoned that, because technically it
was not successfull.
U;□So.. what was the question?
K;□How was the invention is marketed?
U:□It was not applicable. It wouldn't market it because there was_we took
out provisional patent ..we took out that patent.. we try to do some
extra research to see if we could improve the performance of the device.
Ok. We concluded that this was impossible to make them devise to the same
standard of reliability. So we decided to pursue. So there was no
opportunity to market it, because we did not meet that stage. I think we
had write some scientific result about it. That is all ok. I think we
published and market in that sense.
K;□So do you think that patent would be exploited?
U;□I don't think so_unless some one is willing to re-examine _ but I
don't think so. I think the market is too small, and I think the
technology has a lot to develop. Which means some one has to put in some
link up front.. to try to develop this technology. But I think the
overall market is not sufficiently large.
K;□So, let say somebody else let say industry, interested with the
technology, will fund the technology_
U;□Undoubted.. because I don't think the technology is reliable enough_is
not reliable. I don't think that they will fund it. Because the cost,
the money to fund it. .if they fund it they have to find the money. I
don't think is not reliable enough to fund it.
K;□You don't think that somebody else interested with that technology?
U;□Undoubted. I don't think so. ,but we published the technology..
because we wrote_the paper about it. After we abandoned the patent, I
think we write a paper about it. I don't remember_
K;□So_ you published after you abandoned the patent?
U;□I don't remember the exact details. I think we may published the work
after we concluded that we found, its technical reliability was not
enough for the point of view of commercialisation. But is was a novel
idea, and people interested to read the novel idea. That the reason we
published it. I have to double check if we published this., exact patent?
Or wheather is similar with this. But not exactly the same_ I not exactly

broadness of the patent
broadness of the patent
broadness of the patent
broadness of the patent
technology is not realiable
marketing-networking
technology is not realiable
technology is not realiable
technology is not realiable
publish rather than patent

remember. We may have published the work related to this. [publish rather than patent]
K:□Why do you think the patent is not exploited beside the technology?
U:□For one simple reason it was not technologically successful. That the reasons. It was not technologically successfully to meet the requirement to some industry. [technology is not matured]
K:□Is not to do that you were not interested to commercialise it?
U:□No..no is nothing to do…with that. Is to do with the fact that if the technology is 100% reliable, than it be worth to commercialise the technology. If technology only 25% reliable, no body interested to buy from you. [technology is not realiable]
K:□You said just now, you got funding from EPSRC. This organisation did not asked you why your invention is not reliable?
U:□No.. because… they don't know that we've gone to invent anything. What we did was...,we did very general project. .ok.. to do with transformer monitoring.. several ideas we were investigating. Is not one idea. We investigating two three ideas which in parallel.
K:□Oh…I say. .using the same budget.
U:□Using the same budget. That right. The budget allow us flexibility to investigate several technologies. So we had the opportunity to have several different technologies OK. And one of those technologies,from the reasearch we derived.. one of those technology of this patent. So when the project ended we realise that something interesting but need some extra work. We couldn't go and do… and make a … we need a little extra work.. to try to understand, wheather our invention was really useful or not. So we got after that accept programme ended we wrote a report and we wrote down that we have some invention and than our next step is to try to conduct little more research on the invention , may be by getting a research students for one year. [Single Node Lookup 2, funding]
K:□ That have you said just now one year master student?
U:□Yes That's right. So we wrote the report , and after the student finished one year research , we concluded that the material that we invented, the sensor that we invented, was not reliable. So when it was not realiable, nobody interested to take it forward. Of course there was some scientific reasons. To understand the scientific reasons , some one has to give the money. But that stage we could not really expected one could give me money to…investigate that… Infact I remember that....we learnt that followed on application had not been successful. So than we decided.. so well.. application was not successful.. ok what we should we do.. let try .. we put our own person on it for twelve months, under studentship.. we tried to put under studentship for twelve months. We concluded after twelve months we concluded that our sensor materials was not reliable. That follow on application, after the initial research that comes to an end. [not exploited patent]
K:□So you don't try and go to industry…
U:□No …because you have to understand that something not working very well. Industries need much some more ..infact…now,you saying this. I remember this..I remember.. when we.. when we...wrote follow on application.. we got a letter for some industry , to tell us that they..find this technology useful for them.ok .. So we got to industry to write for us..for application form. But than it was not successful application. So we did not get funding. So eventhough we got a letter from industry that say useful technology, and it worth to put some money into this technology, to try to understand and improved the technology. Although we got the letter.. so.. we decides to find our own funding.. from our department..so we try to create a studentship. [Single Node Lookup 2, funding, technology is not realiable.]
K:□So when you wrote to industry.. that industry did research on your invention...how they knew that your invention is not reliable. You told them?

