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Measuring the performance of Oxford University, Oxford Brookes University and the government laboratories' spin-off companies

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Abstract

The paper reports on a recent study, which uses various indicators to provide an insight on the performance of spin-off companies from the public sector research base in Oxfordshire (UK). The study builds upon the other studies and fills a gap in the field by gathering empirical information on the performance of technology-based spin-off companies. While the main geographical focus is the county of Oxfordshire, UK, the findings will also be of value for other researchers and institutions with an interest in assessing the performance of spin-off firms. The evidence shows that the number of spin-offs in Oxfordshire has increased rapidly over recent years, as the result of evolving national policy and the entrepreneurial culture of the universities and laboratories. However, the academics and scientists in Oxfordshire's institutions were already entrepreneurial in the 1950s, less so in the 1960s, but increasingly in the 1970s and 1980s, particularly in Oxford University, which is by far the largest generator of spin-offs in the region.

JEL classification: 018; 031; 032; 033; 034; 038; 052

Keywords: Academic spin-offs; Performance; Oxfordshire

1. Introduction

The entrepreneurial university (Etzkowitz et al., 2000), which emerged first in the US, followed by the UK and subsequently throughout Europe and the rest of world (Rappert et al., 1999), has become the aspirational norm. A common rhetoric that lauds academic enterprise unites universities and governments as a route to political kudos and income for the former and wealth creation and job generation for the latter. Universities are now central players in a policy model that Bozeman (2000, p. 632) describes as a "cooperative technology paradigm", prominent in the US in the early 1990s, in which the university role is expanded to encompass technology-based economic development programmes. While Bozeman's work was referring specifically to the US at a particular time, this model as a political philosophy can be currently recognised across developed and developing countries. The reality is, however, that some countries are better at creating spin-offs than others; and in turn some institutions are more entrepreneurial than others with spin-out successes in specific sectors (i.e. life sciences). Such patterns are revealed by annual national surveys such as by the Association of University Technology Managers (AUTM) for the United States and Canada and in the UK by The Higher Education Funding Council for England (HEFCE) and UNICO[1] (The University Com-

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[1] UNICO was founded in 1994 to represent the technology exploitation companies of UK Universities.

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panies Association) and more extensively by the OECD (2001).

In analysing the causes of these patterns, academic studies have focused on the impact of national systems of innovation and legislation on stimulating academic enterprise (Shane, 2004), the 'entrepreneurial orientation' of universities (O'Shea et al., 2005), the institutional conditions under which spin-offs are incubated (Lockett et al., 2005) and the characteristics of individual academics who become entrepreneurs (see for example Zucker and Darby, 1996). Far fewer, however, have examined the survival and performance of spin-offs over prolonged periods. This is an important omission. This is both because of the time it takes, especially in the UK, for companies to grow to any significant size and because of the priority attached to spin-off activity, especially in biotechnology, which underestimates performance in other sectors. Moreover, most studies focus on those companies which have been formed since knowledge management and technology transfer mechanisms governing the exploitation of intellectual property (IP) were instituted, thereby considerably underestimating the longer term contribution of university spin-off activity.

This paper's contribution is to examine the number and performance of spin-offs of what is arguably the UK's most entrepreneurial university – Oxford[2] – and of the spin-offs from Oxfordshire's two other universities (Oxford Brookes and Cranfield DCMT at Shrivenham) and its seven currently government funded and privatised public research laboratories (PRLs). It presents survey data collected during the period August 2004–May 2005. The distinguishing feature of this study is that it records spin-off activity from the 1950s, thus tracing university-based entrepreneurial activity over five decades. The paper positions the analysis within both the entrepreneurial orientation of UK policy and of the Oxfordshire economy, the fastest growing high-tech economy in Europe (Chadwick et al., 2003).

The next section reviews the evidence on rates of university spin-off activity and explanations for those patterns. The following section provides a brief overview of UK policy on academic enterprise. The Oxfordshire case study forms the third section. In this the number of spin-offs and their performance according to a number of indicators are discussed. In the last section, some conclusions are drawn on the limitations of this kind of study.

2. Patterns of spin-offs

Although spin-off activity is increasing worldwide, there is considerable variation within that trend (Clarysse et al., 2001). Their study showed that it is more common in some countries than others, while Di Gregorio and Shane (2003) show that spin-offs tend to be formed by the more research intensive universities. Overall, the net number of spin-offs is small and their size, growth rates, revenues, and product generation are modest, at least in the first decade of their existence (see Lerner, 2005). Studies also show that sector is strongly associated with spin-off activity, i.e. that spin-offs are mainly in the biomedical and the information technology fields. The employment impact tends to be local as most spin-offs stay within the same geographical area as the institution from which they originated (see Shane, 2004).

Numerous explanations for these disparities have been given. First, national governments have an impact on spin-off activity in various ways (see Shane, 2004). For example, they determine the degree to which universities have the autonomy to make their own rules regarding exploitation of IP; legislation has been passed, for example, in the US with the Patent and Trademark Act of 1980 (the Bayh-Dole Act), which formalised university ownership of IP. The UK provides financial and political 'incentive' structures to encourage entrepreneurship and has enacted legislation designed to stimulated R&D-based entrepreneurial activity such as R&D tax incentives. With respect to university autonomy, in Sweden, Italy and Finland, for example, universities do not own the IPR of their staff, while in contrast in the UK, since 1985, each institution has been able to set their own rules on ownership of IP. In France it was only in 1999 that academic spin-offs became possible after the passing of Allegre's Law, although the national laboratories had long been able to do so (see Lawton Smith, 2003).

Second, reputation and research eminence of individual universities are strongly associated with the rate of spin-off (Di Gregorio and Shane, 2003; Feldman et al., 2002). The argument is that people of higher calibre are more likely to form spin-offs to reap the rewards of their intellectual capital. Reputation also help spin-offs to obtain private funding at times of uncertainty as investors will be able to rely on the university's past ability to succeed (Di Gregorio and Shane, 2003).

