Entrepreneurship in Academia: An Exploratory Study of University Spinout Firms

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Abstract

Studies on academic entrepreneurship have examined various indicators, such as the number of university spinout firms created, the number of patents filed, and the licensing income from the commercialisation of university research. In this paper, we present an overview of a pilot study into spinout firms established during a five-year period at ten universities in the UK. It suggests that merely counting the number of spinouts formed reveals little about the overall efficiency of technology transfer efforts at universities. One has to also consider other aspects, such as the institutional setting from which spinouts emerge, as well as several characteristics of the spinouts themselves, including their origins, growth, investments received and continuing presence in the local economy. The paper also conveys some of the attitudes of directors of technology transfer offices on issues such as technology transfer policy, the management of the spinout process, and the demand to achieve targets for spinout numbers. It reveals reservations among the directors about the legitimacy and value of count data, and their concern about the use of targets as performance indicators.

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Introduction

In recent years, there has been a shift in how society values the knowledge that universities develop and teach, and a corresponding transformation in the role of universities (Gibbons *et al*., 1997; King, 2003; Rochford, 2006). In response to social and economic needs, knowledge has become organised in different ways, reflecting its 'usefulness' and 'relevance', rather than the logically discrete forms of knowledge previously justified (Hirst, 1965), and there is now considerable emphasis on the commercialisation of university knowledge by technology transfer to industry (Pavitt, 1997; Jamieson and Jansen, 2001). In the UK, 'a new compact' between the university and society has emphasised that the driving force should be 'education for business'. Consequently, the language of 'enterprise' and the 'needs of industry' is now common currency in higher education in the UK.

One consequence of the rise of the 'entrepreneurial university' based on the 'market' has been the formation of university spinout firms. Typically, these meet several conditions: they involve the use of the intellectual assets or the transfer of core technology from a university to a firm; the founding members usually include the academic inventor(s), who may or may not remain affiliated to the university; and the spinout is neither wholly-owned nor managed by the university (see Smilor *et al*., 1990; Birley, 2002; Nicolaou and Birley, 2003). In addition to these conditions, and for the purposes of this study, we defined spinout firms as those in which the university holds an equity stake.

Spinouts are the most prominent manifestation of academic entrepreneurship, and various UK government initiatives to support university commercialisation have implicitly fostered the setting of targets for the number of such firms. This was perhaps inevitable, since spinouts, like licences, are

tangible expressions of commercialisation, and their number indicates some measure of the performance of technology transfer. From the government's perspective, it is expedient that this metric be of high value, since it then reflects favourably on the government's commitment to the 'knowledge economy' and justifies its investment in research commercialisation. Such a basic measure of performance might be misleading, however, since there are concerns that universities may have overestimated the number of spinout firms by as much as 50 percent (Davis, 2005b). If true, this may be because the definition of what comprises a spinout is vague. For example, how much knowledge needs to be transferred to a firm, what form should it take, and what structure should the firm assume for it to be recognised as a spinout? Besides semantics, there is also the legitimate concern that public servants (as academics and staff are at UK universities) asked to meet spinout quotas in a target-setting, micro-managed culture where funding is contingent on results, invariably find ways to do so (Barber, 2007; Stern, 2007), although it may mean stretching definitions.

Even if one accepts that the numbers are accurate, they reveal nothing about the long-term viability and business value of spinouts. In fact, many remain small, rarely growing beyond the founding academic and a few employees. Moreover, the directors of university technology transfer offices (TTOs) aver that spinout numbers do not accurately reflect their entire commercialisation efforts. Consequently, for all of these reasons, one can get a distorted view. Although universities may fulfil their 'spinout quota', the quality of the spinouts produced - in terms of their attractiveness to external investment, profitability, or prospects for sustainability - may reveal a different story. Indeed, it appears that relatively few spinouts produce sizeable direct financial benefits to their universities, many strive to attract funding, and only about a quarter are profitable.

These issues raise the concern that the number of spinouts may have been afforded excessive importance in assessments of research commercialisation at UK universities. While it is an indication of the *performance* of technology transfer, there is a need to examine the *efficiency* of technology transfer, i.e., how well technology transfer input is transformed into commercial output, such as intellectual property of genuine business value (Lynskey, 2006b, 2009) and new products and services in the marketplace, and its influence on the local economy (e.g., job creation).

This paper presents the findings of a preliminary study which looked behind the numbers of spinouts, to begin to fill in the picture of spinout activity in the UK, using data on a small sample of universities and their spinout firms. Moreover, and importantly, we sought the opinions of the directors of university TTOs on spinouts and technology transfer policy. Before describing the methodology and results, we review briefly how the entrepreneurial university emerged in the UK.

Changing Role of Universities in the UK

University-industry collaboration in the UK is not new (Macleod, 1971; OST, 1993; Shinn, 1998; Lynskey, 2005, 2006a), and its diversity and extent were recognised decades ago (HOC, 1976). This reflected the changed role of universities from their origins as medieval institutions (beginning with Oxford in the 11th century) for conserving and imparting knowledge (Rashdall, 1896). They later adopted the discovery of new knowledge as an explicit goal, and focused thereafter on two roles – teaching and research – which were exogenous to, and independent from, specific economic and social development imperatives (Jencks and Riesman, 1968). This simple 'social contract' relied on a dissemination model of innovation whereby publicly funded basic research flowed to the economy in a linear process. In this model, universities were seen solely as producers of knowledge (Malecki, 1997); and firms then took forward those ideas the 'market' valued and launched them as products. This drew heavily on several aphorisms worthy of Bacon (1605, 1620): that basic research is performed without thought of practical ends; that advances in basic research will be converted into technological applications by the process of tech-

nology transfer; and that a nation would reap the technological benefit of its investment in basic science.

In the past three or four decades, deficiencies in the linear model and increasing constraints on public funding for research have led to new models of innovation (Jolly, 1997; Nightingale, 1998; Padmore *et al*., 1998) and to a new social contract that reflects the social accountability of university research and the requirement that it address social and economic needs (Kline and Rosenberg, 1986; Lundvall, 1988; Guston and Keniston, 1994; Rappert, 1995; Geuna, 1999). In the USA, universities responded to a shift in government policy following legislation – the Bayh–Dole Act and the Stevenson–Wydler Technology Innovation Act, both of which were passed in 1980 – and created TTOs to patent, license and commercialise their discoveries. Although the legislation was merely one of several factors (Mowery *et al*., 1999; Nelson, 2001; *The Economist*, 2002; Mowery and Ziedonis, 2002), it contributed to an increase in patenting and technology transfer from American universities.

Similar measures were endorsed in the UK at about the same time as policy was being enacted in the USA. These initiatives encouraged universities to meet the needs of industry more closely, and by so doing attract private sector finance. They portrayed a future in which universities would be much more responsive to the needs of industry by: (a) putting greater emphasis on the needs of science and technology; (b) encouraging industry to take an increasingly important role in funding and guiding university activities; (c) linking universities and industry to encourage the transfer of technology; and (d) fostering an entrepreneurial spirit for the improvement of economic prosperity. The UK government also assigned responsibility for promoting commercial exploitation from the various research councils (which oversee and assign funding for research in UK universities) to universities, with the delegation of this responsibility wherever possible to the individual researcher. Similar to the Bayh-Dole Act in the USA, this gave UK universities the right to exploit their own intellectual property, and acted as a stimulus in the generation of spinouts.

Universities, for their part, responded to the call for a vigorous and commercial approach to the exploitation of university research. By 1990 almost all of them had developed formal control or support mechanisms to manage the commercialisation of their research (Lowe, 1993a), since it was recognised that "research carried out in United Kingdom universities is outstanding in its innovative and commercially exploitable results" (UDIL, 1989, p 565) and "has been shown to have considerable commercial potential" (Lowe, 1993b, p 27). The universities were described as developing "constructive and outward-looking attitudes with a willingness to raise money from non-traditional sources, to engage in innovative projects and relationships with businesses and public sector bodies locally, nationally and internationally" (Blackman and Segal, 1991, pp 299-300).

