



**A literature review on the efficiency and effectiveness of university
technology transfer offices and hybrid commercialisation models**

November 2009

DRAFT REPORT

Christian Helmers and Mark Rogers, University of Oxford

David Baghurst and Terry Pollard, Isis Innovation

Isis Innovation Limited
Ewert House, Ewert Place
Summertown, Oxford OX2 7SG
www.isis-innovation.com

The Technology Transfer Company of the University of Oxford

Contents

1. Abstract	3
2. Executive Summary	4
2.1 <i>Aim and Objectives</i>	7
2.2 <i>Methodology</i>	7
3 Introduction	8
4 An overview of technology transfer and TTOs in the UK	8
4.1 <i>Evidence on technology transfer in UK</i>	8
4.2 <i>Overview of the success of technology transfer</i>	23
4.3 <i>The rationale for TTOs</i>	25
5 The channels of technology transfer	27
6 Models of TTO operation	33
6.1 <i>The ‘Cambridge’ Model</i>	33
6.2 <i>In-house model</i>	33
6.3 <i>Establishing a standalone limited company</i>	34
6.4 <i>Hybrid models</i>	34
7 International Comparisons of TTO effectiveness	37
8 Efficiency of TTOs in delivering social and economic outcomes	39
8.1 <i>The identification of inventions and generation of IPRs</i>	39
8.2 <i>Commercialisation success</i>	43
9 Suggested Research Questions	49
10 Data Sources	50
11 References	50

1. Abstract

This report reviews the existing literature on university-industry technology transfer. It focuses on the role played by technology transfer offices (TTOs) in generating and commercialising intellectual property (IP) in the UK. We describe the large range of technology transfer mechanisms employed by universities and TTOs and offer a typology of the different organisational forms used to transfer knowledge from the university to private firms. In addition, we review the theoretical and empirical literature on the relative effectiveness and efficiency of TTOs. The report also lists a number of suggestions for further research.

2. Executive Summary

Universities play a crucial role in the generation of inventions, some of which are path-breaking discoveries that eventually have a fundamental impact on the economy and society. Public funding is at the heart of the university system. This motivates the primary role of universities and academic researchers in disseminating knowledge while not primarily seeking individual monetary profit.

The way in which universities disseminate knowledge has changed dramatically over the past few decades. Universities have explored a large number of new channels to transfer and market their knowledge, including mechanisms involving proprietary knowledge in form of intellectual property (IP). At the centre of universities' increased efforts to commercialise their knowledge, in particular IP, are Technology Transfer Offices (TTOs). While TTOs are relatively new, there is a substantial body of theoretical and empirical research seeking to understand their complex role in mediating between universities and the private sector. Despite the rise in research on TTOs, the literature is only beginning to understand the underlying economic mechanisms. This report offers a review of this literature with a view to understanding the role of TTOs in the generation of inventions, their disclosure, the decision to exploit their commercial potential through IPRs, and in successfully marketing them. We pay particular attention to existing work on the UK in this area.

We find that TTOs are useful in encouraging academics to disclose their inventions and promoting the commercialisation of the resulting IP. The main role of TTOs in the successful commercialisation of university inventions is mediating between the different parties involved in the process. They are central in reducing the inherent uncertainty in inventions that originate from university research and in overcoming the intrinsic asymmetric information between academic inventors and potential industry clients.

Our review starts with 2006 and 2007 survey data provided by HEFCE and UNICO. This shows that, despite the prevalence of TTOs, the share of universities always requiring their academics to disclose inventions is surprisingly low. This said, over 80 percent of universities have specific rewards in place for the generation of IP. The data also shows that, on average, the number of patents filed amounts to approximately half the number of inventions disclosed. The data also reveals that nearly 20 percent of universities do not have either an in-house capability or external agency to license IP. Importantly, the share of universities using the services of external agents is increasing, implying that some universities switch from an in-house to an external model. Looking at licensing, SMEs obtain more licenses from universities than larger companies, although licensing income is generated mainly by large firms. To promote spin-outs, universities mostly rely on incubators, training and business advice, as they are less costly than science parks. TTOs have grown considerably in terms of employees over time, confirming the overall trend of intensified efforts by universities to market their inventions. Also the number of inventions disclosed has increased considerably.

We describe ten channels through which universities transfer knowledge. We divide these channels into formal and informal mechanisms. The informal mechanisms include social and professional networks, public university lectures and workshops (including continuous education), consulting, commissioned research by firms, academic-scientist exchanges and recruitment of university graduates by firms. Such mechanisms are likely to transfer mostly tacit knowledge often without record. More advanced and codifiable knowledge is likely to be formalised into an IPR and transferred through formal

mechanisms such as patents and other IPRs, licensing and royalty agreements, formation of spin-outs and related to this, university incubators and science parks.

Universities use these formal mechanisms in different ways to effectively commercialise university inventions. In our typology, we distinguish between the 'Cambridge' *Inventor-Ownership* Model, the *In-house* Model, the *Stand-alone* Company Model, and the *Hybrid* Model. Prior to 2005, Cambridge relied on the entrepreneurship of academics themselves. Individual academics owned their IP and this allowed any entrepreneurial academics to start their own businesses directly. The advantage of this model is that it gives maximal incentives to the academics and also removes any influence of the university. Its drawbacks are a lack of coordination and reduced incentives for universities to support academics in their entrepreneurial efforts. At the other end of the extreme is the *In-house* model where the university manages the entire technology transfer process through an internal organisation. In the *Stand-alone* Company Model, the university establishes a dedicated, and independent, limited company whose objective is to act as a conduit between university research and business. This may increase incentives for the TTO to engage in successful commercialisation as its performance is more visible and will most likely determine its status within the university. In the *Hybrid* Model, the university signs a long-term partnership agreement that grants a private company a share in the university's IPRs (and income generated from their commercialisation) in exchange for advice, funding and technology transfer management expertise. While this model is very recent, it has already produced some success stories in the UK. The typology is useful in understanding how technology transfer operates. However, in reality, universities may use multiple models and the emphasis on each may change over time.

The literature review on the efficiency of TTOs focuses on two key areas: the identification of inventions and generation of IPRs, and the success in commercialising university IP. While in reality TTOs employ a wide range of technology transfer activities, most of the existing empirical studies focus on only one specific activity, such as licensing or disclosure rates. This makes it difficult to provide a clear conclusion with regard to the efficiency of the different models presented in our typology. Nevertheless, the empirical studies build a body of knowledge that is vital to understanding the efficiency of TTOs.

A concern surrounding TTOs is that they may generate too much focus on commercially valuable applied research and hence neglect basic research. Empirical analysis suggests that there is no particular reason for concern. The relatively recent importance attached to TTOs, university-business links and IPRs appears unlikely to be detrimental to basic research.

Empirical analysis in the US suggests that, despite comprehensive and clear regulations in place, a substantial share of inventions is not disclosed to TTOs (and patent protection is obtained in the name of academic inventors). While TTOs employ different remuneration schemes, the reality is that academics often choose to by-pass the technology transfer scheme in place and opt for the decentralised 'Cambridge' *Inventor-Ownership* Model. When it comes to the decision about whether to take out formal IP, TTOs should have an advantage due to their specialist expertise and institutionalised experience. Hence a centralised organisation is at an advantage over a decentralised model (where individual researchers have to take these critical decisions based on their own limited information).

While there is evidence that IP strategies contribute to successful commercialisation, there is also some concern that overly aggressive attempts by universities in pursuing IP can have detrimental effects on university-industry collaboration. However, empirical support on these issues is lacking.

The reputation of a TTO appears to be critical in its success. Empirical studies use the age and experience of TTOs to proxy for reputation. This leads to suggestions that smaller universities could pool inventions into a common TTO, or bring in external partners that can help with establishing a reputation. More centralised models of technology transfer, i.e., the In-House Model, the Stand-alone Model and the Hybrid Model offer a substantial advantage over the `Cambridge' Inventor-Ownership Model in particular for younger academics (since they cannot rely on their own reputations to market their inventions).

The literature also suggests that the distribution of licensing income is highly skewed, i.e., most licenses generate only very moderate returns while a few licenses may generate millions in royalty payments. The literature suggests that TTOs can have a positive effect on the value of licenses although this may mean a lower number of licenses than the number of IPRs would suggest.

The skewed outcome distribution also applies to academic spin-out companies. With regard to spin-outs, TTOs are found to have a positive role in mediating between academic inventors and funding providers. The use of incubators and science parks by TTOs to support spin-outs appears to be effective, although there is some evidence questioning the long-term effect of incubators on a company's chances of success in the market. Moreover, there is no comparative empirical assessment of the relative merits of incubators and science parks.

The report also provides an overview of what is known from international comparisons of TTO efficiency and effectiveness. From this literature review, the US appears to be better staffed, professionalised and highly specialised in executing technology transfer. Nevertheless, there is also evidence that once the relatively larger employment of resources is factored into the comparison, the US advantage over Europe vanishes. Yet, the essence from this review is that the US appears to be leading the field in organising efficient and effective university-industry technology transfer. The one area in which the UK appears to have a lead is the Hybrid Model.

We conclude by pointing out a number of questions for further research in order to provide a more comprehensive understanding of the complex issues at work with a particular focus on the UK.

2.1 Aim and Objectives

The aim of this paper is to review the literature on technology transfer from universities with a specific focus on technology transfer offices (TTOs). The paper also focuses on the UK situation and includes a review of UK TTO organisational structures and activities. The literature reviewed covers a wide range of methodologies, issues and countries, although particular attention is paid to empirical analysis of the effectiveness and efficiency of technology transfer and TTOs and, within this, on commercialisation of IP based on university inventions.

The objective of the paper is to provide a summary of what is known about these issues together with a statement of the gaps in our understanding. Given this objective, the paper focuses on reviewing the most recent literature.

2.2 Methodology

The methodology adopted is desk-based research. Databases searched include academic journal databases, government and other agencies reports, news and internet sites, and gathering data from the Higher Education-Business and Community Interaction Survey (HE-BCI) conducted by HEFCE, the UK University Commercialisation Survey and the Salary and Incentives Survey by UNICO as well as other sources.

3 Introduction

The national innovation system essentially consists of three sectors: industry, universities, and the government, with each sector interacting with the others, while at the same time playing its own role. (Goto, 2000: p. 104)

Interest in the driving forces of innovation has increased in recent years and, as the above quote makes clear, universities have a vital role in this process. It is also clear that government support and guidance for universities is a critical aspect. Technology transfer from universities through various channels is at the nexus of these issues and the role of TTOs is a critical part of technology transfer. For these reasons alone a paper reviewing the effectiveness of TTOs is important. In addition, TTO activity has grown from a very small base 20 years ago to a situation today where all research active universities have TTOs. Such a rapid growth in activity naturally generates a series of questions about the operation and organisation of TTOs and, ultimately, their effectiveness. In particular, recent years have seen the emergence of a new business sector which lead universities to outsource to private companies activities originally entrusted to TTOs. The UK appears to be a front-runner in this development, which motivates a review of what is known in the literature about the character and effectiveness of this new public-private partnership and its wider implications for diffusion of knowledge generated by universities.

4 An overview of technology transfer and TTOs in the UK

This section provides an overview of technology transfer and TTOs. Section 4.1 considers some summary statistics describing the nature of technology transfer in the UK. The data also describes some of the mechanisms in place at UK universities to promote technology transfer, including TTOs. In addition, the data allows us to look in detail at the performance measures and institutional characteristics of TTOs in the UK. Section 4.2 considers the conceptual factors involved in technology transfer. Section 4.3 considers the economic rationale for TTOs.

4.1 Evidence on technology transfer in UK

In this Section we provide some descriptive evidence on technology transfer at UK Higher Education Institutions (HEIs) using mainly data from surveys undertaken by HEFCE and UNICO. HEFCE undertakes an annual Higher Education-Business and Community Interaction survey (HE-BCI) in which a large range of information on knowledge transfer from universities to the (business) community is captured. We use data from the last two available surveys in 2006 and 2007. The HEFCE data is useful to describe the technology transfer landscape in the UK, i.e., to describe the mechanisms and institutions in place at UK universities. The rich information provided by HEFCE is complemented with data from the UNICO UK University Commercialisation Survey. UNICO's survey collates quantitative information specifically on the commercialisation activities of innovations generated by UK universities. We use the last available data for 2005. This data, therefore, is useful in measuring technology transfer 'performance' by UK universities. In addition, UNICO's Salary and Incentives survey 2007/08 provides

valuable information on salaries paid and reward and incentives strategies in place for TTO staff. This data is particularly useful in the discussion of what the right incentive scheme is within TTOs to achieve successful technology transfer.¹ Note that we only have obtained access to the micro data by institution for the HEFCE surveys but not for the UNICO data. This limits our ability in linking the three different sets of information which prevents us from drawing a more encompassing picture. Also, while the HEFCE survey covers the entire population of universities, all other survey data covers only sub-groups of the population with partly largely varying coverage.

In order to transfer and commercialize knowledge, universities rely on academics disclosing their inventions. Universities can have different policies in place with regard to the disclosure of inventions, they can either require researchers to always report inventions or adopt a more lax stance. The HEFCE BCI survey asks universities directly whether they require university employees to report the creation of different types of intellectual property. The results for the 2006 and 2007 HEFCE surveys are shown in Table 1.

Table 1: Disclosure requirements by type

Type	Always		Usually		Never	
	2006	2007	2006	2007	2006	2007
Inventions	63%	65%	21%	21%	16%	14%
Computer software or databases	45%	45%	38%	38%	17%	17%
Literary or artistic works	20%	23%	32%	32%	48%	45%
Educational software and multimedia	44%	45%	40%	39%	16%	16%
Industrial designs	48%	49%	28%	27%	24%	24%
Trademarks	57%	59%	19%	20%	24%	21%
Integrated circuit topographies	32%	33%	20%	20%	48%	47%
New plant or animal varieties	40%	42%	15%	16%	45%	42%
Other	23%	26%	49%	45%	28%	29%

Source: HEFCE BCI

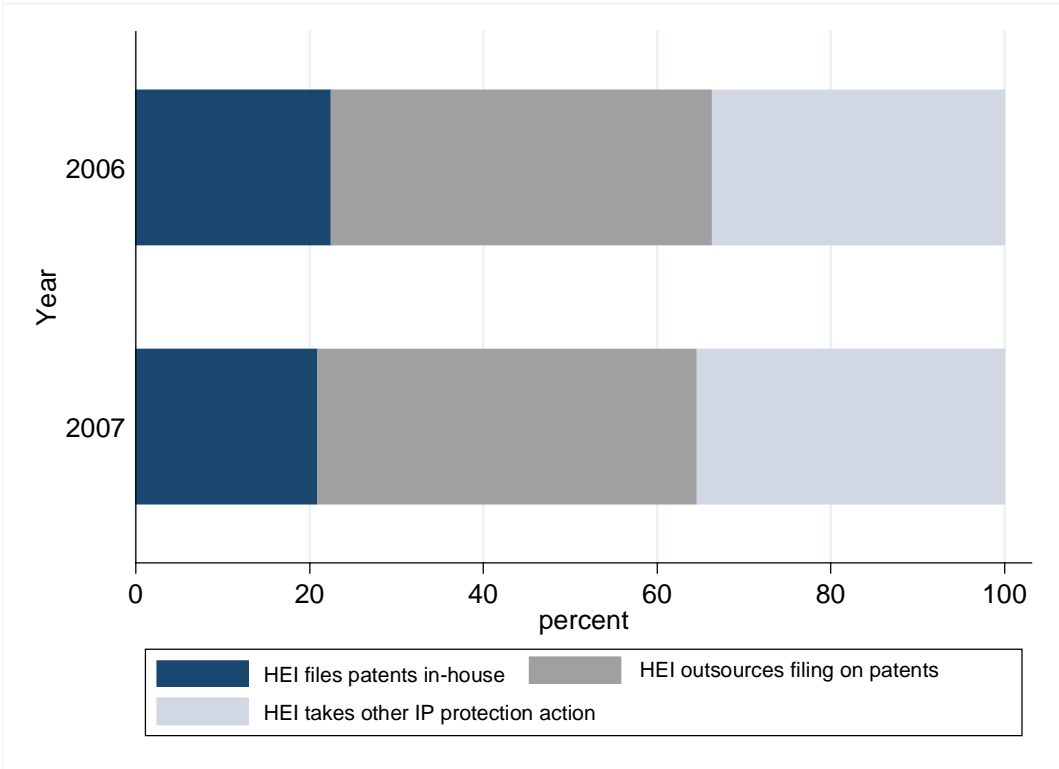
For inventions, most universities require disclosure which is explained by the fact that they are the type of research outcome most likely to give rise to patent applications. Also other registered IP, trademarks and industrial designs, have to be reported in half of the universities included in the survey. Nevertheless, considering the crucial role of disclosures in the commercialisation process of inventions (see also Figure 2), these numbers may appear low.

If inventors are expected to disclose their inventions, the next question is whether universities exert ownership over patents generated from these inventions. Although universities can implement their

¹ Note that a direct comparison of the summary statistics across the three surveys is not possible because the samples differ.

own specific rules regarding IP, the most common practice is in line with private companies, i.e., IP is usually owned directly by universities instead of researchers in direct relation to the Patent Act 1977 which stipulates that an invention made by an employee in the course of his or her normal duties shall belong to his or her employer. The subsequent question is whether universities also file themselves for patents or whether they outsource this. The HEFCE BCI survey suggests that universities mostly outsource the filing of patents. Only slightly more than 20 percent of universities filed for patents in-house in 2007.