Third, institutional factors identified as influencing the rate of spin-off activity include the culture of the university, its attitude toward spin-offs and the com-

[2] Oxford won a competition sponsored by US venture capital firm Cross Atlantic Capital Partners, beating off competition from Imperial College London, and Cambridge—see www.xacp.com/news_detail.asp?news_id=82.

petence of the technology transfer offices (TTOs) (see Siegel et al., 2003; Lockett and Wright, 2005). Inventors are more likely to be interested in creating new firms to develop their research if there is wide support for the process (Nelsen, 1998; Kenny and Goe, 2004). Lockett et al. (2005) summarise the key process issues with respect to overcoming the organizational knowledge gaps that new ventures encounter as opportunity recognition, the decision to commercialise and due diligence, the choice between licensing and spin-off, and the time period over which TTOs are involved in spin-offs and accessing resources and knowledge. Thus, TTOs have a key role to play in making their ventures 'investor ready' (Binks et al., 2004). 'Readiness' includes the potential competence of spin-off companies to overcome the four different critical junctures needed for survival: opportunity recognition, entrepreneurial commitment, credibility and sustainability (Vohora et al., 2004), ideas supported by De Coster and Butler (2005). Kenny and Goe (2004, p. 692) contend that, 'the involvement of professors in entrepreneurial activity is influenced by the social relationships and institutions in which a professor is embedded'. They argue that institutional factors were likely explanations for why entrepreneurship was more common in electrical and electronic engineering faculty in Stanford than at the University of California, Berkeley (UCB) rather than the particular features of the locality, as they find that staff in the two universities in their study had equal access to Silicon Valley support mechanisms.

Fourth, the distribution of spin-offs across industry sectors is highly uneven and spin-offs are diverse in their activities (Druilhe and Garnsey, 2004). The greatest concentration is in the life sciences followed closely by information technologies (with technological advance resulting from the combination of both in fields such as genomics, proteomics and bioinformatics) (PACEC, 2003). While the life science or biotech industry is superior at producing spin-offs because research produces more discrete inventions than other industries, there may be more barriers in commercialising life science discoveries than other sectors (e.g. complex regulations). This suggests that the high number may be a result of the greater need for spin-offs to exploit inventions rather than greater entrepreneurial opportunities (Meyer and Autio, 2004). Moreover, the emphasis on biotechnology as a source of wealth generation may be misplaced, at least in the short-term (Nightingale and Martin, 2004).

Further, it is argued in a number of studies that if the geographical area in which the university is located has many other high-tech activities in progress, the rate of spin-offs is likely to be increased. Lee and Walshok (2003) find that local spin-off firms are distinguishable from other firms. Such firms are more likely to have local university advisers, local expertise and local investors. Thus, areas where universities are particularly active will develop specialised expertise that understands that particular entrepreneurial process. Moreover, investors such as venture capitalists are likely to move to the area as they prefer to make more local investments (Sahlman et al., 1999; Babcock-Lumish, 2004).

With respect to performance of university spin-off companies per se, university spin-offs appear to survive longer relative to other start-ups. In the US, a study by Pressman (2002) found that out of the spin-offs formed in 1980–2001, 65% (2514/3870) were still operational in 2001. In France, only 16% of spin-offs actually fail (Mustar, 1997). These findings contrast with those of the UK's 2003 Lambert Review of University–Business Interaction (HM Treasury, 2003), which suggests that the number of spin-offs in the UK is rising too quickly with the corollary that many will not survive in the long-run. On the other hand, estimates of failure rates of new ventures have improved with 91.4% of UK VAT-registered businesses in 2000 trading for a year, while the percentage of UK businesses surviving three or more years increased from 60 to 64% over the period 1994–2003.[3]

Yet not all university or public research institutions spin-offs have the same propensity for high growth (Druilhe and Garnsey, 2004). With respect to spin-offs from public research institutions, Lockett et al. (2005) develop a knowledge-based view of spin-off formation, which focuses on areas of knowledge gaps to explain why some public research institution spin-offs do not grow rapidly and why it is important to differentiate between spin-offs that do not involve the transfer of IP but are established by PRI employees and those that do—a distinction that is equally useful for university spin-offs. Like Druihle and Garnsey, they are making the point that entrepreneurs and the activity of their enterprises are diverse, hence will not follow the same developmental processes (see also Vohora et al., 2004).

3. The UK context

The UK has one of the most entrepreneurial systems, being in the vanguard of academic capitalism (Slaughter and Leslie, 1999). Academic capitalism in the UK can be dated to the early 1980s. From 1982 onwards universities started to open technology transfer offices. Following the Labour Party's accession to government in 1997, universities received both a growth in research funding and

[3] www.sbs.gov.uk.

Table 1
UK government university commercialisation initiatives

Year	Initiative	Purpose	Details
1998	Higher Education Reach out to Business and the Community (HEROBaC)	Funding to support activities to improve linkages between universities and their communities	£20 million per year allocated to provide funding for the establishment of activities such as corporate liaison offices
1999	University Challenge Fund (UCF)	Seed investments to help commercialisation of university IPR	£45 m was allocated in the first round of the competition in 1999, (with 15 funds being set up) and £15 million in October 2001. 57 HEIs now have access to this funding
1999	University Science Enterprise Centres (SEC)	Teaching entrepreneurship to support the commercialisation of science and technology	SEC initially provided £28.9 million in 99/00 for up to 12 centres. Additional funding of £15 million increased the number of HEIs participating to 60
2001	Higher Education Innovation Fund 1	Single, long-term commitment to a stream of funding to "support universities' potential to act drivers of growth in the knowledge economy"	HEIF was launched in 2001 to bring together a number of previously independently administered third stream funding sources. This was then extended (HEIF2) in 2004 with £185 m awarded

Source: Minshall and Wicksteed (2005).

increased government support for entrepreneurial activities.

Examples of financial incentives to develop their 'third stream' activities – or business orientated research – developing commercially orientated services and so on are shown in Table 1. The UK is more 'efficient' at producing university spin-offs 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).

