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DO THE CHARECTERISTICS OF TECHNOLOGY LEAD TO UNIVERSITY PATENTS BEING UNEXPLOITED?

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Abstract. The role of universities in commercialising their patents has been studied extensively. Some universities have succeeded in commercialising their patents especially through the route of licensing to established companies or forming new spin-off companies. However, there are some university patents remained unexploited, which represent wastage to the universities. This paper discusses what are the features of some patented technologies that are not commercialised. A case study of a university in Scotland was used in this study. Ten patents which are not being exploited by the University were selected. The inventors of these technologies were interviewed in depth, using semi-structured questionnaires. The interviews were recorded, transcribed and the data was analysed based on a case and cross case aided by Nvivo software.

The findings show that the most significant reason why patents are not exploited is associated with the technologies themselves. The technologies were found to be at very early stage of development, thus established companies were wary of taking them to market. Lack of motivation among the inventors to see their inventions being exploited, lack of industry networking and marketing of the TTO and inventor are another important reason that led to the inventions unexploited. Studying why some university patents were not exploited will enhance the understanding of the process of commercialisation of university patents, which would help refine the decision making process of patenting. Understanding the characteristics of the university inventions that have high economic potential thus should seek patent protections would reduce the number of unexploited patents.

Keywords: Unexploited patents; commercialisation and university patent

Abstrak. Fungsi universiti dalam mengkomersilisasikan patent telah banyak dikaji oleh penulis. Setengah universiti telah berjaya mengkomersilisasikan paten mereka terutamanya dengan melesenkan kepada syarikat gergasi atau pun dengan menubuhkan kompeni *spin-off*. Walau bagaimanapun masih terdapat sebahagian paten universiti yang tidak dieksploitasikan. Kajian ini membincangkan apakah karekteristik paten yang tidak dikomersilisasikan. Sebuah universiti di Scotland telah digunakan sebagai kajian kes. Sepuluh jenis patent yang tidak diekploitasikan oleh universiti berkenaan telah dipilih untuk kajian. Penyelidik daripada paten tersebut telah ditemuduga dengan mendalam menggunakan soalan semi berstruktur. Temuduga telah direkod, ditranskrib, dan data telah dianalisis berdasarkan kepada setiap kes dan silang kes berbantukan Nvivo software.

Dapatan menunjukkan sebab yang paling penting kenapa paten tidak dieksploitasikan adalah berkait rapat dengan teknologi itu sendiri. Teknologi didapati berada pada tahap pembangunan yang

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terlalu awal. Ini menyebabkan syarikat yang telah kukuh lebih berhati-hati untuk membangun dan memasarkan teknologi tersebut. Walau bagaimanapun terdapat teknologi yang mempunyai potensi untuk dieksploitasikan jika peruntukan disediakan untuk penyelidikan lanjut. Dalam kes yang lain pula setengah teknologi telah dipintas oleh teknologi yang lebih ke hadapan dan teknologi tersebut telah mendahului pasaran.

Kurangnya motivasi di kalangan penyelidik-penyelidik untuk melihat inovasi mereka ke pasaran, kurangnya jaringan dan pemasaran produk oleh penyelidik dan pihak TTO, adalah juga menyebabkan ia tidak diekploitasikan. Mengkaji kenapa universiti paten tidak dieksploitasikan akan meningkatkan pemahaman tentang proses pengkomersilan bagi paten di universiti. Hasil kajian dapat membantu dalam proses membuat keputusan untuk mengkomersilisasikan hasil penyelidikan universiti. Pemahamam mengenai karekteristik atau ciri universiti paten yang mempunyai potensi nilai ekonomi yang tinggi hanya patut dipatenkan, dan ini akan mengurangi bilangan paten yang tidak dieksploitasikan.

Kata kunci: Paten yang tidak diekploitasikan, pengkomersilisasi; universiti paten

1.0 INTRODUCTION

The role of universities in commercialising their patents has been studied extensively. Some universities have succeeded in commercialising their patents either through licensing to established companies or forming new spin-off companies. The success of Massachussetts Institute of Technology (MIT), Columbia University, and Stanford University in commercialising their research, either through spin-offs or licensing, encouraged governments to believe that universities could be agents for industrial innovations, sources of high technology entrepreneurs who would 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) and Silicon Valley. 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). In the area of Cambridge UK, the spin-offs process has now become multigenerational with spin-off companies becoming the source of further spin-offs. In 1985, there were around 300 high tech firms and 16,000 jobs in the Cambridge high-tech sector (Garnsey and Heffernan, 2005).