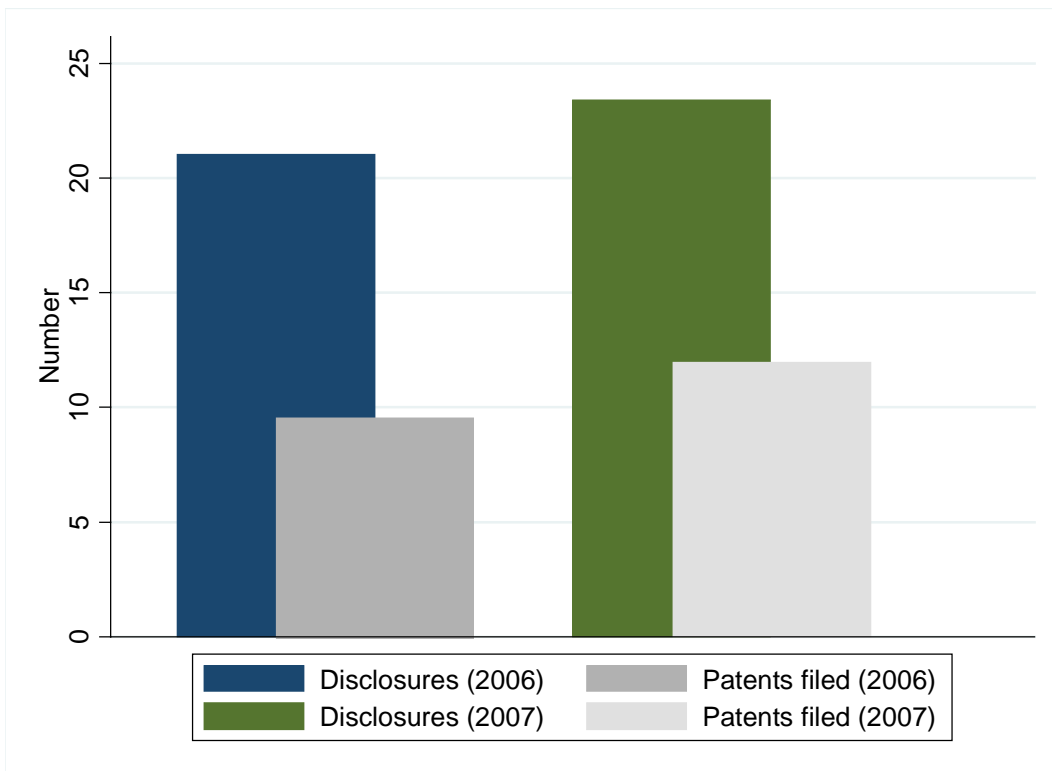
Figure 1: Do universities file for patents in-house?



Source: HEFCE BCI

Figure 2 looks at the relation between the average number of disclosures and patents filed by, or on behalf of, the university. It shows that both the average number of patent filings and the average number of disclosures have increased between 2006 and 2007. In 2007, on average, the number of patent filings amounted to about half the number of disclosures.

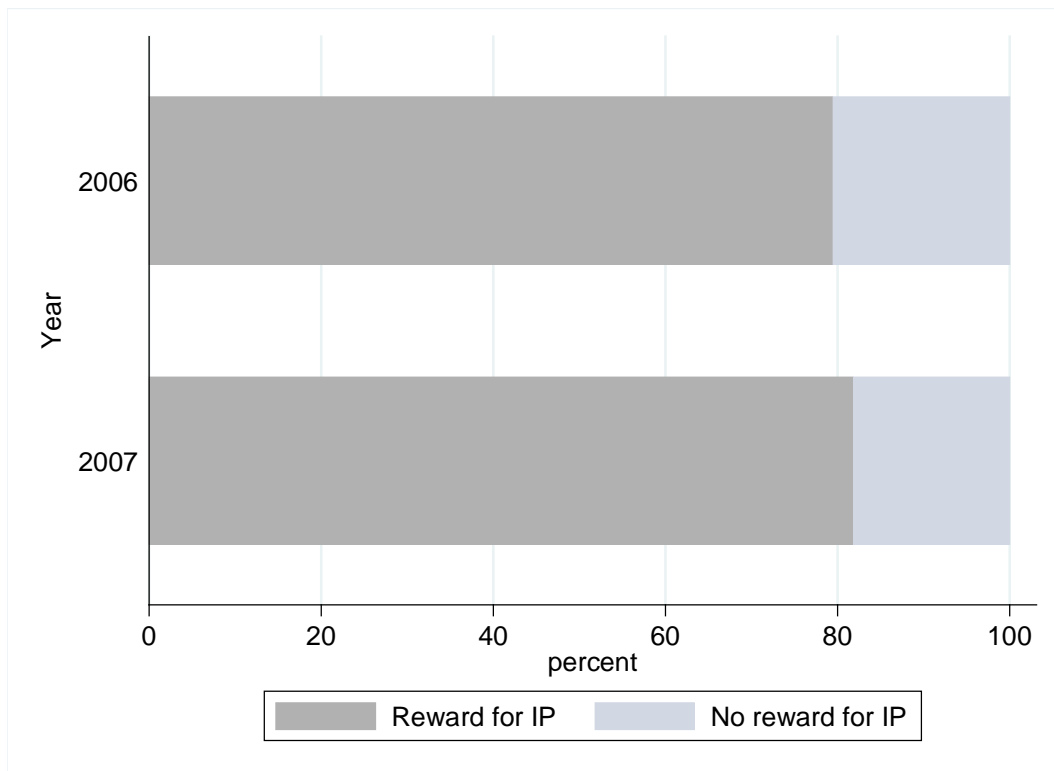
Figure 2: Average disclosures and patents filed



Source: HEFCE BCI

If universities require staff to disclose their inventions and exert ownership over the resulting IP, the question of the incentives in place for university researchers to come up with inventions arises. The HEFCE BCI survey therefore asks universities whether staff is rewarded for the IP they generate. Figure 3 shows that more than 80 percent of universities have some remuneration scheme in place to reward researchers for their IP. This may to some extent mitigate the lack of policies always requiring the disclosure of universities shown in Table 1.

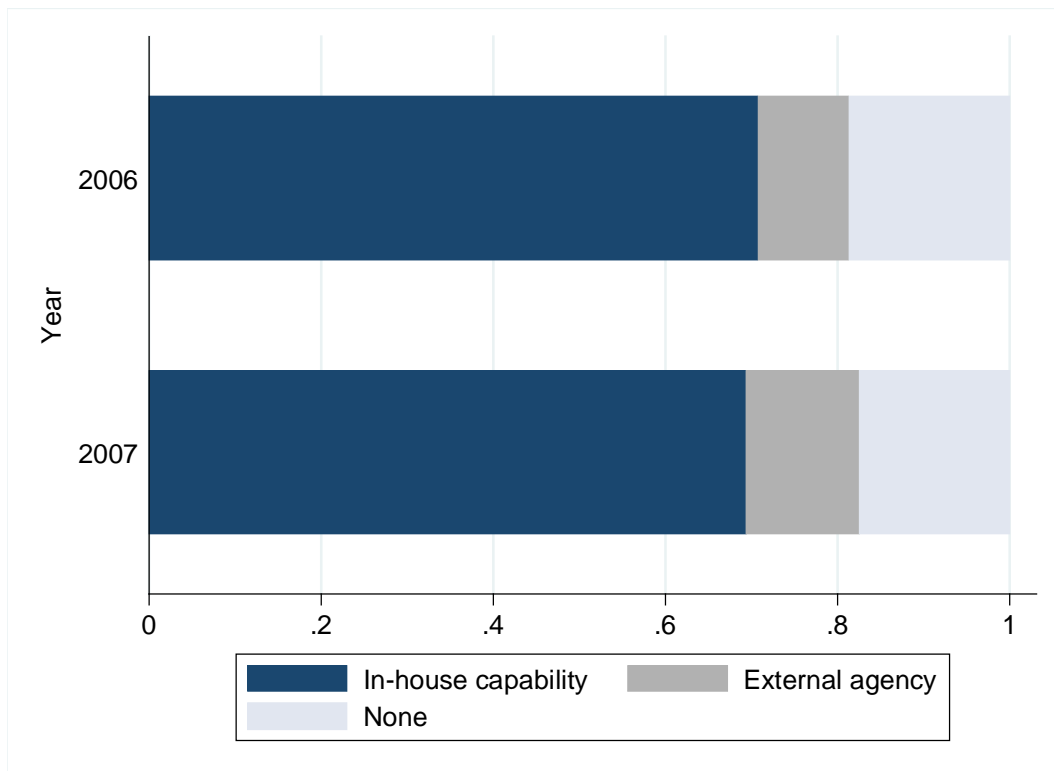
Figure 3: Are researchers rewarded for their IP?



Source: HEFCE BCI

If universities hold ownership over IP generated by its staff, how do they commercialise it? This is where TTOs come into play. The HEFCE BCI survey asks universities whether they have an in-house capability to seek out licensing opportunities for its IP. Alternatively, universities may rely on external institutions to licence university IP to the private sector. Hence, this question contains important information with regard to the type of commercialisation model adopted by universities which will be discussed in detail in Section 6. Figure 4 shows that about three quarters of universities have an in-house capability. Nevertheless, the relatively large share of nearly 20 percent of universities that do not have either an in-house capability or external agency is noticeable. Importantly, the share of universities using the services of external agents is increasing, implying that some universities even switch from an in-house capability to an external agent.

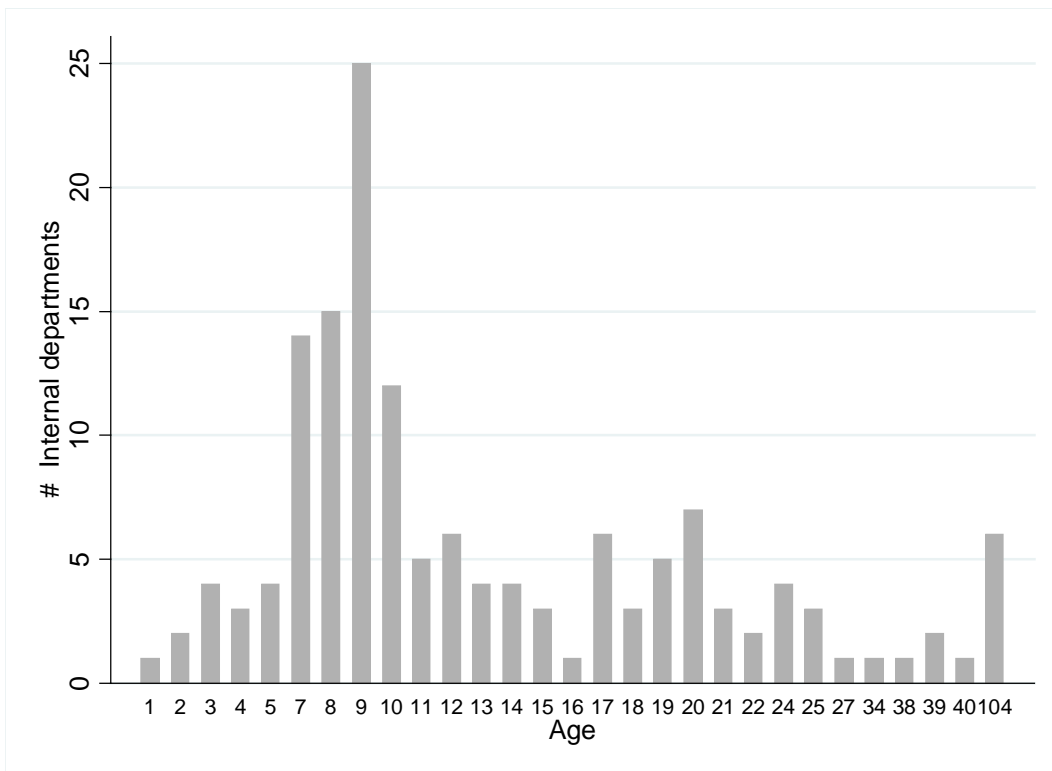
Figure 4: Is IP licensed out through an in-house institution?



Source: HEFCE BCI

Figure 5 shows the age distribution of these in-house departments (counted from 2009). The existence of TTOs appears to be a rather recent phenomenon as the most frequent age is nine years, which means that these TTOs were set up in 2000. At the same time, there are some universities that report to have had some type of in-house institution to commercialize university knowledge in place for more than 100 years.

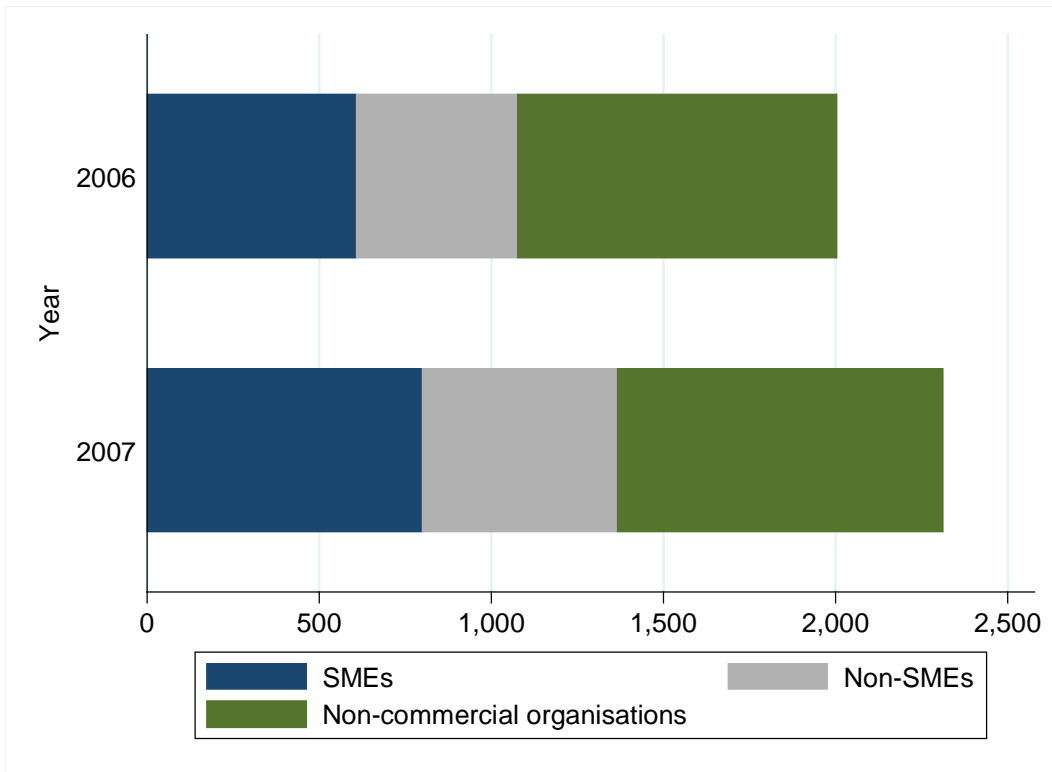
Figure 5: Age frequency distribution of in-house institutions established (2009)



Source: HEFCE BCI

Figure 6 shows the total number of licenses granted by universities in 2006 and 2007. Interestingly, the largest share of licenses is obtained by non-commercial organisations. Among commercial companies, SMEs obtain a larger number of licenses from universities than larger companies. It is important to keep in mind that Figure 6 only informs about the number of licenses and not the value of the underlying IP or any strategic purpose of the acquiring firm. Nevertheless, the figure is in line with the notion that university IP is often far from ready for commercialisation which makes it difficult finding large established firms willing to license these technologies which will be discussed in more detail in Section 5.

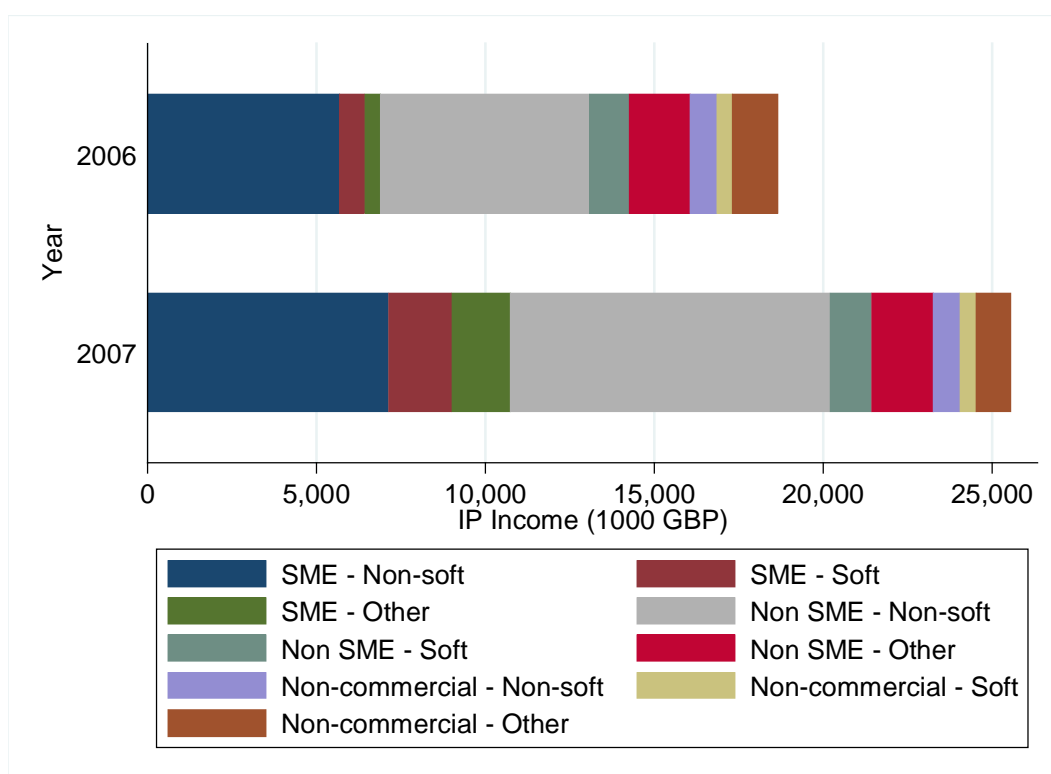
Figure 6: Licence Numbers: Non-software licences granted



Source: HEFCE BCI

In order to account for the underlying quality, Figure 7 plots the income generated from the IP that is licensed to SMEs, large firms and non-commercial organisations. The figure makes clear that most of the income is generated by licensing registered IP to large companies. This implies that fewer, but more valuable, registered IP is licensed to larger companies. In turn, this may imply that larger firms are either better at picking valuable university inventions or that they are in a better position to turn an invention into a commercial success – or both.