It is not only universities that are 'encouraged' to be entrepreneurial; since the year 2000 government-funded laboratories have also been given similar incentives to the universities to be more commercially orientated – patterns also found in the US (Branscomb, 1993), and in other countries in Europe (see Lockett et al., 2005; Lawton Smith, 2003). In 2001, the Public Sector Research Exploitation Fund was introduced along with new guidelines on incentives and risk taking for staff. An initial £25 million was provided, followed by a second round awards worth £15 million, announced in January 2004.[4]

Reflecting political priorities, by 2000 the majority of the UK's universities had dedicated personnel working on technology transfer, around the time that the rate of number of spin-offs began to increase rapidly. The third HEBI survey shows the rapid increase in the number of spin-off companies from around 70 a year on average on the previous 5 years, 203 were formed in 1999/2000, 248 in 2000–2001 and 213 in 2001/2002 (DTI, 2004). This is about half the number (450) formed in the same year in the US and Canada (AUTM, 2003). UNICO's 2002–2003 survey of 75 institutions, including 25 of the top 30 UK universities, based on research income, found that the number of spin-off companies had remained relatively constant with an average of two companies per institution formed during 2003, with most activity concentrated in relatively few universities, that is, as in the US, the most the most research intensive.

4. The Oxfordshire case study

Oxfordshire's three universities and seven national/international research laboratories (the research base) are located in one of Europe's most innovative regions. Not only does the county have a rapidly growing high-tech economy, it also has arguably the most advanced innovation support system in Europe.[5] With respect to the former, Chadwick et al. (2003) report that Oxfordshire has some 1400 high-tech firms employing 37,000 people employing around 12% of the county's workforce. The county has the third largest high-tech employment amongst UK counties (high-tech as a percentage of total employment), and the wider sub-region (Berkshire, Buckinghamshire and Oxfordshire) is the sixth highest in a European listing almost completely dominated by German regions. For high-tech services, the sub-region easily tops the European listings. But it is the rate of

[4] www.ost.gov.uk/enterprise/knowledge/#Public%20Sector%20Research%20Exploitation%20Fund%20(PSRE).

[5] In 2006, Oxfordshire won its third EU Award of Excellence in Innovation Transfer see http://www.oxin.co.uk/news/newsitem.php?newsid=75.

growth of activity which is most remarkable. Between 1991 and 2000, in percentage terms, Oxfordshire was the UK's fastest growing county for high-tech employment. Using a narrow Butchart-based definition of high-tech, the rate of growth was 141.0% and using the broader OECD definition, the rate of growth was 82.5%. Using the OECD definition, the rate of growth was 161.7%. With regard to the latter, in 2002, Oxfordshire won its second EU Excellence award for innovation.

Unlike in the US, however, UK local innovation support systems do not have regional funding of any scale. Most initiatives have funding from the Department of Trade and Industry, although in the early days, the main activities for supporting science and technology enterprise were initiated by a local charitable trust (The Oxford Trust) (see Lawton Smith, 2003). These include networking events, the establishment of incubators and the Oxfordshire Investment Opportunity Network (OION) which matches investors to firms. A number of activities have been dedicated to the biotech/medical instruments sectors such as the Oxfordshire BiotechNet and DiagnOx, which offers services to the diagnostics industry (see Lawton Smith et al., 2003).

4.1. The public sector research base

Oxfordshire's public sector research base comprises three universities and seven research laboratories.[6] The institutions are:

Universities:
- Oxford University.
- Oxford Brookes University.
- Cranfield University, Defence Science, Technology and Management (DCMT) at Shrivenham, part of Cranfield University based in Buckinghamshire.

Public research laboratories:
- Rutherford Appleton Laboratory (RAL): Harwell.
- United Kingdom Atomic Energy Authority (UKAEA): Harwell.
- United Kingdom Atomic Energy Authority (UKAEA): Culham.
- National Radiological Protection Board (NRPB): Didcot.
- National Environment Research Council (NERC) Centre for Ecology and Hydrology: Oxford.
- Medical Research Council (MRC) Units attached to the Pharmacology Department, Human Anatomy and Genetics Department, Institute of Molecular Medicine and the Department of Biochemistry: Oxford.
- Joint European Torus (JET): Culham.

All of these institutions have had spin-off companies identified with founders affiliated to them. Four of the seven public research laboratories have technology transfer offices in one form or another. Oxford University and RAL have both created companies to manage their technology transfer. Both Oxford Brookes University and Cranfield University have set up specific offices for the purpose. As Oxford University is the main source of spin-offs, more detail is provided by way of background.

4.2. Oxford University

Oxford University is one of the world's top universities. In a world ranking of universities published in 2004[7] it is rated 9th. On another list produced by the UK's Times Higher Education Supplement (2004) using a different set of indicators, Oxford was ranked sixth. Its position in these ranking is due to three distinctive features. These are first, that the university has high concentration of 'star scientists'. It has more academic staff working in world-class research departments (rated 5* or 5 in the 2001 Research Assessment Exercise) than any other UK university (Oxfordshire Bioscience Network, 2002). Second, it is ranked the world's third best biomedical university behind Harvard and Cambridge on the basis of citations per paper (Ince, 2005). The Medical Sciences Division, which broadly covers most of the biomedical research at Oxford, in 2003–2004 accounted for 56% of the University's external research income. The university specialises in genomics - 50% of university research groups work on genomics. Third, the University's position as a centre of academic excellence is consolidated by its ongoing development of interdisciplinary research centres (14 in the biomedical field)

[6] These institutions have different sources of funding and have varying status. RAL forms part of the Council for the Central Laboratory of the Research Councils (CCLRC) and is funded out of the research councils budget, the UKAEA laboratories are now funded by the Department of Trade and Industry – and parts of the UKAEA underwent privatisation in the early 1990s (see Lawton Smith, 2003).

[7] Institute of Higher Education, Shanghai Jiao Tong University ed.sjtu.edu.cn/ranking.htm. Universities were ranked by several indicators of academic or research performance, including alumni and staff winning Nobel Prizes and Fields Medals, highly cited researchers, articles published in Nature and Science, articles in Science Citation Index-expanded and Social Science Citation Index, and academic performance with respect to the size of an institution.

and groups cutting across traditional subject boundaries, many of which collaborate with international academic and industrial partners.

Oxford University also has an elite commercialisation system. The main mechanism for university spin-offs is through Isis Innovation, the university's technology transfer company. This organisation although formed in 1988, did not become the driving force for commercialisation of the university's research activities until 1997 with the appointment of Dr. Tim Cook, a successful entrepreneur and business angel in his own right. Under his leadership, Isis Innovation has expanded and now has the largest number of commercialisation staff of UK universities (Minshall and Wicksteed, 2005) and has been very successful in attracting government as well as private funding for spin-off activities, being awarded funds from all of the major government programmes shown in Table 1. Alongside Isis is the Oxford Science Enterprise Centre (OxSEC) based in the Said Business School which received £500,000 in start-up funding from the DTI under the SEC programme.

