2. Entrepreneurship and innovation: Oxfordshire's high-tech economy – firm survival, growth and innovation

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1. INTRODUCTION

High-tech economies are characterized by high levels of innovation-led entrepreneurship. Oxfordshire in the UK is one such example. In this chapter we focus on how high-tech regions develop by examining what happens to a cohort of firms in existence in Oxfordshire in the mid-1980s; in other words the interrelationship of how they and the region have changed. The context is the emergence of more general patterns of entrepreneurship and innovation, and the specifics of a region's entrepreneurial environment (Feldman and Francis, 2006).

An important strand of academic literature in the 1980s was concerned with technical change 'as a fundamental force in shaping the patterns of transformation of the economy' (Freeman, 1988, 2). Certain types of technical change, changes in techno-economic paradigm (technological revolutions) (Freeman and Perez, 1988) were found to have widespread consequences for all sectors of the economy. In the fifth Kondratieff wave of innovation, the information and communication Kondratieff which Freeman and Perez dated to the 1980s, was made possible by microelectronics. Other sectors identified as growing rapidly from a small base included biotechnology products and processes, space activities and fine chemicals. New forms of cooperation between firms associated with this wave included networks of large and small firms.

At the same time, two other parallel strands in the literature on innovation and entrepreneurship emerged. The first was the geography of technical change and the location of the new and emerging industries. A landmark was Annalee Saxenian's 1983 article, 'The genesis of Silicon Valley'. The second was that of 'the entrepreneurial university' (Etzkowitz, 1983).

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Since then many studies have recorded the genesis and growth of other high-tech economies and the importance (or otherwise) of universities to their development. Examples include: in the UK, Cambridge (Keeble, 1989; Garnsey and Heffernan, 2005), Oxford (Lawton Smith, 1990), the 'Western Crescent' (a region that stretches around London from the east of England to the south east (Breheny and McQuaid, 1987); in France, Grenoble (Oxford's twin town) (De Bernardy, 1999; Lawton Smith, 2003); and in the USA, Silicon Valley and the Boston area (Saxenian, 1994).

All show that the impact of entrepreneurship and innovation is not uniform. This results from a strong tendency for firms in knowledge-intensive industries to cluster. Where this translates into regional growth, it is due to specificities of initial conditions and the performance and behaviour of individual firms. Regions and locations are initially and then cumulatively different types of entrepreneurial environments, in both the combinations and scale of activity. Such differences are encapsulated by Markusen's (1996) concept of different kinds of 'sticky places'. Oxfordshire (and Cambridgeshire) are of the neo-Marshallian type, characterized by high densities of small, locally owned firms. Grenoble is rather different, being of a much bigger, state-anchored type. Since the start of the twentieth century, the region has attracted major scientific facilities and the research activities of French and foreign multinational firms (Lawton Smith, 2003).

Although much more is now known about clustering effects in particular locations, especially in the biotech sector (see, for example, Lowe and Gertler, 2008), ICT (Fingleton et al., 2008) and the Hollywood motion picture industry in California (Scott, 2004), few studies have examined how high-tech regions evolve through the survival and growth of long-established firms. This chapter's contribution to the literature is to explore the relative contribution of long-established firms to the development of high-tech economies. We use Oxfordshire as an exemplar, drawing on two studies 25 years apart.

The first was undertaken in the 1980s, a time when interest in the UK's high-tech economy was more on the impact of defence, aerospace and in some cases the associated foreign direct investment than on entrepreneurial small firms (Breheny and McQuaid, 1987), or on the geography of the microelectronics revolution (Keeble and Kelly, 1986). It began before the publication of the report in 1985 by Segal Quince & Partners, *The Cambridge Phenomenon: the Growth of High Tech Industry in a University Town.*

The second is an ongoing follow-up study begun in 2010 which examines what happened to those early firms and the extent to which they rather than newer firms have contributed most to the county's economic development. The research questions are: (i) what is the impact of those firms on the Oxfordshire economy? (ii) to what extent is the University of Oxford and the county's big science research laboratories a source of those firms? and (iii) what do the studies tell us about Oxfordshire as a favourable environment for high-tech firms? It examines which kinds of firms (independent versus merged or acquired or corporate) in which sectors have survived and grown. This evidence is compared with that from other regions such as Cambridgeshire and Grenoble.