Figure 7: IP income by IP type and licensee



Source: HEFCE BCI

Apart from licensing registered IP, universities can employ a range of other channels to transfer and commercialise knowledge (see Section 5). Notably spin-outs are a direct way of capitalising on an invention and the resulting IP. The HEFCE BCI survey asks universities whether they provide specific support to spin-outs. The results are reported in Table 2. The table shows that incubators, training and business advice are the most frequent ways of promoting spin-outs by universities. Since science parks are the most expensive way of fostering spin-outs, it is hardly surprising that 60 percent of respondents do not employ this tool to promote spin-outs.

Table 2: Support for spin-outs

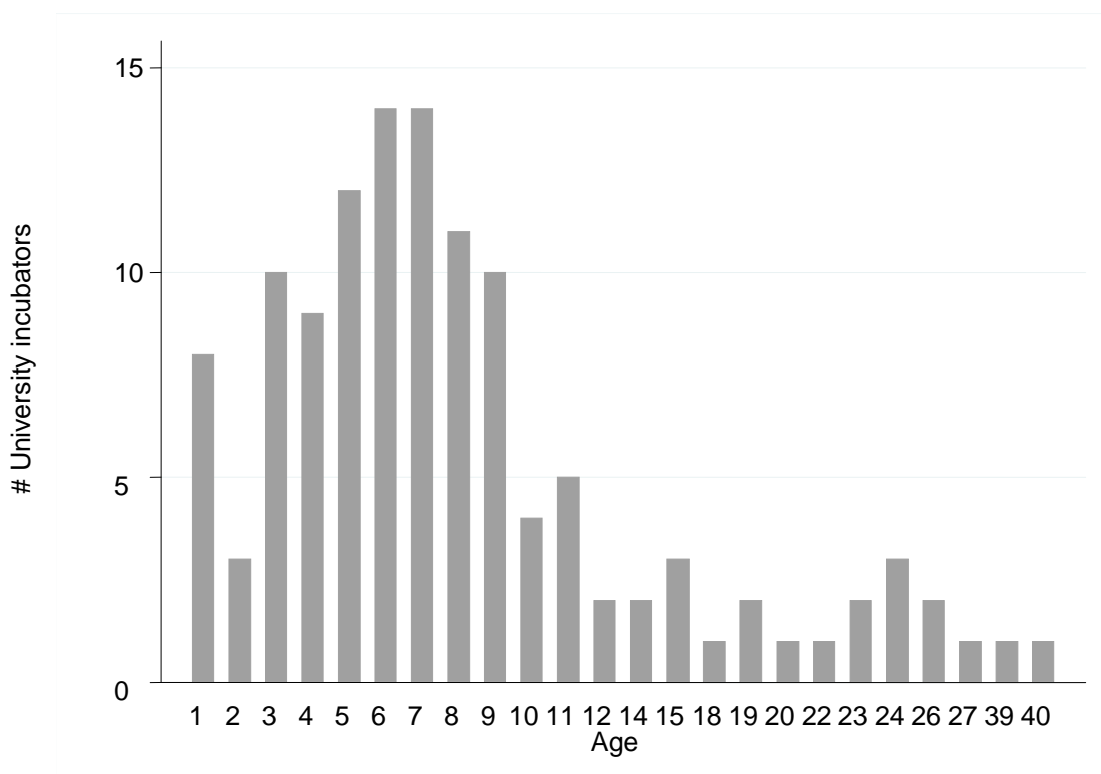
Type of support	HEI		Partner		Both		None	
	2006	2007	2006	2007	2006	2007	2006	2007
On-campus incubators	47%	50%	8%	6%	11%	11%	34%	33%
Other incubators in the locality	9%	8%	41%	47%	10%	9%	40%	36%
Science park accommodation	8%	8%	22%	25%	10%	9%	60%	58%
Entrepreneurship training	51%	51%	4%	4%	31%	34%	14%	11%
Seed corn investment	22%	24%	24%	23%	29%	30%	25%	23%

Venture capital	1%	1%	47%	46%	11%	14%	41%	39%
Business advice	27%	27%	6%	6%	58%	60%	9%	7%

Source: HEFCE BCI

Table 2 shows the popularity of incubators among universities to support spin-out companies. Figure 5 plots the age distribution of the 125 existing university incubators in the UK seen from 2009. It is remarkable that 75 percent of incubators were established since 2000.

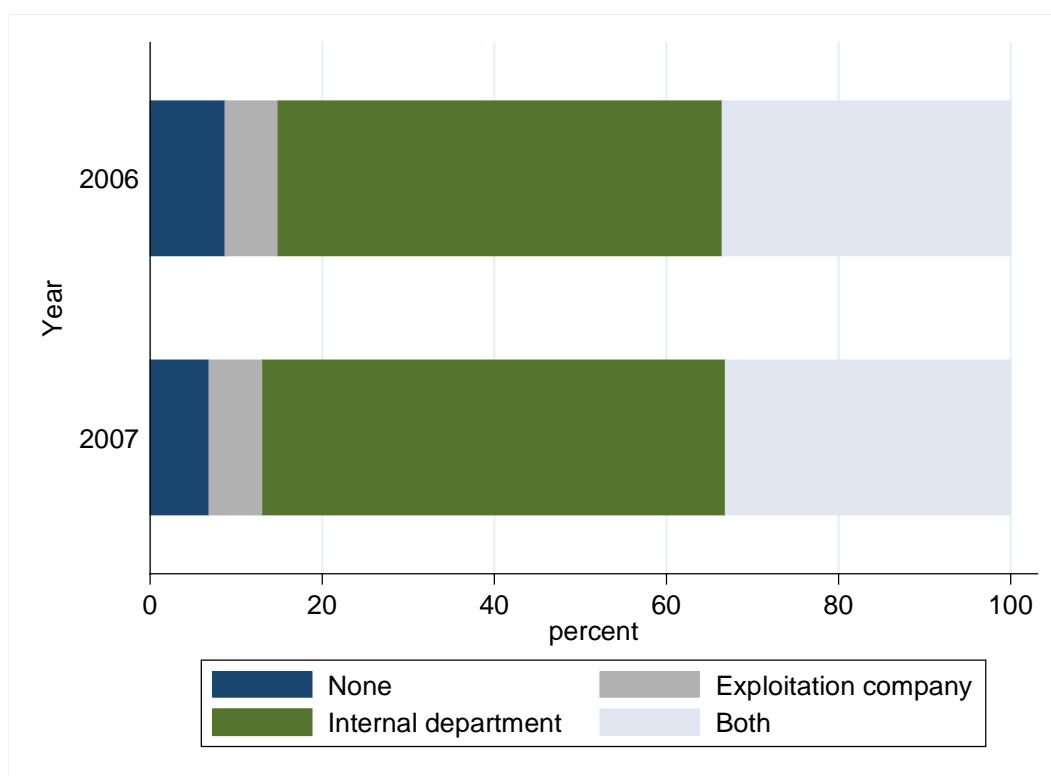
Figure 5: Age frequency distribution of university business incubators (2009)



Source: Helmers (2009)

Another possibility to transfer knowledge is for university researchers to provide consultancies. Universities can set up consultancy organisation for this purpose. HEFCE asks universities specifically whether they have chosen to do so. Figure 9 shows that most universities employ an internal department and only very few have set up a company to exploit this channel of knowledge transfer.

Figure 9: Existence of commercialisation company to manage consultancy links and other external interactions



Source: HEFCE BCI

The UNICO UK University Commercialisation Survey provides additional data on universities commercialisation activities. Table 3 shows a range of metrics that can be used to assess the success of universities in commercialising knowledge through various channels. Note that the samples differ between the HEFCE and UNICO surveys and hence the two are not directly comparable. Table 3 shows that TTOs have grown considerably since 2001 with the number of full time equivalent employees having grown from five in 2001 to eleven by 2005. Also the average number of invention disclosures shows a similar trend increasing from 14 in 2001 to 34 in 2005. However, the average number of patent filings has stagnated between this time period and even fallen in total numbers. License agreements have not seen a corresponding drop probably because of a time lag in the effect of a reduced number of new patents. The total number of new spin-off companies has also fallen in 2005 compared to 2003.

Table 3: Summary data on commercialisation

	2005		2004		2003		2002	2001
	Sum	Mean	Sum	Mean	Sum	Mean	Mean	Mean
Full Time Equivalent Employees	1,154	11	1,019	10	709	10	6	5
Invention disclosures received	3,361	34	2,871	28	2,157	31	18	14
Priority patent applications filed	771	8	885	9	826	11	9	8
Patents granted – total	646	7	569	6	669	10	3	3

Patents granted – UK	118	1	141	1	118	2		
Patents granted – US	73	1	130	1	98	2		
Licences, options and assignments executed	1,416	14	1,406	14	596	8	5	4
Licence agreements Executed	1,143	11	1,188	12	333	5		
Option agreements Executed	72	1	100	1	101	2		
Assignment Agreements executed	186	2	118	1	162	3		
Licences, options and assignments yielding income	1,478	16	2,148	21	775	11		
Licence income received	45,275,333	466,756	40,344,543	395,535	31,370,187	429,729	178,992	165,836
Spin-out companies set up	125	1	229	2	151	2	1	2
Spin-out companies shares held in Existing spin-out Companies shares held in	111	1	118	1	140	2	1	2
Sample size	104							

Source: UNICO UK University Commercialisation Survey 2005

The UNICO Salary and Incentives survey has the smallest coverage with an overall sample size of 63 universities but this may be even lower for certain questions.² The survey asked TTOs whether they set specific annual performance targets at the individual, team and office level. About 80 percent TTOs have overall targets in place and around 50 percent have also targets at the individual and team level. In this survey, universities were asked whether they have a reward and incentive strategy in place for staff involved in technology transfer. Out of 58 respondents, only 16 (28 percent) indicated that they have such a strategy while 42 (72 percent) do not. The most frequently given justification for not implementing a reward and incentive strategy is that university policies do not permit this. The second most frequent justification related to concerns that a conflict of interest may emerge between the university's objectives and staff involved in technology transfer. The survey also contains specific questions about the sources of funding for rewards and specific incentive schemes but the number of responses is too low to consider responses to be representative. Licence income is used in about 60 percent of TTOs as a measure of individual performance which corresponds to a quality measure of technology transfer rather than quantity. Other metrics capturing quantity, such as the number of licence agreements, patents filed, start-ups established, are less frequently used to determine employee rewards.

The survey contains a detailed summary of salaries and additional monetary benefits paid to technology transfer staff. The survey created several salary bands ranging from £15,000 to £125,000 per annum. Table 4 shows a breakdown of salaries by position. The table shows considerable variation in salaries paid for all types of position. Some of this variation is explained by the geographical location of TTOs, i.e., TTOs in the London area pay higher salaries than TTOs North of London. Salaries for directors of TTOs range from £35,000 up to £125,000 p.a. with the majority of respondents paying a salary between £55,000 and £65,000. According to the survey, the highest salaries are paid to directors located in Central London. Technology Transfer and Business Development Managers receive

² Some caution should be exerted as there may be considerable sample-selection at play in the answers received.

very similar amounts, with the majority receiving an annual salary of £35,000-£45,000. The spread in salaries is particularly large for Marketing Managers as it ranges from £15,000-£20,000 to £55,000-£65,000.

Table 4: Summary data on remuneration of TTO staff

Salary (£)/Position	Director	TTM	BDM	IPM	MM	CMLA	TTO
100,000-125,000	5 (11%)	0	0	0	0	0	0
80,000-100,000	8 (17%)	0	0	0	0	0	0
70,000-80,000	8 (17%)	0	0	0	0	0	0
65,000-70,000	8 (17%)	1 (3%)	1 (2%)	0	1 (4%)	0	1 (4%)
55,000-65,000	12 (26%)	6 (16%)	1 (2%)	2 (7%)	1 (4%)	1 (4%)	0
45,000-55,000	5 (11%)	8 (22%)	12 (27%)	7 (25%)	2 (7%)	8 (31%)	1 (4%)
35,000-45,000	1 (2%)	19 (51%)	23 (52%)	13 (46%)	16 (59%)	12 (46%)	6 (22%)
30,000-35,000	0	2 (5%)	5 (11%)	4 (14%)	2 (7%)	5 (19%)	11 (41%)
25,000-30,000	0	1 (3%)	2 (5%)	2 (7%)	4 (15%)	0	5 (19%)
20,000-25,000	0	0	0	0	0	0	3 (11%)
15,000-20,000	0	0	0	0	1 (4%)	0	0
Respondents	47	37	44	28	27	26	27

Notes: TTM: Technology Transfer Manager
 BDM: Business Development Manager
 IPM: Patent/IP Manager
 MM: Marketing Manager
 CMLA: Contract Manager/Legal advisor
 TTO: Technology Transfer Officer

Source: UNICO Salary and Incentives survey

Table 5 looks at the educational background and work experience in technology transfer of the staff according to their position. The figures in Table 5 should be interpreted with caution because of the partly very small sample sizes which make it hard to generalise the patterns found. Nevertheless, the large number of staff holding a doctorate degree is striking. Among directors, technology transfer managers, business development managers and IP managers between 36 percent and 48 percent hold doctorates. Only for technology transfer officers, the share of staff holding only a bachelor degree is larger than the combined share of staff holding masters and doctorates. The table also shows the years of experience accumulated in the field of technology transfer. Directors have clearly accumulated the largest amount of experience in the field. Technology Transfer Managers differ considerably in their experience ranging from 1-3 years up to 19-21 years. Clearly, staff employed as technology transfer officers have much less experience and are probably younger which explains the large share of officers holding only a bachelor degree.

Table 5: Summary data on background of TTO staff

Position	Director	TTM	BDM	IPM	MM	CMLA	TTO
Academic Degree							
Bachelors	7 (19%)	5 (19%)	9 (36%)	7 (41%)	5 (31%)	6 (46%)	9 (75%)
Masters	15 (41%)	9 (33%)	6 (24%)	2 (12%)	8 (50%)	3 (23%)	2 (17%)
Doctorate	14 (38%)	13 (48%)	9 (36%)	8 (47%)	2 (13%)	4 (31%)	1 (8%)
None	1 (3%)	0	1 (4%)	0	1 (6%)	0	0
Respondents	37	27	25	17	16	13	12
Years in TT							
26-33	1 (3%)	0	0	0	0	0	0
22-25	2 (6%)	0	0	1 (6%)	0	0	0
19-21	1 (3%)	1 (4%)	1 (4%)	1 (6%)	0	0	0
16-18	1 (3%)	1 (4%)	0	0	0	0	0
12-15	3 (9%)	2 (8%)	1 (4%)	1 (6%)	0	2 (17%)	0
8-11	14 (40%)	7 (28%)	2 (9%)	5 (28%)	1 (7%)	2 (17%)	0
4-7	11 (31%)	9 (36%)	12 (52%)	10 (56%)	7 (47%)	5 (42%)	3 (25%)
1-3	2 (6%)	5 (20%)	6 (26%)	0	6 (40%)	3 (25%)	9 (75%)
<1	0	0	1 (4%)	0	1 (7%)	0	0
Respondents	36	25	44	18	15	12	12

Notes: TTM: Technology Transfer Manager
 BDM: Business Development Manager
 IPM: Patent/IP Manager
 MM: Marketing Manager
 CMLA: Contract Manager/Legal advisor
 TTO: Technology Transfer Officer

Source: UNICO Salary and Incentives survey

The data so far has looked at technology transfer from an institutional perspective, i.e., from the university's and TTO's point of view. Bruneel et al. (2009) provide data on the industry's view of technology transfer which these authors collected through a survey among firms collaborating with universities through grants received from the Engineering and Physical Sciences Research Council (EPSRC). The EPSRC is UK's largest research council and focuses on engineering and physical sciences. Since these research areas can be expected to lead to highly patentable research outcomes, this survey provides an interesting window to the private's sector perception of university-industry knowledge transfer. At the same time, it is clear that the data obtained from this survey is most likely not representative of the population of firms collaborating with research universities. The survey was undertaken in 2007 and 2008. Bruneel et al. (2009) contacted the entire population of firms that collaborated with universities through an EPSRC collaborative research grant since 1999, although the response rate is with slightly less than 19 percent moderate.³ The largest share of respondent firms belongs to the business services sector (37%) and nearly two-thirds of respondents are SMEs. Importantly, Bruneel et al. follow up on an earlier survey conducted by SPRU in 2004, which allows them to also look at comparisons over time. The survey addresses a range of issues including the

³ The low response rate suggests some caution in the interpretation of the results. However, it remains unclear how important the possible selection bias is since the authors do not report any non-response analysis.

frequency of university-industry interaction, factors influencing the decision to engage in collaborative research, and the type of knowledge transferred. Table 6 reproduces the results of Table 3 in Bruneel et al. (2009) regarding to the frequency of university-industry interaction. The most important result of Table 6 is that informal knowledge transfer in form of conferences represents the most frequent way of university-industry interaction. Another interesting finding is the increase in the importance of the joint creation of physical facilities, a finding possibly partly reflecting the recent sharp increase in the establishment of university incubators described above.