The success of Isis Innovation in managing the spin-offs process and patenting and licensing activities is indicated by Table 2. This shows that Oxford University generates three times as many as the UK average of two university spin-offs a year. Moreover, the success rate is very high, very few of the spin-offs supported by Isis Innovation have failed. The table also shows the investment in spin-off companies and licensing activities. Oxford/Isis is an exemplar of Lockett and Wright's (2005) finding that both the number of spin-out companies created and the number of spin-out companies created with equity investment are positively associated with expenditure on intellectual property protection, the business development capabilities of TTOs and the royalty regime of the university.

5. The Research study

5.1. Methodology

The research study conducted between July 2004 and March 2005, had four elements: (i) defining spin-offs, (ii) the identification of the total population of technology-based firms that had their origins in the county's public sector research base on the basis of that definition, (iii) measurement of performance and (iv) an assessment of factors associated with that performance.

The first task was to define spin-offs. The term 'spin-off' is contested and inconsistent, often referring to any new, initially small, high technology or knowledge intensive company whose intellectual capital has its origins in a university or public research institution. Some definitions restrict the term to those firms where the intellectual property of the university is formally transferred to the

Table 2
Isis Innovation record 1999–2003

	Year ended march					
	1999	2000	2001	2002	2003	5 years
Isis history						
University investment	£500,000	£1 million	£1 million	£1 million	£1 million	
Staff	9	17	21	23	34	
Projects	243	319	415	476	627	
Patents filed	51	55	63	82	65	316
Licences/options	18	21	36	42	71	188
New companies	3	6	8	8	7	33
Investment in spin-out companies						
Business Angel Start Up Investment	£25 million					
Venture Capital Follow on Investment	£153 million					
Total Capitalisation of Spin-outs	£308 million					
Current University Equity in Spin-outs	£10.8 million					
Oxford University Challenge Seed Fund						
Investment (Proof of Concept/Seed capital)	£4 million					
Business Angels Co-investment	£21.4 million					
Number of Projects	68					
Licences	4					
UCSF Equity holding in	21 companies					

Source: Isis Innovation.

start-up firm, for example AUTM and academic studies such as those by Shane (2004), Pirnay et al. (2003) and Lockett and Wright (2005). Other studies, including the majority of OECD countries (OECD, 2001)[8] and UNICO (2003) do not use this criterion. UNICO defines spin-offs as 'companies set up by the institution based upon its IP and people'. Similarly the definition of spin-offs in the Higher Education Business–Interaction (HEBI) surveys for Higher Education Funding Council for England (HEFCE) is broad 'relating to establishing of new legal entities and enterprises created by the HEI[9] or its employees to enable the commercial exploitation of knowledge arising from academic research. Such companies may or may not be partly owned by the relevant HEI, or by existing or previous members of the HEI. Other start-up companies may be formed by HEI staff or students, without the direct application of HEI-owned IP'. The usual criterion is that the new company would not have come into existence without intellectual input from the institution.[10] Druilhe and Garnsey (2004, p. 274) count only those companies that were direct spin-outs, that is, 'companies drawing on university-based technological and scientific knowledge and involving academics or students who were still members or who had just quit the university'. This definition is necessarily less restrictive than those above because Cambridge, unlike Oxford which introduced new rules on the ownership of IP in 1997, does not yet assert the rights to the IP of its staff, students and visitors, although at the time of writing it was on the verge of doing so. Rappert and Webster (1997), Segal Quince and Partners (1985) and Chadwick et al. (2003) use similar but wider set of criteria in order to reflect the range of processes by which companies are incubated within universities.

This study takes a similar approach to defining spin-offs to Druilhe and Garnsey (2004) but makes a distinction between spin-offs and founder affiliates. The former refers to technology-based company founded by a member/former member of a university or one of the seven laboratories using IP developed in the institution by the founding individual(s). The latter refers technology-based companies where the founders were members of the institutions concerned. This category includes former students, as is the case with Lindholm Dahlstrand (1997), in lists compiled by Stanford University[11] as well as by Druilhe and Garnsey (2004) and Segal Quince and Partners (1985). On this basis, the population includes firms that pre-date the technology transfer systems established in the late 1990s. While the study focused primarily on technology-based spin-offs, in collecting data, many other companies were identified for example in the service sector, which are not included in this analysis.

As there are no official records of spin-off companies, the next task was to identify the population of all possible spin-offs from the 10 institutions and whether they were live or had ceased trading, had merged or had been acquired. The main sources of information were the first author's doctoral thesis from the 1980s (Lawton Smith, 1990), Isis Innovation, local newspapers dating back to the 1980s, the universities and individual Oxford colleges' alumni associations, the Oxford Trust, departments within the universities, the laboratories and local innovation centres. Companies House data was used to check the status of the companies. Over 200 companies were investigated over the course of the research, with data collection in two phases. The first, up till December 2004, produced an initial data set of 167 technology-based companies. Further investigation up to the end of March 2005 reduced this number to 114, divided into spin-offs with university/laboratory IP (64 firms) and with founder affiliation (50)—academics, students and technicians.

Standard measures of company performance such as those based on financial data including turnover, position in finance cycle, and equity owned by external organizations and non-financial measures include number of people employed, number of offices/subsidiaries only give a snapshot of performance of the firm. In this study, a small number of performance indicators were chosen because of resource constraints. These were employment, turnover, market capitalisation and patent and licencing activity. And, in order to monitor changes over time, data were collected for each year dating back to 1994 and up to up to and including 2002 as these are the dates for which most complete information is available. After 2002, a number of companies were subject to merger or acquisition by firms not located in Oxfordshire. As data is more difficult to obtain on companies post-acquisition, data is included on firms up to the point of acquisition or merger. The public limited companies (Plcs) were studied as a separate group due to the significant differences in the scale of operation between them and limited companies (Ltds).

[8] OECD surveyed 19 countries on their spin-offs activity, asking for number of spin-offs and definitions used to identify them.