The initial study identified 182 high-tech firms employing some 10 000 people. The new study found that over 40 per cent of these are still active and under the same ownership. A quarter were still in existence but had changed status through merger or acquisition, which meant that just over a third had been dissolved. Therefore over two-thirds of firms are more than 25 years old (some a great deal older than that) and a number of them are now large employers. This finding is consistent with studies (e.g. Cressy, 2008; Mason et al., 2009) that have found that a minority of firms create the majority of jobs. This pattern is regionally important because of the greater potential impact of large firms on employment creation, recruitment and training, local purchasing power, knowledge spillovers, and engagement and leverage within local systems of governance when compared with one dominated by smaller firms.

The chapter places the research questions within what is known about entrepreneurship, survival and growth of firms and favourable regional environments. University spin-offs are treated as a special case of entrepreneurship. This is followed by evidence from the two studies of Oxfordshire firms.

2. ENTREPRENEURSHIP, SURVIVAL AND GROWTH OF FIRMS

2.1 Entrepreneurs and Firm Development

Entrepreneurship is the focus of much recent analysis, particularly with respect to rates of firm formation and the contribution of new businesses to regional employment (Fritsch and Schindele, 2011). The fundamental rationale for this focus 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 deploying new combinations of resources and transforming organizational forms (Schumpeter, 1911 (translated 1934), cited in Witt, 2002). The spotlight on entrepreneurship is also part of the debate about the contribution of universities to wealth creation and employment generation though academic spin-offs.

Since 1999, with the advent of the Global Entrepreneurship Monitor (GEM), considerable monitoring has been undertaken of the rate of firm 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 per cent of the world's entrepreneurs expect to create almost 75 per cent of the jobs generated by new business ventures. The OECD (2008) defined a high-growth firm as one with employment or turnover growth of greater than 20 per cent per year over a three-year period. High-growth firms have often been referred to as 'gazelles', although the term is now increasingly taken to refer only to young, and usually small, high-growth enterprises that are up to five years old (BERR, 2008). Therefore, as Fritsch and Schindele (2011) point out, more important than the mere presence of start-ups in a region is their quality in terms of survival and growth rates.

A study for NESTA by Mason et al. (2009) found that the UK economy possessed a small but significant minority of high-growth firms that have achieved annual growth rates of 20 per cent or higher in a recent three-year period. About 6 per cent of firms passed this threshold for employment growth between 2002 and 2005, 12 per cent in growth in turnover and 18 per cent in growth in average turnover per employees (the vital 6 per cent). Of these, high-tech and manufacturing firms (particularly those that 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. It is important, however, to recognize that three years is a relatively short period over which to examine growth.

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 North America and Europe. Like the OECD (2008), Mason et al. (2009) and GEM (2007), this study found that manufacturers cite launching new products and services as the most important driver of revenue growth and 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: mastering innovation, exploiting innovation and building innovation capabilities. These have profit levels up to 73 per cent higher than other companies studied.

In evaluating performance beyond employment growth, labour productivity and turnover, a number of other indicators have been suggested as yardsticks for growth (Table 2.1). Some of these have obvious local implications relating to the direct and indirect benefits from increasing assets,

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Table 2.1 Yardsticks for growth

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

Source: Bridge et al. (2003).

profitability and spend. These include employment and local purchases of various kinds and also the gains from profile and image.

Age, and 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 per cent of the vital 6 per cent have been established for more than five years.

This pattern is rather different from the general tendency of failure: most firms die within the first two and a half years of life (Cressy, 2008). If a firm survives that period, then its chances of long-term survival are high. A key explanation is the availability of finance. Cressy's theoretical model states that initial capitalization is important. More money at start-up increases survival rate. Initial capital lengthens the honeymoon period, and more money reduces risk. In the 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 and hence have higher survival rates. At more mature stages, design matters less and there is less entry. Technology-based firms are more likely to survive than new firms generally and are no more likely to fail than other small firms (Mason and Harrison, 2004).

