ENTREPRENEURSHIP AND INNOVATION: OXFORDSHIRE'S HIGH-TECH ECONOMY –FIRM SURVIVAL, GROWTH AND INNOVATION

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INTRODUCTION

This paper is about how entrepreneurial landscapes change over time through the survival, growth and innovative activities of high-tech firms. In focusing on how entrepreneurs are agents of change (Feldman and Francis 2006), it explores how the Oxfordshire high-tech economy has evolved over time. It takes as its benchmark the 1980s, when the first study of Oxfordshire's high-tech economy was undertaken (Lawton Smith 1990).

The literature of the 1980s, the period at which our analysis begins, was concerned with techno-economic changes (Freeman and Perez 1988) associated with the fifth Kondratieff wave, in which entrepreneurship was a key component. This view emphasized the reduced importance of scale economies, emergence of new industries with new organizational forms associated niches for small firms, and limited consolidation (Radosevic 2007).

This paper reports on a follow-up to the first Oxfordshire study – twenty years on. It revisits 177 of the 182 companies identified as 'advanced technology' i.e. firms that undertake R&D in one or more of science, computer science and engineering. The study has found that over 40 percent are still active and under the same ownership, 24 percent have changed status and 35 percent have been dissolved. Therefore over two thirds of firms are more than twenty five years old, some a great deal older than that. The study will therefore contribute to a better understanding of processes of change, and where particular locations fit into broader systems of entrepreneurship and innovation.

ENTREPRENEURSHIP, SURVIVAL AND GROWTH OF FIRMS

Entrepreneurs and firm development

Entrepreneurs are the focus of much recent analysis and policy agenda. The fundamental rationale is Schumpeterian. This is that change that is endogenously generated within the economy is brought about by the innovative capacity of entrepreneurs, the only agents who are capable of carrying out new combinations of resources and transforming organizational forms (Schumpeter 1911 (translated 1934) cited in Witt 2002). Modern thinking analyses the entrepreneur from a systemic rather than a psychological perspective, but like Schumpeter, who drew on Kondratiev wave theory, sees entrepreneurship as a reflection of broader technological and economic trends.

Since 1999, with the advent of the Global Entrepreneurship Monitor (GEM), considerable monitoring has been undertaken of the rate of formation in different countries with a particular focus on high growth companies. The 2007 GEM report on Total Early-stage Entrepreneurial Activity (TEA) highlighted that 9.8% of the world's entrepreneurs expect to create almost 75% of the jobs generated by new business ventures. These rapidly growing companies have been described by the OECD (2008) as ‘gazelles’.

A study for NESTA by Mason et al. (2009) find that the UK economy possesses a small but significant minority of high growth firms that have achieved annual growth rates of 20 percent or higher in a recent three year period. About 6 percent of firms passed this threshold for employment growth between 2002-5, 12 percent in growth in turnover and 18 percent in growth in average turnover per employees (the vital 6 percent). Of these, high-tech and manufacturing firms (particularly those who employ more than 250 people), performed more strongly on labour productivity improvements rather than on employment growth. Younger firms and those in business services grew fastest on the employment indicator.

Consistent with the Mason et al study that found that growth was associated with innovation, were the findings reported by Deloitte (2004) of a study of 650 companies from N. America and Europe. Like the OECD, Bishop et al and GEM (2007) this study found that manufacturers cite launching new products and services as the No. 1 driver of revenue growth, yet also view supporting product innovation as one of the least important priorities. Only a small percentage of manufacturers that have achieved success excel in three areas, including mastering innovation, exploiting innovation and building innovation capabilities – profit levels up to 73% higher than other companies studied.

Age, hence survival, of firms has also been explored as a factor in explaining growth and innovation performance. Mason et al (2009) found that half of high growth firms are older firms (10+ years). Their ability to outperform slower growing rivals is due to greater innovativeness (new market and technological opportunities). The study found that at least 70% of the vital 6 percent have been established for more than five years.

This pattern is rather different to the general tendency of failure. Most firms die within the first two and a half years of life (Cressy 2008). If a firm survives past that period, then its chances of survival are high. One of the key explanations for that is the availability of finance. Cressy’s theoretical model states that initial capitalisation is important. More money at start up increases survival rate. Initial capital lengthens the honeymoon period, and more money also reduces risk. In long run, however, initial conditions do not matter: closure rates for initially small and large firms converge. Firm exit rates relate to the firm and the industry life cycle. Small firms enter new industries in large numbers based on innovative skill in producing superior product designs, of these the larger ones have an advantage hence higher survival rates, at more mature stages, design matters less and there is less entry. Technology-based firms more likely to survive than new firms generally and are no more likely to fail than other small firms (Mason and Richardson 2004).

University spin-offs are a subset of high-tech firms. The spin-off process relates to the establishment of new legal entities and enterprises created by the HEI 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' (HEFCE 2005). Personal characteristics, motivations, opportunity recognition, role model effects influence entrepreneurial decisions, resulting in a diversity of types of firms (consulting, development, software etc Druihle and Garnsey 2004) and stages of development.

Like other high-tech firms, evidence shows that not only is there an increasing numbers of spin-offs, but more are surviving (Figure 1) and those that do, are growing both in turnover and employment. The official annual survey of spin-offs in the UK shows that growth tends to occur after 10 years and a few large firms account for the bulk of growth HEBC1 (2009). Furthermore, there have been substantial increases in the number of graduate start-up firms created in 2007-08 (from 1,508 to 1,977) and in the number that have existed for three or more years (from 1,038 to 1,322). These companies appear – on average – to be smaller than HEI spin-offs although there are problems in data collection on those firms.