[9] Higher Education Institute (HEI).

[10] Establishing of new legal entities and enterprises created by the HEI.

[11] www.stanford.edu/group/wellspring/.

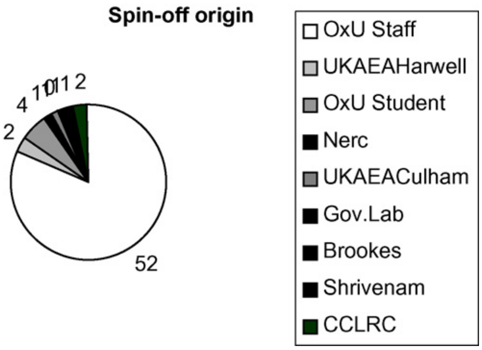

Fig. 1. Spin-off origins ($n = 64$). *Source*: Authors' survey.

The main database used was FAME[12] which contained detailed profiles of the companies including the company's registered address, date of incorporation, board of directors, any subsidiaries which the company may have, whether the company was still trading and financial data. The second primary source of information on the firms was company websites. Most of the companies have published company histories on the internet. In cases where company websites were unavailable, searches were done through the internet including sources such as university departmental websites and, government laboratory websites.

Discovering IP exploited by the companies proved to be more difficult than identifying the founders of companies. For firms which did not go through Isis, company websites and patent searches had to be utilised. The patent searches to which this study had access to were limited to the free public databases which were less comprehensive than the subscription databases. ESP@CENET on the European Patent Office website contained records of the patents held by companies which were searchable by various criteria such as applicant name, inventor name, etc. Another problem encountered was the fact that when patents were filed, it was not clear what name it was filed under (e.g. it could have been the academic, business entrepreneur or the public research institution/technology transfer office).

5.2. The firms

The vast majority (80%) of the 114 firms (spin-offs and founder affiliation) have been formed by Oxford University staff (Fig. 1). While very few originated in Oxford Brookes or Cranfield University, rather more have spun-out of the public research laboratories. Among the non-Oxford University spin-offs are Psion PLC 'a world leader in mobile computing', formed by a former Culham scientist in 1980; Oxford Applied Research – another Culham founder; Exitech founded in 1984 by two Rutherford Appleton Laboratory scientists; and Harwell Scientifics, a Harwell spin-off. In addition there were another 50 non-technology-based firms, such as Lastminute.com, Pizza Express, Majestic Wine, SQW, Talkback Productions and McKinsey & Co – all formed by Oxford graduates. Of the 114, 12 are Plcs (7 spin-offs), the rest are limited companies. The subsequent analysis differentiates between spin-offs and founder affiliate firms, and between Plcs and Ltd companies as appropriate.

How does Oxfordshire compare to other universities in the number of spin-offs? The answer depends on the comparison. Leaving aside the 1200 from the Stanford Community, for some of which connections to that university are somewhat dubious (Rowen and Sheehan, 2002), Oxford underperforms compared to Gothenburg's universities in Sweden which by 1995 had spun-out 350 firms, of which 250 came from Chalmers University of Technology (Lindholm Dahlstrand, 1997). On the other hand, the rate of spin-offs is comparable with Cambridge University. Garnsey and Heffernan (2005) reported that 109 direct spin-out companies drawing on university-based scientific and technological knowledge have been founded by the members of Cambridge University (staff and students) since 1979. The conclusion is that Oxford University performs very well by UK and most other European country standards but underperforms when compared to exceptional technology-based universities such as Chalmers and Stanford.

5.3. Age profile and survival rate

The majority of the 114 firms were formed in the 1990s (Fig. 2). Just over a third, 40, have been founded

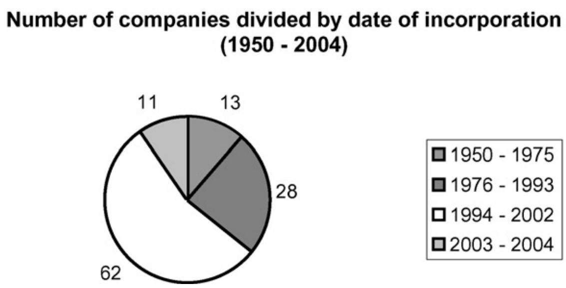

Fig. 2. Date of incorporation of 114 firms. *Source*: OEO survey.

[12] Financial Analysis Made Easy (FAME). FAME is a database that contains information for companies in the UK and Ireland. FAME contains information on 3.1 million companies, 1.9 million of which are in a detailed format [http://www.bvdep.com/fame.html].

between 1998 and 2004. However, there was considerable entrepreneurial activity earlier than that. By 1987, some 35 firms (including consultancy companies not counted here) had their origins in Oxford University (Lawton Smith, 1990). These include Littlemore Scientific Engineering Company (1954) and Oxford Instruments (1959) and Oxford Lasers (1977). Nearly 40% had been established by 1993, considerably pre-dating the 1997 Labour Government's initiatives, Oxford University's own radical change in policy on technology transfer and Dr. Cook's arrival. This suggests that in spite of the adverse university culture in the 1980s (see Lawton Smith, 1990), there was, as in Cambridge a nascent pattern of academic entrepreneurship and of a similar magnitude (Segal Quince and Partners, 1985).

The survival rate is high, 90%, well above the national 3-year firm survival rate, in spite of the inherent risks for new technology ventures (De Coster and Butler, 2005). Of the 8 Ltds which were dissolved, three traded for over 20 years. Another dimension to survival is whether firms have been acquired or merged. Of the 114, 9 firms have been acquired or merged in the last few years, 8 biomedical firms, reflecting the much broader trend of M&A in biotech felt across Europe – but led by the UK (DTI, 2005). The DTI Report concludes that the disappearance of such companies was the consequence of their failure to translate significant fundamental and clinical research into tangible value in the form of advanced products. This is not necessarily the case, however, as in Oxfordshire two of the fastest growing biotech companies were acquired; Powderject was bought by Chiron in 2003, in turn acquired by Novartis in 2005, and Medisense bought by Abbott Laboratories in 2002 – which at the time of acquisition employed 1100. An earlier merger was Oxford Asymmetry formed in 1991, merged with Evotech of Germany in 2001, to form Evotech OAI and floated on the stock market in 1998. At the time of merger, Oxford Asymmetry's shares were valued at £316 million and the company was making profits of £3.7 million a year. Other spin-offs have been subject to hostile takeovers. For example two biomedical companies (which predate Isis Innovation), Oxford GlycoSciences (OGS) (formed in 1988) was acquired by Celltech which was in turn bought out by the Belgian company UCB, while Oxford Molecular (1989) was acquired by Vernalis in 2003.