The political consensus in the UK in recent years has regarded university research as generating new products and processes whose commercial exploitation is a contribution to wealth creation (e.g., ACOST, 1993; OST, 1993; HM Treasury, 2004; HEFCE, 2003, 2004, 2005). The government's White Paper, *Realising our Potential* (OST, 1993), reflected the policy interest in innovation from universities as an engine of economic growth, and the *Dearing Committee of Inquiry into Higher Education* appealed for alliances between universities and the economy, recommending that universities foster research aimed at attracting investment (NCIHE, 1997). Government policy was directed to "ensuring that those investments yield an adequate return, a return ultimately reflected in enhanced competitiveness, wealth creating potential, and the quality of life" (Metcalfe, 1997: 723).

Consequently, universities are now recognised as enablers, even leaders, of regional economic and social development (Etzkowitz and Leydesdorff, 1997, 2000; Salter and Martin, 2001). This is captured in the idea of a 'third mission' for universities, encompassing those activities outside the traditional remits of teaching and research (Howells *et al*., 1998). The government has introduced various schemes to support universities with research

exploitation, key among which has been the introduction of a 'third stream' of funding for universities to develop 'third mission' activities. Examples of such initiatives include the provision of essential seed funding for university spinouts, the teaching of entrepreneurship to support the commercialisation of research, and funding to improve linkages between universities and their communities.

Using such initiatives, UK universities have exhibited growth in all forms of 'third mission' activities – patents, licences, consultancy and spinouts (Charles and Conway, 2001; HEFCE, 2003, 2004, 2005; Howells *et al*., 1998; OECD, 2002; UNICO, 2004, 2005).

Measures of Commercialisation Activities

Despite the success of UK universities, in terms of the commercialisation of intellectual property, where they exhibit a similar pattern of concentration of activity as US universities (O'Shea *et al*., 2005), the perception of a cultural mismatch between the objectives of universities and industry persists (Patel, 1998; Lambert, 2003; Davey, 2005).

Some have questioned whether universities adequately encourage or reward entrepreneurship (Handscombe, 1996), and suggest that the formation of spinout firms may have been hindered by the lack of clear procedures on spinning out, the shortage of resources in industrial liaison offices, and the lack of incentives to attract commercial management into technology transfer offices and the spinout firms themselves (HEFCE, 2005; Lambert, 2003; UNICO, 2004). Another concern peculiar to the UK is that the Research Excellence Framework (REF) – a series of exercises conducted nationally to assess the quality of UK research and to inform the selective distribution of public funds for research by the UK higher education funding bodies – does not encourage entrepreneurship among academics. Although the REF examines industrial research metrics, such as submitted patents, it does not explicitly measure entrepreneurship and takes no account of universities setting up spinout firms. Its emphasis on academic publications over the commercialisation of research therefore ties funding in a way that does not reflect overall government objectives (Davis, 2005a; RSC, 2005).

On the other hand, the suggestion that research excellence, as measured by the REF, diverts academic focus away from commercialisation seems at variance with studies that find a positive and statistically significant relationship between academic excellence and academic entrepreneurship (Shane, 2004; O'Shea *et al*., 2005; Powers and McDougall, 2005). Indeed, several outstanding academic entrepreneurs, who recognise the complementary aspects of academe and business, attest to a changed entrepreneurial landscape in UK universities (Shepherd, 2005, 2006). Perhaps a more significant criticism is that, although UK universities have produced hundreds of technology-based start-up firms in recent years, most have produced little direct benefit to the universities themselves. For example, despite all the commercialisation activity in and around Cambridge, Cambridge University's intellectual property royalties bring it relatively modest sums (e.g., Broers, 2005).

Notwithstanding these issues, the government has been keen to demonstrate that third stream funding activities, including its support for spinouts, have led to a marked increase in performance. Studies conducted to date have attempted to assess such performance, using such data as the number of spinouts, patent filings, licensing income and spinouts/research expenditure, as reported by UNICO (UNICO, 2004; Wright *et al*., 2002, 2003) and HEFCE (2003, 2004, 2005).

Although such measures are informative, we suggest that they should not be applied uniformly across all universities, which are quite different in terms of their research funding income, their attitude to commercialisation, and the availability of resources for technology transfer. Nor does such data necessarily give a useful indication of the ongoing effectiveness of commercialisation activities appropriate for the wide range of different situations facing universities in the UK, and they may, if used in league tables, lead universities to channel resources into inappropriate activities. Finally, such data reveals nothing about the views of those directly responsible for university technology transfer.

Research Design

The aim of this research was to gain an understanding of the background to the data on university spinouts by considering the institutions from which they emerged, and to explore some of the primary characteristics of the spinouts themselves (e.g., their origins, growth, investment received and continuing links with the universities and the local area). This would allow us to assess what weight of interpretation should be put on data simply expressing numbers of spinouts. In addition, and significantly, we wished to elicit the views of those primarily responsible for commercialisation efforts, by interviewing the directors of university technology transfer offices (TTOs).

To address these issues, we contacted the director of each TTO at a sample of ten UK universities and conducted interviews with them and their colleagues, to gather information on the universities, the TTOs and the spinout firms in which the universities had equity stakes. We chose to analyse only those spinouts formed in a specific five-year period. The universities were selected at random, but could be grouped according to their research funding budgets as follows:

Group A: The four universities with the largest research budgets: Cambridge University; Imperial College, London; Oxford University; University College, London (UCL)

Group B: Three other large universities in major cities with substantial research budgets: Edinburgh University; Newcastle University; Southampton University

Group C: Three universities with smaller research budgets, reflecting in part their lack of medical research activities, but each with a high proportion of research funds from UK industry: Cranfield University; Loughborough University; Strathclyde University

The interviews with the TTO directors and their colleagues followed a structured format in which we asked for responses on the following topics:

(a) Background to the TTO, its ethos and achievements (e.g., number of spinouts in which the university has equity holding, past and current)
(b) Contextual indicators (e.g., research income, sources of income, life science vs. physical science expenditures, returns to the university from spinouts - current holdings and disposals)
(c) Strategy for commercialisation (e.g., targets for spinouts, emphasis on spinouts within the portfolio of commercialisation activities)
(d) Resources allocated to support spinouts (e.g., full-time equivalent staff, how many dedicated to spinouts, any internal sources of funding)
(e) Internal linkages (e.g., with departments and institutions in the university)
(f) External linkages (e.g., with venture capital firms)
(g) The requirements of spinout firms
(h) Physical resources (e.g., incubators, entrepreneurship centre, training & support facilities)
(i) Lessons learned in retrospect on the spinout process (how many spinouts have failed and why, was a spinout appropriate for exploiting IP in these cases)

With the permission of the TTO directors, we then approached every spinout firm by e-mail and telephone with a questionnaire survey to gather information on the following:

1 . Age (year of incorporation)
2 . Size (number of employees - current and projected in three years' time)
3 . Sales (current and projected in three years' time)
4 . Founder(s) and originating department(s) within the university
5 . Ownership (and percentage of university stake)
6 . Field of activity (description and SIC code(s))
7 . Funding history (equity investments received, revenues)
8 . Valuation (date of valuation and on what it is based)
9 . Location (region of postal code) and type of premises (e.g., incubator or Science Park), indicating level of institutional embeddedness.
10. Continuing links with the university.

To ensure the accuracy of the replies received directly from the spinouts and the data collected elsewhere, we confirmed with the TTO directors that the balance between completed questionnaires and any non-responses reflected a realistic overall picture. Depending on their response, further efforts were made to obtain specific information from a small number of the spinouts to complete the data.