U: We told them that we have new sensor, new materials, and we want to do some more research on this materials and we are to apply to EPSRC.. because we want to do some more research..so.. could you write a letter to support the idea. So they wrote the letter to support the idea. That was a novel idea that could be useful for them providing that we could make work in a proper way.
K: I though you asked industry to support funding for you.
U: No.. no.. we asked to write us a letter to allow us to apply to EPSR.
ra.
K: You failed to get the second grant?
U: Yes, we failed to get the second grant even though we got the letter from the companies to say it worth investigating..we failed to get the second grant and the last option we try to see weather we can do something internally and when we did that project, internally after twelve months, the student finished the research we concluded that it was not reliable enough. Th at the backround.
K: Do you think that if you get the funding from the government or industry will increase the number patented technology. Or increase the chances to exploit it.
U: For this technology.
K: Ya, for this technology
U: What the question? 11 /24?
K: 11.
U: This is general question...or it is for me.
K: For both.
U: With my invention I cant really the answer that..because is that not the situation that when you get the funding you neccessarily get the patent. Sometimes you get funding to investigate the idea. The idea has a negative outcome. But obviously if you put more money,we cannot say obviously... generally if you put more money.into research then.. your chances generally of generating some intellectual new property will be high. For this particular research, if we got funding from industry.. we got some extra funding.it will give us a patent to pull outcome. Very difficult to say.. because we already investigate for twelve months..If after one year you cannot make any successful work .. the technology.. then you have seriously think that the technology is reliable or not.
K: So ,if you think that if the technology is reliable, do you think that the industry will fund the technology at the later stage?
U: I think different company have different attitude..
K: So what kind of companies that interested with your technology.
U: manufactured transformers, ok.. That not many companies in this world that manufacture transformer. That may be six companies in the world that manufactured transformers. So is not that we have a choice of one hundred companies. That only five or six companies who interested in the technology. Some of them are American.. some of them are in Europe ..and one in UK ..may be two.
K: So let say.. somebody else interested with the technology.. how long it will be to take the technology to the market?
U: You need more than one year.. because we already put one year on it. We did not get the result. May be two or three years. I think the market has change now.. people has not so interested .. I don't know.. because it was seven years in the lab. So I haven't tell you about the market. Seven years is a long time and many things can change. I have not following the subject. For this time. Because after we lost interest on it, we just moved to other area. I haven't followed this topic to find out what is the stage of the art of this field.

K:□Do you think that inventors that have networking with industry at the early stage will enhance the exploitation of the technology? For this particular technology
U:□I think yes also..because it is small field.. I told you that it was only 6 companies in the world. Is not one thousand companies.. it is small field…every body knows everbody…so every body regularly networked together.
K:□You don't have nay networking with industry before you start this project?
U;□Yes, my colleuges did.

networking

K;□What did the respond from industry at that time?
U:□The responds is a good ideas.. proved it to us..so we decided to apply EPSRC money. Let them support and may be can generate some money. They not willing to put they own money…because the technology not matured. Its risky.

technology is not realiable old technology—new technology supersede,

K:□university has to put money first..
U;□For this particular technology –yes..because it was rely with the market that not so big.
K;□So… what other person that you talk about your invention?
U;□we talk to all…it is a small community… in UK it only 2/3 companies interested. We talked to all of them.. it is not like sandwich companies… so we talked to all of them. May be in UK they have 5/6 people. Everbody knows every body. It is a good idea, but we cannot give you the funding, because ethe invention is very new and immature. It gave mo more convincing result..on his application..So we talked to person.

who funded—amount, industry, technology is not realiable,

K:□What do you think of the university policies in promoting commercialisation activities?
U;□Is that a policy? I am asking you ..is that a policy?
K;□When I spoke to the director of TTO, he said it was no particular policy on commercialisation activity.
U;□yes, I think university doesn't have particular policy. I think universiety is open minded. If you go and say with them, I believe I have some inventions.. and I would like to try to make a patent application. I think they are quita open minded, and they try to support you in positive way. Weather it is policy a such I don't know, I certainly find that attitude.. and general approach is usually positive.

reward and support commercialisation

K;□So whatever the invention that disclose to R …Cs, they will patent it?
U;□No.. because that is a form that you have to fill, and in the form you have to answer the question for every inventions for patented. So you have to describe what is the novel ideas..there are three or four question…you have to answer in standard form.. they will look at the form and discuss with you and some other information may be if that information is not clear, and than decide weather something novel to patent it or not.