There is some evidence that these mergers and acquisitions have stimulated recycling intellectual property that formed the original spin-off company, and have led to further entrepreneurial activity. For example, post-acquisition by Chiron, PowderMed acquired its powder injection technology from PowderJect and, following OGS's acquisition by Celltech, the proteomics business emerged in 2004 as a service business called Oxford Genome Sciences after a management buyout. This activity is likely to be made easier by the wealth of local entrepreneurship expertise referred to earlier, which other studies suggest contributes to the entrepreneurial culture of the county (Lawton Smith, 2003).

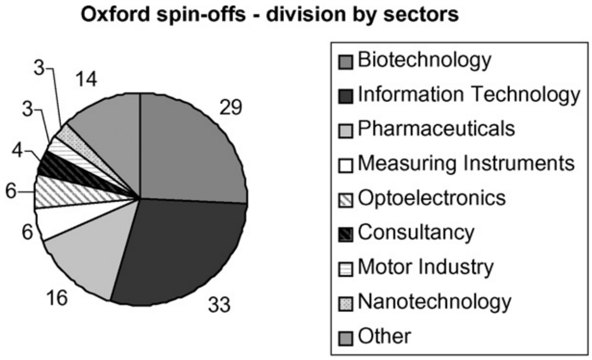

Fig. 3. Sector profile Oxfordshire's technology-based spin-off firms (spin-offs and founder affiliation). *Source*: OEO survey. Others includes: aerospace (1), nuclear industry (2), crystallography (2), electromagnetic engineering (1), wire chamber technology (1), medical instruments (2), glass engineering (1), biology (2), materials (1), robotics (1), scientific consultancy (1).

5.4. Sector

The diversity of firms is illustrated by Fig. 3 which shows 8 main sectors and a variety 'others'. Not surprisingly given the research profile of Oxford University, the largest group within the 114 firms is the biomedical sector: 29 are biotech, 16 pharmaceuticals which together account for 40% of firms and all are spin-offs. This combined figure is very similar to that of biomedical spin-offs in Cambridge and over a similar timeframe (Garnsey and Heffernan, 2005). IT is the largest single sector with 33 firms (29%). In 2002, the two sectors employed similar numbers of people (3435 biotech) compared to 3082 (IT) and combined account for over two thirds of the total employment.

5.5. Employment

The number of employees generated by the companies for which data is available (Table 3) between 1994 and 2002 reflects the overall increase in the population of firms. By 2002 employment stood at just over 9000, approximately 3.5% of total Oxfordshire employment (Fig. 4). Not all firms could be tracked for employment totals, however, hence the data underestimates the

Table 3
Data on employment in Oxfordshire's spin-offs

Year	Companies	Plcs	Ltds
2002	56	11	45
2001	41	10	31
2000	47	9	38
1999	31	10	21
1998	32	10	22
1997	20	10	10
1996	18	8	10
1995	17	8	9
1994	15	5	10

Source: OEO survey.

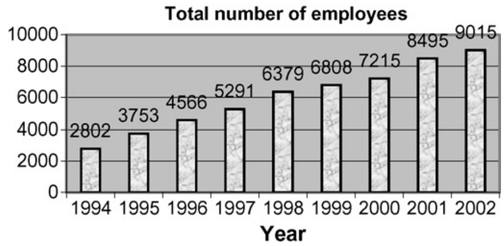

Fig. 4. Total number of employees including all the Plcs and the Ltds. *Source*: OEO survey.

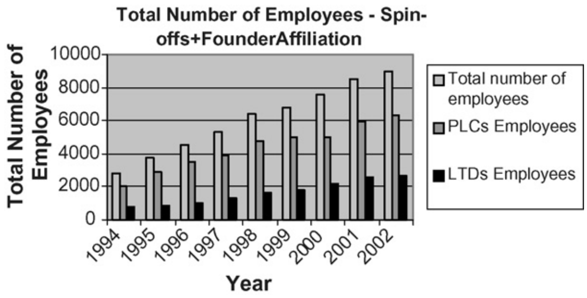

Fig. 5. Total number of employees—spin-offs and founder affiliation. *Source*: OEO survey.

total employment generated. Fig. 5 summarises all the employment data. A breakdown of the data showed that the spin-offs employed the most, nearly 60%. The most significant pattern, however, is of polarisation with the majority being employed in the Plcs such as Psion and Research Machines (computers and computer software) and Medisense and PowderJect (both biomedical) (see Table 6), which are growing faster than the Ltds. The Ltd spin-offs collectively employed nearly 30% of the total (2697). This pattern reinforces the point made by Druilhe and Garnsey (2004) that only a small number of spin-offs will be high growth.

The small size and slower rate of growth of the Ltd is a reflection of their generally younger age profile. This study shows that the rate of employment growth is associated with maturity. Companies that were more than 10 years old showed a combined increase in employment of 46% between 1994 and 2003. In line with a recent study by Lindholm Dahstrand (2005) this study shows that the rate of employment growth accelerates after companies have been established for around 10 years or more. Fig. 6 shows that the average size of firms for 40 companies incorporated before 1994 has shown a steady increase to 2001. The mean size rose from 140 in 1994 to 354 in 2001. This represents an increase of 60.45%. The rate, however, varies year-by-year. Fig. 7 also illustrates the positive year-by-year growth rate of employment: the best increment in 1995 (24.26%) and the minimum increment in 2000 (1.21%). The mean value of year-by-year growth rate of employment is 10.61%. 2001 is the cut-off point because of the limited data availability following the process of mergers and acquisitions which took place in 2001 and 2002. Using a computation by which the increases for each year in reference to the year to the base are determined and then the average among these increases is calculated, the annual increase is almost 47%.