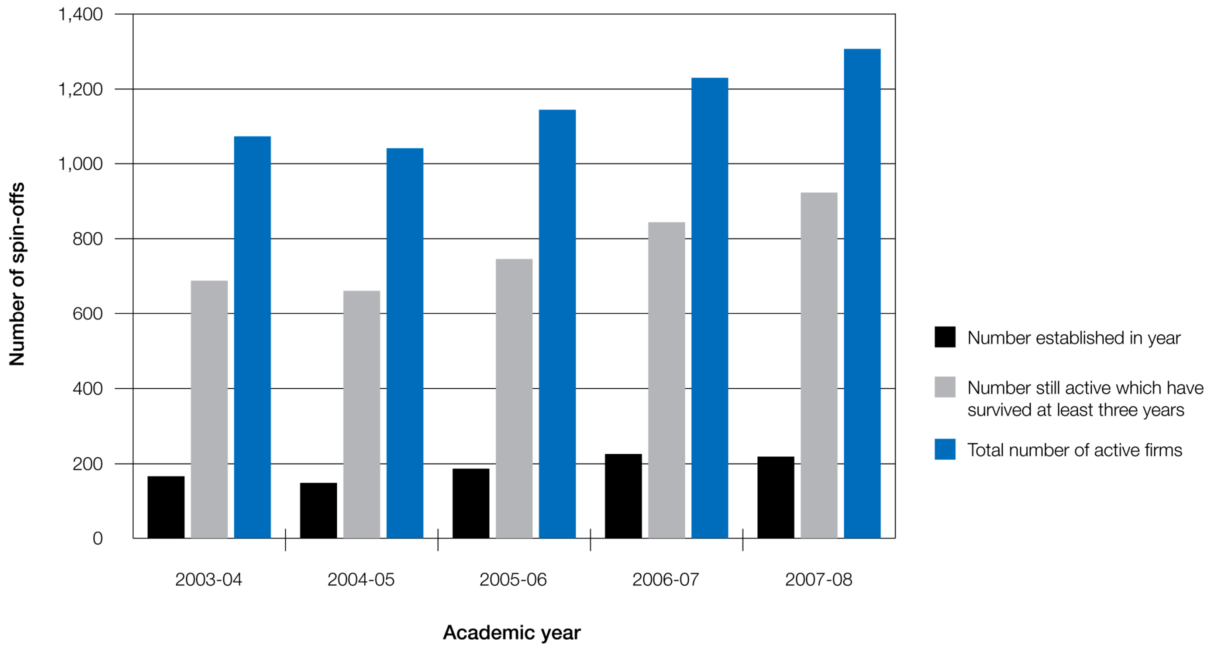


Figure 1 Spin-off company formation (with and without HEI ownership) 2003-2008

Source: HE-BCI Part B Table 4d

For all high-tech firms, internal and external conditions for new firms are increasing complex. Arbaugh and Camp (2000) find that for some firms these are magnified by the challenge and opportunity of rapid growth. The pace of internal complexity has accelerated meaning that there is greater emphasis on the resources, competences and structures required for growth (see the resource-based view Penrose 1959 and Barney 1991). Externally, growth redefines relationships with suppliers, customers, sources of financing – and the market (new competitors). Firms are assumed to grow over time but many never grow beyond a particular stage in their development.

In evaluating performance beyond employment growth, labour productivity and turnover, a number of other indicators have been suggested as yardsticks for growth (Table 1). Some of these have obvious local implications relating to the direct and indirect benefits from increasing assets, profitability and spend. These include employment and local purchases of various kinds and also the gains from profile and image.

Share value	**Return on investment**	**Market share**
Net worth	**Size of premises**	**Exports/imports substitution**
Profit	**Profile/image**	
Employment	**Number of customers**	**New products/services**
Turnover		**Patents etc**
		Added value

Table 1 Yardsticks for Growth
Source: Bridge et al (2003)

Entrepreneurship and favourable regional environments

The impact of entrepreneurship and innovation is found to be disproportionately in selected regions. This is due to a strong tendency for firms in knowledge-intensive industries to cluster. These are due to differences in initial conditions, the performance and behaviour of individual firms, as well as support from public and private organisations with an interest in regional development. Best (2001) has argued that regional growth depends as much on the capabilities of local firms and entrepreneurs as upon conditions in the business environment. An effective innovation system marries the capabilities of entrepreneurs and firms to conditions in the business environment to ensure a rich flow of information and knowledge in the generation of new products and processes.

Where favourable environments exist, high-growth firms generate spillovers in their regions (NESTA 2009). Levie et al (2009) reporting on the most recent GEM study identified regional differences in the UK. They argue that ambitious entrepreneurship … is regional'. They find some regional effects on the propensity to engage in early-stage entrepreneurial activity in addition to individual level effects. It appears that wealthy regions enable more ambitious entrepreneurs (and possibly, make entrepreneurs more ambitious).

There is also a reinforcing effect of increasing rates of entrepreneurship and associated employment of the highly-skilled. High performing are firms attracted to locations of high-skill density. High-tech university spin-offs and other kinds of companies which have their origins in universities, public and private research laboratories, are also found to have particular geographies. Most spin-offs are from research universities (Shane 2004), most stay close to their home institution (Zang 2008) and are mostly in ICT and biotech. As these are necessarily innovative, it would also be expected that a high proportion of these would be high-growth, thus being of particular benefit to their local region.

Part of the explanation for why some environments are more favourable than others is the kinds of institutional support that grow concomitantly with economic development, which produces an 'enabling environment' (Acs 2003). Feldman and Francis (2006, 118) identify a three stage process for successful regions: (i) region inert – few start-up companies, latent assets such as universities, government labs and large companies; (ii) regional response to exogenous shock – formation of a cluster; and (iii) "fully functioning entrepreneurial environment within an innovative and adaptable industrial cluster." The environment is not just local it also refers to national business climate and policy framework.

Against this background, what this paper does is to use the framework comprising entrepreneurial activity, survival, high growth-innovation, and regional environments to examine how the Oxfordshire high-tech economy has grown over time. It thereby adopts a temporal framework to see the relative importance of firms that were in existence in the mid-1980s compared to the overall stock of high-tech firms in the late 2000s. It identifies which kinds of firms (independent versus merged or acquired or corporate) in which sectors and the contribution of university-based entrepreneurship.

THE OXFORDSHIRE CASE STUDY

Early stages

Oxfordshire's high-tech economy has grown up alongside national expansion in scientific research and has to some extent replaced employment in the dominant industrial sectors. Its roots can be traced to even earlier. The first recorded high-tech firm was established 1946 (Penlon, a medical equipment firm): a spin-off from Oxford University. It was in the late 1970s that the high-tech economy began to take root and contribute to the changing industrial structure of the economy which had begun to change rapidly a decade earlier. In the 1960s the dominant sector was the automotive industry with some 28,000 employees. By the late 1970s, employment in the automotive sector had fallen to 5000 but was still the largest sector in the county. The number of high-tech firms and employment was estimated at 50 firms employing 7,731 in 1979 (Lawton Smith 1990).