Table 6: Degree of engagement across different types of interaction with universities, 2004 and 2008

Types of interaction	2004	2008
	at least once (%)	at least once (%)
Attendance at conferences	88.8	90.0
Recruitment of graduates	66.6	72.2
Joint research	66.5	65.7
Student placements	58.4	61.9
Contract research	45.6	48.3
Training of company employees	49.2	44.4
Consultancy	42	41.5
Postgraduate training	43.6	40.8
Creation of physical facilities	15.5	34.2

Source: Bruneel et al. (2009)

The survey also asked firms specifically about the benefits from university-industry collaboration and the barriers to successful collaboration. Table 7 lists both benefits and barriers. The most important perceived benefits are the creation of long-term links with universities and the identification and recruitment of employees. This underlines the importance of university graduates in university-industry knowledge transfer also indicated in Table 6. At the same time, commercial motivations, such as IP or the speeding up of R&D projects are far less important in the perception of firms. The most important barriers to university-industry collaboration relate to different research orientations. Firms perceive universities to be long-term oriented while firms are more interested in short-run benefits. However, this must not be confounded with universities being more oriented towards fundamental research, as firms do not perceive this feature as a significant barrier to collaboration. Interestingly, also potential disputes over IP and unrealistic expectations of TTOs with regard to the market potential are perceived as significant barriers. This is confirmed by the fact that firms do not perceive low profile TTOs as a barrier. Firms appear to be able to find appropriate partners within universities themselves, which implies that they have some interest in circumventing TTOs to avoid disputes over the market value of university inventions and the resulting IP.

Table 7: Degree of engagement across different types of interaction with universities, 2004 and 2008

	2004	2008
Benefits	% responding 'very important' or 'crucial'	% responding 'very important' or 'crucial'
Creation of long term links	66.9	52.8
Identification and recruitment of employees	24.8	33.9
Improved understanding of foundations	40.3	26.7
Assistance in problem solving	36.6	24.1
Sources of information for new projects	27.6	23.6
Reducing time for completion of R&D projects	16.2	17.9
Generation of new equipment	19.2	16.8
Generation of intellectual property	9.0	16.0
Generation of procedures or techniques	20.9	16.0
Contribution to successful market introduction	20.6	12.5
Cost reduction in product/process development	10.8	9.3
	2004	2008
Drawbacks	% responding 'agree' or 'strongly agree'	% responding 'agree' or 'strongly agree'
Long term orientation of university research	31.1	65.4
Lack of suitable government programmes to support university-industry interactions	51.9	61.4
Potential conflicts with regards to IPR	32.4	55.6
Rules and regulations imposed by University or Government	42.4	52.9
Unrealistic expectations from TTOs	24.0	49.3
University researchers seeking immediate dissemination	22.3	39.8
Lack of information about what university does	27.8	37.4
Difficulty in finding the appropriate partner	19.9	33.5
University oriented towards pure science	22.3	33.4
Mutual lack of understanding about expectations	25.7	33.0
Absence or low profile of TTOs	16.7	28.7

Source: Bruneel et al. (2009)

4.2 Overview of the success of technology transfer

The success of technology transfer – or, more generally, knowledge transfer – can be thought of as determined by the two fundamental factors of demand and supply. The 'demand side' concerns the activities and strategies of private firms. These firms will develop innovation strategies that focus on specific areas. In basic terms we can think of these as frontier strategies or follower strategies. Frontier strategies involve basic research, working with universities, patenting, as well as development and marketing. In contrast, follower strategies require less basic research and less interaction with universities. The development part of R&D may be substantial, but the need for substantial and long lived contact with universities is likely to be low, although using universities for consultancy or short term contacts may certainly be present. Hence, in an economy where the dominant strategy is follower innovation, the nature and extent of technology will be channelled into specific types.

The other side of the equation is the 'supply side', which can be defined as the structure and incentives present in university research. The nexus of the research funding model, the management of universities and faculties, the employment contracts for scientists and the culture of entrepreneurship and enterprise will all interact to generate a 'supply' of technology.

While it is simplistic to think of technology transfer as a market with a single good, it is important at the outset to realise there are two sides to the transfer. It also helps to understand the basic rationale for IP, since it acts to establish property rights so that, in theory, the market can function more efficiently. Lastly, it highlights the basic rationale of TTOs, which is to act as a middle man between the university and firms as, in practice, academics may not fully understand what it is that they 'supply' and firms may be uncertain of how and where to get what they 'demand'.

The latter issue leads us to recognise that there is, in fact, not a single 'good' being supplied and demanded. University research can be thought of as generating knowledge. Some of this knowledge will give rise to potential inventions (i.e. a body of knowledge that might generate a new product which can be produced, or a new process that improves existing production techniques). In the 'open science' model of university research the academics would publish full details of their research, including any potential inventions, and make this freely available to their peers and also any commercial firms. Commercial firms would be free to convert this research into products and processes that generate profits and ultimately benefit society (called 'innovations'). While this model might appear to encourage wide diffusion of knowledge and subsequent innovation, there are a number of possible shortcomings.

First, even though the basic research may indicate potentially valuable innovations, firms need to make investments to create the innovation. To make such investments firms need the incentive of making future profits, however, the lack of IPRs on the knowledge can reduce or remove this incentive. This is because as soon as the innovation hits the market other firms can freely imitate the product. Note that the publication of the research may have removed any possibility of the firm filing for patent protection, hence the 'open science' model undercuts IPRs.

Second, the 'open science' model is driven by academics interest in publishing and, behind this, a 'curiosity driven' approach to research where rewards emerge mostly from peer recognition and the attitude towards monetary rewards is ambivalent. This can be a powerful motivator and one that has led to many world-changing breakthroughs. Nevertheless, there is some concern that 'open science' can generate too much research that is unrelated to real world problems or too obscure for firms to understand its potential benefits.

The debate about the effectiveness of university research, where 'effectiveness' means the impact on the wider economy, was partly the issue behind the Bayh-Dole Act in the US in 1980. This act made it clear that universities were entitled to own the IPRs that their research could generate. Prior to 1980 the US federal government tended to hold patents on federally funded research and had acquired a large patent portfolio that was little used. Allowing universities to exploit IPRs gave an incentive to the universities to re-focus their research strategy on potential innovations (and the potential licensing fees or other monetary payoffs). Moreover, once IPRs were held it gave firms more security to invest in potential inventions. There has been a lively debate about the causal link between the Bayh-Dole act and an observed rise in knowledge transfer in the US (Cohen et al., 1998; Mowery et al., 2001; Mowery and Ziedonis, 2002). Nevertheless, since 1980, many other countries have followed the US lead in allowing (and encouraging) universities to own IPRs on their research. For example, in 1987 the UK government allowed universities to own IPRs derived from government funded research projects

(Richards, 2009). More recently, in 2002, Germany abolished a privilege which excluded university researchers from a law that obliges employees to disclose job-related inventions and transfers the corresponding property rights to employers (Buenstorf et al., 2009). As noted by Buenstorf et al. (2009), the underlying motivation for the abolishment of the privilege was the idea that TTOs would be better suited to pursue commercialisation of university research than individual researchers.

The movement away from the 'open science' model in the 1980s and 1990s is not without its critics (see, for example, David, 2005), but nowadays many would argue that most research intensive universities follow the 'licensing' or 'innovation' models. These models create the rationale for TTOs discussed in the following section. The report of an EU expert panel in 2004 – entitled *The management of IP in publicly-funded research organizations: towards European guidelines* – stressed the prominence of the 'innovation' model. In their definition the innovation model is "a more active policy of collaborative research with industry, in particular through EC Framework Programmes, and by a pro-active involvement in the creation of spinout companies" (EU, 2004: p.vii). It is the movement towards these models that reinforces the rationale for TTOs.

4.3 The rationale for TTOs

University inventions that are turned into IP and subsequently licensed attain commercial applicability and thus commercial value. This potentially generates benefits for private firms, universities and thus for society as a whole. Licensed university inventions can make a crucial contribution to the birth of new firms and growth of existing firms. Universities can benefit from increased income through licensing and other forms of knowledge transfer, such as spin-off companies. It may also create job opportunities for university graduates and generate local and regional spillovers boosting employment and innovativeness.

Siegel, Veugelers and Wright (2007: 641) argue that "TTOs serve as an intermediary between suppliers of innovations (university scientists) and those who can potentially (help to) commercialize them, i.e. firms, entrepreneurs, and venture capitalists". The relevant question is why is there a role for a TTO to organise technology transfer between universities and the private sector?

To clarify the issues at work, we briefly describe the typical trajectory of an academic invention within the technology transfer system in place in the UK. An academic researcher makes an invention which she is obliged to disclose to the TTO at her institution according to the policies in place at her university. The TTO appraises the invention with regard to its commercial potential and decides whether to attempt its commercialisation. One important aspect to proceed with commercialisation is the filing of a patent application for the invention. As stressed by Siegel et al. (2003), academics often do not readily disclose their inventions which makes it necessary to put in place an appropriate incentive scheme. Moreover, TTOs have to decide on the commercial viability of an invention when the invention is usually still at a very early stage of its development and before any private firm has expressed its interest. Once the patent has been filed, the TTO will seek potential licensees. If the search results in finding either an established firm, or an entrepreneur willing to start up a company based on the invention, the TTO engages in licensing negotiations. At the end of these negotiations stands the signing of a (non-)exclusive licensing agreement. However, the development of a commercially viable product usually requires the participation of the original academic inventor also beyond the conclusion of the license agreement, which implies further involvement of the TTO. As can easily be seen, the process of commercialising university inventions involves a large number of different actors, with different objectives and characterised by diversity in their organisational culture,

all in an environment of considerable uncertainty. It is the role of TTOs to deal with these difficulties and to achieve successful commercialisation of university inventions. Given this overview we can now move to a more detailed analysis of the various issues.

Siegel et al. (2007) argue that there are three broad arguments supporting the existence of TTOs in mediating technology transfer.

(1) Disclosure of inventions and IP ownership

The Bayh-Dole Act in the US gives universities ownership over IP resulting from federal research funding and it also requires academics to disclose their inventions to the university or TTO. In the UK, in line with the Patent Act of 1977, IP is also overwhelmingly owned by universities and academics are generally obliged to disclose their inventions to the university (see Table 1). TTOs, therefore can collect invention disclosures across the entire university and decide whether to transform inventions into IP based on its evaluation of the invention's potential commercial value. This sets clear rules applicable for all university staff and gives the TTO oversight over inventions across a university's entire research spectrum. At the same time, it places the burden of eliciting researchers to disclose invention with TTOs. Despite the basic obligation to disclose inventions, there is evidence that disclosure rates vary across universities and academic departments. Hence, a key role for TTOs is in achieving an optimal disclosure rate via an appropriate incentive structure, monitoring and networking activities. The TTO must then decide which disclosures to seek to protect using IPR. The evidence base surrounding these issues is discussed in Section 8.

(2) Commercialising university IP

Once a TTO has decided to file for a patent, it seeks to commercialise the IPR through diverse channels (see Section 5). TTOs should have a comparative advantage over individual scientists in doing this given their specialisation, experience and contacts. However, Jensen and Thursby (2001) show that a critical element in successfully commercialising IP is the participation of the original inventor. To achieve participation of the academic inventor the contract and license fee have to be carefully designed. There are a number of options including whether a fee is levied upfront and the form of running royalty payments. When commercialisation is done through spin-outs, again there are important decisions about allocation of shares between universities, researchers and external investors. Macho-Stadler et al. (2008) show that an optimal contract involves allocating financial shares of spin-outs to academic inventors, as well as allowing researchers to own part of the IP on which the venture is based.

(3) Information asymmetry and uncertainty

There is likely to be asymmetric information between university researchers and private firms with respect to university inventions. On the one hand, firms may find it difficult to assess the quality and novelty of the invention made, on the other, academics may fail to correctly predict the commercial value of their inventions.⁴ Macho-Stadler et al. (2007) develop a dynamic theoretical model in which TTOs have a role in bridging informational asymmetries between private firms and universities on the quality of inventions. TTOs achieve this role by building a reputation. This may lead TTOs to attempt to

⁴ One may also interpret this situation as one characterised by a total lack of information rather than asymmetric information. This view could have important implications for the rationale for the existence of TTOs, but has not been addressed so far in the literature.

commercialise less inventions than are actually made within the universities to positively influence firms' beliefs about the quality of inventions sold. This may lead to a lower number of licensing agreements but higher income from the agreements made. Macho-Stadler et al. (2007) also argue that size of universities and TTOs matters. They show that very small universities do not gain from pooling their inventions in a TTO. At the same time, this may also be true for very large research departments as they are able to overcome the problem on their own. Hoppe and Ozdenoren (2005) show theoretically that organisations such as TTOs can help firms reduce uncertainty with regard to the future potential of inventions. TTOs, which require an initial sunk investment to build specific expertise, are able to discern promising from less promising inventions and to also assess the quality of potential licensees. This helps to overcome the information asymmetry. Notably, the fixed set-up costs of TTOs can be recovered if the invention pool is large enough as this allows for economies of scope. Nevertheless, the model also shows that there is considerable scope for inefficiencies in commercialisation due to intermediation. Regarding the optimal contract in case of spin-outs under asymmetric information, Macho-Stadler et al. (2008) find that TTOs may have to signal the positive expectations about a spin-off's future success by not only owning IP but also taking financial stakes in the start-up (whereas without asymmetric information TTOs would only own the IP). Lerner (2005) also argues that in the context of university spin-outs, TTOs have a crucial role in overcoming problems emerging from the specific nature of university start-ups by offering formal and informal entrepreneurial education to academic inventors and by playing an 'honest broker' (Lerner, 2005: 54) between academic entrepreneurs and outside investors.

5 The channels of technology transfer

The next stage of our review of the effectiveness of TTOs needs to take a broad view of technology transfer. Without this there is a danger of focusing too much on specific TTO activities. As is well known, the UK government has strongly emphasised the need for improving the quantity and effectiveness of university-business technology transfer in recent years. The White Paper *Our Competitive Future* in 1998 (DTI, 1998) stressed the need for business to develop knowledge-based competition and the role of universities in this. A University Challenge Seed Fund was launched in 1998 and aimed to bring new technology to the market, especially via spin-out companies. The Higher Education Innovation Fund (HEIF) directly funds universities to increase their interaction with business. HEIF 4 allocates up to £150 million per year over 2008 – 2011 (Abreu, 2008). The UK's Research Councils are also increasingly focused on the economic impact of their research and have introduced various changes including academic-business exchange schemes (Warry, 2006).

Technology transfer ultimately occurs via the exchange of knowledge between university academics and firms in the wider economy where TTOs assume the role of an intermediary. The precise mechanisms for an exchange can be numerous and, importantly, it is likely that a series of mechanisms will be at work, either sequentially or simultaneously. Traditionally, the focus in knowledge transfer has been licensing of patents generated by university research and held either by academics or universities. However, the focus on licensing of patents reduces the complex process of transferring knowledge from universities to the private sector to a single, narrow mechanism omitting a large range of other mechanisms which often are not based on formal IPRs.

There is a broad distinction between formal and informal mechanisms. The term informal may appear somewhat misleading as such mechanisms often do involve formal agreements between the involved parties. Examples of such informal mechanisms are: informal social and professional networks, public university lectures and workshops including continuous education, consulting, commissioned research by firms, academic-scientist exchanges and recruitment of university graduates by firms (Yusuf, 2008). Such mechanisms are likely to transfer certain types of knowledge (in particular tacit knowledge) continuously and often without record. More advanced and codifiable knowledge, for example related to inventions or 'break through discoveries', is likely to be formalised into an IPR. In such cases there may be the need for on-going formal technology transfer and also the creation of IPRs. Hence, the formal mechanisms include patents and other IPRs, licensing and royalty agreements, formation of spin-outs and venture capital. The formation of spin-outs is also closely related to the formation of university incubators and university science parks.

There are advantages and drawbacks associated with formal and informal mechanisms which have substantial bearing on their relative effectiveness in transferring knowledge. The advantages of informal collaboration are mostly access to industry funding of basic and applied research, exposure to applied problems allowing the application of basic research results, and the possibility of obtaining new ideas for basic research. The salient drawback of informal agreements is the time needed by academic researchers to develop the relationship and to deliver the agreed product. Licensing in contrast does in principle not require the involvement of the academic inventor. Although empirical work shows that this may also be its main drawback as a large number of theoretical and empirical studies have shown that the involvement of the academic inventor is crucial for the success of the licensing agreement or the spin-off resulting from IPRs.

Below we outline ten formal and informal technology transfer mechanisms. In each case, we provide a definition and some discussion, especially when the mechanism is not a core TTO activity. Core TTO activities are discussed in full in section 8.

1) Formal and informal social and professional networks

Definition: A network is commonly defined as a collection of nodes and associated links. Nodes can be individual researchers, TTOs, universities, firm employees, firms or any other actor. Links, which can be undirectional or directional, can be any form of personal or professional tie or interaction.