The issue of growth as a strategy is complex. For example, Mueller (1972)'s life cycle theory of the firm proposed that the tendency of managers to pursue growth rather than stockholder welfare increases as a firm grows and matures. It is suggested that firm life cycle phases (start-up, growth, maturity and decline) are distinct and identifiable, and arise from changes in internal factors (strategy choice, financial resources and managerial ability) and/or external factors such as the competitive environment and macroeconomic conditions (Jaafar, 2010). In its initial stages, a firm invests all of its resources in an innovation (the rationale for its formation) and improving its profitability (Baker, 2009). A firm's growth is likely to be slow until it has overcome its teething problems and establishes a foothold in the market. Thereafter it is likely to grow by entering new markets, and expanding its customer base before competitors come into the market.

Druihle and Garnsey (2004), in discussing university spin-offs, disagree with the Vohora et al. (2004) stage model of growth, and by implication with Mueller (1972). Instead they classify firms according to the activity of a company, how it is resourced, the way it creates value, and how returns are realized. They argue that the maturity of entrepreneurs' internal resources and the business model selected influence the phases that ventures experience. Their argument about growth phases might also apply to high-tech firms in general.

Moreover, for new 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. Internal complexity has accelerated. Thus there is greater emphasis on the resources, competences and structures required for growth (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, however, are assumed to grow over time. Many never grow beyond a particular stage in their development, remaining small and, if innovating, only through incremental innovation (Deloitte, 2004). For some, however, there is an optimum size of firm in which resources such as design talent and customer service are fully utilized: resources that would be diluted in a larger firm (Smart, 2008). Others merge or are acquired (M&A) by other firms.

Weitzel and McCarthy (2009) argue that merger theory needs to be modified for SME M&A, as the behaviour and financial success differ from those of larger public firms. They find that SMEs are more likely to rely on M&A as an external growth option. Agency costs are significantly reduced for smaller firms, and boundedly rational value-destroying actions are less prevalent as smaller firms are more flexible and able to withdraw from unsuccessful M&A activity. Hence M&A activity has regional consequences arising from patterns of ownership and control of small high-tech firms. These are positive for the region if it means that firms perform better post merger or acquisition or negative if their operations are closed or transferred to other locations.

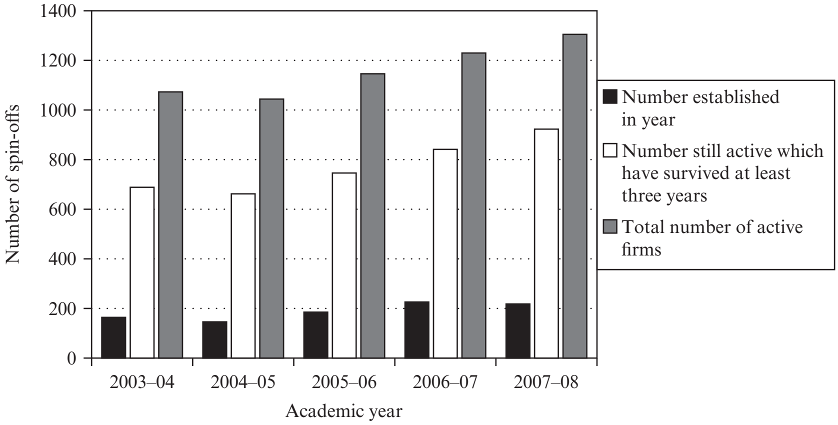
From this discussion it would therefore be expected that in Oxfordshire, age and merger or acquisition will have a positive impact on employment growth.

2.2 Entrepreneurship in Universities

University spin-offs are mainly a subset of high-tech firms. The spin-off process relates to the establishment of new legal entities and enterprises created by the university and other higher education institutes (HEIs), academics and student to commercialize knowledge arising from academic research. Such companies may be partly owned by their home universities. Other start-up companies may be formed by staff or students without the direct application of HEI-owned intellectual property (IP) (Higher Education Funding Council for England – HEFCE, 2004).