Growth in the number of start-ups (university and non-university related) was slow until the mid-1980s. Lawton Smith (1990) identified 182 R&D intensive advanced technology firms in existence in 1987. The criterion used was that firms were undertaking research and development (R&D) in one or more of science, computer science and engineering. Collectively these firms employed 10,659 people. The majority had been formed in the late 1970s and early 1980s. Those that were active in

1979 employed nearly 8000 people. Of the 182, the majority were in manufacturing (125), followed by R&D/consultancy (32) and software (25).

The rise in the number of high-tech firms reflects national trends. Between 1979 and 1986, while UK manufacturing as a whole was in steep decline, employment in high-tech manufacturing fell less sharply and output increased rapidly. In computer sectors (both hardware and software) over a similar period, both showed significant job and firm formation increases (Keeble and Kelly 1986).

Increasing maturity

While the early high-tech economy was dominated by manufacturing, the Oxfordshire high-tech cluster has grown to be being services dominated.[1] There are far more high-tech service companies than high-tech manufacturing companies and service employment is higher than that in manufacturing overall. The sector with most businesses is computer services, with almost half of all the high-tech companies in the county (635 firms, 45% of companies) which has twice as many companies as technical consultancy & technical testing (22.5%) which is also an important high-tech services sector. The largest manufacturing sector is instruments, medical and optical equipment, followed by biotech/pharmaceuticals. Certain sectors, although important in employment terms, consist of only a small number of companies. For example the motorsport and automotive engineering/design sector accounts for less than 2% of the county's high-tech firms but 7% of its high-tech jobs. The emerging biotech sector has 73 firms but only comprises 5.2% of the county's high-tech firms (Table 2). Table 3 shows the distribution of employment within the high-tech economy (percentages rounded).

[1] Some of this material is taken from Lawton Smith, H (2008) The high-tech cluster in Oxfordshire' United Kingdon. Chapter 3 in J.Potter and G.Miranda (eds) *Clusters, Innovation and Entrepreneurship* Paris:OECD 73-102

Table 2 Number of high tech companies in Oxfordshire, analysed by sector – end of 2001

Sector	Number of Companies, end of 2001	As % of All High Tech Companies
Manufacturing:		
Publishing – specialist electronic only	9	0.6
Biotech, Pharmaceuticals & Medical Diagnostics	73	5.2
Computer Equipment	23	1.6
Electrical Equipment (Butchart categories)	14	1.0
Electronic & Telecoms Equipment	46	3.3
Instruments, Medical & Optical Equipment	112	7.9
Motorsport & Automotive Engineering/Design	24	1.7
Aerospace & Related Services	12	0.9
Other Manufacturing	70	5.0
Services:		
Telecommunications	30	2.1
Software, Web/Internet & Other Computer Services	635	45.1
Other R&D Activities (Not Included Above)	44	3.1
Technical Consultancy & Technical Testing	317	22.5
Other/Not Classified	8	-
Total: All Sectors	1,417	100.0

Source: OEO 2003

Table 3 Sectoral breakdown of high tech employment in Oxfordshire, end of 2001

Sector	Number of employees, end of 2001	As % of All High Tech Companies
Manufacturing:		
Publishing – specialist electronic only	93	0.3
Biotech, Pharmaceuticals & Medical Diagnostics	3,257	8.9
Computer Equipment	1,825	5.0
Electrical Equipment (Butchart categories)	657	1.8
Electronic & Telecoms Equipment	1,550	4.2
Instruments, Medical & Optical Equipment	5,026	13.7
Motorsport & Automotive Engineering/Design	2,503	6.8
Aerospace & Related Services	840	2.3
Other Manufacturing	1,498	4.1
Services:		
Telecommunications	2,335	6.4
Software, Web/Internet & Other Computer Services	7,899	21.6
Other R&D Activities (Not Included Above)	5,907	16.1
Technical Consultancy & Technical Testing	3,257	8.9
Other/Not Classified	35	-
Total: All Sectors	36,682	100.0

Source: OEO 2003

Mature stages

The mid-1990s saw a rapid expansion of the high-tech economy, including the number of university spin-offs (see below). New SMEs have played a major role in driving the cluster. The cluster began to grow rapidly from in mid 1990s. Table 4 shows that the take off period of growth began in the period 1991-1995, but accelerated from the middle of the 1990s. This is significantly faster than that of Berkshire, which has the highest absolute number of high-tech jobs, many of which are in multinational companies such as Microsoft and Mars.

Table 4 Date of incorporation of high tech companies in Oxfordshire – end of 2001

Year in which Company Was First Registered at Companies House	Number of Companies	% of Total
2001-2002	29	3.1
1996-2000	357	38.1
1991-1995	233	24.8
1986-1990	139	14.8
1981-1985	92	9.8
1980 & Earlier	88	9.4
Year Not Known or Company Not Registered	479	-
Total	1,417	100.0

Source: OEO 2003

More recent data shows that growth of entrepreneurship in the Oxfordshire economy continues to accelerate. In the absence of local data, the Office of National Statistics data show that Oxfordshire has some 3,500 high-tech firms employing 45,000 people, around 14 percent of the county's workforce[2] in 12 percent of businesses in Oxfordshire. Using these figures, the county has the third largest high-tech employment amongst UK counties (high-tech as a percentage of total employment). The county is characterized by "diverse specialization" (Lawton Smith et al. 2007), with leading sectors being high-tech services, including software consultancies and biotechnology. Larger businesses are in high-tech manufacturing, including pharmaceuticals, medical instruments, and computers.

Using GLASSON *et al*'s (2006, 507) definition of high technology industry there were 37,300 employees in 3,600 high technology firms in Cambridgeshire in 2007 compared to 35,500 in 3,800 in Oxfordshire (Table 5). With 13.6 per cent of all employment being in high technology industry, Cambridgeshire ranks first of all county council areas in England, with Oxfordshire ranking fifth.

Oxfordshire is one of the four leading locations in the UK. Studies by the Oxfordshire Bioscience Network have found that the number of bioscience firms is increasing. By 2008, Oxfordshire had some 142 biotech and healthcare firms. Two thirds were more

[2] ONS uses data from the annual Business Inquiry which uses a more comprehensive dataset with a less restrictive definition of high-tech and includes higher enumerate numbers of businesses in IT and computer-related services)

than 6 years old and 13% had been formed between 2007 and 8. Estimates of employment rose from 1000 in 2002 to just under 2000 in 2005 and to 5000 in 2008 (OBN 2008).