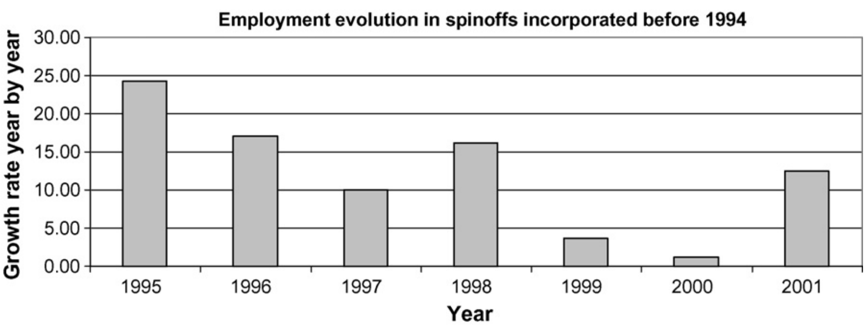

Fig. 6. Employment growth in spin-offs incorporated before 1994. *Source*: OEO survey.

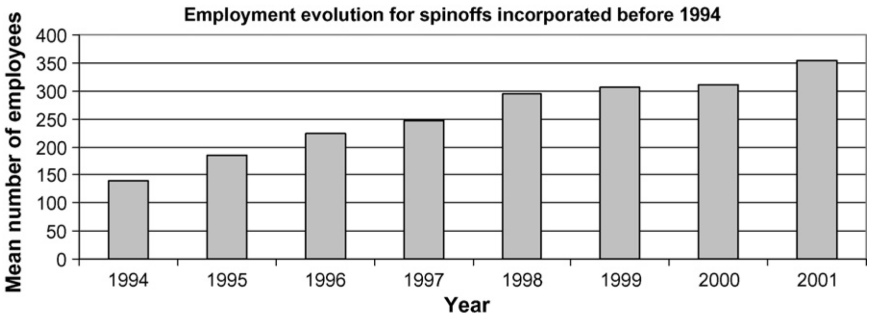

Fig. 7. Average size of spin-offs incorporated before 1994. *Source*: OEO survey.

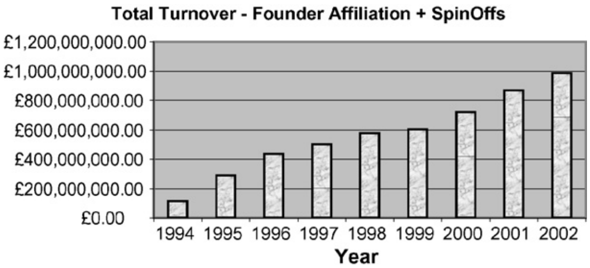

Fig. 8. Total turnover of 45 Oxfordshire companies. *Source*: OEO survey.

5.6. Turnover

Fig. 8 shows turnover data for the years between 1994 and 2004. Table 4 shows the number of companies covered for each of those years. Table 5 shows the turnover data for a maximum of 45 firms between those dates. This data has the same problem of consistency as the employment data as figures for turnover was not available for all the firms and that the number of firms included in the calculation increases as the population expands.

Table 4 shows that total turnover for the 45 companies in 2002 was nearly £1 billion. As would be expected, turnover was dominated by the Plcs (see also Table 6). The largest companies by turnover are two of the oldest, Oxford Instruments (c£214 million in 2002) and Research Machines (£197 million) in the same years. There is then a large gap to the third largest, Psion and the largest biomedical company (PowderJect) and then a further sharp decreased to the next group of Plcs and then of course the much smaller Ltds. The average turnover for the Ltds is c£564,000.

5.7. Market capitalization

Details of the top 10 performing companies by turnover, seven of them Plcs, are shown in Table 6, with values of market capitalization of five of the top six companies, and patents for all of them. The remarkable features of top three are that they are all manufacturing firms and none have been subject to merger or acquisition. Five of the top 10 are manufacturing companies and four are in the biomedical sector. The table also shows big variations in the relationship between turnover and market capitalisation, with Medisense, which has been acquired, having by far the largest market capitalisation value on the figures available, whilst the Plc spin-off still under original ownership has a value of £121 million (Oxford Instruments).

Table 6 also shows that there are five major employers employing around 1000–1500. There is then a big gap to the next set of companies. This shows that one of

Table 4
Turnover data availability

Year	Companies	Ltds	Plcs
2002	45	36	9
2001	40	31	9
2000	32	24	8
1999	32	22	10
1998	24	14	10
1997	23	13	10
1996	19	11	8
1995	16	11	7

Source: OEO survey.

Table 5
Turnover of 45 Oxfordshire spin-offs

	Total (£)	Plcs (£)	Ltds (£)
1994	116,720,545.00	66,252,000.00	50,468,545.00
1995	291,259,336.00	230,337,206.00	60,922,130.00
1996	437,345,208.00	372,116,355.00	65,228,853.00
1997	504,020,522.00	420,282,038.00	83,738,484.00
1998	579,161,388.00	492,611,324.00	86,550,064.00
1999	602,516,956.00	512,288,697.00	90,228,259.00
2000	722,487,276.00	586,648,000.00	135,839,276.00
2001	869,062,933.00	677,839,220.00	191,223,713.00
2002	985,843,120.00	783,036,000.00	202,807,120.00

Source: OEO survey.

Table 6
Top 10 performing Oxfordshire spin-offs and founder affiliation

Name	Date of incorporation	Sector	Turnover 2002	Employment 2002	Patents	Market capitalisation
Oxford Instruments Plc	9/30/1963 (established 1959)	Optoelectronics	£213,680,000.00	1773	49	£121.00 million
Research Machines Plc	11/30/1973	Information Technologies	£202,158,000.00	1518	25	£170.97 million
PSION PLC	10/3/1980	Information Technologies	£137,920,000.00	1054	30	£260.32 million
PowderJect Pharmaceuticals Plc	1/1/1994	Pharmaceuticals	£113,000,000.00	984	1	N.A.
Medisense Ltd.	10/12/1990	Pharmaceuticals	£65,362,000.00	1151	22	£379.81 million
Evotec OAI Plc	12/19/1991	Biotechnology	£31,636,000.00	358	13	N.A.
Sophos Plc	2/4/1987	Information Technologies	£31,582,000.00	301	1	N.A.
Crystalox Ltd.	10/3/1994	Crystallography	£30,924,678.00	75	1	N.A.
Penlon Ltd.	7/23/1996	Medical Instruments	£20,509,147.00	276	10	N.A.
Solid State Logic Ltd.	1/6/1970	Console Manufacturer	£19,710,000.00	235	6	N.A.