The official UK annual survey of spin-offs by the Higher Education Business Interaction (HE-BCI) for HEFCE shows that, as for other high-tech firms, not only is there an increasing numbers of spin-offs, but more are surviving (Figure 2.1). Those that do are growing both in turnover and in employment. Consistent with studies elsewhere (see Lindholm Dahlstrand, 1997), growth tends to occur after about ten years and a few large firms account for the bulk of growth (HEFCE, 2009). The number that have existed, including those with and without HEI ownership of IP, for three or more years has risen from 1038 to 1322.

In the context of the general increase in spin-off activity plus that of survival and growth, university spin-offs would be expected to be of increasing importance in the Oxfordshire high-tech economy. This would be both in the number of firms and in those that survive.



Source: HEFCE (2009), Part B, Table 4d.

Figure 2.1 Spin-off company formation (with and without HEI ownership), 2003–08

2.3 Entrepreneurship and Favourable Regional Environments

Survival and growth of firms are very difficult to measure directly (Fairlie and Chatterji, 2011). One line of argument is that favourable regions for entrepreneurship are typically those with high knowledge density (Audretsch and Keilbach, 2005) such as areas with strong research universities and other scientific centres. Another is that high-skill labour markets produce conditions that provide a source of entrepreneurs. Fritsch and Schindele (2011) find that a large share of innovation activities in a region, a high educational attainment of the regional workforce, and a wide availability of labour collectively all make a significant positive impact on the survival and growth rates of firms (see also NESTA, 2009).

Levie and Hart (2009), reporting on the most recent GEM study, identified regional differences in the UK. They argue that ambitious entrepreneurship, that is, where firms that seek to grow rapidly, 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). Hence firms might be larger in favourable regions.

In developing an understanding of the endogenous component of regional growth and therefore how economies develop and change, Camagni and Capello (2010) use the concept 'territorial capital' to describe the localized natural, human, artificial, organizational, relational and cognitive assets that make each region distinctive, and that explain differences in rates of return on investments. Assets include agglomeration and district externalities; and human capital, entrepreneurship and leadership.

Taylor (2010) summarizes the main features of endogenous growth theory, which he argues emphasizes five aspects of change. They are very similar to the list of territorial assets given by Camagni and Capello (2010): technological change and innovation; human capital; agglomeration and externalities; knowledge spillovers; and sectoral specialization and diversification. Taylor, however, argues that endogenous growth theory is simplistic in its assumptions. It is under-socialized, and particularly in its assumptions of cost reduction, with free flows of information rather than the contractual nature of inter-firm/inter-organizational interactions. Taylor compares this with an alternative approach to explaining the dynamics of local growth – that of the 'new regionalism'. This is based on the concept of embeddedness, particularly the work of Granovetter (1985). This focuses on the social and institutional drivers of growth and hence has great policy appeal. It also has limitations due to being 'anti-clarity'. It is less concerned with definition, measurement and time, places less emphasis on economic consequences and rather more on network processes and on structural barriers to interaction, power relations and profits. Instead, Taylor claims that proximity is fetishized and often based on theoretical speculation rather than empirical research.

In an attempt to include time, one of Taylor's gaps in theory, 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 the national business climate and policy framework.

Earlier, Feldman (2003) had introduced the concept of 'anchor firms' to explore the locational concentration and specialization of the emerging biotech industry. She suggests that established anchor firms who use a new technology may create knowledge externalities that benefit smaller firms and increase overall innovative output in the region. Stam and Martin (2011) suggest that one of the factors that may have contributed to the problems of the recent decline of the Cambridgeshire high-tech economy is the lack of anchor firms. They found in 2006 that in the whole regional high-tech economy there were only seven establishments with more than 500 employees and 81 establishments (5.1 per cent) with 100 or more employees. They speculate that the presence of anchor firms could have made the high-tech region more robust against external shocks, as smaller firms are more likely to exit in unfavourable economic circumstances (either via bankruptcy or by acquisition) than larger anchor firms.