Table 5: High Technology in Oxfordshire and Cambridgeshire, 2007

	Firms			Employment		
	No	%	Rank	No	%	Rank
Cambridgeshire	**3,657**	**13.6**	**3**	**37,278**	**13.6**	**1**
Cambridge	891	15.6	15	11,579	13.7	30
East Cambridgeshire	394	11.3	104	1,813	7.5	137
Fenland	255	7.5	308	1,080	3.4	350
Huntingdonshire	959	13.0	58	6,674	9.4	89
South Cambridgeshire	1,158	16.7	8	16,141	26.0	3
Oxfordshire	**3,866**	**12.3**	**6**	**35,523**	**11.2**	**5**
Cherwell	723	11.1	111	6,068	9.0	101
Oxford	644	11.1	112	8,075	7.9	124
South Oxfordshire	1,033	13.5	44	5,647	10.4	60
Vale of White Horse	843	14.8	23	11,376	21.1	7
West Oxfordshire	623	10.9	122	4,361	11.4	48
East	**27,110**	**11.2**	**2**	**194,068**	**8.2**	**2**
South East	**48,423**	**12.5**	**1**	**392,266**	**10.6**	**1**
Great Britain	**243,240**	**10.2**	**-**	**1,984,733**	**7.5**	**-**

Source: ABI, ONS, 2008

Source: Waters and Lawton Smith forthcoming

University and laboratory spin-offs

Formal engagement by Oxford University and indeed from the local authorities has been only recent. Since the end of the 1990s, Oxford University has become an "entrepreneurial university" (Etzkowtiz et al 2000) within an enterprising Oxfordshire economy. In the mid-1980s, Oxford University, however, had contributed to over a fifth of Oxfordshire's high-tech companies. Some 40 firms had been established by academics, technicians and former students, broadly defined as spin-offs (see Lawton Smith and Ho 2006). These spin-offs[3] were not associated with any mechanisms for entrepreneurial support in Oxford University.

Most originated in the departments of Engineering Science and Metallurgy but already the medical research units and life sciences had produced a number of firms.

[3] The definition of spin-offs used in this study is broadly consistent with that used in the Higher Education Business-Interaction (HEBI) surveys for Higher Education Funding Council for England (HEFCE)—spin off creation is "… establishing of new legal entities and enterprises created by the Higher Education Institute (HEI) or its employees to enable the commercial exploitation of knowledge arising from academic research." Spin-offs are defined as companies set-up to exploit IP that has originated from within the Higher Education Institution (HEI). Spin-offs, not HEI-owned, are those companies set-up on IP that has originated from within the HEI but for which the HEI has released ownership (usually through sale of shares and/or IP). Staff start-ups are those companies set-up by active (or recent) HEI staff but not based on IP from the institution. Graduate start-ups include all new business started by recent graduates (within 2 years) regardless of where any IP resides. HEBI surveys show that the number of spin-offs with some HEI ownership older than 3 years is increasing. In 2003-2004, 2004-2005 and 2005-2006 there were 521, 2004-05, 521, 529 and 669 respectively.

Examples of academic spin-offs including Penlon (medical products) established in 1946, Littlemore Scientific Engineering (1954) and the largest of all spin-outs Oxford Instruments (scientific instruments) in 1959 are still in existence. Oxford Instruments was formed by then Dr Martin Wood, a research fellow in the Clarendon Laboratory. This firm has had a considerable impact on the Oxfordshire economy being the source of internal spin-outs creating a group of companies such as Oxford Magnet Technology in 1983 (later acquired by Siemens) and firms formed by former employees such as Magnex (1982) (Lawton Smith 1991). By the late 1990s, the company employed some 2000 people worldwide, a half in Oxfordshire.
Figure 2 shows the number of academic spin-offs formed between 1950 and 2004. The existence of the majority was therefore, not associated with institutional mechanisms within Oxford University.

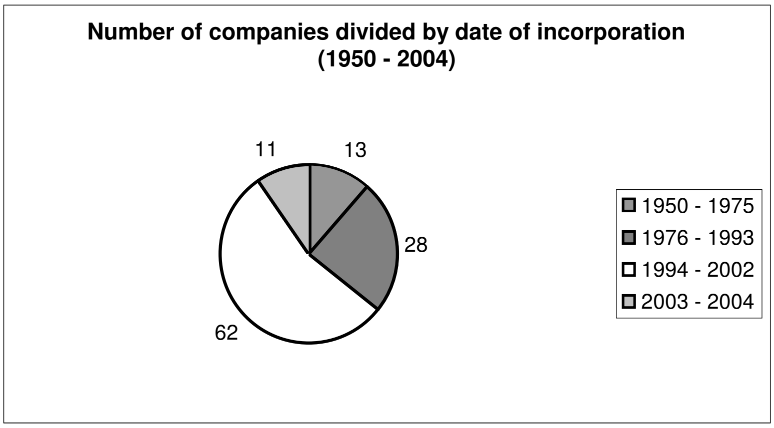
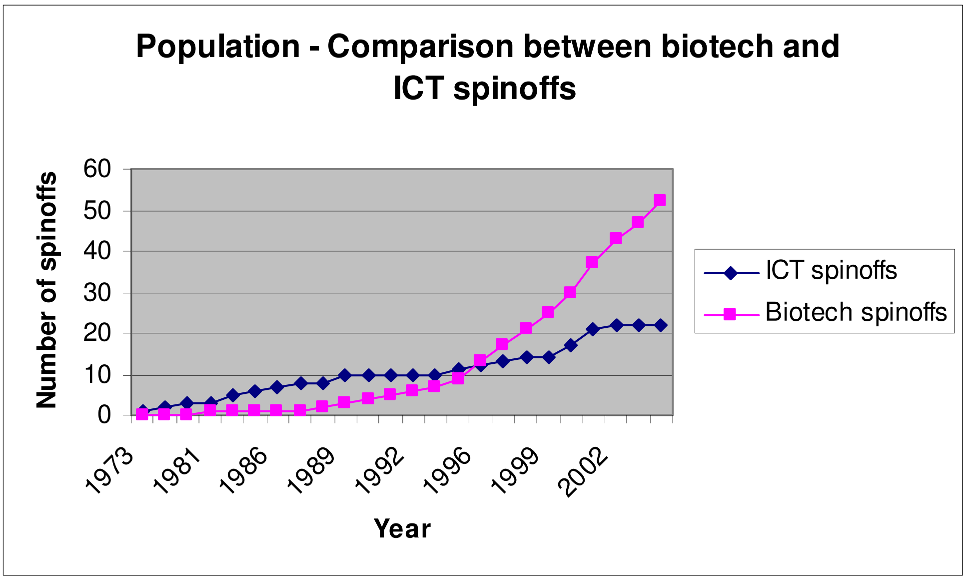