The increasing number of university spin-offs, led government to provide various grants to encourage more university spin-offs. This leads to remarkable increase in universities patenting. However, not all patented technologies were exploited. This paper explains what are the features of some patented technologies that are not being commercialised. This would help TTOs in refining the decision making process of patenting.

2.0 LITERATURE REVIEWS

Studies on patenting activities were mostly carried out by US universities. Data on patenting activities and exploitation are very rarely available in European universities. Most of the literatures focused on patenting and licensing activities (Agrawal and Henderson, 2002; Henderson *et al*. 1998; Jansen and Dillon, 2000; Jansen *et al*. 2003; Jensen and Thursby, 2001; Thursby and Thursby, 2002; Thursby and Thursby, 2003; Thursby and Thursby, 2000; Thursby *et al*. 2001a; Thursby *et al*. 2001b) and only one study on academic motivation of patenting was found (Owen-Smith and Powell., 2001). Literature reviews that particularly focus on patent exploitations and why some of university patents are not exploited is not found.

1.1 Patent and its Importance

A patent is "*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"* (Knight, 1996). While Presman (2004) defined "*a patent permits its owner to exclude members of the public from making, using, or selling* (http:// www.patents.com/ patents.htm) *the claimed invention*." For a patent to be granted, the invention must be non obvious, useful and new or original with no prior art (Knight, 1996).

Patent protection secures a legal monopoly in the products that use the patented technology. A patents owner has the exclusive use of the technology (Sullivan, 1995; Knight, 1996; Jackson, 2003; Panagopoulos, 2003), which then creates incentives for further research and development (Thumm, 2004). Patents create innovations due to many of them being granted quite early in the innovation process, with a lot of follow on research and innovations needed before the technology is ready for actual use (Mazzoleni and Nelson, 1998).

Patents also are regarded as a valuable resource for the competitive advantage of the university. The owners could 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 it had proprietary rights or the patent was licensed to them exclusively.

Unexploited patents represent wastage and opportunity cost to university. As more patents were filed and granted, the greater the numbers of them were left unexploited and increase the opportunity cost. Patenting cost is expensive, from a low of US$20,000 for domestic protection to a high of US$250,000 or more for global protection (Horng and Hsueh, 2005). The decision to patent normally is based on the potential economic benefit that the patent will bring or from the derivative technology based on that patent. Thus it is more surprising that many of the patents are not exploited.

As a rule of thumb if 100 disclosures went to the TTO, 25-30 of them will be filed for patent. Out of that only 10% of them were commercialised either through established

firm or through a spin offs (Interview with Scottish TTO directors). OECD (2002) reported that only 20-40% of granted patents was exploited. In the US the number of patents that were licensed and commercialised were only 21.9% (Presman, 2003) of the total number of granted patent. In the UK the total number of active licensing was 1 616 in 2002 and only 635 (39%) have yielded incomes of a total of £22.4 million (Wright *et al*. 2004).

2.2 Why Patents are not Exploited

2.2.1 Embryonic Technology

Most universities technologies are at embryonic or early stage when they are patented. At early stage or embryonic stage the potential application of the technologies are difficult to identify. Some of the technologies are only concept or idea. Jensen and Thursby (2001) reported that many university technologies are not ready to be commercialised and it was found that only 12% of the universities technologies were ready for commercialisation. The technologies are uncertain and high investments are needed if further research and development of the technologies need to be done. This is supported by Markman *et al.* (2005) study. The study found that the least preferred commercialisation strategy by the TTOs and industries is licensing technologies at the early stages of their development.

Thursby and Thursby (2000) found that 66% (199 businesses out of 300) of business managers from industry, do not license intellectual properties from universities. Of those, 49% had said that most university inventions were generally at too early a stage of development. Established companies prefer to exploit technologies that are at the late stages of development as they are of less risk and the potential for relatively quick returns is possible (Shane, 2001; Shane, 2004). Shane further suggested that early stage technologies, radical and are of major technical advance normally would normally be exploited through spin offs formation to commercialise the technologies (Shane, 2001, 2004).

2.2.2 Scope of Patents

Industries favour a broad patent scope than narrow patent (Shane, 2004). A broader patent scope allows the companies wider powers to block competitors from exploiting the technology that they licence. This would have given them a strong competitive advantage. For exploited patents, Shane (2001, 2004) further suggested that the broader the scope of patent, the more likely the technology will be commercialised through spin-off formation. On the other hand, the narrower the scope of patents, the higher is the chances that the patents will be commercialised through licensing to established companies.