As this broad definition suggests, formal and informal networks capture a vast range of interactions between individuals and organisations and thus concern a large number of actors involved in technology transfer. A recent report by Library House (Holi et al., 2008) suggests that networks (in particular social and professional networks between academics and staff of private firms) constitute the most important channel of knowledge transfer. While there exists plentiful empirical evidence of the importance of networks as a channel of knowledge transfer between researchers and inventors (Breschi and Lissoni, 2004; Singh, 2005), the empirical evidence on the relevance of networks in the context of university technology transfer is scant.

2) Continuing professional development and education, including public university lectures and workshops

Definition: Continuing professional development includes any activities conducted by universities to update existing and transfer of new knowledge to professionals in specific areas of (technical) expertise. Teaching is commonly tailored towards part-time adult students with an existing stock of specific knowledge and offers the option of acquiring formal higher education degrees. Public lectures and workshops are events addressing specific topics open to a public audience.

3) Consultancy

Definition: The provision of expert advice to address and solve specific questions and (technical) problems which requires knowledge possessed by academic researchers. It may involve the temporary physical presence of academics in client companies.

Cohen et al. (1998) provide empirical evidence suggesting that consultancy contracts are more important as a channel for knowledge transfer than patents or licenses. Link et al. (2007) present an analysis of survey data collected among 1,514 university scientists and engineers at 150 research intensive US universities in 2004/05⁵ for which they find that 18 percent worked as consultants for the private sector during the past 12 months. They also find a positive correlation between a faculty member enjoying tenure and his engagement in consultancy contracts. Yet, Thursby et al. (2009: 23) state that '[b]ecause consulting is less visible, it is one of the less researched aspects of university to industry technology transfer'.

While being in principle an informal mechanism of knowledge transfer that usually is negotiated directly between individual researchers and companies, consultancy contracts can also be channelled through TTOs or university-owned consultancy companies in a more formal way. If consultancy contracts are negotiated without the involvement of the university, Link, Siegel and Bozeman (2007) suggest that consultancy engagements by faculty should be seen as a substitute to a university's formal technology transfer efforts. At the same time, Mansfield (1995) finds for his sample of 321 university researchers in the US that often problems encountered in consultancy projects motivated researchers to undertake new basic research. This positive view of consultancy engagements by academics is partly confirmed by Thursby, Fuller and Thursby (2009). These authors look at a sample of 5,811 US patents where one or more of the listed inventors is a faculty member in one of 87 US research universities. They find that only 62 percent of patents are exclusively owned by universities. Thursby et al. (2009) explain the relatively large number of patents not held by universities by academics engaging in consultancy contracts which lead to patenting of the resulting invention.⁶ Hence, it appears that consultancy contracts lead to patentable inventions, although ownership of these IPRs remains with companies and scientists.

⁵ The data comes from the Research Value Mapping Program Survey of Academic Researchers.

⁶ Thursby et al. (2009) assume that patents not assigned to universities but containing an academic among the inventors is the result of a consultancy contract if it is less basic in nature than comparable university patents.

4) Joint, contract, and commissioned research, academic-scientist (at firms) exchanges

Definition: Research that is funded to a significant extent by outside companies or institutions that may involve the direct participation of employees of the outside firm or institution and lead to tangible and intangible joint research output in the form of academic publications, reports and IPRs.

This form of technology transfer is limited to a well-defined period of time, commonly one to three and more years (D'Este and Fonatana, 2007). This implies that there is more time for exchange between academic and private sector researchers. Similar to the findings by Cohen et al. (1998), it seems reasonable to assume that research collaboration is more widespread than licensing of IP (D'Este et al., 2005). In their US survey, Link, Siegel and Bozeman (2007) found that 15 percent of academics in their sample co-authored a scientific paper with someone from the private sector. D'Este and Fonatana (2007) use data on academic researchers that received research grants from the UK engineering and Physical Sciences Research Council (EPSRC) during 1991-2003. They look specifically at 3,535 researchers that received grants that included different types of partners such as industry, public organisations, and non-profit organisations. Their data shows that the degree of collaboration varies across discipline with engineering and architecture leading with over 90 percent of grants being of collaborative nature. Their data also reveals substantial heterogeneity among researchers in terms of the network size reflecting previous findings by Agrawal and Henderson (2002) who showed that the distribution of academic researchers engaged in university to industry knowledge transfer is highly skewed.

5) Licensing of patents

Definition: The university as the owner of the patent gives an outside firm or organisation the exclusive or non-exclusive right to use and modify the patented invention. This is different from selling the patent right to a third party (assignment). Royalty schemes can differ and include up-front lump-sum or running payments contingent on the commercial success of the invention.⁷ Instead of license payments also equity stakes in companies may be taken by the university.

Thursby, Jensen, and Thursby (2001) provide evidence collected from TTOs at 62 major US universities providing evidence for the early stage character of university IP at the moment of licensing. Only 12 percent of inventions were ready for practical or commercial use and for only 15 percent manufacturing feasibility was known. The early-stage character is emphasised by TTOs reporting that only 12 percent of licensing deals covered inventions covered by granted patents or registered copyright. Hence, knowledge licensed out by universities is of an early-stage type and commonly remote from commercial application. This has important implications for the type of licensee and the modalities of license agreements. Thursby, Jensen, and Thursby (2001) also provide some evidence on the prevalence of running royalty schemes for licenses as 81 percent of respondents report to 'almost always' include them in license agreements. Also common payments involve patent fee reimbursements and up-front fees. Up-front fees are

⁷ Royalty schemes are important as Lach and Schankerman (2004) provide some empirical evidence for faculty license income to be increasing in the academic inventor's royalty share.

problematic because of the early-stage nature of most university inventions. Licensing is a core activity of TTOs and a full discussion is left to section 8.

6) Other IPRs (industrial designs, database rights, copyright, trademarks)

Definition: Universities generate a range of other IPRs. These are often called 'soft' IP, but can generate royalties and even spin-outs as with patents.

This is an under researched area of university and TTO activity and is in part the subject of a companion paper.

7) Formation of spin-outs and joint ventures

Definition: The British Venture Capital Association defines spin-outs as "a company engaged in business that is dependent upon licensing or assignment of technology for initiation from a public research institute (e.g. university, government laboratory, etc.)" (BVCA, 2005). This may involve universities receiving equity stakes in start-up and established companies in exchange for the right to use university-owned IPRs.

In their comprehensive literature review on academic spin-outs, Djokovic and Souitaris (2008) point out that the formation of spin-outs involved four parties: (1) the university from which the technology originates, (2) the inventor, (3) the entrepreneur that aims at commercialising the invention through the formation of a start-up, and (4) the initial investor. The BVCA report also lists typical characteristics of technology spin-outs. Notably the value of such start-ups derives from long-term potential based on the exploitation of scientific inventions and IPRs. Moreover, due to the high-tech nature of their business, spin-outs initially lack tangible assets and offer and develop products which are largely new to the market. Hence, spin-out companies are usually established in the objective to capitalise on an existing IPR. However, it is also possible to set up a company that capitalises on a business idea that cannot be patented. Spin-outs may also involve the 'transfer of people', such as university inventors or researchers working for the new venture (Djokovic and Souitaris, 2008). In the UK, university researchers have the right to start up companies and own equity stakes of these start-ups. Moreover, there is no UK-wide policy with regard to rules governing equity ownership of academics in university spin-outs which implies that universities can set their own rules (Wright et al., 2009). Spin-out companies are a core activity of TTOs and are discussed in Section 8.

8) Formation of university incubators

Definition: The UK Business Incubation defines business Incubation as "a unique and highly flexible combination of business development processes, infrastructure and people, designed to support entrepreneurs and grow new and small businesses, products and innovations through the early stages of development and/or change" (UKBI, 2007).

As discussed in Section 4, university incubators are a rather recent phenomenon in the UK. Helmers (2009) finds that 80 out of 139 UK universities (58 percent) offer incubator facilities to start-up companies. Interestingly, some universities are associated with more than one incubator which explains the total of 125 incubators found by Helmers (2009). Incubators can differ substantially in terms of type of start-ups hosted (high-tech firms or student ventures) and in terms of their organisation ranging from virtual incubators to incubators physically integrated into large science parks. This is a core activity of TTOs and a full discussion is in section 8.

9) Formation of science parks

Definition: The UK Science Park association defines a science park as “[...] essentially a cluster of knowledge-based businesses, where support and advice are supplied to assist in the growth of the companies. In most instances, Science Parks are associated with a centre of technology such as a university or research institute”.⁸ More specifically, Link and Scott (2006) define university science parks as “a cluster of technology-based organizations that locate on or near a university campus in order to benefit from the university’s knowledge base and ongoing research. The university not only transfers knowledge but expects to develop knowledge more effectively given the association with the tenants in the research park”.

Hence, a distinguishing feature between university science parks and science parks more generally is their geographical proximity to universities. Also note the distinction between incubators and science parks: science parks are not restricted to start-up companies and thus may host large and well-established companies or their subsidiaries. Again, science parks are a core activity of TTOs and a full discussion is in section 8.

10) Recruitment of students from universities by firms

Definition: Graduates from universities are formally employed by companies and are physically located within these companies. They provide the knowledge acquired at the university to the company.

The Lambert Report (2003) and the Leitch Report (2006) provide an overview of the role of graduate education in the UK. An example of a more detailed study is Arvanitis et al. (2008) who survey data on technology transfer activities for 671 Swiss firms. They find that employment of graduates in R&D and contacts to universities through university graduates employed in R&D are perceived by firms as important channels of technology transfer.

⁸ <http://www.ukspa.org.uk/about/faq>

6 Models of TTO operation

Universities use the formal mechanisms described in Section 4 in different way to transfer knowledge. In this section we provide a brief typology of the four most common ways for universities to organise technology transfer.

6.1 The 'Cambridge' Inventor-Ownership Model

In this organisational model, individual academics act as the catalyst in technology transfer activities. This is sometimes referred to as the 'Cambridge model', which is a reference to the situation at Cambridge University prior to 2005. Cambridge University, one of the leading universities in the world, has its name associated with a model that relies on the entrepreneurship of academics themselves. Prior to 2005 the individual academics owned their IP and this allowed any entrepreneurial academics to start their own businesses directly. The advantage of this model is that it gives maximal incentives to the academics and also removes any influence of the university. Assuming that academics are entrepreneurial and that the 'university influence' largely imposes additional constraints and bureaucracy, this model can be very effective. In Cambridge's case there were many examples of successful spin-outs. Library House (2006) estimates that there were 250 surviving companies in 2005 that were started directly from Cambridge University technology transfer (accounting for around £0.5bn in revenue). In some countries, such as Finland, Italy and Sweden, the model where academics own their IP is still widespread and is often called 'professor's privilege'. Although, in some universities within these countries academics may have to sign specific contracts that assign all IP to the university. Other countries, such as Germany in 2002, have opted to abandon the 'professor's privilege' in favour of Bayh-Dole type regulations.

The Cambridge Inventor-Ownership model can have relevance even in situations where there is an established policy that universities have the IPRs. This is for two reasons. First, there is some evidence, especially from the US, that a significant number of academics 'by-pass' the official rules and file for IP in their own name (Markman et al. 2008; Thursby et al., 2009). Second, even when an academic discloses their invention it may be that the university or TTO decides not to pursue formal IPRs. In this situation the university may allow the academic to act as an individual and choose whether to file for formal IPRs.

The advantages of the 'Cambridge model' are that it provides maximal incentives to academic inventors and does not require the setting up of centralised systems. In some universities where there is a long history of decentralised activity (Cambridge and Oxford are examples of this) this may be important. However, the model does rely on academics being entrepreneurial and, in reality, many academics may be solely interested in research. It also means that the individual academic must also coordinate other resources (legal advice, financing, marketing, etc). The model also reduces any incentive for the university to support such activities and limits its ability to coordinate technology transfer activities across research departments.

6.2 In-house model

At the other end of the extreme from the Cambridge model is when the university manages the entire technology transfer process, although this might often be through a particular research department or group. This corporate approach can be seen as 'business development', in the sense that the university

sees itself as a business engaging in consultancy and licensing and, in some cases, spin-outs. An example is Oxford Brookes University which has a Research and Business Development Office with two staff for technology transfer and around £0.6 million in revenue for 2005/6. However, even in this case, external consultants are used. Portsmouth University has a department for Research and Knowledge Transfer Services, which acts as a TTO. These situations represent relatively clear cut cases of the in-house model, although external consultants may be brought in to advise. In many other cases universities retain some, but not all, functions in-house. Imperial College, for example, has a well known TTO called Imperial Innovation, which was listed on the stock market in 2006 (with Imperial College retaining majority ownership), but also has Imperial Consulting as an in-house group (albeit a profit centre) and also an in-house Business Development Unit. In the UK, it is often the case that some in-house technology transfer functions are supported by national or regional government funding (e.g. the Higher Educational Innovation Fund). Hence, in practice the decision is not whether to have a fully in-house model, but rather which parts of the technology transfer process should be kept in-house.

6.3 Establishing a standalone limited company

In this model the university establishes a dedicated, and independent, limited company whose objective it is to act as a conduit between university research and business. The company – whose name often includes both the University name and words like ‘innovations’, ‘enterprise’ or ‘technology’ – is initially resourced by the university, but the underlying objective is that it becomes largely self funding. Its decisions are independent of the university. For example, decisions on when to patent or what incentive contracts to give its staff can, in theory, be made independently. In most cases the university retains a majority shareholding in such companies, but other investors are also allowed substantial stakes. This has the advantage of providing long term incentives to venture capitalists, investment banks and alike to develop the company by using their contacts and skills. It also means that the standalone company takes on some of the features of the hybrid model discussed below. An example of such a company is ULive which is a subsidiary of the University of Liverpool and engages in the commercialisation of IP generated within the university. Since 2007, ULive has been listed on London's Alternative Investment Market (AIM).

6.4 Hybrid models

Before explaining the nature of ‘hybrid models’ some background on the finances surrounding licenses and equity shares relating to IPRs and spin-outs is useful. In particular, there is normally a split between academic, faculty and university in the case of license income. When a spin-out is established the key split is the allocation of equity between academic, faculty, university and any private firm involved in the spin-out. The exact allocation of finances will vary across universities but Oxford University's current allocations are in Table 8.

Table 8: License and equity shares for Oxford University

	Academics	University general funds	Department	Private firms
Net revenue for licenses				
To £50k	87.5%	12.5%		
To £500k	45%	30%	25%	
Over £500k	22.5%	40%	37.5%	
Spin-outs				
Equity share	25%	25%		50%*

Notes: * this includes share to management of spin-out (say 10%). Table based on Richards (2009)

In 2000, Oxford signed an agreement with Beeson Gregory (a stockbroking firm), later to become IP2IPO and now IP Group Plc, to pay £20 million to partly fund a new chemistry building in exchange for half of the University's equity stake (i.e. 12.5%) in any spin-out from chemistry research and half of the University's share in any licensing agreements. IP2IPO subsequently signed similar deals with Southampton University (providing a £5million spin-out fund), King's College London and York University. Oxford University signed another agreement with Technikos worth £12million in 2006 to help funding its Institute of Biomedical Engineering. In exchange, Technikos is to receive stakes in future spin-off companies of the institute.

This type of hybrid model where private firms pay for a stake in university IP and spin-outs has occurred in a number of cases. In 2005, BioFusion paid the University of Sheffield over £8million for a share of medical research IP and spin-outs. Others include Techtran Group (Leeds), Frontier IP Group plc (with Dundee and Robert Gordon Universities), Angle (with Reading University), and IPSO, which focuses on life sciences, environmental sciences and technology (with Loughborough).

The University of Leeds cooperates since 2003 with privately owned Techtran Group (which is since 2005 a fully owned subsidiary of IP Group). In this cooperation, academics are still required to disclose their inventions directly to the university's Enterprise and Innovation Office (EIO) which decides whether to seek IP protection. EIO notifies Techtran of the new patented invention, which Techtran then appraises in terms of its commercial potential and decides whether the invention should be licensed or serve to found a spin-out company. The commercialisation phase of IP is thus entirely dealt with by Techtran. Techtran sees the main advantage in its collaboration with the university in its ability to provide access to initial funding and a large network of partners to help spin-out companies (including accounting, marketing, banking and insurance services). Techtran gains from preferential access to the university's IP and equity stakes in spin-out companies. Notably, it claims part of the share that would otherwise be awarded to the university. This implies that the involvement of Techtran has initially no negative financial implications for the academic inventor.

Frontier IP Group plc which is fully owned by Sigma, a private asset management company, is engaged in long-term partnerships with the University of Dundee and Robert Gordon University. Frontier IP is

listed on PLUS Markets since May 2009. In 2009, Frontier IP Group plc was successful in establishing Robert Gordon University's first private equity fund (RGU Ventures Investment Fund LP) with committed funds of £1.1 million destined specifically for investment in IP.⁹ In addition, Scottish Enterprise's Scottish Co-Investment Fund entered a partnership to potentially invest in university spin-out companies through a matching fund arrangement.

The case of the initially envisaged 20-year strategic partnership agreement between Reading University and Angle plc signed in 2006 is also instructive. According to the university (O'Hare, 2008), the main motivation to partner with Angel was the perceived need for funding, management expertise and resources which was obtained through the agreement. In compensation, Angel received the time-limited right of first refusal to invest in all university IP to be commercialised, a 60 percent equity stake in return for up to £500,000 investment in spin-offs, and a 15 percent share in all commercial returns from IP where Angel chose not to invest covering licensing agreements and spin-offs. The deal came to an abrupt end in May 2007 when Angle retracted from providing funding and consultancy support which led to the termination of the partnership in July 2007. As a consequence, Reading University focused again on strengthening the own in-house TTO.