Figure 2. Spin-offs from Oxford University
Source: Lawton Smith and Ho 2006

The OEO survey also includes analysis of the firms identified the connection between age of firm and employment generation, while other surveys have often only focused on the number of spin-offs (for example in annual surveys conducted by HEBI and UNICO in the UK and AUTM in North America). By 2002, the available data showed that spin-offs accounted for over 3 percent of Oxfordshire's employment. The average firm size of 40 firms founded before 1994 rose from 140 in 1994 to 354 in 2001, with the rate of employment growth accelerating after firms had been established for ten years. Of the spin-offs created by the region's universities, most have stayed within Oxfordshire, so contributing to the extraordinary rate of growth in the county's high-tech cluster.

The OEO survey identified the greatest impact on employment to be concentrated in a few sectors, of which ICT is the largest single sector and biomedical is the largest composite sector accounting for 40 per cent of firms: 25 spin-offs are biotech and 16 are pharmaceuticals companies. Until 2001, the ICT group had more employees than the biomedical group, enjoying sharp employment growth between 1994 and 1996 when the growth slowed. Conversely, the biomedical sector has experienced a strong increase in the number of employees since 1997. This change is related to a correspondence with the rapid increase in the number of biomedical companies (Figure 3)

Figure 3 Comparison of numbers of ICT and Biotech spin-offs



Source: Lawton Smith and Glasson 2005

METHODOLOGY

A central task of the first study (1985-1990) was to define and identify the population of high-tech firms in Oxfordshire. Given the confusion at the time of what constituted 'high-tech' a decision was made to categorise the firms according to whether firms conducted R&D in science, computer science and engineering. On the basis of that decision, a database was established by ringing 2000 firms from lists of engineering/software/science-based companies from such sources as commercial bus industry directories and Yellow Pages. From these 182 firms were identified as advanced technology. Of these 164 firms were interviewed, following an extensive structured questionnaire with some open questions. The 72 questions provided a comprehensive view of each firm's profile (locational factors, about the entrepreneur and their background, employment, finance, products, R&D, patents & licenses, social and technological links with local and non-local universities and government laboratories).

This new study explores what has happened to those firms. It examines the performance of the surviving firms (and those have ceased trading where possible) and their impact on the Oxfordshire economy. The set of criteria to assess impact includes such indicators as employment (number and categories of employees), turnover, market capitalisation, technological advance (inventions and innovations - patents and licenses, product development). The study is at an early stage with only preliminary data being available at this stage. The following four hypotheses are being tested.

1. The older firms are the largest
2. greatest employment growth is in manufacturing firms
3. mergers and acquisitions are mostly in biotech
4. university spin-offs are a growing importance in the economy

The evidence

Number and type of companies

The dataset is composed of 171 companies. These companies have been grouped into three macro-categories: information and communication technologies (ICT), manufacturing and engineering, and biotech that includes medicals and natural sciences (Figure 4). This shows that Manufacturing and Engineering are the largest group, comprising well over half the sample. The second largest is the biomedical grouping (a fifth of firms) with the ICT group being the smallest. This suggests that the manufacturing tradition of the county is continuing through the robustness of the manufacturing sector and does run counter to the general decline in manufacturing in the UK economy (although see below).

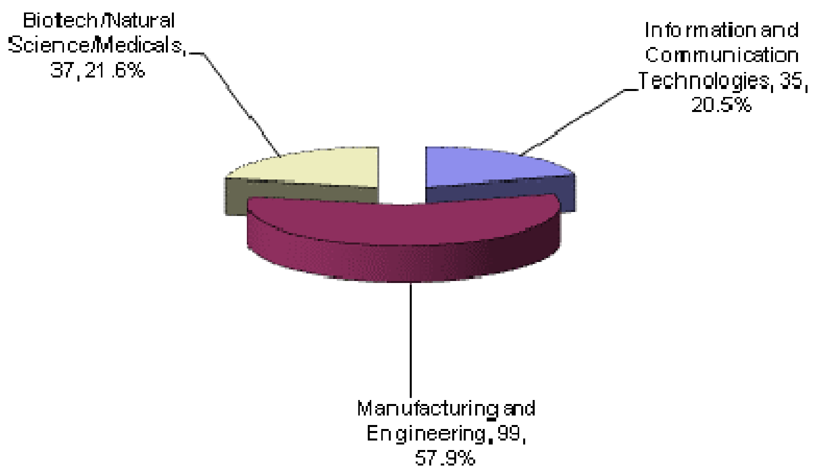


Figure 4 number and type of Oxfordshire high-tech companies from original sample

Status and growth

The companies have been grouped into three categories: dissolved (they do not operate anymore), change status (they have been acquired or they have merged with other companies), active (they still operate in the market). The study has found that around two-thirds of the companies are still operating. Nearly 40 percent are still active and under the same ownership and a quarter have changed status. Therefore over two thirds of firms are more than twenty five years old, some a great deal older than that.

Consistent with general trends, the large majority of companies that have changed status are part of the biomedical sector, and includes a number of university spin-offs (see Lawton Smith and Glasson 2005). The current status of the companies by sector is shown in Figure 5. This shows that manufacturing and engineering companies have the highest death rate. The biotech group has the lowest death rate, but the highest rate of status changing (acquisition mainly). The ICT group has the highest active rate.