decision to patent

K;□So..do you think other things could be done to promote the invention? by the government, by the university..
U;□You meant for particular invention or general?
K:□Might be you can answer for both.
U;□For specific question is nothing that anybody else has been done. because if the technology is not successful. We finally came to the conclusion that some time you have to give up..because you cannot putting money on you have no clear outcome.. so we realise that we couldn't find more resourcesand reliable result. It is original technology but not realiable. Nobody will take it from us…and interested to develop it. We just decided it to abonden it.So that specifically answer to that. No body could help us….the faculty or the university .because this is science.. the science that is not work … there must be some reason for it. An the more general situation. I Think to answer to your question is

technology is not realiable

also related to your previous question ..the policy..i thin the university policy is reasonable. I think the university attitude is a right attitude. I know for example that university has got a small fund of money..that allow people to apply for some proof of concept fund. Within the university, I don't think external from university..so the university has some grant may be % grant a year to bit a proof of concept a year. That attitude is positive.
K;□they try to encourage people.
U;□Yes ,..they try to encourage invention. It is fair to say that. May be they don't have systematic policy. They do they best to look at the good ideas and try to support this ideas.
K:□Why you said just now, that they don't have systematic policy?
U;□Because no one had shown me the letter, tell me the document on the policy
K:□can I say that there is no written policy..
U;□Yes.. they don't have policies that written some where..there is no written policy that I know about. That say.. we try to encourage innovation and activities.
K:□..and commercialisation
U:□Commercialisation is different issues.. if you don't have invention.. that commercialisation is not that issues. But I think the policy that university has or the methodology the university has is tries to be very clear to staffs and they are willing to try and help you exploited in some way. In That sense the university has positive attitude. I don't if they have an overall strategy and support in inventiveness and creating the environment which inventiveness will flourish…If there is I haven't seen.
K:□Do you have any invention that you commercialise it through spin off companies or licensed it to existing companies?
U;□No , I don't have…any invention that commercialise to spin out.. and licensed it to established company.
K;□But you got two patent. that...that..
U;□I have few patent.. I don't know.. may be they have been abandoned. Because it very expensive to keep the patent life.
K;□Yes
U;□you have to pay fees every year ..
K;□This patent is abondoned?
U;□ yes as far as I know. Is not life..
K;□Ya, if you cannot commercialise it.. it will be abandoned
U;□yes, you have to make decision.. you have to be serious..if it don't work .. no point to keep it.
K;□so how long that patent will be abandoned from the date of granted?
U;□ I think …probably after one year.. because after one year.. the R … Cs office will contact you … this patent is due to renewal , have you got any further success, have you got new commercial project. That based on this patent.. and the answer to all question is no. and they say.. look it is a good idea we have to abandoned . it very expensive to keep it and maintain the patent. …what is your deal?…so.. you have to tell them what is your view.. If you don't have agree with them.. you have to explain to them why you don't agree and worth to keep it. After some time in year 2002 and we must have received a letter saying " you want a keep the patent" because now we have to complete it and we have to protect it in different part of the world, North America, Australia or Asia that will cost us may be £5000 to keep it… Do you have any…progress in this area.
K :□If you have any progress and you find any licensees interested with

university supports
university supports
university supports
other patents
not exploited patent

your patent…they can patent it your invention in other part of the world?

U:Exactly…but we are not in that situation…so we couldn't take forward…
K:How long it will abandon after the patent was granted?
U:I think after one year. They may have kept another one more year.. I didn't remember…they will have the detail…or something.. but I am sure the patent been abandon.
K:Do you have any other things that you want to say that might be university has something to do to encourage commercialisation of technology?
U:I think that university has positive attitude…to its staffs and try to help them as much as they can. And but the end of the day, it depend on how successful the ideas. I think the university put quite a lot of time and effort and money to help their staffs to try get the maximum intellectual property out of any ideas they have...but at the same time I was also understand that they don't have infinite budget…so they cannot put all the resources into this area. I think the whole university has a good attitude but quite positive attitude .. if you go and say " you have some ideas, they genuinely do that to help you.

reward and support commercialisation

K:Normally, if inventors go to R _CS they try to patent the invention?
U:Yes, my experience has been like that, so..I can confirmed that is generally true.
K:That the last question… thanks for your time and nice meeting you…

APPENDIX E: COMMERCIAL OPPORTUNITIES APPRAISAL PROCESS (COAP) USED BY WARWICK UNIVERSITY

Criteria	Explanation	Sco-ring
1. Uniqueness of the technology	1) For a family patent, will be granted world wide, which covers several interlinked aspects of the technology	5
	2) For a single patent, will be granted worldwide, which covered the fundamentals of the technology or for a very major suite of software that would take many years to duplicate.	4
	3) For a strong patent application, or for a significant suite of software	3
	4) For smaller software suite, or extensive know-how	2
	5) For interesting research result which might be protectable	1
	6) For a bare idea, with no evident uniqueness or protectability	0
2. Readiness of the technology	1) Technology well proven and bug free, and a process for volume manufacture has already be proven by manufacture of significant quantities (or is trivial, as for example, with software duplication)	5
	2) the technology has successfully completed beta testing (i.e. field testing with real customers) and is thus relatively bug-free, and a small-scale manufacturing process has been demonstrated.	4
	3) The technology worked well in laboratory, but not yet been tested by customers. Manufacture seems to be relatively straightforward in theory.	3
	4) The technology can be made to work sometimes in the laboratory, though this is still considerable 'black art' in doing it repeatedly. Not much thought has yet been given to larger scale manufacture.	2
	5) Closely related technologies have been made to work in this lab, and there seems to be no theoretical reasons why this one shouldn't work too.	1
	6) The technology should work in theory, but hasn't yet been tried.	0