Source: OEO survey.

Table 7
Top 10 spin-offs from Stanford University

Company	Revenues (US$ million) 2001	Net income (US$ million) 2001	Market capitalisation (US$ million) on 3/28/2002
Hewlett-Packard	44,211.0	751.0	34,855.0
Cisco Systems	18,290.0	−2294.0	123,953.1
Sun Microsystems	14,059.0	−563.0	28,651.1
Agilent	7,257.0	−241.0	16,216.5
SGI	1,684.5	−405.0	836.4
Electronic Arts	1,562.2	36.3	8,765.7
Atmel	1,472.3	−418.3	4,735.2
Cadence Design	1,430.4	141.3	5,664.5
Intuit	1,372.4	−48.1	8,158.8
Nvidia	1,371.4	177.1	6,413.3

Source: www.stanford.edu/group/wellspring.

the smallest companies by employment, Crystalox, has a proportionately very high turnover. The distribution of patents is concentrated in the largest firms with the exception of PowderJect which had only 1.

In comparison with the major US universities, such as Stanford, Oxford University's spin-offs are small beer. In FY2001, the largest Stanford spin-offs were responsible for generating 42% (US$ 106.3 billion) of the total revenue of The Silicon Valley 150—an annual list of the largest Silicon Valley firms. The Stanford-founded companies on the list had a total market capitalization of US$ 332.5 billion, or 36% of the total market capitalization of the Silicon Valley 150 firms (Table 7).[13]

Rowen and Sheehan (2002), however, are cautious about the Stanford data. Three main problems exist. First, is the definition of Silicon Valley – given the university's research and teaching activities are not geographically bounded. Second, is defining a "Stanford" startup or product. They argue that most companies and ideas for products do not originate from just one source. The third is causation and whether the high level of entrepreneurship by graduates from the Graduate School of Business during the 1990s reflects changes in the School, changes in the character of the students, or increased opportunities in the Valley. The authors conclude that some combination of these has been involved.

5.8. Patent data

Patent data is an indicator the technological innovative abilities of the company. What happens to technological advance might be more important to society as a whole than job generation (Piva and Colombo, 2005).

[13] www.stanford.edu/group/wellspring/economic.html.

These authors find that academic spin-offs, because they emphasise technical activities, achieve superior innovative performances than other new technology-based firms in spite of lower growth performances. In this study, data was available on patenting for a total of 45 companies of the 114 companies for both the US Patent and Trademark Office (25 companies) and European Patent Office (41). A total of 265 patents are registered with the former and 373 with the latter. The Plcs dominate the number of patents in both cases (219 in the former and 245 in the latter). Some companies have registered patents in Europe and not in USA and vice versa. While this suggests a high rate of patenting, we have not been able to find other studies which have looked at the rate of patenting by university spin-offs.

6. Conclusions

The case study of spin-offs in Oxfordshire illustrates a number of conceptual and empirical issues relating to the identification of the rate of spin-offs from particular institutions and their performance. Conceptually, academic and PRL spin-offs are a manifestation of particular normative political agenda firmly embedded in late 20th century and early 21st century liberal philosophy about universities' role in society (Bozeman, 2000). In the UK, the cooperative technology model is driven by a series of funding mechanisms designed to encourage out-reach and entrepreneurial activity. In the case of Oxford University, the recent rapid rise in the number of spin-offs is associated with the business capabilities of Isis Innovation (cf. Lockett and Wright, 2005) and recent government policy. Oxford, like Cambridge, considerably outperforms the UK average for the number of spin-offs.

Isis Innovation, a highly professional operation, is now achieving its entrepreneurial objectives by appointing Dr. Tim Cook in the first instance, followed by a recognition within the university of the importance of what Dr. Cook was achieving, which led to further resources and a greater willingness invest in spin-off companies (institutional change). This change coincided with the availability of funds from national initiatives such as the Universities Challenge Fund (see Table 1) to further support those activities. The ability of the Isis team to draw on local expertise and funds in the form of business angels, who mentor start-ups as well as invest, and who are part of the entrepreneurial milieu of the Oxfordshire high-tech economy, further provides the resources that both underpin the rate of spin-off (O'Shea et al., 2005) and potentially the survival of the new ventures (Druilhe and Garnsey, 2004). On the other hand, many pioneering and surviving companies date back to the 1950s, 1960s and 1970s, from both Oxford University and the laboratories.

Empirically, there are problems in defining spin-offs and in analysing performance. This study has used a broader definition than one specifying that the university should own the IP that forms the basis of the company. Using such a restrictive definition would not only exclude comparisons with Cambridge University and with universities in countries such as Sweden and Italy, but would also mean that the overall, long-term extent of university entrepreneurial activity would be underestimated. The main problem with measuring performance is the lack of consistent data over a long period of time. Yet we argue that this kind of study is essential, as it demonstrates both that the survival rate of spin-off companies tends to be high but also, as this study shows, it generally takes at least 10 years before their rate of growth begins to accelerate. Thus, spinning out new companies is not a 'quick fix' for government economic development strategies.

The evidence from Oxfordshire is that the rate of formation has increased rapidly over recent years, thereby making a significant contribution to the Oxfordshire high-tech economy. By 2005, over 9000 people were employed by the surviving companies of the total population of 114 firms, about 3.5% of the county's employment. The study shows that most firms are in the IT and biomedical sectors and that a few companies, predominately the 12 Plcs, which include manufacturing and biomedical firms, have generated most employment, turnover and patents. None, however, have grown to the size of some of the companies originating in Stanford University. One of factors explaining this is that those in engineering and computing tend to be in niche markets, while in the biomedical field, there appear to be structural problems within the UK and Europe as whole which limits their growth and makes leading companies vulnerable to take-over.

Finally, while this study has focused on the technology-based spin-offs, there is an argument for studying the total pattern of entrepreneurial activity generated by universities and for universities to broaden their focus of potential entrepreneurs.

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