Survey and Interview Results

Descriptive data on the ten universities were collated from various sources, such as publications by the Higher Education Statistics Agency (HESA) and from interviews with TTO directors[1]. This included information on:

- full time equivalent (FTE) figures for academic staff and postgraduate research students
- total research funding, classified according to the proportion from various research councils, industries and charities
- proportion of research funding devoted to medicine and the biological sciences
- FTE staff engaged in the commercialisation of research

Referring specifically to the universities' spinout activities and performance, Table 1 shows the key quantitative findings for the five-year period, analysed by the three university groups. Selected extracts from discussions with the TTO directors, grouped according to several issues, are shown in Tables 2 to 7. To maintain confidentiality, the identities of the specific universities are not revealed, but only the university group to which they were classified.

- INSERT TABLE 1 ABOUT HERE -

Numbers of Spinout Firms

Table 1 reveals that universities in Group A had the largest number of spinouts. This was anticipated since these universities have more academic staff, more substantial research funding, and more personnel engaged in research commercialisation, than the universities in Groups B and C (as revealed in our descriptive data). This suggests a direct correlation between the number of spinouts and university resources. However, the universities in Group B, and certainly the ones in Group C with relatively modest financial and human resources, punched above their weight in terms of spinout numbers. This implies a decreasing return to scale in spinout activity, although it may simply indicate less efficiency at the TTOs of group A universities, possibly in part because incentive structures for research commercialisation are not considered attractive enough at UK universities generally (Chapple *et al*., 2005).

While resources are clearly important, other factors also affect the number of spinouts formed. It is likely to depend also on the entrepreneurial culture at universities, on internal decisions about the allocation of resources to commercialisation and, subsequently, on the TTO's view about the priority given to spinout formation vis-à-vis other routes to commercialisation, such as patenting and licensing. Interviews with the TTO directors indicated that technology transfer is difficult, whatever route to commercialisation is selected. Furthermore, they all emphasised that they either have no targets for the number of spinouts, or that setting such quotas is futile because numbers do not reveal the full extent of commercialisation efforts. Instead, they considered that other measures, such as the amount of equity finance spinouts attract or the numbers of jobs created, are more meaningful indications of the value of spinouts and of the efforts of the TTOs.

Another key finding was that at some universities there were more start-up firms (i.e., firms originating from the university, but where the university had no claim on – and thus received no benefit from - intellectual property) than spinout firms. Start-up activity is likely to depend on relevant university policies, such as those relating to intellectual property, and the overall 'culture' of the

1 The descriptive data for all the universities is not shown here, but is available from the author.

university in relation to enterprise. Start-ups may well be difficult to identify, categorise and track systematically, but they may form a significant area of activity for a university's commercialisation office.

Bearing this in mind, one can conclude that the number of spinouts from a university:

(a) should not be interpreted as an independent indicator of the relevance of the university's research to the business community; and
(b) should not be used as an objective indicator of the level of entrepreneurial enthusiasm amongst staff and other researchers.

Types of Spinout Firms

Lambert (2003) highlighted the concern that there may be an over emphasis in the UK on creating spinouts, rather than seeking to licence a technology to an established business. Lambert (2003) argued that spinouts are often too complex and unsustainable, and of low quality; a third in the UK are fully funded by the parent university and attract no external private funding. Our study revealed that, as a proportion of R&D expenditure, UK universities place greater emphasis on spinouts than their US counterparts, and less on licensing. Lambert (2003) suggested that UK universities may value their intellectual property (IP) too highly, and that contracts often lack clarity of ownership. Both of these characteristics discourage businesses from licensing IP from universities, and may encourage universities to commercialise their technologies through wholly-owned spinouts.

In response to the question, "How do you decide when to form a spinout?" the TTO directors replied that they were inclined to do so:

(a) where the inventors are keen to commercialise the technology themselves and have a preference for forming a company;
(b) when the spinout is a licensing and development vehicle (e.g., when the idea needs to attract substantial investment to develop the technology and subsequent licensing of the technology or its intellectual property);
(c) when the technology is not readily licensable or no existing company is able to take it up on a licensing basis; or
(d) for a generic or 'enabling' technology with many potential applications (e.g., "platform technologies", such as diagnostic equipment in biotechnology).

Owing perhaps to the different circumstances under which spinouts are formed, an important finding from our discussions with the TTO directors was that any analysis of spinouts that implicitly assumes they are a generic, homogeneous class of new business is inherently flawed. As clarified in the literature, they differ markedly according to their resources and capabilities (Powers and McDougall, 2005), equity funding (Wright *et al*., 2006), academic linkages (Nicolaou and Birley, 2003) and the entrepreneurial ability of their founding academics (Roberts, 1991; Shane, 2004; Stuart and Ding, 2006). Studies suggest that they are heterogeneous, and various categorisations have been proposed (Clarysee *et al*., 2005; Nicolaou and Birley, 2003). Our study suggested that there are three distinct categories of spinout companies:

1 . *High-growth potential*. Spinouts with identifiably high growth potential, even if there are considerable risks that the potential will not be realised, that attract more investment than others;
2 . *Steady-growth potential*. Spinouts that are likely to be serious businesses in that they create employment and ultimately generate profits, but which may have limited or slower growth potential;
3 . *Technology vehicles*. Spinouts that are legal vehicles for the commercial development of a technology that, in due course, is likely to be commercialised through the license or sale of the IP.

Characteristics of Spinout Firms

Origin

Table 1 shows the numbers of spinouts that originated from researchers in the life/clinical sciences and the physical sciences, respectively. Together, these account for approximately 90 percent of the total number of spinouts, with the remainder emerging from the arts, humanities and social sci-

ences. The striking difference between the three groups of universities in terms of the proportion of spinouts emerging from the life/clinical sciences - 47% at group A compared with 11% at group C - is accounted for by the large share of the research budgets in these fields at the Group A universities. These universities had the most richly-endowed research funding in medicine and life science as a percentage of total expenditure. They also have renowned medical schools, life science institutes and dedicated teaching hospitals.

Conversely, Group B universities, and particularly Group C universities, had a lower proportion of spinouts originating from the life/clinical sciences, and a correspondingly higher percentage from the physical sciences. This reflected the research funding allocation in different fields, and may also be because such spinouts - for example those in information and communication technology (ICT) - generally require less start-up capital than those in life science, which often require wet labs and sophisticated clinical equipment. Moreover, technology transfer in life sciences is substantially different from that in physical sciences (Owen Smith and Powell, 2001). Also, Group C universities arguably have a reputation as being more focused on practical or 'industrial' concerns and are not as generalist as those in groups A and B.

Growth and equity finance

Growth performance was considered in terms of employment and revenue. There are shortcomings, however, in both measures. Revenue depends crucially on the nature of the business, as it masks considerable variations in value added, whereas employment can encompass widely different qualification requirements and salary levels. The data show that, assuming there has been a generally even level of spinouts over the five-year period (which was broadly the case), approximately a quarter to one-third of spinouts had reached a position in which they have ten or more employees, and a similar proportion (approximately one-fifth to one-third) had attained a revenue level equal to, or exceeding, £250,000. Thus, a reasonable proportion had attained a level of some substance over the five-year period.

This was borne out by the proportion of firms securing equity finance and by the average level of such investments. The figures in the final column of Table 1, for Group C universities (those with smaller research budgets), averages the experience of Strathclyde University, which has a long history of involvement with research commercialisation, and Loughborough University, whose experience is much more recent. Their lower levels of equity finance – both the proportion of firms obtaining finance and the average level obtained – probably reflect their relatively low proportion of firms from the life/clinical sciences, which typically need significant equity funding from the outset. Conversely, these two universities had a relatively high proportion of firms achieving revenue of £250,000 or more; and, again, the absence of life/clinical science businesses, which often have to undertake lengthy clinical trials before they have any commercial product, may be part of the explanation. Spinouts based on physical sciences, ICT and engineering – which comprised 80 percent of those from Group C universities – are more likely to have earlier revenue streams compared with those based on life/clinical sciences.