3. Value of the market	1) The worldwide market for this product and its direct competitors is likely to be excess of 1 billion Pound Sterling p.a.	5
	2) the world wide market is likely to be excess 100 million Pound Sterling p.a.	4
	3) the world wide market is likely to be excess 30 million Pound Sterling p.a.	3
	4) the worldwide market is likely to be excess 10 million Pound Sterling p.a.	2
	5) the world wide market is likely to excess 3 million Pound Sterling p.a.	1
	6) the world wide market is likely to be less than 3 million p.a.	0
4. Anticipated profit margin	(if considering a license, score on the anticipated royalty rate)	
	1) the gross profit margin per sale is likely to be over 70% (royalty >7%)	5
	2) the gross profit margin per sale is likely to be over 50% (royalty >5%)	4
	3) the gross profit margin per sale is likely to be over 30% (royalty 3%)	3
	4) the gross profit margin per sale is likely to be over 20 % (royalty 3%)	2
	5) the gross profit margin per sale is likely to be over 15% (royalty 11/2 %)	1
5. Intensity of Competition in the market	1) this is a brand new market, and there are currently no actual or potential competitors.	5
	2) the market is relatively new, and the competitors are very small firms which have no current technological or marketing lead.	4
	3) the market is relatively new, and the competitors are very small, though some may have a small lead in some areas, or have access to significant venture funding.	3
	4) the market is becoming established, and competitors have grown to medium size (£5 m plus sales p.a.) and gained a reputation as market leaders.	2
	5) the market is well established, and the competitors are already substantial companies with the ability to quickly adopt or duplicate new technologies.	1
	6) the market is mature, and is dominated by a few multinational companies with major research capabilities, marketing reach and financial muscle.	0

6. Competitive edge of your product or service	1) the product/service is several times as good as the competition in one or more customer-critical areas, and is not worse in other areas.	5
	2) the product/service is significantly better than competition in at least one customer-critical area, and not worse in other areas.	4
	3) the product/service is marginally better (e.g. 25% better) than competition in at least one customer-critical area, and not worse in other areas, or is significantly better in one area, but has minor disadvantages in other less critical areas.	3
	4) the product/service is marginally better (e.g. 25% better) than competition in at least one customer-critical area, but has disadvantages in other less critical areas.	2
	5) the product/services has advantages over the competition in one or more areas, but they do not appear to be areas that are critical to the customers.	1
	6) the product/services has no evident advantages over competition.	0
7. Ease of access to the Market	1) the potential customers worldwide have already been listed (or can very easily be listed) and sales contact can be initiated as soon as the product is completed, or well-established worldwide distributors are enthusiastic.	5
	2) the potential customers or enthusiastic distributors can be easily be listed in some territories, and it appears that with enough work, other territories can be brought up to the same level.	4
	3) the potential customers and distributors can be described in general, and there are no evident barriers to accessing them, though generating the lists would be significant work.	3
	4) it is still fairly unclear what the profile of the potential customers is, or the profile is clear but there are some significant barriers (e.g. regulatory approval) to reaching them.	2
	5) some potential customers can be described, but there are substantial barriers (e.g. regulatory approval) preventing short-term access to them.	1
	6) some potential customers can be described, but the barriers to reaching them are very substantial	0

8. Commitment of the team	1) The inventors and other team members of the team are glad to leave their current jobs, invest their life savings and mortgage their houses in order to see the commercial opportunity realised.	5
	2) the inventors and other members of the team are willing to take full –time leave of absence from their current jobs, and invest meaningful sums (e.g.25% of more than their annual salary)	4
	3) the inventors and other members of the team are willing to take spend 50% or more of their time on the commercial opportunity, on an agreed split with their current jobs, and to invest modest sums (over £1,000).	3
	4) the inventors and other members of the team are willing to take spend a small portion of their time (20% or less) on the commercial opportunity, but are not willing to make even a modest investment.	2
	5) the inventors and other members of the team are willing to act as consultants, in addition to their normal jobs, providing they are paid consultation fees but are not willing to make even a modest investment,	1
	6) the inventors and other members of the team are unwilling to send any further time on the opportunity.	0
9. Customer conservatism	1) The customer group is very innovative and experimental, buying new products or services just to try them out.	5
	2) the customer group is fairly innovative, and are willing to try out new products and services which seems to have some advantages	4
	3) the customer group is not especially innovative, but is willing to give a fair hearing to any product or service which seems to offer clear advantages.	3
	4) the customer group is relatively conservative, preferring to stick to established methods unless new ones offer a strong advantage	2
	5) the customer group is relatively conservative, tending to prefer 'tried and trusted' methods and resist new ones for years even, though they strong advantages.	1
	6) regulatory, legal, moral or religious reasons lead to new methods being rejected irrespective of their advantages.	0