In summary, the hybrid model has gained rapidly in importance in funding the commercialisation of university IP in the UK. In an interview in 2008, Rob Rule, then the managing director of Techtran, answered the question of whether there are similar models abroad stating "I am not aware of any other country in which this model has grown so rapidly. [...] I am not aware of anywhere that has followed a similar model to ours, raising finance for the specific purpose of being a specialist investor in university IP" (November 2008, Optics & Laser Europe Magazine). This underlines the front-runner role the UK has assumed in this market.

The advantages of such schemes are that they bring finance to the university, which can allow capital projects (e.g. the building of Oxford's chemistry department) and fund creation. They also bring the expertise and contacts associated with stock brokers, venture capitalists and investment banks. This is done in a context of a medium to long term horizon where the private firm's return is closely aligned with the success of the research. In a recent report, Klein (2009) adds the achievement of the hybrid model in often managing to bring spin-off companies within a minimum amount of time to the AIM. One of the controversies of such schemes is whether the initial lump sum, or share of revenues, accurately reflects the benefits and whether the exclusive long-term contracts (usually between 10 and 25 years) are in the interest of universities. Klein (2009) also points out that the aggressive strategy of bringing spin-outs as fast as possible to the publicly traded market depends to a large extent on the willingness and ability of the market to absorb these companies. If this enthusiasm slackens, the hybrid business model may suffer. In more basic terms: do the sophisticated financiers negotiate deals that ultimately do not reward the university appropriately. Pinch and Sunley (2009: 19) cite opinions expressed by spin-out firms resulting from the partnership between Southampton and IP Group stating that "it it demanded a relatively large surrender of equity for relatively small amounts of investment". Moreover, the experience of Reading University cautions that the hybrid model depends on the commercial viability of the private partner. Difficulties on its side may lead to damaging disruptions in the technology transfer process and jeopardise long-term achievements.

⁹ Frontier IP and Robert Gordon University have respectively invested £300,000 and up to £800,000 in the Fund at First Closing.

In summary, while this model is very recent, it has already produced some remarkable success stories in the UK, although there is also some evidence for its limits as it depends on the business success of the private partner company in the competitive market. Knowing that the overwhelming share of TTOs in the UK operates at a loss (Heher, 2006), this is problematic.

Evaluating the issues of effectiveness and fairness of the hybrid scheme is difficult also in light of the few and relatively recent experiences, but the general premise is that both parties need to be well informed in order for outcomes to be effective and equitable. In addition, basic auctioning theory suggests that the seller (the university) should try and have more than one bidder (the financier). Evaluating the effectiveness of such schemes is an important area for future research.

This review of models of TTO operations has shown that in many cases there are a variety of models at work in a university. In most cases the TTO itself is central to technology transfer, but its exact sphere of influence varies. This suggests there is no single, optimal model for a TTO that would apply in all situations. This is also the conclusion reached by Tang (2008) in a review of university IP in the UK. She states "There is no single 'best practice' model for the exploitation of university IP. Successful universities display a variety of approaches and methods for IP creation, management and exploitation" (2008: 1).¹⁰ However, a key issue is evaluating the empirical support for such statements and it is to this we now turn.

7 International Comparisons of TTO effectiveness

A starting point for thinking about the effectiveness of different types of TTO models, and technology transfer regimes in general, is to look at international comparisons. We start with a study that looks at patent citations. Bacchiocchi and Montobbio (2009) find, in a sample of EPO patents (1978-1998), that patents granted to US universities and public research organisations are more likely to be cited than patents belonging to private firms in the US in Chemicals, Drugs and Medical, Mechanical and others. In contrast, no such positive association between university patents and citation frequencies is found for the other countries in their sample, the UK, France, Germany, Italy, and Japan. In another broad-based paper, Aghion et al (2009) look how university patenting is influenced by autonomy (from regional or federal government) and competition (specifically for research grants). They find that more autonomous and competitive universities, in both Europe and the US, are associated with higher numbers of patents. This said, there is considerable variation around this positive association. They also conduct some more detailed analysis of changes in funding to US state universities and again find that more autonomous state universities, which face more competition from private Universities, produce more patents. For our purposes this paper is too limited since a) it does not control for TTOs b) it does not control for patent quality, for example by looking at licensing or business success. Lehrer et al. (2009) also draw attention to competition and autonomy, but stress that a diversified system of funding university research is also important.

¹⁰ Wright et al (2008), in a paper about university-industry links in general, confirm this basic message by stressing that universities need to use different strategies that reflect their research strengths and the region's characteristics.

Bekkers et al. (2006) offer a descriptive comparison of the role played by TTOs in commercialising IP through university spin-outs between the US and the Netherlands. They conclude that TTOs in the US are far better staffed, professionalised and highly specialised resulting in far more effective technology transfer activities than in the Netherlands. They also argue that the pro-small firm bias built in Bayh-Dole, i.e., TTOs must give preference to firms with less than 500 employees, helps in commercialising IP through start-ups. Moreover, Bekkers et al. (2006) also see the clear policies in place at US universities with regard to commercialisation, including royalty sharing and equity stakes in spin-outs, as an advantage leading to more effective technology transfer than in the Netherlands.

While the Bekkers et al. (2006) study indicates that US TTOs are better, Thursby and Thursby (2007) estimate that “a very large” number of US TTOs are a net drain on university finances (i.e., the royalties do not even cover their own costs). Although, overall, license payments are close to 3 percent of research funding in the United States.¹¹ On average in UK universities in 2004, according to survey data in Unico (2005), annual rates of license income (royalties) were around 1 percent of research funding. Although, in directly funded UK public-sector research establishments, recently surveyed by Technopolis (2007), large rises in the number of licensing agreements were found, alongside rising incomes from intellectual property licensing and from business consultancy. There is also some evidence that the UK is more ‘efficient’ at producing university spin-outs than the US, measured by the number of research dollars. On average one spin-off firm is formed for every £15 million of research expenditure in the UK, compared with one for every £44 million in the US (UNICO, 2003).

Conti and Gaule (2009) attempt to provide a more comprehensive analysis on licenses. They seek to understand differences in the ability of TTOs to sign license agreements, specifically between EU and US universities. They use data from recent surveys of TTOs in the EU and the US. The basic data show that the median number of licences for an EU university is four per year, whereas it is 13 for a US university TTO. Similarly, the licensing revenues per university are dramatically lower for EU universities (only 18 EU universities have license revenues greater than 1 million; 71 US universities do so). As discussed above, in the ‘open science’ model it is wrong to use licensing as an indicator of success, in fact, the opposite may be true (i.e. the objective is to disseminate technology at low cost). However, since most European policymakers now accept that the ‘licensing’ or innovation model is often appropriate, these figures suggest European universities in general, and TTOs specifically, are performing poorly. In order to investigate these issues, Conti and Gaule consider licensing to depend on four factors: university research output (publication volume and number of ‘star’ scientists), legal situation regarding academics need to disclose inventions (which varies across the EU), the experience and resources of the TTO (proxied by age of TTO and number of staff), and the demand for technology by business (proxied by GDP per capita at the regional level). Once all of these factors are controlled for, they find that the US advantage in licensing becomes insignificant. These results indicate that the average smaller size and younger age of TTOs in the EU compared to the US are important to outcomes (TTOs in EU have mean age of 10 years compared to 17 in US; mean number of staff in EU is 2.3 compared to 4.6 in US). Also, as expected, allowing academics not to disclose inventions also reduces licensing revenues to university (although there is no information on extent, or revenue generated, by direct academic-business licenses).

¹¹ See also Turk-Bicakci and Brint (2005) for an overview of licensing income among US universities pointing to large disparities among universities in terms of income generated from licensing.

Finally, von Ledebur (2008) argues that both the higher chances of obtaining a patent granted and the shorter time period needed from filing of a patent application to its grant in the US adds to the advantage US universities have in licensing over their European counterparts. Different regulations regarding software patents may further distort EU-US comparisons.

8 Efficiency of TTOs in delivering social and economic outcomes

This section reviews the empirical evidence that is available on the efficiency of TTOs. As has been made clear in Section 4, TTOs are involved in a wide range of technology transfer activities, which means it is very difficult to evaluate the overall performance of TTOs. In acknowledgement of this, most of the empirical studies focus on only one activity, such as licensing or disclosure rates. Clearly this is less than ideal and makes it impossible to provide a clear conclusion with regard to the different models presented in Section 5, but it reflects the complexity of issues at stake. Given the nature of the empirical work, this section is organised into sections that focus on specific TTO activities. With regard to the different methodologies used in the empirical literature, we find two types of research attributable to the complex nature of the research object. On the one hand, there are largely qualitative case-study based studies that rely on in-depth surveys of a small number of organisations and actors involved in technology transfer. On the other, there exists some work attempting to quantify for example the output of TTOs and to relate it to measured inputs. Nearly all of this work does not go much beyond pointing out correlations between the variables as establishing causality is a challenging task in this context.

8.1 The identification of inventions and generation of IPRs

One key aspect of TTO performance is the generation and identification of IPRs. This section considers the empirical evidence on these issues. It is clear from the above discussion that IPRs in themselves cannot be the sole indicator of TTO performance. Nevertheless, they are an important issue and one worthy of detailed discussion.

The 'applied' vs 'basic' research debate

An initial issue to consider is whether the pursuit of IPRs biases the type of research conducted at universities. A distinction is often made between 'applied' research, which in simple terms is focussed on innovation, and 'basic' research, which is focussed on understanding the nature of the world. It is clear that both types of research are necessary, but there is a concern that the relatively recent importance attached to TTOs, university-business links and IPRs may be creating too much 'applied' research (David, 2001, 2005). While this might be beneficial in the short run it could be detrimental in the long run.

Although the evidence base on whether there is a 'detrimental bias' is far from conclusive, it appears to have relatively little support. Zucker and Darby (1996) found that prominent researchers in biotechnology had outstanding research records even though they were involved in patenting and other forms of commercialization. Similarly, Czarnitzki and Toole (2009) find that US biomedical scientists that leave to become involved in a commercial project have just as good publication records if they return to academia. There is also some evidence that researchers with commercial interests tend to reinvest some of the funds in new equipment and student support (Siegel et al. 2003). Fabrizio and Di

Minin (2008) find that patenting and publication by university faculty members are complementary. Although publications are not a direct measure of basic research, such evidence still suggests the best researchers can do both applied and basic research. However, there are some studies that suggest commercial links can be detrimental. Louis et al. (2001) found that university and research institute scientists with commercial links tended to reject requests for research results from other academics more than academics with no such commercial links. Czarnitzki et al (2009) consider a data set of 4,737 patent applications (1978-2000) that have one or more German academics as inventor(s). They find that companies are much more likely to have agreements involving patents that are 'less complex' and focused on the short run (as assessed by patent citations and patent scope metrics). They suggest that firms avoid the more complex, long run patents – even though these may have higher value (since firms may lack the advanced competencies to absorb and develop the knowledge associated with such patents). These results suggest a greater emphasis on university-business links may impede fundamental research.

The disclosure of inventions

The starting point for a TTO is to have a steady stream of disclosures from academics (or faculties). Ideally, the disclosure of all inventions that have the potential to be patented (or protection by other IPRs) should occur.¹² In practice, there is widespread debate over the proportion of 'potentials' that are disclosed and the 'quality' of disclosures. Surveys of faculty and TTOs in the US indicate that not all inventions are being disclosed (Siegel et al, 2004; Markman et al, 2008), but gaining accurate data is difficult.¹³ Markman et al. (2008) find that over 42 percent of the 3,200 patenting scientists in their sample of 54 US universities bypassed their university at least once between 1989 and 2003 when filing for a patent. Out of the total 7,650 patents filed by these scientists, 2,557 (33 percent) were found not to be owned by universities. Thursby et al. (2009) offer a more nuanced view. For their sample of 2,900 patenting scientists and engineers in 87 universities, who appeared as inventors on patents applied for in 1993, and/or granted in 1997, 1999, and 2004. Out of the total number of patents, Thursby et al. find 26 percent to be assigned solely by private companies. However, Thursby et al. argue that most of these patents emerged from consultancy contracts between firms and faculty members and should therefore not be regarded as bypassed. They estimate the share of bypassed patents at only around 15 percent which is nevertheless considerable.

One reason for non-disclosure, and the by-passing university rules by a researcher, is to exploit the IP directly (clearly this is only an issue where university IP rules require disclosure). The extent to which by-passing occurs is related to incentives and culture (relating to university, faculty and

¹² Thursby, Jensen, and Thursby (2001) provide empirical evidence resulting from a survey of 62 US universities that the number of patent applications by TTOs increases one-to-one with an increase in the number of disclosures. They also provide some quantitative evidence suggesting that royalties increase with the share of university inventions licensed at more advanced stages of development. This is in line with the view that the large uncertainty attached to early-stage inventions makes it difficult for TTOs to negotiate large royalties.

¹³ Note also the title of Jensen et al. (2003) 'Disclosure and Licensing of University Inventions: The best we can do with the s**t we get to work with', which indicated the views of some TTO directors.

entrepreneurship more generally). The 'incentives' are a package of direct financial payments and related benefits (including kudos) that a disclosure sets in place (see Section 5 and 6).

Jensen, Thursby and Thursby (2003) report survey evidence suggesting that only a share of all inventions is actually reported to TTOs. Reported reasons for low disclosure rates are manifold, including a lack of awareness of the commercial potential, concerns over the need for further time investment to promote the commercialisation of the invention, and the desire to circumvent the TTO to profit from the invention directly. Therefore, in order to incentivise researchers to disclose their inventions, TTOs need to put in place appropriate incentive schemes. Such incentive schemes are applicable both to generate IP to license out as well as start-up companies. The importance of the incentive scheme is confirmed by empirical evidence by Lach and Schankerman (2004) who find royalty shares allocated to academic inventors to be positively correlated with licensing income. The need for specific incentive schemes is also supported by Jensen, Thursby and Thursby (2003), who model theoretically a researcher's decision problem whether, and at what stage of the development process, to disclose an invention to the TTO. In their setting, the researcher's faculty acts as an agent of the university administration whereas a TTO serves both the faculty and the administration. The university administration sets a university-wide binding share in licensing income. Once an invention is disclosed, the TTO decides whether to commercialise the IP and determines the resulting licensing income. The model yields the prediction that higher quality staff discloses a larger share of inventions early in their development phase which confirmed by their survey data of 62 TTOs at US universities. Their empirical application also provides descriptive support to the notion of a TTO as a 'dual agent'. Hence, the reliance on researchers' willingness to disclose inventions implies that TTOs act not only as a mediator between inventors and outside firms as suggested by Siegel et al. (2007), but also to bridge possible diverging interests between a university administration and individual researchers.

Owen-Smith and Powell (2001) collected data on two research intensive US universities through interviews to investigate motivations of academic inventors to disclose their inventions. They find that the beliefs scientists hold about the benefits attached to patenting are crucial in their decision to disclose their inventions. Owen-Smith and Powell (2001) argue that the differences in disclosure rates found between the two universities can be explained mainly by the perceptions of academics of the efficacy of their TTO. However, according to Owen-Smith and Powell (2001), also the wider institutional environment forms scientists' beliefs about the benefits attached to disclosing and patenting their inventions. As the main institutional factors, Owen-Smith and Powell list awareness among scientists of prior patenting success and commercial activity, a supportive peer environment, and commercial success translating also into academic recognition.

Larger sample empirical evidence on incentive packages to encourage disclosure is scarce. As might be expected, Markman et al. (2008) find for the US that larger royalty payments to scientists and their faculties reduces by-passing and also autonomous TTOs reduce by-passing. This they attribute to autonomous TTOs having an 'open house' approach, with frequent visits to faculties, and a clear message concerning incentive packages. However, they also find that larger universities and more entrepreneurial environments increase by-passing, and that higher quality inventions (as proxied by patent citations) are more likely to by-pass.

Overall, despite refined incentive schemes in place employing different ways of remunerating researchers, it is unlikely to achieve full disclosure of inventions to TTOs. While the In-house Model, the Stand-alone Company model, as well as the Hybrid Model crucially rely on disclosure, the 'Cambridge' Inventor-Ownership Model does not. The reality that academics choose to a significant extent to by-

pass the technology transfer scheme in place may favour the decentralised 'Cambridge' Inventor-Ownership Model.

The decision to file for IPRs

Once a disclosure has been made it is the TTOs role to decide on whether to take out formal IPRs. This is a decision about commercial possibilities, which must be weighed against the costs of obtaining IPRs. This is an area where the experience of both the TTO office and its staff are very important. We have already noted that many TTO staff have PhD's, but in this instance it is commercial experience and contacts that are critical. Here a centralised organisation of technology transfer is at an advantage over a decentralised model where individual researchers have to take these critical decisions based on their own (limited) information set. Nevertheless, financial resources may be the limiting factor in TTOs decision to obtain formal IPRs.

One issue stressed by Richards (2009) is the paramount importance of being absolutely clear that the IP does indeed belong to the University before the TTO starts the process of filing for patents, etc. Since academics undertake a range of research and consultancy for different organisations, it is important to make sure that none of these involved a contract where IP was shared or allocated to other parties. At Oxford University the Research Services Office vets all research contracts signed by academics. Richards (p.19) states "it is all too easy for a researcher to accept funding for a post-doctoral assistant but in so doing sign away their rights not only to work legitimately claimed by the backer, but also to all similar work for all time." Empirical studies that investigate the relationship between decisions on filing and aspects of TTO performance appear absent.