Geographic location

The proportion of firms that have remained in the same sub-region as their parent university, as designated by their postal code, is an indicator of their level of embeddedness and contribution to local economic development. The majority of spinouts, across all three groups of universities, remained in the same sub-region, thereby benefiting from university spillover effects (Zucker *et al*., 1998; Lynskey, 2008) and proximity to tacit knowledge. Since, as already mentioned, about 25% of all spinouts achieved a reasonable revenue stream and employed ten or more people after a five-year period, these firms thereby contributed to the local economy. This is not meant to imply that the 25% ongoing contribution to the local economy is similar for all three Groups and that, thereby, there is a common regional experience across these firms. In fact, as Table 1 indicates, Group C firms have a higher

turnover and so perhaps longer-term potential. This is very much to do with regional factors (see Webster et al., 2003).

The relatively lower percentage (70%) for Group A universities remaining in their sub-region is chiefly a reflection of the 'London' factor, i.e., spinouts from Imperial College and UCL were more likely to move outside London, due to the high costs associated with the capital city. Interestingly, though, both Oxford and Cambridge had retention rates similar to the other non-London universities, despite the high costs associated with these two locations. It should not, however, be assumed that the lower proportion (24%) of Group A university spinouts in university facilities or a related incubator is also accounted for by the London institutions. The proportions in Cambridge, Imperial, Oxford and UCL were, in fact, similar to one another.

Linkages

The final row of data shows that approximately a half to two-thirds of spinouts retained on-going links to their parent university. Despite a greater spatial separation from their spinouts (fewer spinouts remaining in the sub-region or in university facilities), the Group A universities had marginally more continuing links with their spinouts, though there was considerable variation concealed within the average and it was not explained by the 'London' factor. In addition, although we could not quantify the effect, the interviews revealed that firms were able to use their links with the universities to tap into wider networks, drawing, for instance, on alumni as sources of managers, finance and commercial connections. This alumni link was often strong in connection with the universities' business schools and may well become of growing importance as universities invest greater effort in their alumni relationships. Business schools also provided a link to a 'free' commercial resource in the form of MBA student projects.

Qualifications to the Data

The ten university TTOs were spinning out on average three firms per year, and most of the TTO directors thought that three to five per year was a 'manageable' number, although this seemed high by average US standards (O'Shea *et al*., 2005). The spread in the number of spinouts was from less than one per year to nine per year. This underlines the fact that spinouts – and their parent universities - are not a homogenous group.

Our survey only captured data on spinouts that had survived to the point at which our study was undertaken. We did, however, cross check this aspect and found that the average failure rates for spinouts across all the ten universities were very low: fewer than 10 percent, compared to the average for high-technology firms generally of 60-70 percent.

Using data such as these to measure the performance of university TTOs is not straightforward, since TTOs can only take a spinout to a certain point of its development, after which the firm's success depends on a number of other endogenous and exogenous factors. In assessing their own performance, university TTOs often consider the attraction to external investment of the spinouts as a useful measure, which is why we have shown these figures.

We have not tabulated returns to the universities from dividends or the sale of their equity in spinouts. Such returns are regarded as unpredictable rarities, especially in the short to medium term. Equally, it would be inappropriate to record such benefits without also recording other direct benefits from spinout firms, including research commissions for academics and jobs for students. Indirect benefits also need to be factored in, and they include fulfilling institutional ambitions to support the local community and economy, and helping to encourage positive attitudes to entrepreneurship among staff and students.

Discussion and Conclusion

Arguably, the transition in universities to a position of reduced dependence upon government support has occurred most significantly in the UK than it has elsewhere during the past three decades, as the government has attempted to change the structure and function of universities and emphasise their

relevance to commerce. This change is most evident in the growth of all forms of university 'third mission' activities, such as patents, licences, consultancy and spinouts.

Of these activities, university spinouts have been afforded a high a profile in various policy pronouncements and have tended to be viewed, perhaps uncritically, as an entirely positive manifestation of the commercialisation of university research results. As such, there have been calls recently for a more measured and objective assessment of their true business and economic value, as the government wishes to assess the benefits of its deployment of funding for third mission activities.

Certainly, any direct financial benefits to universities of spinout activity may well accrue only in the long term, and the distribution of such benefits may well be heavily skewed towards only a few spinouts. Investment in spinouts involves significant resource commitments from the universities and TTOs and, in the short term, the costs they entail almost certainly exceed any financial returns. Continuing resources are also needed to ensure that the university's investment stakes in spinouts are appropriately managed. Such management requires specific expertise, which may need to be drawn in from beyond the TTOs. Clearly, then, just as attempts at measuring academic entrepreneurship invariably underestimate the extent of the phenomenon (see Vesper and McMullan, 1988; Chrisman *et al*., 1995), there is an analogous 'iceberg effect' when viewing the extent of university commercialisation efforts. A point that emerged from our interviews was that it can take up to ten years before significant returns start to flow from spinout activities. There are, however, a number of valuable spillover effects (Lynskey, 2008) to regional and national economies that are likely to be felt more immediately, such as job creation. It is important, therefore, that any policy encouragement towards university spinouts reflects their full range of contributions and not simply their financial impact.

Several universities gave estimates of the number of spinouts they were likely to establish in an average future year. Levels were determined in part by the availability of resources in the TTO, but individual academic enthusiasm is also an important element in the choice of commercialisation route. Most universities mentioned engagement with spinouts (and start-up firms) as being part of their strategic commitment to the regional economy. A common theme to emerge from our interviews, however, was that target setting for such spinouts inevitably leads to behavioural change, as universities attempt to meet their quotas. It is, therefore, arguable that, if targets are set for spinouts, then there ought to be corresponding targets set for other means to commercialisation also, if distortion is to be avoided.

The majority of TTOs have established informal or formal links to a range of industrial and venture capital sources. Some of these links are 'first right to fund' arrangements, whereby a company or venture capital firm is given the first option to consider possible deals with a spinout before other investors. All the TTO directors emphasised, however, that obtaining funding was not always easy, and venture capitalists and others naturally had to be persuaded of the business case of a spinout proposition. It was stressed by some TTO directors that more time might be needed to incubate a potential spinout within the university setting in order to develop a technology, if they are to attract quality management and sufficient investment from venture capitalists.

University spinouts remain a key area of interest for policymakers seeking to ensure that outputs of publicly-funded research are successfully applied and commercialised. In this study we sought to look behind mere spinout numbers to consider some aspects of the underlying context: the UK institutions from which they emerged; several characteristics of the spinouts themselves; and the views of university TTO directors responsible for spinout activity. We suggest that there is a need to analyse carefully the data on spinout activity in informing public policy. Spinout numbers by themselves - and the use of spinout quotas - measure something that is of little substantive value; and one needs to be wary of spinout counts as a marker of commercial efficacy (see Rappert et al., 1999; Pavitt, 2001). Instead, better interpretation of the

institutional background and outcomes of spinout activity, especially with respect to spillover effects, may have more direct relevance to what the REF and similar evaluations attempt to capture in determining university research funding and entrepreneurship at universities.