10. Commercial experience of the team	1) the inventors and other members of the team have a previous, very successful, experience in the commercial exploitation of a new technology.	5
	2) the inventors and other members of the team have a previous, not very successful, experience in the commercial exploitation of a new technology, and f eel that they have learnt to do it better this time.	4
	3) the inventors and other members of the team have worked for commercial companies in a management role, though their role was relatively narrow (e.g. managing a research team, rather than a general management)	3
	4) the inventors and other members of the team have worked for commercial companies in a management role, though not in a management role, and have maintained good contacts with various commercial companies joining universities.	2
	5)) the inventors and other members of the team have worked for commercial companies but have had regular contacts with a number of commercial companies through , for example, joint or sponsored research projects.	1
	6) the inventors and other members of the team have not worked for commercial companies and their University research has almost all been publicly funded.	0

The scores are totaled and then doubled to get the percentage score. The invention that gain more than 56 % score would proceed to patent filing stage and hopefully to full commercialization.

APPENDIX F:
DISCLOSURE FORM USED BY UNIVERSITY OF STRATHCLYDE RCS.

Invention Disclosure

The University of Strathclyde in Glasgow

The purpose of this invention disclosure document is to enable the staff member to notify Research and Consultancy Services of the potential invention and of any relevant sponsorship and publication history. The set questions are also designed to tease out an initial overview of the commercial potential for the technology.

1. Please generate a descriptive title to identify the invention (10 words max.)
2. Has there been any publication or oral disclosure describing the invention?
3. Who are the inventors? (names, titles, department). Include information on students, former colleagues and inventors from other institutions.

4. Was the invention developed using any research grants/funds? If so, please name the sponsor, project title, principal investigator and start/end dates.
5. Please attach a 2-3 page description of the invention, including: what is the problem the invention is trying to solve; advantages and improvements over existing methods, devices or materials; What is the novel and inventive step; details of any patent searches. Please include any diagrams if possible.
6. Have you any data/experiments to show that your idea will work: what stage (technically) are you at, e.g. what development is necessary for the product to reach market/approach a company? Please attach a summary of any supporting evidence, and copies of experimental data, graphs/photos.

7. Please attach details of potential commercial applications (economic potential, etc.), including: who will be the end users of your invention; what sectors of industry and/or society would benefit from this technology; what would the benefits be; list any background market information.
8. Please attach information on your current best guess for how your idea may be commercialised. e.g. Licence to a company, spin-out company formation. Please list any companies/individual contacts that may be interested, or have already expressed interest, in the invention.

Disclosure submitted by:

Name ______________________________

Department ______________________________

Extension no. ______________________________

Email Address ______________________________

Date of submission ______________________________

APPENDIX G: SUMMARY OF FINDINGS

	Inventions	Age	Education	Position	Reseach Funding	Motivation	Triggers factors/ opportunity recognition	Decision to patent	Decision routes	Types of technology	Scope of patent	Spin-Off funding	TTO's Roles & resources	Inventors' roles	Exclusive license/ ownership	Incentive. & Rewards
Unexploited																
1	3D imaging	52	PhD	HD	University	would like to see patent exploited	NA	TTO	NA	POC	Broad	NA	Limited budget	Did not market	NA	No incentive/not counted in promotion
2	Sensor & Microsystem	50	PhD	HD	EPSRC	would like to see patent exploited	NA	Inventors	NA	POC	Broad	NA	Good in patenting management	Tried develop product	NA	Supportive
3	LED	47	PhD	HD	University	would like to see patent exploited	NA	TTO	NA	POC	Broad	NA	Don't have resources	Did not market	NA	More action
4	Black Strip Sensor	62	PhD	HD	Industry	would like to see patent exploited	NA	TTO	NA	POC	Broad	NA	Lack of resources	Stop invention	NA	Supportive
5	Submer-sible	59	PhD	HD	Industry	would like to see patent exploited	NA	Industry	NA	POC	Broad	NA	Did not comment	Stop invention	NA	Qlv student/not counted in promotion
6	Gas Membrane	44	PhD	SL	EPSRC & Industry	would like to see patent exploited	NA	Industry	NA	Concept stage	Broad	NA	Lack of resources	Did not market	NA	High Work Load
7	FENN	52	PhD	HD	University	would like to see patent exploited	NA	Inventor	NA	POC	Broad	NA	Lack of resources/skills	Did not market	NA	TTO is helpful/Not counted in promotion
8	Vescle formulation	46	PhD	SL	WHO	would like to see patent exploited	NA	TTO & inventor	NA	POC	Broad	NA	Did not comment	Stop invention	NA	TTO is helpful/Not counted in promotion
9	DNA Minor Grove	55	PhD	HD	POC, SF& Industry	would like to see patent exploited	NA	TTO & inventor	NA	POC	Broad	NA	Good in patenting management	did marketing	NA	Supportive/not counted in promotion
10	Non-Lipo protein	56	PhD	HD	POC & M Council	would like to see patent exploited	NA	TTO & inventor	NA	POC	Broad	NA	Lack of resources	Did not market	NA	Reduce work load
Licensed to Spin-off companies																
A	3D Visualisation Images	35	PhD	Full time	Industry	High motivation	Ford Motors	Inventors	Inventors	POC to prototype	Broad	Govt grants	Supports	Built networking	University's Ownership	Equity& incubator
B	Activity Monitor devices	43	MSC	Full time	EPSRC	High motivation	HCE	Inventors	Inventors	POC	Broad	Govt.grants	Supports	Built networking	University's Ownership	Equity& incubator
C	Hydrol Gel	45	MSC	Full time	EPSRC	High motivation	Unsecured Job	The TTO	Inventors	Prototypes	Broad	Govt.grants&saving	Little supports	Built networking	Assigned lisensed	Did not get support
D	Power Monitoring System	47	PhD	Full time	EPSRC& Industry	High motivation	Giant companies	Inventors	Inventors	POC to prototype	Broad	Indst & Govt.grants	Little supports	Built networking	Assigned lisensed	Equity& incubator
E	Gas Sensor System	32	PhD	Full time	EPSRC	High motivation	HCE	TTO & inventor	Inventors	POC	Broad	Govt.grants & saving	Supports	Built networking	Assigned lisensed	Equity& incubator
F	Video Compression	43	PhD	Full time	EPSRC& Industry	High motivation	Orange's consultant	The TTO	Inventors	POC	Broad	VC and Govt. Grants	Little supports	Built networking	University's Ownership	Equity& incubator
Licensed to Established Companies																
1	Prosthetic elbow joint	55	PhD	HD/Prof.	Charity & industry	would like to see patent exploited	Reseacher's industry	Research's team	Research's team & licensees	POC	Broad	NA	Supportive	Net work & product development	Exclusive	Not counted in promotion
2	Elect. angular displ. sensor	55	PhD	HD/Prof.	Charity & industry	would like to see patent exploited	Reseacher's industry	Research's team	Research's team & licensees	POC	Broad	NA	Supportive	Net work & product development	Exclusive	Not counted in promotion
3	Nucleic acid sequence Ident.	45	PhD	Professor	Industry/licensee	would like to see patent exploited	Reseacher's industry	TTO & inventor	Research's team & licensees	Lower than POC	Broad	NA	Supportive	Net work & product development	Exclusive	Not counted in promotion
4	Recognition systems	43	PhD	Entrepreneur	EPSRC & Industries	would like to see patent exploited	Consulting job	The TTO	The TTO	POC to prototype	Broad	NA	Supportive	TTO	Exclusive	Not counted in promotion
5	Leucovorin	55	PhD	HD/Prof.	Government	would like to see patent exploited	Industry/strong network	The TTO	The TTO & inventor	Prototype level	Broad	NA	Supportive	Net work & product development	Exclusive & n.exclusive	Not counted in promotion
6	Drugs for reducing weight	60	PhD	HD/Prof.	Industry	would like to see patent exploited	TTO	The TTO	The TTO	POC	Broad	NA	Supportive	Net work & product development	Exclusive	Not counted in promotion

Note: HD = Head of Department   HCE = Hunter Center for Entrepreneurship   Nw = Networking

APPENDIX H:

WARWICK-ISMAIL MODEL:

COMMERCIAL OPPORTUNITIES APPRAISAL PROCESS WITH 13 DIMENSIONS

APPENDIX H1: LIST OF DIMENSIONS

This is the suggested new Commercial Opportunities Appraisal Process based on 13 dimensions (named as WARWICK-ISMAIL MODEL). These 13-dimensions rating system is the amended COAP scoring system used by Warwick University)

The 13 dimensions chosen are:

*A. Opportunity Recognition**
*B. Sources of funding**
C. Uniqueness and the broadness of the technology**
D. Stage and readiness of the technology for production**
E. Value of the market
F. Anticipated profit margins
G. Intensity of competition in the market
H. Competitive edge of the product or service
I. Ease of access to the market
J. Customer conservatism
K. Commitment and motivation of the team
L. Management and Commercial experience of the team
M. Business Management and industry experience of the team*

Note: * New elements	**A:**	**Opportunity Recognition**
	B:	**Sources of funding**
	M:	**Business Management and industry experience of the team**
** Amended elements:	**C:**	**Uniqueness and the broadness of the technology**
	D:	**Stage and readiness of the technology for production**

This work is directly related to Dimensions A, B, C, D and M. Dimensions A, B and M are additions and Dimensions C and D are amendments to COAP as practiced by Warwick University. These additions and amendments are put forward to include influences or factors, which were found in the course of this work, to affect the overall appraisal for technology disclosures.