2.2.3 Inventor Involvement in Marketing and Networking

The role of inventor-academic is crucial in finding licensees to exploit an invention. Thursby *et al.* (2001) reported that 71% of licensed inventions required inventor cooperation for commercial success. This cooperation is more important for the early stage technologies, where the tacit knowledge and contributions from the inventors are needed in order to bring the product to the market place (Shane, 2004). The inventor's involvement cannot be more emphasised as empirical evidences showed that more than 45% of the university technologies were either proof of concept or at lab scale prototype level (37%) (Thursby *et al.* 2001a). The inventors' involvement with industries in commercialisation efforts from the earliest point of the project is important in order to steer the development of the technology to match with the industries' needs (Colyvas *et al.* 2002). This involvement is very critical to the success of the commercialisation effort (Shane, 2004). This normally leads to more networking and to easier access to further funding for the inventors (Shane and Stuart, 2002; Shane and Cable, 2002). Shane and Stuart, (2002) further examined why some university start-ups are more successful than others. They found that ventures, whose founders had social ties to ventures capitalist before the founding of their firms, were more likely to receive funding and were less likely to fail. Furthermore the social ties play an important role in licensing to established companies or formation of spin off companies (Nicolaou and Birley, 2003). A study reported top ten universities in the UK have external network that facilitate the process of spin off formations (Lockett *et al.* 2003)

According to TTOs, inventors' networking are useful for marketing their inventions. Thursby and Thursby (2000) said that personal contacts between their companies' R & D staff and faculty staff were extremely important in identifying technologies to license. Another study by Jansen and Dillon (2000), of 1,140 licenses from six institutions concluded that inventors and licensing professionals were the best source of leads to licensees, with 56% licensing leads coming from the inventors themselves. The chances of inventions being licensed are high if inventors can work closely with a company's representative or company's researchers. Through close working relationships, the company will know which inventions match their needs and funding would be easier to obtain when networking is strong (Jansen and Dillon, 2000). The relationship then led to contract research, sponsored research grants, contracts and consulting arrangements, conferences and graduate students.

2.2.4 The Roles of Technology Transfer Offices (TTOs)

Technology Transfer Offices (TTOs) of each university plays an intermediary role in bringing universities' patents to industries to be commercialised. The simple model of commercialisation process which involves TTOs start with the decision to patent or not to patent the invention after it has been disclosed to the TTO. The decision is normally decided after a few stages of meetings with the inventor(s), the IPR officer,

the TTO director of the university and the Patent Agent or the universities have special committees to decide which inventions should filed for patent.

TTOs also provide services to academic staff to obtain funding and to manage their research and research related activities. The most important role is synergistic networking between inventors, entrepreneurs, investors, external advisors and managers who provide the human and financial resources to forming a company (O'Shea *et al.* 2005). Furthermore TTOs provide company formation expertise such as evaluating markets, writing business plans, raising venture capitals, assembling venture teams and obtaining space and equipment (O'Shea *et al.* 2005). In addition, TTOs encourage academic staff to disclose and protect their inventions by managing the intellectual properties, market the intellectual properties and finding licensees to exploit them.

In order to achieve all of these objectives, the TTOs must have enough resources, due diligence systems, skills and knowledge. Skills and knowledge are not confined to negotiation skills but the knowledge about the business, the market and the technology that is going to sell. Shane (2004) cited three important characteristics of TTOs; sufficient level of investment in its licensing office, expertise and network to stake holders. TTOs often have budget constraints and many universities lack sufficient staff to undertake these extra activities adequately, thus have lower rate of company formation than other universities (Wright *et al.* 2001; Wright *et al.* 2002). It was also reported that when TTO officers have greater experience in the process of company formation, the number of spin off formations are greater (Wright *et al.* 2002, and Lockett *et al.* 2002). Lack of business experience, technical knowledge, marketing, management and networking particularly among nascent universities hinders the formation of spin-off companies (Locket *et al.*, 2003). Lack of due diligence system in patenting process may lead TTOs make the decision based on the motivation of the inventors or based on their self intuition.