- INSERT TABLES 2 TO 7 ABOUT HERE -

Table 1. Summary data on spinout firms from three categories of universities

Characteristic		Average per institution for Group A universities	Average per institution for Group B universities	Average per institution for Group C universities
Total number of spinouts (in 5-year period)		24.8	12.0	12.5
Origin in life science + clinical (a)	Number	11.8	3.7	2.0
	%	47%	31%	16%
Origin in physical sciences and engineering (a)	Number	10.0	7.0	10.0
	%	40%	58%	80%
Employees ≥ 10	Number	6.8	4.0	3.0
	%	27%	33%	24%
Revenue ≥ £250K	Number	4.3	2.3	4.5
	%	17%	19%	36%
Equity financing	Number	17.8	8.3	5.0
	%	72%	69%	40%
	Total raised/£K	86,143	40,602	9,356
	Average per spinout with equity/£K	4,853	4,872	1,871
Remained in sub-region (b)	Number	17.3	10.3	10.5
	%	70%	86%	84%
In university facilities or incubator (c)	Number	6.0	5.0	8.5
	%	24%	42%	68%
On-going links to the parent university (d)	Number	16.3	6.0	8.0
	%	66%	50%	64%

Notes:

(a) According to founders' department(s). Physical sciences include not only physics-based sciences, but also such fields as chemistry and computer science.

(b) Postcode of firm and university designates same sub-region.
(c) Firm address is in university facilities or in related incubator.
(d) Includes collaboration/sponsorship of academics or students, use of university facilities, IP agreement, and staff secondment.

Table 2. Opinions on university-industry technology transfer policy

University	Extracts from interviews with TTO directors
Group A	"Over the past few years - and the University Challenge Seed Fund is a good example - the government, through HEFCE and through the HEIF programme, has provided resources to support the development of technology transfer, commercialisation, and knowledge transfer activities in universities. Most university managements and vice chancellors have actively taken part, in the sense that one sees the allocation of HEIF funding being spread across all the universities. I think most universities still recognise, however, that knowledge transfer or technology transfer is but a small third part of what universities are really there for: research and teaching. So I think universities are embracing it [commercialisation and technology transfer], but are not letting it take the focus off the key mission of universities."
Group A	"We don't audit, but what we do is work in the departments to try and raise the awareness of IP. We go out and perhaps we'll have an event in a department and just gently raise the awareness of IP, and simple things like the fact that you can publish and also file a patent. Whilst we don't actually audit the departments, we do try to raise their awareness and ensure that they know they can come and talk to us. […] We create an environment in which they all know we exist, that commercialisation is a good thing, and so they should come along if they want to."
Group B	"We see our remit is to undertake a cultural change within the University; to make it a very entrepreneurial body […] As a result of that, a lot of the other stuff we do, such as knowledge transfer and consultancy, will be a natural expression of that entrepreneurial culture. […] We are already seeing, for example, that we are differentiating ourselves in attracting academic staff to come here. We have several instances now where we have been able to attract the academic staff purely because the culture here will support them in exploiting their research."
Group C	"My job really is about value creation. Technology transfer from my point of view is about value creation. It's not about numbers of spinouts or licences. It's about value creation. That's capital value and income. Then you're back to the metrics debate, aren't you? Well, what capital value do you want to achieve? It's much easier to say, 'how many spinouts and how many licences do you have?', and put that surrogate measure in for value creation."

Table 3. Opinions on the strategy for spinout firms (e.g., setting targets)

University	Extracts from interviews with TTO directors
Group A	"It is completely senseless to set any targets on spinning out companies. The idea is simply to spin out good quality companies and to make money from the process. What one needs to do is recognise, and differentiate early on, between large opportunities that are investment propositions, and others that are good businesses and will make money, but for which external money will not be raised because it is not that type of business. One has to treat these opportunities differently."
Group A	"There has been a lot of focus on high-growth companies, and this is necessary if one has to go to the VC community for funding. There is not enough support for 'middle-of-the road' firms. Where do they go to fund a business opportunity, because they are unable to attract VC funding?"
Group A	"When we talk about metrics for spinouts, we have projected forward about how many companies are likely to be formed. But that is not a target."
Group B	"There are no targets set for spinout activity. You know the acronym WYMIWYG? What You Measure Is What You Get! I'm very much with that. If someone wants to measure me on patents or spinouts, patents are a £100 a pop, and so are spinouts. Well, how many would you like?"
Group B	"Government works on a three-year treasury cycle. Two years into the cycle, they want to see the evidence or benefits of the last money they allocated, before they allocate the next amount. Now, the US experience is that it's at least five years in licensing, and five-to-10 years in spinouts. […] There's so much that goes on in between, that the ability to show a causal link between what we did at the beginning and what actually transpired, is zero, because it depends so much on other people. There are so many variables. So I think it's very difficult to measure, other than you can measure activity, but you can't say whether that activity is good or bad. If you want to measure this thing, there is – and I think one sees this also in the funding streams – there is a lot of doing what they think people want. I hope one of the things we have got here – and it is embedded in the University – is we don't care what people want to measure us by, we're going to do what we think is right for the University. If we're successful, they'll find it damn hard to shoot us; and if we're unsuccessful, then we shouldn't be doing it anyway."
Group B	"There are no targets. We focus on what we believe is the right quality of activity to achieve the result. So if we do no spinouts this year, we're fine. If there's nothing good enough, we shouldn't be spinning it out."
Group B	"People have targets; and they also have career aspirations. I have very serious concerns. […] has always trotted out figures, but one needs to dig beneath the numbers. […] has made a lot of fuss about the numbers of spinouts in the UK being better, comparably, than the USA, but I actually think, 'no, we're not better; just more naïve.' What we have said is: our measure of success is that we produce something where independent external investors support our judgement. So, count as successful, not a company that we spinout, but a company that raises a substantial next round of investment."
Group B	"I have a concern about numbers of companies. […] in terms of […] promoting this and saying, 'oh, look at the number of companies created.' What I would more like to see associated with [this University] is that over the past five years [our spinouts] have raised between them something like $300 million of external finance. Also, probably 600-700 jobs have been created in the UK from those companies. I think that is actually more important: what we've actually produced in terms of money that people are prepared to put behind these companies and the jobs created."

Table 3 (cont). Opinions on the strategy for spinout firms (e.g., setting targets)

University	Extracts from interviews with TTO directors
Group C	"One of the conditions of our HEIF bid was to achieve certain targets. We have the legacy of these targets, which are a huge millstone round my neck. […] Targets are set for spinouts because of HEIF. Nobody wants them, but we're stuck with them. It was an externally imposed target, and I suppose the University might say, 'if you're going to do something, you need some sort of measure of success … you have to measure something'. A more realistic view, if you were a non-listed, privately-held company, you might say, 'well, we know what we want to achieve, we want to create value from exploiting our IP. We'd like to create something that's going to be worth a few million [pounds] in a few years' time.' It might be something as vague as that. So, as long as you can see yourself making progress towards that objective, that's okay. Whereas if you say, 'we've got to create 10 businesses with a turnover of £20 million by five years' time', I mean, it's just unreal, it's impossible to legislate for that."
Group C	"By all accounts, these are ambitious targets. They are ambitious because we're starting from zero, from a standing start. They are ambitious when you compare them with [Group A universities], with whom we're expected to benchmark against. And they're ambitious because of the economic climate. So there's a bit of an issue there."
Group C	"[A Group A university] has probably done this [set targets] in the past and probably regrets it now. They've spun out companies like shelling peas. I have no view of how successful or how big they are, but we all know you can form a company in five minutes on the phone. If that's how they're doing it, I think most people agree there's no point actually. And yet, there is a point because you've got to meet your HEIF targets!"
Group C	"When I meet people at UNICO (University Companies Association) meetings and such like and say 'how are you doing with your HEIF targets?' people run around laughing. They all have the same problem, I think. They have targets, which are … well, even if they were the right thing to do, because there's a debate about whether spinouts and licences are, what the balance is and everything. If you accept that they are the right thing to do, are the numbers right? Well, who knows? There's a huge debate. This work is interesting, what you're doing, but there are lots of other questions. We fill in lots of questionnaires giving the raw data, but the discussion around that is the important bit."