APPENDIX H2: WARWICK-ISMAIL SCORING SYSTEM

Each Project should be scored from 5 (excellent) to 0 (very poor) on each dimension. The scores on each of the thirteen dimensions can be totalled to give a score of 65. The total score needs to be converted to percentage by multiplying by 100 and dividing by 65.

A. Opportunity Recognition *

Score 5: The opportunity is recognised by the inventors or members of the team.
Score 4: The opportunity is recognised by the inventors/ members of the team or jointly by the TTO or by industry
Score 3: The opportunity is recognised by the industry
Score 2: The opportunity is recognised by the TTO.
Score 1: The opportunity is recognised by the inventors but difficult to convince.
Score 0: The opportunity is not recognised by either inventors; TTO nor industry.

B. Sources of Funding*

Score 5: The project was funded totally by industry
Score 4: The project was funded by various sources of funding such as government, charity organisations and industries.
Score 3: The project was totally funded by the government
Score 2: The project was funded by internal University fund
Score 1: The project only used petty cash to buy simple equipment.
Score 0: The project only used the existing sources of equipments or recycle resources.

C. Uniqueness of the technology**

Score 5: for a broad scope, family of patents, granted worldwide, which covers several interlinked aspects of the technology
Score 4: for a broad scope, single patent, granted worldwide, which covers the fundamentals of the technology, or for a very major suite of softwares that would take many years to duplicate
Score 3: for a broad scope, strong patent application, or for an incremental technology or significant new development of existing technology
Score 2: for narrow scope of patent, less significant development of the existing technology, or extensive know-how
Score 1: for an interesting research result which might be protectable
Score 0: for a bare idea, with no evident uniqueness or protectability

D. Readiness of the technology**

Score 5: the technology is well proven and bug free, and a process for volume manufacture has already be proven by manufacture of significant quantities (or is trivial, as for example, with software duplication)

Score 4: the technology has a prototype, successfully completed beta-testing (i.e. field testing with real customers) and is thus relatively bug-free, and a small-scale manufacturing process has been demonstrated.
Score 3: the technology a prototypes stage, works well in the laboratory, but has not yet been tested by customers. Manufacture seems to be relatively straightforward in theory.
Score 2: the technology has proof of concepts stage, can be made to work sometimes in the laboratory, though this is still considerable "black art" in doing it repeatedly. Not much thought has yet been given to larger scale manufacture.
Score 1: closely related technologies have been made to work in this lab, and there seems to be no theoretical reason why this one shouldn't work too
Score 0: the technology should work in theory, but hasn't yet been tried

E. Value of the Market

Score 5: the worldwide market for this product and its direct competitors is likely to be in excess of £1 billion p.a
Score 4: the worldwide market is likely to be in excess £ 100 million p.a
Score 3: the worldwide market is likely to be in excess £30 million p.a
Score 2: the worldwide market is likely to be in excess £ 10 million p.a
Score 1: the worldwide market is likely to be in excess £3 million p.a
Score 0: the worldwide market is likely to be less than £3 million p.a.

F. Anticipated profit margins (if considering a license, score on the anticipated royalty rate)

Score 5: the gross profit margin per sale is likely to be over 70% (royalty >7%)
Score 4: the gross profit margin per sale is likely to be over 50% (royalty >5%)
Score 3: the gross profit margin per sale is likely to be over 30% (royalty >3%)
Score 2: the gross profit margin per sale is likely to be over 20% (royalty >2%)
Score 1: the gross profit margin per sale is likely to be over 15% (royalty >1%%)
Score 0: the gross profit margin per sale is likely to be under 15% (royalty <1 %%)

G. Intensity of Competition in the Market

Score 5: this is a brand new market, and there are currently no actual or potential competitors
Score 4: the market is relatively new, and the competitors are very small firms which have no current technological or marketing lead.
Score 3: the market is relatively new, and the competitors are still relatively small, though some may have a small lead in some areas, or have access to significant venture funding.
Score 2: the market is becoming established, and competitors have grown to medium size (£5m plus sales p.a.) and gained a reputation as market leaders.
Score 1: the market is well established, and the competitors are already substantial companies with the ability to quickly adopt or duplicate new technologies.