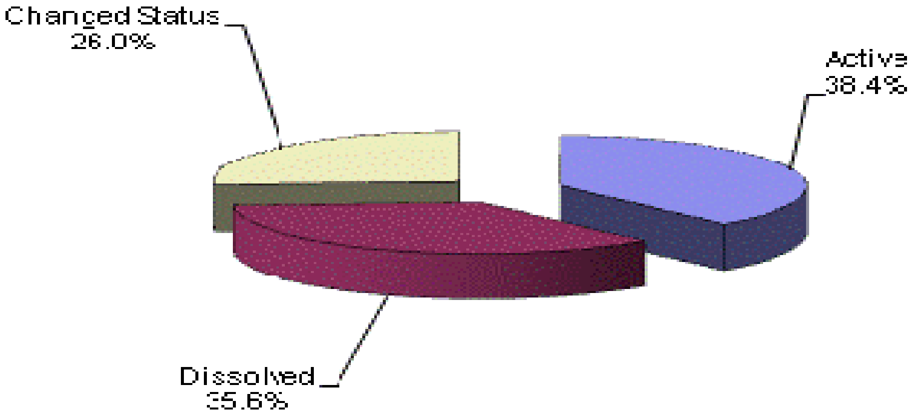
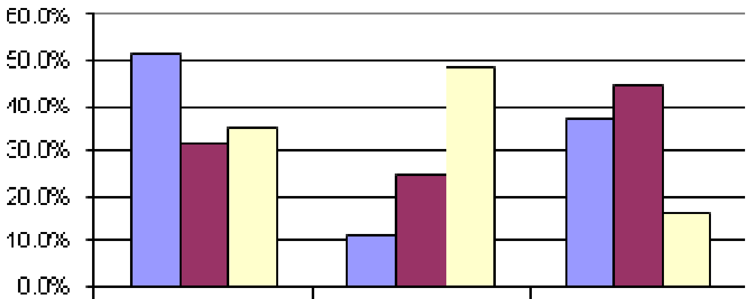


Figure 5 current status of Oxfordshire high-tech companies from original sample



	Active	Changed	Dissolved
Information and Communication Technologies	51.4%	11.4%	37.1%
Manufacturing and Engineering	31.3%	24.2%	44.4%
Biotech/Natural Science/Medicals	35.1%	48.6%	16.2%

Figure 6 current status of the Oxfordshire high-tech companies from original sample by sector

The study revealed a high ratio of activity (Figure 6). Combining the active companies and the companies that changed status, it can be said that the data set shows a high ratio of activity. The biotech group performs particularly well: the 83.8% of the biotech companies analysed in the thesis are still in the market. A notable failure was British Biotechnology Ltd, which was at one time was the UK's largest biotech company. British Biotechnology Limited was founded in 1986 and was the first British biotechnology company to be publicly listed when it was floated on 1 July 1992. In 2003, British Biotech merged with RiboTargets and then into Vernalis. The British Biotech company name disappeared after this merger and remaining staff integrated into the Vernalis organisation in Winnersh, Berkshire

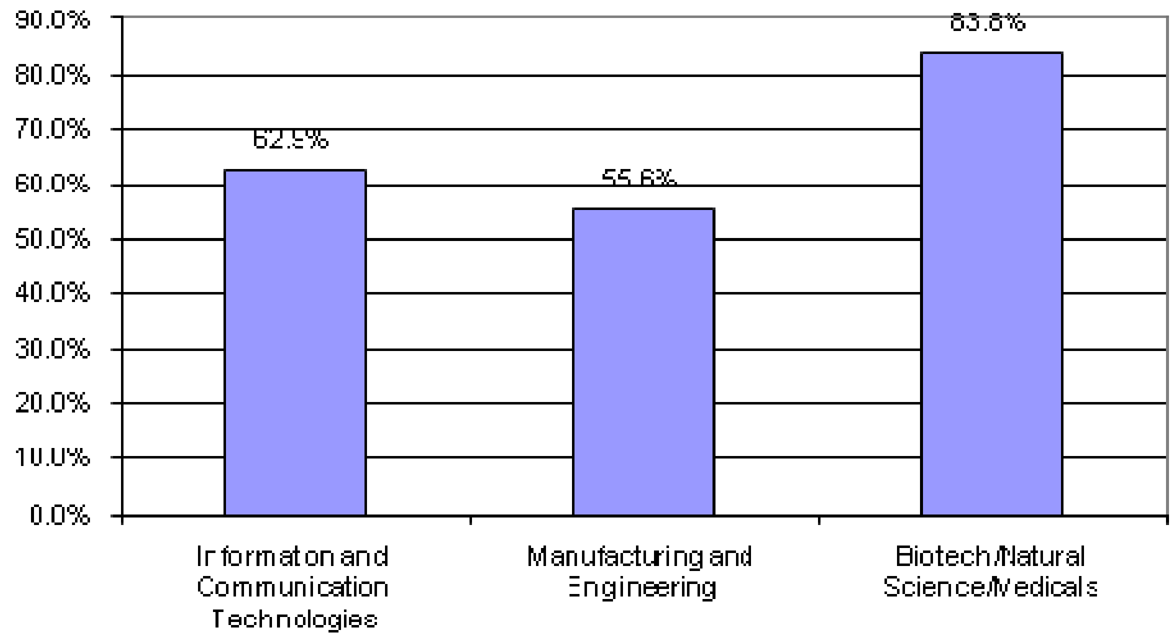


Figure 7 Ratio of activity of Oxfordshire high-tech companies from original sample

The "Active" Group, i.e. those that have remained under the same ownership, are despite the highest death rate, in "Manufacturing and Engineering" (Figure 8). This group remains the largest of the companies currently active. The "Information and Communication Technologies" group becomes the second growing group from the 20.5% at the time of the thesis to the current 29.0%.

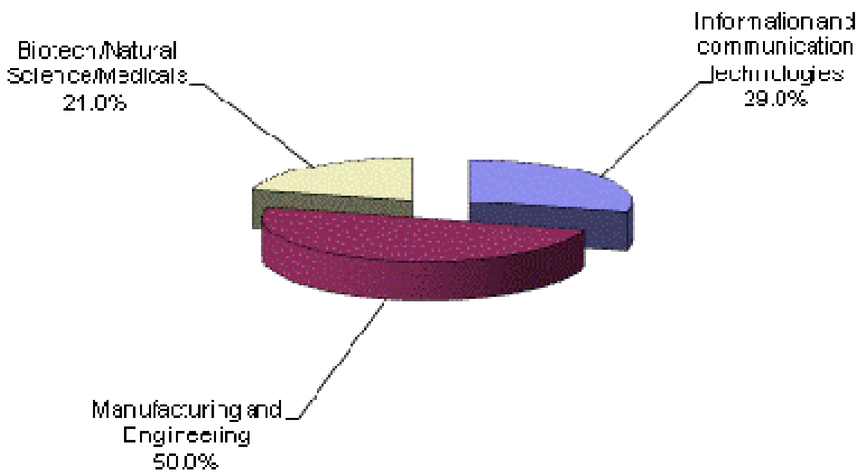


Figure 8 The Active Group by sector of the Oxfordshire high-tech companies from original sample

Some indications of the impact of the "Active" Group are employment and revenues. The "Active" group includes 61 companies. Data on employment and revenues has been collected for 19 companies, 31.1% of all the group. Taking into account this consideration the total revenues for 2009 were £11.095 billion; the total number of employees for 2009 is 12834. Using the figures in Table 5, this represents more than a third of the total number of employees in the high-tech sector as at 2007, but only 1.6% of the firms. Thus the high-tech economy is dominated by a few very large and long established firms.