Table 4. Opinions on the route to commercialisation and the spinout process

University	Extracts from interviews with TTO directors
Group A	"The fundamental points are that all university research is pretty fundamental, and so not very near market, so the challenges are to develop it in the university so it is sufficiently advanced to be attractive to industry. But then we don't expect it to appear on the shop shelves within months after that. But in the companies that are taking these technologies on, there is a lot of development. So it is a good few years before commercialisation."
Group A	"What is the preferred route to commercialisation – licensing or spinouts? My view on that is clear: it's that there isn't a preferred route. My comments on this are that technology transfer is difficult; licensing technologies to an existing company is hard because finding an existing company that wants to spend their money on our ideas is hard. Putting technologies into new businesses is difficult because you have to create the right business case for managers to want to take the company forward and for investors wanting to put their cash in. So there is no preferred route."
Group A	"Generally, from an academic approaching one of the project managers to licensing or spinout, that can be normally, realistically, anything from 9 to 12 months, up to 6 years, I think, before one of the spinouts went out. […] it's not that we'd been trying to do a spinout for those six years, but the technologies take some time to develop and get ready for the market."
Group A	"Technology transfer is a challenge and finding the right route to market is what it's all about. Whether you find that through licensing or spinning out, both are hard work."
Group A	"There are three types of route to market or business that we manage. The first is licensing. Licensing, because the technology is early stage. It tends to be a fairly long-term business because you need a licensee who'll invest in developing the technology, and then there's the life of the patent for it to be commercialised. The second business activity we manage is consulting. Researchers can do consulting, and they've got a choice: they can either do it privately, or they can do it through us. For both of those, they need to get permission from the University. If they come through us, what we do is we help researchers market their consulting expertise. And we also help companies find experts within the University who might be able to help solve the company's problems. The third thing is the spinout companies."
Group B	"The formation of a spinout tends to be an intense burst of activity, which happens round an opportunity, and, generally, we get it once the gut feeling says, 'this looks interesting.' We'll generally get it to spin out within three months or kill it. Part of it is academic expectations. So we say to academics, 'we can do no more than five spinouts this year with the resources we have. We don't care if we do zero, but we can't do more than five, and we're not going to do more than five, so are you good enough?' We actually lay down the gauntlet. It's not me telling you we're not going to do it: it's you telling me that you're the best there is out there, and make them sell themselves. The target, if one exists at all, is an absolute upper limit."
Group B	"We [the universities] are offering a technology, not a product opportunity or a service opportunity. Most of the people that are out there who we might license to in the UK are incapable of evaluating the potential of that technology in their business, or its value, and are usually not set up to then invest in the work needed to understand that. So we actually see spinouts as a vehicle for two things: one is as a vehicle for developing the commercial case for that technology in terms of licensing; and the other is to develop a standalone company."

Table 4 (cont). Opinions on the route to commercialisation and the spinout process

University	Extracts from interviews with TTO directors
Group B	"I think people underestimate, in the absence of other routes to do that in the UK, that a spinout is not purely a standalone company. They may be basically licensing and development vehicles for particular technologies. And that's the way we approach licensing, unless there is a very obvious host for it. If we can, we go down the very obvious host route. But if we can't, we'll create the value ourselves because we think we can see it better than anyone else. The exit is if the trade sale is the same as the licence with the know-how package. And if you look at timescales, as well, I think it's five years versus 5-10. So actually thinking that licensing is a quick hit … if you talk to people like […] of the MIT Technology Licensing Office, they don't make money out of licensing."
Group C	"There are those who think spinouts are racy and universities should be doing this and who say, 'look at what [other universities] have done, so we should be doing it, too.' And there is the other side of the coin, which says, […] there's a suspicion around spinouts, 'is the academic trying to rip off the University?' That comes up time and time again. It's never quite said, but it's there, obviously. That will be the same in any university, I suppose, but it's certainly an issue here."
Group C	"The University has not had a revenue-sharing policy to date. That is currently being finalised. […] Also, we [the TTO] are looking at equity stakes in spinouts. Many of the staff at the University would not expect to get anything out of any IP. There is a lack of expectation and general naiveté among the staff about IP issues."

Table 5. Opinions on continuing links with the universities

University	Extracts from interviews with TTO directors
Group A	"We encourage the businesses to move away from the university sooner rather than later. What tends to happen in some places, I think, is that university spinout companies operate from within the labs; they just carry on in the labs where they were doing the research. We don't think that's a particularly good approach because what we want to see is the company becoming independent from the university base and growing as an independent, strong company. I think it is only when the company becomes independent from the research base and the university and has management and has investment that it is going to grow and become a company."
Group B	"[Some universities] take a view that if an academic licenses or spins out a technology, he can have no further dealings with that company. They do that because of conflict of interest. Here we take the view that conflicts can be managed. We would rather encourage the company to stay close to the university; and for the company it is actually quite a remarkable opportunity. […] We actually encourage that there is this close, symbiotic link between the company and the research group, and that we manage the conflict of interest so that it's all done in an ethical and properly-costed basis."
Group B	"We've got our own science park and incubator, owned by the University. So we have this facility here, which is pre-incubation. We have incubation at the science park, followed by move-on accommodation at the science park properly."
Group C	"Proximity [to the University] is so important to take companies through the various stages of growth and, luckily, we have the space here to do that – lots of land."

Table 6. Opinions on the management of spinout firms

University	Extracts from interviews with TTO directors
Group A	"We've helped all of them become companies and find management and raise finance. Generally what happens is that the head of a research group will stay in the University, but members of the research team might move across into the company. Because the culture in a university is so different from the culture in a company, it's highly unlikely that these people coming from the university will have the right skills to manage the company. So we try and find someone who can. […] Joint appointments don't work well at all, so we encourage the researchers to either stay in the University - I mean, it's entirely up to them – but if they want to get involved in the company, to leave the University and join the company. Generally, our experience shows us that it's very hard for a researcher to have afoot on each camp as the two camps get further and further apart."
Group A	"We identify an individual who can manage the company, somebody who's got experience of managing businesses in the past and then, when we think the business is going to take off, we introduce the team to lawyers, accountants, bankers, who will manage it once it's up and running as a company. And then, afterwards, researchers who stay in the University can be shareholders, non-executive directors and consultants. Researchers who leave the university, they become employees of the company."
Group A	"I think that events have skewed the figures. On the University Challenge Seed Funds, apart from the fact that suddenly some universities had access to funding, I think how that was managed was different in different universities. Larger universities had their own University Challenge Seed Fund, which meant they could manage it in their own way. A lot of the smaller universities had to collaborate. So you'd get two or three universities applying for one fund. There was no way that could go to one of the universities, so what was happening was that they were getting external fund managers to manage the fund, which meant they were forced to go down the spinout route. They couldn't develop the technology within the university and then try to license it. Instead, they were forced to go down the spinout route, which in some instances maybe they wouldn't have done had they had a free choice."
Group A	"The VC community places emphasis on finding a track-record entrepreneur and there is perceived to be a crisis because there is a shortage of such people in the UK. But we have to give people a chance to run these businesses. The way to do so is to ensure there is a good board, with people of track record and experience. We have to grow our own pool of entrepreneurs in the UK. It is a mistake to think we have to attract people from the US. There are good people here who, if encouraged in the right way, can build good businesses."
Group A	"Problems arise if the companies are not well funded. Then one often asks people to come in on a risk and not to be paid for a while. That is much harder. We still operate on a shoestring and still build our businesses relatively slowly. In the US, if you see a big opportunity, you put a lot of money into it. We do not do that here."
Group C	"VCs nowadays do not invest in spinouts."