Score 0: the market is mature, and is dominated by a few multinational companies with major research capabilities, marketing reach and financial muscle.

II. Competitive Edge of your product or service

Score 5: the product service is several times as good as the competition in one or more customer-critical areas, and is not worse in any other areas.

Score 4: the product or service is significantly better than the competition in at least one customer-critical area, and is not worse in other areas.

Score 3: the product or service is marginally better (e.g. 25% better in at least one customer-critical area), and is not worse in other areas, or is significantly better is one area, hut has minor disadvantages in other less critical areas.

Score 2: the product or service is marginally better (e.g. 25% better) compared to the competition in at least one customer-critical area, but has disadvantages in other less critical areas

Score 1: the product or service has advantages over the competition in one or more areas, but they do not appear to be areas that are critical to the customer

Score 0: the product or service has no evident advantages over the competition

I. Ease of access to the Market

Score 5: the potential customers worldwide have already been listed (or can very easily be listed) and sales contacts can be initiated as soon as the product is completed, or well-established worldwide distributors are enthusiastic.

Score 4: the potential customers or enthusiastic distributors can be easily listed in some territories, and it appears that with enough work, other territories can be brought up to the same level.

Score 3: the potential customers and distributors can be described in general, and there are no evident barriers to accessing them, though generating the lists would he significant work

Score 2: it is still fairly unclear what the profile of the potential customers is, or the profile is clear hut there are some significant barriers (e.g. regulatory approval) to reaching them.

Score 1: some potential customers can be described, but there are substantial barriers (e.g. regulatory approval) preventing short-term access to them

Score 0: some potential customers can he described, but the barriers to reaching them are very substantial.

J. Customer conservatism

Score 5: the customer group is very innovative and experimental, buying new products or services just to try them out

Score 4: the customer group is fairly innovative, and are willing to try out new products and services which seem to have some advantages

Score 3: the customer group is not especially innovative, but is willing to give a fair hearing to any product or service that seems to offer clear advantages

Score 2: the customer group is relatively conservative, preferring to stick to established methods unless new ones offer a strong advantage

Score 1: the customer group is very conservative, tending to prefer "tried and trusted" methods and resist new ones for years even, though they offer strong advantages

Score 0: regulatory, legal, moral or religious reasons lead to new methods being rejected irrespective of their advantages

K. Commitment and motivation of the team

Score 5: the inventors and other members of the team are willing to take risk to leave their current jobs, invest their life savings and mortgage their houses in order to see the commercial opportunity realised.

Score 4: the inventors and other members of the team are willing to take full-time leave of absence from their current jobs, and invest meaningful sums (e.g. 25% or more of their annual salary).

Score 3: the inventors and other members of the team are willing to spend 50% or more of their time on the commercial opportunity, on an agreed split with their current jobs, and to invest modest sums (over £1,000).

Score 2: the inventors and other members of the team are willing to spend a small portion of their time (20% or less) on the commercial opportunity, but are not willing to make even a modest investment.

Score 1: the inventors and other members of the team are willing to act a consultants, in addition to their normal jobs, providing they are paid consultancy fees, but are not willing to make even a modest investment.

Score 0: the inventors and other members of the team believe that their job is now finished, and are unwilling to spend any further time on the opportunity.

L. Commercial experience of the team

Score 5: the inventors and other members of the team have a previous, very! successful, experience in the commercial exploitation of a new technology.

Score 4: the inventors and other members of the team have a previous, not very successful, experience in the commercial exploitation of a new technology, and feel that they have learnt to do it better this time.

Score 3: the inventors and other members of the team have worked for commercial companies in a management role, though this role was relatively narrow (e.g. managing a research team, rather than general management).

Score 2: the inventors and other members of the team have worked for commercial companies, though not in a management role, and have maintained good contacts with various commercial companies since joining the University.

Score 1: the inventors and other members of the team have not worked for commercial companies but have had regular contacts with a number of commercial companies through, for example, joint or sponsored research projects

Score 0: the inventors and other members of the team have not worked for commercial companies and their University research has almost all been publicly funded.

M. Business Management and Industry Experience

Score 5: the inventors and other members of the team had a previous, very successful experience in the management of business (s) in new technology and have broad industry contacts

Score 4: the inventors and other members of the team had previous, not very successful, experience in the management of business of a new technology, but have strong industry link and feel that they have learnt to do it better next time.

Score 3: the inventors and other members of the team had experience in management of business (s), but the role was relatively narrow (e.g. managing a department, rather than general management) and do not have strong industry contact.

Score 2: the inventors and other members of the team had very little experience in management of the business, (ie, as an employee) and limited industry contact.

Score 1: the inventors and other members of the team had limited business experience and industry contact

Score 0: the inventors and other members of the team had no business management experience and industry contact at all.