The role of IP strategy

Various commentators point to the need for a clear, stable and well publicised IP strategy on behalf of universities. Further, some stress the importance of IP being a crucial link in establishing productive university-business links. For example, Paul Tiltman and Richard Ball state "At Exeter, as with many Research-led Universities, the primary purpose of focusing on IP is to drive collaborative research engagement with external organizations," and "The use of an effective IP policy, with good rewards for the inventors, that allows early disclosure of progress on research projects, buys time and allows early filings of disclosures, which not only adds value, but allows publication in a timely and effective manner."¹⁴ Research reported on in the Times Higher Education Supplement (2008)¹⁵ also suggests that many universities are relatively poor in exploiting their IP.

While such views on IP strategy may appear common sense, there are dissenting views. The Lambert Review (2003) argued that fixation on IP could sometimes disrupt university-business technology

¹⁴ This is a web page summary of contribution to The European Business Review at <http://www.europeanbusinessreview.com/?p=989> accessed Sept 2009. Paul Tiltman is Head of IP & Commercialisation, University of Exeter, and Richard Ball is Head of Economic Development, Exeter City Council, UK.

¹⁵ The article is entitled 'A penny for your thoughts' by Hannah Fearn (28/2/2008).

transfer by creating a barrier to collaboration. Wellings (2008), in a review of university IP entitled 'Intellectual Property and Research Benefits' also highlights the possibility of universities becoming overly focused on IP, he also added (Wellings, 2008: 5) "[e]arly over-valuation of the worth of IP can result in university staff being concerned over selling key IP too cheaply and industry representatives worrying about disproportionate royalty costs". It is clear, therefore, that there is a balance to be made between using IP as part of efficient structure for technology transfer and allowing IP to create obstacles. Wellings (2008) provides a series of recommendations that provide more detail to this end.

Hall et al. (2001) use information on the Advanced Technology Program (ATP) in the US. The ATP has the objectives to commercialise new scientific discoveries and technologies rapidly and refine manufacturing technologies. It provides public funding for research undertaken by private firms. Hall et al. consider 38 randomly selected projects funded by the ATP between 1993 and 1996. These projects cover single participant projects, as well as projects jointly undertaken with other organisations. Hall et al. report that a third of the lead private sector participants in the 38 projects indicated that IP issues were an insurmountable barrier in collaborating with universities. The analysis by Hall et al. (2001) suggests that the larger the ATP share in project funding, the larger the chance that IP emerges as an insurmountable barrier to collaborate with a university. This is interpreted as evidence for a conflict between firms' desire to appropriate research results of probably more basic nature and the university's desire to publish the results. They also find that IP as a barrier is more likely the shorter the project horizon. This is related to the uncertainty involved in research which mitigates instant concerns over IP that may eventually result from a long-term project. More surprisingly, past collaboration with universities is positively associated with lead participants regarding IP as an insurmountable barrier. Hall et al. interpret this as evidence of learning about university IP policies by private firms which makes them aware of problems related to IP in working with universities. Apart from this study, there appear no empirical studies that investigate the relationship between IP strategy and technology transfer outcomes.

8.2 Commercialisation success

There is a great deal of interest in assessing the commercial success related to TTO technology transfer activities. At the outset, it is important to realise that there are a range of ways of assessing commercial success, with many of these requiring looking back over many years to assess the performance of the private firms involved. For example, one metric of commercial success is the survival rate of the firms involved. However, it is possible to increase survival by subsidising such firms, which means metrics of 'success' must be treated with caution.

Reputation of TTO

An issue already mentioned is how the reputation of the TTO can influence its success. As noted above, disclosure rates may be influenced by academic perceptions of the effectiveness of the TTO. Equally, the ability of the TTO to attract interest from private firms will depend on its reputation. Reputation is important due to the problems of asymmetric information. It also creates a 'chicken and egg' situation where a reputation is needed to attract commercial interest, but one cannot obtain a reputation until one has had a number of commercial successes. Empirical analysis – in a range of contexts – confirms that the age and experience of the TTO is positively associated with its performance (e.g. numbers of patents or licences). It also suggests that a critical part of establishing a TTO is to generate a reputation. For smaller universities, this could involve pooling inventions into a common TTO, or

bringing in external partners that can help with establishing a reputation. In this respect, more centralised models of technology transfer, i.e., the In-House Model, the Stand-alone Model and the Hybrid Model offer a substantial advantage over the 'Cambridge' Inventor-Ownership Model in particular for younger academics that may have less chances to rely on their own reputation to market their inventions. This may be particularly important as Fini et al. (2009) suggest a positive correlation between the age of an academic and his likelihood to found a company based on a patent.

Organisational Structure of TTO

Bercovitz et al. (2001) use a case-study approach to analyse the organisational structures of three TTOs of US research universities, Duke University, Johns Hopkins and Pennsylvania State University. Bercovitz et al. (2001) define three performance measures of TTOs according to which organisational structures adopted by these universities are evaluated: Information processing capacity, coordination capabilities, and incentive alignment properties. While according to Bercovitz et al. (2001) all three universities are considered to be 'best-practice' institutions with regard to technology transfer, there exist substantial differences in their respective organisational structures. Bercovitz et al. (2001) argue that the history, culture and norms in place at each university exert considerable influence on the organisation of technology transfer activities. As such, they find Johns Hopkins employs a decentralised organisational structure, with a fragmented technology transfer system spread over four widely autonomous units that are only loosely connected. Duke University in contrast has a single centralised unit. Bercovitz et al. (2001) argue that while the decentralised model optimises unit-level information processing capacity and unit-level incentives, which results in larger numbers of disclosures and higher average licensing income, the centralised model results in more coordination across units and incentive alignment. This results in a larger number of client firms that are shared across units (those that deal with licensing and sponsored research respectively). Pennsylvania State University has adopted a centralised administrative office with decentralised units. According to Bercovitz et al. (2001), this offers more across-unit coordination and incentive alignment than the model adopted by Johns Hopkins. While this type of research is very valuable to discern between TTOs that seemingly employ the same technology transfer channels, it is based on mostly qualitative information collected through in-depth interviews which limits the size of the sample and makes it difficult to generalise the results. Nevertheless, this discussion on the organisational structure of TTOs is closely related to the discussion of different technology transfer models in Section 6. It makes clear that there is no empirical work directly assessing the different models and comparing their relative performance, mainly due to the need for very detailed information of mostly qualitative nature.

Licensing

Licensing agreements can be complex as they also involve issues such as the academic's rights to publish the corresponding research results in academic journals. The main difficulty, however, in forming license agreements is in the evaluation the commercial value of a license. There are also considerable time lags between the licensing out IP and the commercial success of the resulting product. Jensen and Thursby (2001) indicate that only a small fraction (12%) of licensed inventions can be readily commercialised. Hence, licensed IP requires considerable additional investment and

potentially cooperation between the licensee and the original academic inventors.¹⁶ This implies that while the main income from licensing accrues from royalty payments, licensing may also create demand for other more informal technology transfer services such as consultancy and contract research. Lach and Schankerman (2004) show that the distribution of returns to licensing is highly skewed. In their data on US university license agreements, 96 percent of all license agreements generated income of less than US\$ 50,000. There are very few highly valuable licenses that generate large incomes for the university (the most famous example is the Cohen Boyer gene splicing technique patented by the University of California and Stanford).

The large uncertainty implies that license agreements are highly negotiable. Hence experience and relative bargaining power play an important role in these agreements. Thursby, Jensen, and Thursby (2001) report survey evidence suggesting that due to the early-stage character of university inventions, they are more likely to be licensed to small firms than to large established firms which was confirmed by Figure 6 which shows that SMEs are also important licensees in the UK.

Spin-outs

There are several famous examples of hugely successful companies that originated in university spin-outs, Cisco Systems, Netscape Communications, Google in the US, and Oxford Instruments and Oxford Glycosystems in the UK. Note that some of these companies did not base their incorporation on formal IPRs, such as Google.¹⁷ Such successful ventures can create colossal returns for universities and academic inventors.¹⁸ Yet, there is considerable uncertainty paired with such large potential which can make it difficult to obtain outside venture funding (Lerner, 2005). Moreover, while there are a number of impressive successes, this reflects that the entire outcome distribution is skewed with the overwhelming share of firms producing only modest returns. This, in turn, means it can be complex to undertake empirical analysis, since one cannot rely on standard measures of central tendency (e.g. means or medians). Nevertheless there are a range of empirical studies.

The notion of a TTO as a dual agent, as discussed above, is not only relevant for invention disclosure but also at the commercialisation stage. Clarysse et al. (2007) argue that spin-outs originated by a TTO are larger at the moment of incorporation than firms started by individual researchers because universities form overly positive expectations about its market potential. Yet, this TTO effect is found not to persist as TTO-backed spin-outs are not more successful in raising subsequent funding (i.e. compared to start-ups without TTO support). These findings are obtained for a sample of 97 spin-outs from five European countries (Germany, Belgium, the UK, France, and Italy) and suggest that the dual agent role may lead, in fact, to suboptimal outcomes.

¹⁶ Particularly, biomedical inventions require large-scale additional investments as several test phases have to be passed in order to obtain approval for drugs.

¹⁷ This is a point made also by Fini et al. (2009) who conduct a large-scale survey among scientists at US universities to find that a large share of spin-off companies is not based on patent rights.

¹⁸ The Times Higher Education Supplement (20 January 2006) lists UK's top academic entrepreneurs who earned considerable wealth through their academic spin-offs in the fields of physical and chemical sciences, mechanical and electronic engineering and computing (www.timeshighereducation.co.uk/story.asp?storycode=200859).

Feldman et al. (2002) list the main advantages attached to holding equity instead of reaping licensing income. First, holding equity means that gains depend on the overall destiny of the company rather than the success of a single product. Hence, even if the product based on the licensed IP fails to generate income, the company may still prosper due to other products and hence the university gains regardless. Second, holding equity may also reduce uncertainty attached to the university invention as universities can wait until they have learnt about the commercial viability of their IP before selling off their equity stakes. Moreover, equity may help aligning university and firm objectives which helps avoiding future conflict of interests and litigation over IP. Third, it can have a signalling function strengthening the entrepreneurial image of a university. This argument also applies to firms that may use the fact that a research university holds equity to signal about the quality of its innovation and faith in its future development. This may help the firm to raise funding from third parties.

There are also risks associated with this more direct involvement of universities. In particular liability for product defects and negative publicity may be consequences. It may also divert the university's attention from its original role and cause significant financial losses to universities (Lerner, 2005, gives some examples). Nevertheless, Feldman et al (2002) report results from a survey indicating that 70 percent of research universities in the US included in their sample frame participated in at least one equity deal, which shows how widely distributed this form of technology transfer is. However, there is a risk that conflicts of interest arise between the university and individual researchers, as well as society as a whole. Individual researchers may divert attention from their university duties and exploit university resources in favour of the company they hold equity in. Also, universities may face decisions that represent a trade-off between promoting the interest of a start-up they partly own and society as a whole which jeopardises the traditional role of a university to promote the overall good of society. Matkin (2001) lists a number of policies taken by US universities to avoid such conflict of interest. He states that in the US it is common for universities to limit the equity stake in companies to 10 or 20 percent in order to keep their influence limited. Similarly, some universities also choose not to vote as shareholders in companies that have equity stakes in in order to avoid getting trapped in controversial decisions. A university may even impose on itself restrictions with regard to the management of companies in which it holds stakes. As such, a university may choose not to serve on the management board of a company altogether. This may also involve rules about the timing when equity stakes have to be sold in case a company goes public in order to avoid long-term involvement of universities in companies.

Meyer (2006) analyses a dataset of 530 inventions by Finish university researchers that were patented at the US PTO, finding that only 15 percent of these patents are used in start-up companies (most patents are used by established large firms). Unfortunately, the data used in Meyer (2006) does not answer the question whether more valuable patents are used to start-up companies, or rather end up being licensed to large companies.

Bray and Lee (2000) compare the average income generated by licensing against the average value of equity sale. They estimate the average value of a license in the US in 1996 of nearly US\$ 64,000 while a conservative estimation of the average equity sale is nearly US\$ 140,000. Although this comparison is based on a very small sample of spin-outs, and is possibly subject to sample selection, it provides some suggestive evidence of the relative returns of the different commercialisation channels.

While these studies suggest there are benefits to spin-outs some concerns have also been raised. The Lambert Report (2003: 60) suggested that the number of spin-outs was rising too quickly, with too many poor quality spin-outs being supported. The Lambert Report suggested the proportion of start-up

finance supplied by the private sector is an important indicator of quality. Van Geenhuizen and Soetanto (2009), in a study of spin-outs from Delft University of Technology (the Netherlands), lend some support to such a view since they find high survival rates for spin-outs and suggest this is due to over-subsidising. However, there is limited empirical evidence on these issues.

Incubators

As discussed in Helmers (2009), university business incubators provide start-up companies with a range of support measures including physical space within the incubator building, training and coaching, business contacts, access to finance etc. University incubators have the additional advantage that they can draw upon the resources available at the university, including academic support, access to research facilities, as well as easy access to the student pool to recruit employees. Nevertheless, to our knowledge, there exists no research on the relative effectiveness of incubator facilities offered by universities themselves and those offered by external agencies.

The notion that incubators provide a safe environment for start-ups is supported by Schwartz (2009) for Germany who finds a negative correlation of firms' leaving an incubator and subsequent firm survival within three years of graduation. Schwartz shows that the largest drop in survival among firms graduating from an incubator occurs immediately after graduation. This can be interpreted as evidence in favour of a sheltering environment provided by incubators. Moreover, Schwartz finds that six years after graduation, about a third of former tenants have gone out of business, which is a considerable share of firms. For comparison, Helmers and Rogers (2008) find a similar share of failures for the entire cohort of new firms in the UK during a similar time period. This may question in how far incubators help firms to survive beyond incubation.

In addition, Helmers (2009) reports evidence that market entry of firms through incubators have had a significantly positive effect on incumbent firms' patenting activity where this effect was found to decay with distance between incubator and incumbent. This evidence can be interpreted as support of the commonly encountered assumption that incubators not only increase chances of success for their tenant firms but also generate local and regional spillovers.¹⁹

Science parks

Although science parks are conceptually distinct from the operations of TTOs, in practice science parks and TTOs are complementary. Section 5 has already given a standard definition of a science park, but it is important to note that there are some variations. In the US the term 'research park' is common and the General Accounting Office (GAO, 1983, p. ii) defines university-related research parks as "clusters of high technology firms or their research centres located on a site near a university, where industry occupancy is limited to research-intensive organizations." In the UK, the term 'science park' is often used and, again, Monck et al. (1988, p. 62) point out: "There is no uniformly accepted definition of a Science Park [in Britain] and, to make matters worse, there are several terms used to describe broadly similar developments—such as 'Research Park,' 'Technology Park,' 'Business Park,' 'Innovation Centre,' etc." In any event, research or science parks all have some element of encouraging the formation of knowledge-based firms within an environment that is active in technology transfer from

¹⁹ See website of UK Business Incubation (UKBI).

universities. It is for this reason that the effectiveness of TTOs overlaps with the prevalence and scale of parks and, in turn, their efficacy.

In the US the first parks included Stanford Research Park (established in 1951), Cornell Business & Technology Park (established in 1952), and the Research Triangle Park of North Carolina (established in 1959). In the UK, the first science parks were established by Cambridge University and Heriot-Watt in 1972. By 1992 there were 32 parks and by 1999 there were 46 (Siegel et al, 2003). Link and Scott (2007) review the formation of university science parks and note that their number rises considerably at the end of the 1970s and early 1980s. Siegel et al. (2003) conjecture that the emergence of science parks is related to increased efforts to intensify knowledge transfer and the strengthening of university ownership of IP. Link and Scott (2006) attribute the rise in numbers of science parks to the desire among private companies to engage in research collaboration with universities. There is no properly developed theory explaining the emergence and presence of science parks. However, the location of them close to a university, as well as close to other technology intensive firms, should increase the scope for knowledge spillovers and other forms of support received. Location within a science park may also give firms higher visibility and credibility with regard to its prospects for its future development.

The empirical literature is better developed than the theoretical and has recently been reviewed by Link and Scott (2007). They classify the empirical literature into several fields. Studies in one field look at the determinants of firms' decisions to locate in science parks. They cite evidence by Westhead and Batstone (1998) that firms' main motivation is access to university resources and academic staff. Leyden et al. (2008) estimate the likelihood of a firm being invited to locate at a university science park and find that the amount spent on R&D is positively correlated with the probability of being invited. This is interpreted as a sign that science parks are concerned with maximizing inter-firm spillovers (although there is potentially a serious selection problem in their analysis). Link and Scott (2003b, 2006) use data on a sample of science parks in the US and relate employment growth within science parks to a number of variables. They find that the distance to the university is inversely correlated with employment growth. Link and Scott (2007) also cite some studies using UK data that assess the comparative performance of firms located on science parks and outside firms. For example, Siegel et al (2003) conduct an analysis on the relative performance of firms in UK science parks compared to a 'control group' of similar firms not in science parks. Their paper looks at the R&D effectiveness of 89 science park firms and 88 control group firms in 1992. R&D effectiveness is assessed by new products, patents and copyrights. They find some evidence that science parks foster greater R&D effectiveness, although they note that the results are preliminary. The evidence from other studies cited in Link and Scott (2007) is mixed, with some studies finding no statistically significant difference (Westhead, 1997) and others finding some differences in innovative output (e.g. Siegel et al., 2003). In summary, Link and Scott (2007: 662) state "In sum, URPs [university research parks] are not well understood and attendant research on them is just beginning to burgeon. We speculate that this gap in understanding stems from the lack of well-defined constructs about what constitutes a URP, the variety of goals of a URP, and the general lack of clear metrics for measuring their impacts and successes."