Marketing efforts by TTOs are important to close the gap between academia and industry (Markman *et al.* 2003; Colyvas, 2002). To encourage marketing effort by TTO personnel, monetary incentive should be given to them (Markman *et al.* 2003). However, by giving a higher salary to TTO personnel, Markman *et al.* (2003) argued that it would give significant impact on firm creation but not for licensing revenue. This is supported by Colyvas, citing that TTOs contribute 'marginal effect' to promote technology transfer through licensing. Markman *et al.* (2005) supported Colyvas' finding. They reported that the least preferred strategy by TTOs and corporations is finding sponsored research. This may be due to potential dispute on the direction and ownership of the research when additional R & D and capital are required (Markman *et al.* 2005). To get the inventions licensed by industries, marketing activities by TTO staff is important as well as from inventors.

2.2.5 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.

2.2.6 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 and Hitchen, 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).

3.0 METHODOLOGY

A university in Scotland was selected as a case study in this paper. It's patents portfolio list of 82 patents was obtained, and of that 33 were identified as unexploited. Of these

many inventors were not available for interviews because they were unwilling, had left the University or just could not be contacted during this research. This left 15 patents and from these 10 were chosen to represents different departments of the university. The inventors of these technologies were interviewed in depth, using semi-structured questionnaires. The interviews were recorded, transcribed and the data was analysed using content analysis aided by Nvivo software.

4.0 FINDINGS

4.1 Characteristics of Technologies

The findings show that the most significant reason why patents are not exploited is associated with the technologies. The technologies were found to be at a very early stage of development, thus established companies were wary of taking them to market. Nevertheless, some of the technologies have the potential to be exploited if funding was available. In other cases the technologies were superseded by other technologies, which then became the market leader. This is shown in Table 1.

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:

4.1.1 Early Stage Technology

The technologies for these unexploited patents were all at the very early stages or at proof of concept stage (Table 1.). 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. 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

Table 1 Reasons why patents are not exploited

Patents	Inventions	Technology early stage/proof of concept	Used in conjunction with other	New TechnologySuperseded	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 Stripsensor	✓		✓	✓		✓	✓		✓		✓	✓		✓
5	Submer-sible	✓		✓	✓		✓	✓		✓			✓		✓
6	Gas Membrane	✓				✓			✓	✓	✓		✓	✓	✓
7	FENN	✓						✓	✓		✓		✓	✓	
8	Vesicle Formulation	✓		✓	✓		✓	✓		✓					
9	DNA	✓	✓					✓							
10	Non-natural Lipo Protein	✓						✓	✓		✓			✓	

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.

4.1.2 Scope of Patent

All 10 inventors agreed that they were granted patents that were broad in scope. 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 create difficulties in narrowing down the application (as in the case of Patent 3).

This 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.

4.1.3 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. 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 ... .*"

4.1.4 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 development. However, as explained earlier, the technology is far from market ready and industry has stopped funding the project.

4.1.5 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 2).

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 paper 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 2 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.

4.3 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 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 1). Unwillingness of the inventors to network is related to the technologies themselves. They are far from market application as discussed. 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 ....*"

Another 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 were found to comply with the drug regulations of various countries.

The finding is consistent with the works 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.

4.4 The Role of Technology Transfer Office (TTO)

The finding shows that there was no consistency in the decision to patent. The decision either has been made by the TTO, the inventors or the industry. 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). 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, 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 that a systematic due diligence system by qualified and experienced TTO staff would reduce the number of unexploited patents.

4.5 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 is consistent with Locket *et al.* (2003; 2004) who found that monetary rewards were not a significant factor in the commercialisation of technology.

5.0 DISCUSSION

This study is an exploratory study focusing on why some university patents were not exploited. It was concluded that the technologies themselves were the main reasons (more than half of the cases as shown in Table 2) patents were not exploited. Most of the inventions were found to be at an early stage of the technology cycle and were not yet reliable, even though all the patents claimed to have broad scope. New technologies then superseded them.

Failure to commercially exploit the technologies could also be attributed to lack of marketing due to constraints on academic inventors to devote time and effort to commercialisation activities. Inventions that have market potential with further development were abandoned as seed funding for commercialisation is difficult to obtain. Rewards and incentive from the university, for technology exploitation, or lack of them also contributed to why patents were not commercially exploited. These reasons will be discussed in turn.

In this finding the technologies are at an early stage of development, although having broad patent scope, are not exploited. Early stage technologies with broad patent scopes do not guarantee exploitation. Patented technologies at an early stage of the technology cycle need to be developed further. Then only their chances of being exploited are greater. To increase their commercial exploitation further, a spin off company should be formed to do this, as suggested by Shane (2004).