Table 7. Retrospectives on the spinout process

University	Extracts from interviews with TTO directors
Group A	"It is usually not so clear, not black and white, but there are things we should have done differently. For example, in the two companies that failed, far too much reliance was placed on the ability of chief executives, who really drove the strategies of the companies. In both cases, the chief executive was not the right person for that stage of the company's business. They were trying to grow the firms too quickly, but the technology was not advanced enough to match the management. Both went for an aggressive strategy of raising sizeable VC funding before the technology had developed through certain stages. They needed someone more hands-on with the technology, instead of someone with more experienced ability to grow the management team and skills. They were brought in too early; they would have been ideal 18 months later."
Group A	"When, in ten years' time, when social scientists and management researchers come to study this, I don't know, really, what the big conclusions will be. And, I mean, human nature comes into play because there may have been some – well, there were - some big success stories in terms of university spinout companies floating […] and researchers making good sums of money. So human nature comes in and researchers say, 'well, I might have a go at that'. But, equally, there are stories of very successful licensing transactions and researchers making good amounts of money from that. So I think what is happening, broadly, is that researchers are more and more aware of the commercialisation opportunities. Spinout activity tends to get more press – more local press, national press, you know, if a company floats it gets into the Financial Times and all that stuff. Licensing activity has been growing as well, but tends not to attract the attention of the journalists quite so much."
Group C	"A question arises: Why not just license a technology? Why mess around with this spinout company stuff? I think the reason for that is, who's going to run it? The academics don't have the time or the skills, and maybe the motivation. [This TTO] does what it can, but the workload is too much."
Group C	"To be honest, spinouts – if you regard these as spinouts, or not – I don't think they have had any great impact on the profile or success of the University financially."
Group C	"Don't assume that spinouts are the right thing to do."

References

ABRC (Advisory Board for the Research Councils) (1986) *Report of the Working Party on the Private Sector Funding of Scientific Research.* HMSO, London.

ACOST (Advisory Council on Science and Technology) (1993) *A Report on Medical Research and Health.* Cabinet Office, Office of Science and Technology. HMSO, London.

Bacon, F. (1605) *The Advancement of Learning*.

Bacon, F. (1620) *Novum Organum Scientiarum*.

Barber, M. (2007) *Instruction to Deliver: Tony Blair, Public Services and the Challenge of Achieving Targets.* Politico's, Petersfield, Hampshire.

Birley, S. (2002) 'Universities, academics, and spinout companies: lessons from Imperial', *International Journal of Entrepreneurship Education,* 1 (1), 133-154.

Blackman, C. & N. Segal (1991) 'Access to skills and knowledge: managing the relationships with higher education institutes', *Technology Analysis & Strategic Management,* 3 (3), 297-303.

Broers, A. (2005) 'Wake up to the future', *Times Higher Education Supplement,* 8 April, p. 14.

Chapple, W., Lockett, A., Siegel, D., & Wright, M. (2005) 'Assessing the relative performance of U.K. university technology transfer offices: parametric and non-parametric evidence', *Research Policy*, 34 (3), 369-384.

Charles, D., & Conway, C. (2001) *Higher Education Business Interaction Survey.* Centre for Urban and Regional Development Studies, University of Newcastle upon Tyne.

Chrisman, J. J., Hynes, T., & Fraser, S. (1995) 'Faculty entrepreneurship and economic development: the case of the University of Calgary', *Journal of Business Venturing,* 10, 267-281.

Clarysse, B., Wright, M., Lockett, A., Van de Elde, E., & Vohora, A. (2005) 'Spinning out new ventures: a typology of incubation strategies from European research institutions', *Journal of Business Venturing,* 20, 183-216.

Davey, S. (2005) 'A lay-by on the road to market', *Times Higher Education Supplement,* 8 July 2005, p 16.

Davis, C. (2005a) 'Hefce "failing" to reward spin-offs', *Times Higher Education Supplement,* 11 March 2005, p 7.

Davis, C. (2005b) 'Spin-off numbers inflated', T*imes Higher Education Supplement,* 10 June 2005.

DfES (Department for Education and Skills) (2005) *Departmental Report.* HMSO, London.*The Economist* (2002) 'Innovation's golden goose', 365 (8303), 14 December 2002.

Etzkowitz, H., & Leydesdorff, L. (1997) *Universities and the Global Knowledge Economy: A Triple Helix of University-Industry-Government.* Pinter, London.

Etzkowitz, H., & Leydesdorff, L. (2000) 'The dynamics of innovation: from national systems and 'mode 2' to a triple helix of university–industry–government relations', *Research Policy,* 29 (2), 109–123.

Geuna, A. (1999) *The Economics of Knowledge Production: Funding and the Structure of University Research.* Edward Elgar, Cheltenham.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994) *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies.* Sage Publication, London.

Guston, D. H., & Keniston, K., (Eds) (1994) *The Fragile Contract: University Science and the Federal Government.* MIT Press, Cambridge, MA.

Handscombe, R. D. (1996) 'Rewards for inventors: a review of current practice in UK universities', *Industry and Higher Education,* 10 (3), 189–198.

HEFCE (2003) *Higher Education-Business Interaction Survey 2000-1*. Higher Education Funding Council for England, Bristol.

HEFCE (2004) *Higher Education-Business Interaction Survey 2001-2*. Higher Education Funding Council for England, Bristol.

HEFCE (2005) *Higher Education-Business Interaction* Survey *2002-3*. Higher Education Funding Council for England, Bristol.

Hirst, P. (1965) 'Liberal education and the nature of knowledge', in R. D. Archambault (ed) *Philosophical Analysis and Education.* Routledge and Kegan Paul, London.

HM Treasury (2004) *Science and Innovation Investment Framework 2004 – 2014.* HMSO, London.

House of Commons (1976) *Select Committee on Sci-*

ence and Technology Third Report: University-Industry Relations. HMSO, London.

Howells, J., Nedeva, M., & Georghiou, L. (1998) *Industry-Academic Links in the UK*. HEFCE, Bristol.

Jamieson, D. W., & Jansen, C. (2001) 'Technology transfer and economic growth', *Industry & Higher Education,* 15 (3), 189-196.

Jencks, C., & Riesman, D. (1968) *The Academic Revolution.* Doubleday, New York.

Jolly, V. K. (1997) *Commercializing New Technologies: Getting from Mind to Market*. Harvard Business School Press, Boston, MA.

King, R. (Ed) (2003) *The University in the Global Age (Universities into the 21st Century)*. Palgrave Macmillan, Basingstoke, Hampshire.

Kline, S. J., & Rosenberg, N. (1986) An overview of innovation. In R. Landau and N. Rosenberg (Eds) *The Positive Sum Strategy: Harnessing Technology for Economic Growth*. National Academy Press, Washington, DC, pp 275-305.

Lambert, R. (2003) *Lambert Review of Business-University Collaboration: Final Report.* HMSO, London.

Lowe, J. (1993a) 'Academic enterprise and organisation control', *Discussion Papers in Business and Management,* 4. Bristol Business School, University of the West of England, Bristol.

Lowe, J. (1993b) 'Commercialisation of university research: a policy perspective', *Technology Analysis & Strategic Management,* 5 (1), 27-31.

Lundvall, B.-A. (1988) 'Innovation as an interactive process: from user-producer interaction to the national system of innovation', in G. Dosi, C. Freeman, R. Nelson, G. Silverberg & L. Soete (eds), *Technical Change and Economic Theory.* Pinter Publishers, London, pp 349–369.

Lynskey, M. J. (2005) 'Moving beyond metaphors: university-industry collaboration in biotechnology', *Journal of Commercial Biotechnology,* 11 (4), 301-304.

Lynskey, M. J. (2006a) 'The dismantling of redundant dichotomies: biotechnology as an exemplar of university-industry collaboration', *Journal of Commercial Biotechnology,* 12 (2), 1-20.