9 Suggested Research Questions

Suggestions for further research

- 1) The organisational structure of TTOs in the UK. So far there does not exist any collection of information on the organisational structures employed by TTOs. While we see a convergence in the technology transfer mechanisms employed by TTOs, we lack knowledge about the way in which TTOs organise themselves to effectively implement these mechanisms. Research suggests that differences in TTOs organisational structure have a bearing on their performance and are most likely rooted in the history and culture of universities.
- 2) The outcomes of university licensing. In general licensing is thought of as an end in itself, however, some attention should be given to the subsequent performance of the firms involved. In particular, are there trade-offs between licensing to SMEs (e.g. low initial payments, but possible long run growth) and larger firms (e.g. high initial payments, but few growth opportunities)?
- 3) Would it be more efficient to license university inventions through auctions via a centralised platform? Bundling inventions on a single platform could solve the problem of insufficient number of potential bidders so far preventing auctioning of licences. Are there lessons to be learnt from www.ip-auction.eu?
- 4) The performance of spin-outs. While the Lambert review suggested there was the possibility of too many poor quality spin-outs, there is little empirical evidence on this issue. Comprehensive private databases with information on all registered firms are now available. Equally, ONS data could be used. There is a need, however, to collate specific data on the nature of each spin-out (e.g. share holdings, staffing, whether inventor was involved).
- 5) Do incubators effectively help high-potential spin-outs to prepare for competition in the market or do they only delay failure? Are there differences in the impact of incubators on spin-outs holding IP and those that do not? Are universities better suited to provide incubator facilities to spin-outs than (private) external agencies?
- 6) IP strategy by universities. There is now an accepted view that IP is beneficial to technology transfer. There are good theoretical justifications for this and the empirical evidence on patents, licensing and spin-outs also lends support. There is also some evidence that universities could get much better at exploiting their IP. However, at the same time, concern was raised by the Lambert Review (2003) and Wellings (2008) that *too great a focus on IP* by universities could damage technology transfer. The evidence by Hall et al. (2001) supports such a view. This suggests the need for more research, especially in the role of IP in possible joint research projects between universities and business.

- 7) Hybrid technology transfer models where business makes up-front payment for subsequent IPRs. The activities of the IP Group PLC and other venture-IP companies are a relatively new feature in technology transfer. There appears to be little evaluation of these models from a social welfare perspective.

10 Data Sources

- Higher Education Funding Council for England (HEFCE): BCI survey
- Higher Education Statistics Agency (HESA)
- The University Companies Association (UNICO):
 - (a) UK University Commercialisation Survey
 - (b) Salary and Incentives survey
- Scottish Funding Council Knowledge Transfer Grant (KTG)
- Library House: Venture-backed companies in the UK
- UK Science Park Association (UKSPA)
- UK Business Incubation (UKBI)
- Advanced Institute of Management (AIM) Research (Bruneel et al., 2009)

11 References

Abreu M., Grinevich V., Hughes A., Kitson M. and Ternouth P. (2008): 'Universities, Business and Knowledge Exchange,' Report by The Council for Industry and Higher Education, and Centre for Business Research.

Aghion P., Dewatripont M., Hoxby C., Mas-Colell A. and Sapir A. (2009): 'The Governance and Performance of Research Universities: Evidence from Europe and the US,' NBER Working Paper No. 14851.

Arvanitis S., Sydow N. and Woerter M. (2008): 'Do specific forms of university-industry knowledge transfer have different impacts on the performance of private enterprises? An empirical analysis based on Swiss firm data', *Journal of Technology Transfer*, Vol. 33, pp. 504-533.

Bacchiocchi E. and Montobbio F. (2009): 'Knowledge diffusion from university and public research. A comparison between US, Japan, and Europe using patent citations,' *Journal of Technology Transfer*, Vol. 34, pp. 169-181.

Bekkers R., Gilsing V., and van der Steen M. (2006): 'Determining Factors of the Effectiveness of IP-based Spin-outs: Comparing the Netherlands and the US,' *Journal of Technology Transfer*, Vol. 31, pp. 545-566.

Bercovitz J., Feldman M., Feller I., and Burton R. (2001): 'Organizational Structure as a Determinant of Academic Patent and Licensing Behavior: An Exploratory Study of Duke, Johns Hopkins, and Pennsylvania State Universities,' *Journal of Technology Transfer*, Vol. 26, pp. 21-35.

Bray M. and Lee J. (2000): 'University revenues from technology transfer: licensing fees vs. equity positions', *Journal of Business Venturing*, Vol. 15, pp. 385-392.

Breschi S. and Lissoni F. (2004): 'Mobility and social networks: Localised knowledge spillovers revisited', In *The Role of Labour Mobility and Informal Networks for Knowledge Transfer*, Dirk Fornahl, Christian Zellner, and David Audretsch (eds.), Berlin: Springer Verlag.

Bruneel J., D'Este P., Neely A., Salter A. (2009): 'The Search for Talent and Technology – Examining the Attitudes of EPSRC Industrial Collaborators Towards Universities', AIM Research Paper.

Buenstorf G., Hummel M. and von Ledebur S. (2009): 'University Patenting in Germany before and after 2002: What Role Did the Professors' Privilege Play?', Jena Economic Research Papers No. 2009-068.

Clarysse B., Wright M., Lockett A., Mustar P., Knockaert M. (2007): 'Academic spin-outs, formal technology transfer and capital raising', *Industrial and Corporate Change*, Vol. 16, No. 4, pp. 609-640.

Conti A. and Gaulé P. (2008): 'The CEMI survey of University Technology Transfer Offices in Europe.'

Conti A. and Gaulé P. (2009): 'Are the US outperforming Europe? A new perspective on the European paradox,' CEMI working paper.

Czarnitzki D., Hussinger K. and Schneider C. (2009): 'The Nexus between Science and Industry: Evidence from Faculty Inventions,' ZEW Discussion Paper No. 09-028.

Czarnitzki D. and Toole A. (2009): 'Is There a Trade-Off between Academic Research and Faculty Entrepreneurship? Evidence from U.S. NIH Supported Biomedical Researchers,' ZEW Discussion Paper 09-022.

D'Este P. and Fontana R. (2007): 'What drives the emergence of entrepreneurial academics? A study on collaborative research partnerships in the UK', *Research Evaluation*, Vol. 16(4), pp. 257-270.

David P. (2005): 'Innovation and universities' role in commercializing research results: second thoughts about the Bayh–Dole experiment,' Stanford Institute for Economic Policy Research Discussion Paper 04-27 (May).

David P. (2001): 'Will building good fences really make good neighbors in science?', in *Intellectual property protection and internet collaborations*, A report of the EC-DG Research Strata Working Party.

David P. (2005): 'Innovation and universities role in commercializing research results: second thoughts about the Bayh–Dole experiment,' Stanford Institute for Economic Policy Research Discussion Paper 04-27.

Di Gregorio D. and Shane S. (2003): 'Why do some universities generate more start-ups than others?', *Research Policy*, Vol. 32, pp. 209-227.

Djokovic D. and Souitaris V. (2008): 'Spinouts from academic institutions: a literature review with suggestions for further research', *Journal of Technology Transfer*, Vol. 33, pp. 225-247.

DTI (1998): 'Our Competitive Future - Building the Knowledge Driven Economy,' Department of Trade and Industry, London

Feldman M., Feller I., Bercovitz J., and Burton R. (2002): 'Equity and the Technology Transfer Strategies of American Research Universities', *Management Science*, Vol. 48, No. 1, pp. 105-121.

Fini R., Lacetera N. and Shane S. (2009): 'Inside or Outside the IP-System? Business Creation in Academia', available at SSRN: <http://ssrn.com/abstract=1314361>.

General Accounting Office (US) (1983): 'The Federal Role in Fostering University–Industry Cooperation,' GAO, Washington, D.C.

Goto A. (2000): 'Japan's national innovation system: current status and problems,' *Oxford Review of Economic Policy*, Vol. 16(2), pp.103–13.

Hall B., Link A. and Scott J. (2001): 'Barriers Inhibiting Industry from Partnering with Universities: Evidence from the Advanced Technology Program,' *Journal of Technology Transfer*, Springer, vol. 26(1-2), pp. 87-98.

Heher T. (2006): 'Return on Investment in Innovation: Implications for Institutions and National Agencies,' *Journal of Technology Transfer*, Vol. 31, pp. 403-414.

Helmers C. (2009): 'The Effect of Market Entry on Innovation: Evidence from UK University Incubators', mimeo, Department of Economics, University of Oxford.

Helmers C. and Rogers M. (2008): 'Innovation and Survival of New Firms Across British Regions', Department of Economics Working Paper No. 416, University of Oxford.

Holi M., Wickramasinghe R. and van Leeuwen M. (2008): 'Metrics for the Evaluation of Knowledge Transfer Activities at Universities', Library House, available at http://ec.europa.eu/invest-in-research/pdf/download_en/library_house_2008_unico.pdf

Hoppe H. and Ozdenoren E. (2005): 'Intermediation in Innovation', *International Journal of Industrial Organisation*, Vol. 23, pp. 483-503.

Jensen R. and Thursby M. (2001): 'Proofs and Prototypes for Sale: The Licensing of University Inventions', *American Economic Review*, Vol. 91, No. 1, pp. 240-259.

Jensen R., Thursby J. and Thursby M. (2003): 'Disclosure and Licensing of University Inventions: The best we can do with the s**t we get to work with', *International Journal of Industrial Economics*, Vol. 21, pp. 1271-1300.

Jensen R., Thursby J., and Thursby, M. (2003): 'The Disclosure and Licensing of University Inventions: The Best We Can Do With the S**t We Get to Work With', *International Journal of Industrial Organization*, Vol. 21(9), pp. 1271-300.

Klein J. (2009): 'The Commercialisation of IP – Executive Summary', Sagentia.

Lach S. and Schankerman M. (2004): 'Royalty Sharing and Technology Licensing in Universities', *Journal of the European Economic Association*, Vol. 2, No. 2/3, Papers and Proceedings of the Eighteenth Annual Congress of the European Economic Association, pp. 252-264.

Lambert (2003): 'Lambert Review of Business: University Collaboration', HM Treasury.

Lehrer M., Nell P. and Gärber L. (2009): 'A National Systems View of University Entrepreneurialism: Inferences from Comparison of the German and Us Experience', *Research Policy*, Vol. 38(2), pp. 268-280.

Leitch Report (2006): 'UK Skills: Prosperity for all in the global economy –world class skills', HM Treasury, December

Lerner J. (2005): 'The University and the Start-Up: Lessons from the Past Two Decades', *Journal of Technology Transfer*, Vol. 30, No. 1/2, pp. 49-56.

Levy R., Roux P. and Wolff S. (2009): 'An analysis of science-industry collaborative patterns in a large European University', *Journal of Technology Transfer*, Vol. 34, pp. 1-23.

Leyden D., Link A. and Siegel D. (2008): 'A Theoretical and Empirical Analysis of the Decision to Locate on a University Research Park', *IEEE Transactions on Engineering Management*, Vol. 55, Issue 1, pp. 23 – 28.

Library House (2006): 'The Impact of the University of Cambridge on the UK Economy and Society,' <http://www.admin.cam.ac.uk/news/dp/2006062601>

Link A., Siegel D. and Bozeman B. (2007): 'An empirical analysis of the propensity of academics to engage in informal university technology transfer', *Industrial and Corporate Change*, pp. 1-15.

Link A. and Scott J. (2007): 'The economics of university research parks', *Oxford Review of Economic Policy*, Vol. 23, No. 4, pp. 661-674.

Louis K. S., Anderson M. S., Jones L., Blumenthal D. and Campbell E. (2001): 'Entrepreneurship, secrecy, and productivity: a comparison of clinical and nonclinical life sciences faculty', *Journal of Technology Transfer*, Vol. 26(3), pp. 233-45.

Macho-Stadler I., Perez-Castrillo D., and Veugelers R. (2008): 'Designing Contracts for University Spin-outs', *Journal of Economics & Management Strategy*, Vol. 17, No. 1, pp. 185-218.

Macho-Stadler I., Perez-Castrillo D., and Veugelers R. (2007): 'Licensing of university inventions: The role of a technology transfer office', *International Journal of Industrial Organization*, vol. 25, pp. 483-510.

Markman G., Gianiodis P. and Phan P. (2008): 'Full-Time faculty or part-time entrepreneurs?', *IEEE Transactions on Engineering Management*, Vol. 55, No. 1, pp. 29-36.

Matkin G. (2001): 'Spinning Off in the United States: Why and How?', *STI Review*, Special Issue on Fostering High-tech Spin-outs: A Public Strategy for Innovation, Organization for Economic Cooperation and Development (OECD), No. 26, pp. 97-119.

Meyer M. (2006): 'Academic Inventiveness and Entrepreneurship: On the importance of start-up companies in commercializing academic patents', *Journal of Technology Transfer*, Vol. 31, No. 4, pp. 501-510.

Monck C.S.P., Porter R.B., Quintas P., Storey D.J., Wynartczyk P. (1988): 'Science Parks and the Growth of High Technology Firms', Croom Helm, London.

O'Hare S. (2008): 'Strategic Partnerships at the University of Reading: Second Time Around?', University of Reading.

Owen-Smith J. and Powell W. (2001): 'To Patent or Not: faculty Decisions and Institutional Success at Technology Transfer', *Journal of Technology Transfer*, Vol. 26, pp. 99-114.

Panagopoulos A. (2003): 'Understanding When Universities and Firms Form RJVs: The Importance of Intellectual Property Protection', *International Journal of Industrial Organization*, Vol. 21, pp. 1411-1433.

Pinch S. and Sunley P. (2009): 'Understanding the Role of Venture Capitalists in Knowledge Dissemination in Technology Agglomerations: A Case Study of the University of Southampton Spin-Off Cluster', *Venture Capital* (in press).

Richards G. (2009): 'Spin-Outs: Creating Businesses from University Intellectual Property', Petersfield, Harriman House Ltd.

Schwartz M. (2009): 'Beyond incubation: an analysis of firm survival and exit dynamics in the post-graduation period', *Journal of Technology Transfer*, Vol. 34, pp. 403-421.

Siegel D., Veugelers R., and Wright M. (2007): 'Technology Transfer Offices and Commercialisation of University Intellectual Property: Performance and Policy Implications', *Oxford Review of Economic Policy*, Vol. 23, No. 4, pp. 640-660.

Siegel D., Waldman D. and Link A. (2003): 'Assessing the impact of organizational practices on relative productivity of university technology transfer offices: an exploratory study', *Research Policy*, Vol. 32, pp. 27-48.

Siegel D, Waldman D. A., Atwater L., and Link A. N. (2004): 'Toward a Model of the Effective Transfer of Scientific Knowledge from Academicians to Practitioners: Qualitative Evidence from the Commercialization of University Technologies', *Journal of Engineering and Technology Management*, Vol. 21(1-2), pp. 115-42.

- Siegel D., Westhead P. and Wright M. (2003): 'Assessing the Impact of University Science Parks on Research Productivity: Exploratory Firm-Level Evidence from the United Kingdom,' *International Journal of Industrial Organization*, Vol. 21(9), pp. 1357-1369
- Singh J. (2005): 'Collaborative networks as determinants of knowledge diffusion patterns,' *Management Science*, Vol. 51, pp. 756-770.
- Tang P. (2008): 'Exploiting University Intellectual Property in the UK,' Report for UK IPO, IP Institute, London.
- Thursby J., Fuller A. and Thursby M. (2009): 'US Faculty patenting: Inside and outside the university,' *Research Policy*, Vol. 38, pp. 14-25.
- Thursby J., Jensen R., and Thursby M. (2001): 'Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major US Universities,' *Journal of Technology Transfer*, Vol. 26, pp. 59-72.
- Thursby M., Thursby J., and Gupta-Mukherjee S. (2007): 'Are there real effects of licensing on academic research? A life cycle view,' *Journal of Economic Behavior & Organization*, Vol., 63, pp. 577-598.
- Turk-Bicakci L. and Brint S. (2005): 'University-industry collaboration: Patterns of growth for low- and middle-level performers,' *Higher Education*, Vol. 49, pp. 61-89.
- van Geenhuizen M. and Soetanto D. (2009): 'Academic Spin-outs at Different Ages: A Case Study in Search of Key Obstacles to Growth,' *Technovation*, Vol. 29, pp. 671-681.
- von Ledebur S. (2008): 'Technology transfer offices and university patenting – a review,' Jena Economic Research Papers No. 2008-033.
- Warry P. (2006): 'Increasing the Economic Impact of Research Councils,' Advice to the Director General of Science and Innovation, DTI from the Research Council Economic Impact Group 06/1678.
- Wellings P. (2008): 'Intellectual Property and Research Benefits,' Report commissioned by The Rt Hon John Denham MP, Secretary of State for Innovation, Universities and Skills.
- Wright M., Clarysse B., Lockett A. and Knockaert M. (2008): 'Mid-Range Universities' Linkages with Industry: Knowledge Types and the Role of Intermediaries,' *Research Policy*, Vol. 37, pp. 1205-1223.
- Wright M., Piva E., Mosey S., and Lockett A. (2009): 'Academic Entrepreneurship and Business Schools,' *Journal of Technology Transfer*.
- Yusuf S. (2008): 'Intermediating Knowledge Exchange between Universities and Businesses,' *Research Policy*, Vol. 37, pp. 1167–1174.
- Zucker L. and Darby M. (1996): 'Star Scientists and Institutional Transformation: Patterns of Invention and Innovation in the Formation of the Biotechnology Industry,' *Proceedings of National Academy of Sciences*, Vol. 93 (23), pp. 12709-12716