For that, funding is needed and the role of the inventors is crucial in securing the funding. Shane and Cable (2002) found that networking has a positive relationship to get funding from financiers. But in this study more than half of the respondents did not aggressively market their products and did not have any contact with industries.

The dilemma of early stage technology was demonstrated by requiring further development and securing exploitation seed money from industries and was showed clearly in the case of the sensors and micro-system patent. The technology was not really reliable to be used in commercial products thus need further research. But to do that more resources are required, but industries were afraid that this unproven technology will not be fruitful. In this case, a little further research done by the university, proved that the reliability problem could not be solved. Thus the industry in this case is vindicated.

Most of the university patents in this study (except one) have some chance of being exploited if resources are present. The academic workload of inventors should be reduced and the commercial exploitation effort should be included in their appraisal for promotion purposes.

A good example is the inventor of the gas separation membrane. The research project was originally funded by EPSR and the second round funding came from industry. The technology has good potential but the invention is still at its early stage or to be more precise not ready for the market yet. The inventor has limited time for marketing, but if a commercial partner with industry is found, it may help to speed the

process of further development on the mechanical structure of the project that needs a huge investment. This is consistent with Colyvas, *et al.* (2002) and Shane and Cable (2002) findings. Colyvas *et al.* (2002) who reported that inventions would fail to transfer to industry if the inventor did not have contacts with the industry. Even though this patent is currently not exploited, but the potential exploitation is there after more tests are done.

Networking with industries will help inventors to choose the right inventions to target from the start of the project. Greater access to funding through sponsored research is then more probable. Networking would also provide a prior knowledge of the possibility (Shane, 2004) of licensing certain kind of invention (anti drug cancer case). This would give the inventor more entrepreneurial awareness in which area there are opportunities.

Shane (2004) said that projects funded by industries have potential value, or to be more precise the industry had seen the market potential of the result of the project. Interestingly in this study, it was found that the potential of failure is high even though they were funded by the industries. The failure of early stage of technology is difficult to predict and the market is uncertain. Many of the inventions were ending up unexploited. In this study three of the inventions were funded by industries. Two of the research ideas also started from the industries while the inventors were consultants to the industries. They are now still not exploited and are now superseded by other more advance technologies and the industries stopped the funding for the two projects.

Empirical evidences (Lockett *et al.* 2003, 2004) concluded that there was no direct correlation of the effect of rewards and direct monetary incentives towards commercialisation of research results by academic inventors. This is consistent with this study which found reward and incentive did not give direct effect to commercialisation activities as in the fourth proposition of this paper.

Lastly, half of the inventors are of the opinion that the TTO has very limited resources to do marketing on their behalf and is quite slow in linking them with industry. University inventions are for various sectors which make it difficult for the TTO to find a suitable match. To market the inventions the TTO officers need experience in negotiation skills, technical knowledge, customers and market environment awareness. Enough resources should be allocated to the TTO to promote the technologies. The opinion of the inventors here is consistence with Wright *et al.* (2002), and Lockett *et al.* (2003).

Finally there is no doubt that the factors mentioned above are inter related. All of them contributed to the technologies in this study not being commercially exploited.

6.0 IMPLICATIONS

Studying why some university patents were not exploited will enhance the process of commercialisation of university patents through refining the decision making process of patenting. Understanding the characteristics of the university inventions that need

to seek for patent protection by the policy makers or the TTOs directors would reduce the number of unexploited patents. University should consider commercialisation activities in promotion exercise as reward and incentive by university policy makers. Special grant with reasonable amount should be provided by government to fund 'blue sky research'.

7.0 LIMITATION

This study only used one university as a case study which may give bias results. The way samples were selected also effect the generalisation of the findings. The sample was selected based on the University TTO recommendation and some of the inventors have left the University. The interviews only were conducted to the inventors that willing to be interviewed.

8.0 FUTURE RESEARCH

The case should be conducted to a few universities to get the broader scope in understanding university patents that unexploited. The scope of the study also may include other type of intellectual properties such as university know-how. This will give a bigger sample size and different views of understanding the decision making in patenting and know-how process.

9.0 CONCLUSION

The study answers the question: what are the features that contribute to patents not being exploited. The reasons that influence patents being unexploited can be divided into five main factors: the technologies, the inventors, the TTO, University policy and the funding. 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 funding which relates to 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 which restricted access to funding. It was found that the factors mentioned were interrelated.

Understanding why patents are not exploited will help TTOs to refine their decision to patent or not the inventions.

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