Lynskey, M. J. (2006b) 'Editorial: a strategy to optimise the business value of intellectual property', *International Journal of Biotechnology,* 8 (3/4), 146-168.

Lynskey, M. J. (2008) 'Knowledge spillovers from public research institutions: evidence from Japanese high-technology start-up firms', in A. Groen, R. Oakey, P. Van der Sijde and G. Cook (eds), *New Technology-Based Firms in the New Millennium, Vol. VI.* Bingley, York, Emerald, pp. 117-145.

Lynskey, M. J. (2009) 'Aligning strategy and intellectual property to maximise business value: a proposal for new technology-based firms', *International Journal of Intellectual Property Management,* 3 (4), 301-325.

Macleod, R. M. (1971) 'The support of Victorian science', *Minerva,* 9, 197-230.

Malecki, E. J. (1997) *Technology and Economic Development.* Addison Wesley Longman, London.

Metcalfe, J. S. (1997) 'Science policy and technology policy in a competitive economy', *International Journal of Social Economics,* 24 (78), 723-740.

Mowery, D. C., Nelson, R. R., Sampat, B. N., & Ziedonis, A. A. (1999) 'The effects of the Bayh-Dole Act on U.S. university research and technology transfer', in L. M. Branscomb, F. Kodama, & R. Florida (eds), *Industrializing Knowledge: University-Industry Linkages in Japan and the United States.* MIT Press, Cambridge, MA, pp. 269–306.

Mowery, D. C., & Ziedonis, A. A. (2002) 'Academic patent quality and quantity before and after the Bayh-Dole act in the United States', *Research Policy,* 31 (3), 399-418.

NCIHE (National Committee of Inquiry into Higher Education) (1997) *Higher Education in the Learning Society.* HMSO, London.

Nelson, R. R. (2001) 'The contribution of American research universities to technological progress in industry', paper presented to RIETI (Research Institute for Economy, Trade and Industry), Tokyo, 11 December 2001.

Nicolaou, N., & Birley, S. (2003) 'Academic networks in a trichotomous categorisation of university spinouts', *Journal of Business Venturing,* 18 (3), 333-359.

Nightingale, P. (1998) 'A cognitive model of innovation', *Research Policy,* 27 (7), 689–709.

OECD (Organisation for Economic Co-operation and

Development) (2002) *Benchmarking Industry-Science Relationships.* OECD, Paris.

OST (Office of Science and Technology) (1993) *Realising Our Potential – A Strategy for Science, Engineering and Technology.* HMSO, London.

OST (Office of Science and Technology) (2005) *Science, Engineering and Technology Indicators,* Table 3.1, available at http://www.ost.gov.uk/setstats/3/t3_1.htm.

O'Shea, R. P., Allen, T. J., Chevalier, A., & Roche, F. (2005) 'Entrepreneurial orientation, technology transfer and spinoff performance of U.S. universities', *Research Policy,* 34 (7), 994-1009.

Owen Smith, J., & Powell, W. W. (2001) 'To patent or not: faculty decisions and institutional success in technology transfer', *Journal of Technology Transfer,* 26 (1-2), 99-114.

Padmore, T., Schütze, H., & Gibson, H. (1998) 'Modelling systems of innovation: an enterprise-centred view', *Research Policy,* 26 (6), 605–624.

Patel, K. (1998) 'Money man makes serial killings', *Times Higher Education Supplement,* 27 March 1998.

Pavitt, K. (1997) 'Academic research, technical change and government policy', in J. Krige & D. Pestre (eds), *Science in the Twentieth Century.* Harwood, Amsterdam, pp 143-158.

Pavitt, K. (2001) 'Costing innovation: vain search for benchmarks', *Research Technology Management,* 44 (1), 16.

Powers, J. B., & McDougall, P. P. (2005) 'University start-up formation and technology licensing with firms that go public: a resource based view of academic entrepreneurship', *Journal of Business Venturing,* 20 (3), 291-311.

Rappert, B. (1995) 'Shifting notions of accountability in public and private sector research in the UK: some central concerns', *Science and Public Policy,* 22 (6), 383–390.

Rappert, B., Webster, A., & Charles, D. (1999) 'Making sense of diversity and reluctance: academic-industrial relations and intellectual property', *Research Policy,* 28 (8), 873-890.

Rashdall, H. (1896) *The Universities of Europe in the Middle Ages.* Oxford University Press, Oxford.

Roberts, E. B. (1991) *Entrepreneurs in High Technology: Lessons from MIT and Beyond.* Oxford University Press, Oxford.

Rochford, F. (2006) 'Is there any clear idea of a university?', *Journal of Higher Education Policy & Management,* 28 (2), 147-158.

RSC (2005) *Chemical Science Spin-outs from UK universities - Review of Critical Success Factors, 2005.* Royal Society of Chemistry, London.

Salter, A. J., & Martin, B. R. (2001) 'The economic benefits of publicly-funded basic research: a critical review', *Research Policy,* 30 (3), 509-532.

Shane, S. A. (2004) *Academic Entrepreneurship: University Spinoffs and Wealth Creation.* Edward Elgar, Aldershot, Hampshire.

Shepherd, J. (2005) 'Drug specialist doubles value', *Times Higher Education Supplement,* 28 October, p. 7.

Shepherd, J. (2006) 'Academics strike gold', *Times Higher Education Supplement,* 20 January, p 1.

Shinn, T. (1998) 'The impact of research and education on industry: a comparative analysis of the relationship of education and research systems to industrial progress in six countries', *Industry and Higher Education,* 12 (5), 270–289.

Smilor, R. W., Gibson, D. V., & Dietrich, G. B. (1990) 'University spin-out companies: technology start-ups from UT-Austin', *Journal of Business Venturing,* 5, 63-76.

Stern, S. (2007) 'The mania for measuring that will send you off target', *Financial Times,* 24 July, p 12.

Stuart, T. E., & Ding, W. W. (2006) 'When do scientists become entrepreneurs? the social structural antecedents of commercial activity in the academic life sciences', *American Journal of Sociology,* 112 (1), 97-144.

UDIL (University Directors of Industrial Liaison) (1989) 'University intellectual property: its management and commercial exploitation', *International Journal of Technology Management,* 4, 4/5.

UNICO (2004) *UK University Commercialisation Survey: Financial Year 2003.* University Companies Association, Cambridge.

UNICO (2005) *UK University Commercialisation Survey: Financial Year 2004.* University Companies Association, Cambridge.

Vesper, K. H., & McMullen, W. E. (1988) 'University

spin-offs: what we think we know and what we'd like to know', *Working Paper No. 8847, Faculty of Management, University of Calgary.*

Webster, A., Rappert, B., & Charles, D. R. (2003) 'Controlling intellectual property across the high-tech frontier: university spin-offs, SMES and the science base', in R. A. Blackburn (ed), *Intellectual Property and Innovation Management in Small Firms*. Routledge, London and New York, pp 105-122.

Wright, M., Lockett, A., Clarysse, B., & Binks, M. (2006) 'University spinout companies and venture capital', *Research Policy,* 35 (4), 481-501.

Wright, M., Vohora, A., & Lockett, A. (2002) *Annual UNICO-NUBS Survey on University Commercialisation Activities: Financial Year 2001,* UNICO/NUBS, Nottingham University Business School, Nottingham.

Wright, M., Vohora, A., & Lockett, A. (2003) *Annual UNICO-NUBS Survey on University Commercialisation Activities: Financial Year 2002,* UNICO/NUBS, Nottingham University Business School, Nottingham.

Zucker, L. G., Darby, M. R., & Armstrong, J. (1998) 'Geographically localized knowledge: spillovers or markets?', *Economic Inquiry,* 36 (1), 65-86.