The group of "Active" companies can be divided in two main groups: "Large Enterprises" and "Others". The "large enterprises" substantially contribute to the group in terms of revenues and employees. Examples of larger companies are: Oxford Instruments, Sophos and Research Machines (now RM). Each of these have their origins in Oxford University and were the best performing firms in the survey of Oxfordshire's university and public sector laboratory spin-offs (see Glasson and Lawton Smith 2005). This finding suggests that the hypothesis that university spin-offs are an important component of the Oxfordshire high-tech economy.

Case studies

Oxford Instruments is the county's major success story. This manufacturing firm was established in 1959 by then Dr Martin Wood, a researcher in Oxford University's Clarendon laboratory. It specialises in high technology tools and systems for industry and research, including cryogenics, the technology with which the firm began. It was launched on the UK Stock Exchange in 1983 (OXIG). With over 25 offices and factories in Europe, USA, China and Japan, Oxford Instruments is a global company with offices and manufacturing sites in over 25 locations, world-wide in Europe, USA, China and Japan[4]. In 2009 it employed 1522 and had a turnover of £206,500,000. Its fortunes have changed over the years. It has a smaller number of employees and turnover than in 2002 when it employed 1773 world wide, and had a turnover of £213.7m. It is responsible for a number of spin-offs, incubating its own and as a source of founders who were former employees (Lawton Smith 1991).

Sophos is a software company specialising in antivirus software. It was incorporated in 1987[5]. In 2002 it employed 301 people, and had a turnover of £31.6m. Its founders were academics in Oxford University. By 2009, it has expanded to employ 1339 worldwide with a turnover of £125250,000.

RM began life in 1973 as a manufacturing of computers in educational markets, mainly schools but also universities[6]. It was founded by an Oxford Graduate (Mike Fischer) and a Cambridge Graduate (Mike O'Regan). When they first started the company they supplied electrical components to hobbyists. Then, they started building machines for the scientific, research and education market and they called

4 http://www.oxinst.com/Pages/home.aspx
5 http://www.sophos.com/sophos/docs/eng/marketing_material/sophos-company-profile-cpna.pdf
6 http://www.rm.com/company/Generic.asp

the company Research Machines. By 1977 they built their school computer. It is still in that market but manufacturing is conducted overseas and more of the business is now in software and other services in the education market. In 2002 it employed 1518 and had a turnover of £202.16m. By 2010, the company as a whole employs 2000. It has regional offices in Scotland and the North West of England. The company also has a number of group companies across the UK, giving wide geographical coverage and expertise in lots of areas of education other than ICT.

CONCLUSIONS

On the basis of previous studies of high-tech entrepreneurship in Oxfordshire and elsewhere plus studies of survival and growth of firms, the study set out to test four hypotheses.

The first was that the older firms are the largest. Preliminary evidence confirms that hypothesis. The largest firms recorded date back to the 1950s, 1970s and 1980s, decades when there were a few start-up companies (Feldman and Francis 2006). The county is dominated by a few very large and long established firms. Using figures for 2008 as a baseline this represents more than a third of the total number of employees in the high-tech sector, but only a very small percentage of total high-tech firms. This is consistent with studies (e.g. Cressy 2008, Mason et al 2009) which have find that it is a minority of firms which create the majority of jobs.

The second is that greatest employment growth is in manufacturing firms. The Largest firms are manufacturing firms which comprise the largest group, comprising well over half the sample. However, much of the manufacturing is now overseas. For example, RM no longer manufactures in the UK. However, consistent with national trends manufacturing and engineering companies have the highest death rate.

The third is that mergers and acquisitions are mostly in biotech. The study showed that consistent with general trends, the large majority of companies that have changed status are part of the biomedical sector, and includes a number of university spin-offs. Moreover, the biotech group has survived remarkably well. Over four fifths of the biotech companies analysed in the thesis have survived in one form or other. The number of biotech firms has increased, but not as much overall as ICT firms, but both form a key part element in the maturing high-tech economy. Further research will verify if the biomedical companies are more volatile in terms of change of status. This will answer hypothesis 3 about biomedical companies being more involved in M&As.

The fourth is that university spin-offs are a growing importance in the economy.
The case studies illustrate that the first, second and fourth are not mutually exclusive. The number of university spin-offs has been increasing over time, but some of these are also manufacturers of medical equipment and some are among the oldest firms. Penlon formed in the 1940s is an example.

More evidence will be produced to fill the gaps in the "Live Group" in order to have a better understanding of the impact on the economy of these companies even if this is already quite clear. More detailed information on growth rates is needed to see how many of these can be described as ‘gazelles’ and at what stages in their development.

Patent data will be used to see the impact on technological developments. As the study develops, it will therefore provide such information on topics such as: Company genealogies – have they spun-off new firms, been acquired or merged? Ownership and boards of directors – how much overlap is there between the firms? Is there any evidence of serial entrepreneurs, or serial CEOs and business angels? At what stage in their development did firms which left the county or ceased trading do so? Are there episodes of high growth? What impact have these firms had on the composition of the highly-skilled workforce in Oxfordshire?

What is less easy to demonstrate empirically is that of regional effects on the propensity to engage in early-stage entrepreneurial activity in addition to individual level effects (Levie et al 2009). It is entirely possible that Oxfordshire, which is a wealthy county with growing high-tech economy, does have a positive impact encouraging ambitious entrepreneurs (and possibly, make entrepreneurs more ambitious) by providing an 'enabling environment' (Acs 2003). The Oxford Trust established in 1985 was very much part of the formation of the 'entrepreneurial environment' (Feldman and Francis 2006). That environment has changed as new actors and organisations have become more important. Further research is needed on how the growth of firms and the environment affect the other.

REFERENCES

Acs, Z (2003) 'The value of entrepreneurial start-ups to an economy' The Diebold Institute Entrepreneurship and Public Policy Project Working Paper Number 5 London: LSE

Arbaugh, J. & M. Camp (2000). Managing growth transitions: theoretical perspectives and research directions, in *Handbook of entrepreneurship*, D. Sexton & H. Landström (eds.), 308-328. Oxford: Blackwell.

Barney, J. B. (1991) 'Firm Resources and Sustained Competitive Advantage', *Journal of Management*, 17, 1, pp. 99-120.

Best, M (2001) *The New Competitive Advantage: The Renewal of American Industry*, Oxford: Oxford University Press

Bridge, S, O'Neill, K and Martin, F (2003) *Understanding Enterprise: Entrepreneurship and Small Business* Basingstoke:McMillan

Cressy, R (2008) 'Venture Capital' Chapter 14 in M. Casson, B Yeung, a.Basu and N. Wadeson (eds) *The Oxford Handbook of Entrepreneurship* Oxford:OUP 353-386

Deloitte (2004) *Mastering Innovation: Exploiting Ideas for Profitable Growth* London:Deloitte http://www.deloitte.com/dtt/research/0,1015,sid%253D15288%2526cid%253D40280,00.html

Druilhe, C and Garnsey, E (2004) 'Do academic spin-outs differ and does it matter' *Journal of Technology Transfer* 29, 265-285

Etzkowitz, H, Webster, A, Gebhardt, C and Cantisano Terra, B R (2000) 'The future of the university and the university of the future: Evolution from ivory tower to entrepreneurial paradigm' *Research Policy* 29, 2 313-330

Feldman, M and Francis, J. L. (2006) 'Entrepreneurs as agents in the formation of industrial clusters' Chapter 6 in B.Asheim, P.Cooke and R Martin (eds) *Clusters and Regional Development* Abingdon: Routledge

Florida, R (2002). *The Rise of the Creative Class*, Basic Books: New York.

Freeman CC and Perez C (1988) Structural crisis of adjustment, business cycles and investment behaviour, in Dosi G, Freeman C, Nelson R, Silverberg G and Soete L (eds) *Technical Change and Economic Theory* London:Pinter 38-66
Glasson, J, Chadwick, A and Lawton Smith, H (2006) 'Defining, Explaining and Managing High tech Growth: The case of Oxfordshire' *European Planning Studies* 14, 4 503-524
Global Entrepreneurship Monitor (2007) http://www.gemconsortium.org/download/1278054886854/GEM_2007_Executive_Report.pdf (accessed July 2nd 2010)
Higher Education –Business and Community Interaction Survey 2007-08 http://www.hefce.ac.uk/pubs/hefce/2009/09_23/09_23.doc (accessed June 2010)
Keeble, D and Kelly, T (1986) New firms and high technology industry in the United Kingdom: the case of computer electronics Ch 4 in D.Keeble and K.Weaver (eds) *New Firms and Regional Development in Europe* London:Croom Helm
Lawton Smith, H. (1990) *The location and development of advanced technology in Oxfordshire in the context of the research environment.* Unpublished D.Phil Thesis, University of Oxford.
Lawton Smith, H (1991) 'The Role of Incubators in Local Industrial Development: The Cryogenics Industry in Oxfordshire' *Entrepreneurship and Regional Development* 3, 2 175-194
Lawton Smith, H and Glasson, J (2005) *Public Research High-tech Spin-offs: Measuring Performance and growth in Oxfordshire* Oxford: Oxfordshire Economic Observatory
Lawton Smith, H, Glasson, J, Simmie, J, Chadwick, A and Clark, G (2003) *Enterprising Oxford: The Growth of the Oxfordshire High-Tech Economy* Oxford: Oxfordshire Economic Observatory
Lawton Smith, H and Ho, K W (2006) 'Measuring the performance of Oxfordshire's spin-off companies' *Research Policy* 35, 1554-1568
Lawton Smith, H (2008) 'The high-tech cluster in Oxfordshire', United Kingdom Chapter 3 in J. Potter and G. Miranda (eds) *Clusters, Innovation and Entrepreneurship* Paris:OECD 73-102
Levie, J (2009) Presentation at Association of American Geographers Annual Conference, April 2009, Las Vegas
Mason, C and Harrison, T (2004) 'Does investing in technology-based firms involve higher risk? An exploratory study of the performance of technology and non-technology investments by business angels' *Venture Capital* 6, 4 312-331
Mason, G, Bishop, K and Robinson C (2009) *Business growth and Innovation* http://www.nesta.org.uk/library/documents/Business-Growth-Innovation-report-v2.pdf (accessed July 2 2010)
McCann, P (2006) 'Regional development: clusters and districts' Chapter 25 in M. Casson, B Yeung, a.Basu and N. Wadeson (eds) *The Oxford Handbook of Entrepreneurship* Oxford:OUP 651-770
NESTA (2009) Nesta 2009 http://www.nesta.org.uk/library/documents/Report-Summary-Vital-6-per-cent-v13.pdf (accessed January 2010)
Oxfordshire Bioscience Network (2008) *BioCluster Report* http://www.obn.org.uk/seeb/images/publications/OBN_BioCluster_Report_2008_Exec_Summary_for_web.pdf
Parkinson, M., Hutchins, M., Simmie, J., Glark, G. and H. Verdonk (2004). *Urban Renaissance characteristics of EU Non-capital Cities*, ODPM: London.
Penrose (1959) *The Theory of the Growth of the Firm* New York:John Wiley

Shane, S (2004) *Academic Entrepreneurship: University Spinoffs and Wealth Creation* Cheltenham: Edward Elgar
Radosevic, S. (2007) 'National systems of innovation and entrepreneurship: in search of a missing link' London:UCL-SSEES Economics Working Paper No 73
Waters, R and Lawton Smith, H 'Universities and Regional Knowledge Production in High Technology Local Economies – the Cases of Oxfordshire and Cambridgeshire' in I.Bernard and C. Karlsson (eds) Knowledge and Talent in Regional and Global Contexts", Cheltenham: Edward Elgar (forthcoming)
Witt, U (2002) 'How evolutionary is Schumpeter's Theory of Economic Development?' *Industry and Innovation* 9 1/2 7022
Zang J. 2008. The performance of university spin-offs: an exploratory analysis using venture capital data. *Journal of Technology Transfer* 34, 255–285