High-tech university spin-offs and other kinds of companies that 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), stay close to their home institution (Zang, 2008) and are in ICT and biotech sectors. As these are necessarily innovative, it might also be expected that a high proportion of these would be high-growth, thus being of benefit to their local region.

Next we examine evidence from the Oxfordshire case studies to address the three research questions. These are designed to explore the relationship between the survival and growth of the county's older firms, the extent to which these are university spin-offs and the county's favourable environment.

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3. THE OXFORDSHIRE CASE STUDY

3.1 Context

The city of Oxford is one of Britain's heritage cities and is most famous for the University of Oxford. It is located on good transport routes some 50 miles north-west of London and 40 miles from Heathrow Airport. Oxford is a medium-sized city with a population of 143 000 people. The county of Oxfordshire (the city-region) has a population of 598 000, very similar to that of Cambridgeshire. Although it is the most rural county in the South-East of England, it has become one of the most innovative and enterprising economies in the UK (Lawton Smith et al., 2003).

It has three universities (Oxford, Oxford Brookes and Cranfield University at Shrivenham) and some ten research laboratories, including atomic energy (Harwell) and the Rutherford Appleton Laboratory (RAL). RAL has a broad science portfolio and works with the academic and industrial communities in materials science, space and ground-based astronomy technologies, laser science, microelectronics, wafer scale manufacturing, particle and nuclear physics, alternative energy production, radio communications and radar. It is funded by the Science and Technology Facilities Council, which is an independent, non-departmental public body of the UK government's Department for Business, Innovation and Skills (BIS).

A major indicator of Oxfordshire as a favourable environment for entrepreneurship and innovation is that it has one of the most highly skilled workforces in the UK. This is associated with the growth in the high-tech economy and in the public sector, particularly higher education, which accounts for one in five jobs in the city of Oxford. In 2008, 38.6 per cent of Oxfordshire residents were qualified to degree level to rank as England's third most qualified county. Oxfordshire's workforce also has a very high percentage of people with professional skills. It ranks third of all county council areas in England for the proportion of residents employed in professional occupations (Waters and Lawton Smith, 2011).

3.2 Methodology

A central task of the first study (1985–90) was to define and identify the population of high-tech firms in Oxfordshire. Given the confusion at the time of what constituted 'high-tech' (see for example Glasmeier et al., 1983), a decision was made to categorize the firms according to whether firms conducted R&D in science, computer science and engineering. These were defined for the purposes of the study as 'advanced technology'.

On the basis of that decision, a database was established by telephoning

2000 firms from lists of engineering/software/science-based companies from such sources as commercial business industry directories and Yellow Pages. From these, 182 firms were identified as advanced technology and formed the population of the study. All of the firms were contacted and, of these, 164 firms agreed to be interviewed. The interview took the form of an extensive, structured questionnaire of 72 questions, some of which were open ended. The interviews provided a comprehensive view of each firm's profile (locational factors, about the entrepreneur and their background, employment, finance, products, R&D, patents and licences, social and technological links with local and non-local universities and government laboratories.

This new study (2010–11) explores what has happened to as many of the 182 firms as possible. Not all, however, could be traced and the new data set is composed of 170 companies. The analysis focuses on their performance (of the surviving firms and those have ceased trading where possible) and their impact on the Oxfordshire economy. The set of criteria used to assess impact includes such indicators as employment (number and categories of employees), turnover, market capitalization, technological advance (inventions and innovations – patents and licences, product development). Additional data are included from other surveys of Oxfordshire university and research laboratory spin-offs, which feed into this study as benchmarks.

3.3 Early Stages

The 'Cambridge Phenomenon' provided a useful benchmark for entrepreneurship in Oxfordshire's high-tech economy, although it seriously underestimated the number of high-tech firms in Oxfordshire (Lawton Smith, 1990). In fact Oxfordshire and Cambridgeshire have followed similar trajectories in both the rate of growth in the number of firms and employment (Garnsey and Lawton Smith, 1998; Waters and Lawton Smith, 2011).

Yet, in spite of their high profile, both city-regions were then (as now) of less importance in the scale of high-tech activity than other parts of the South-East and South-West (Keeble, 1989). By comparison, in 1997, Grenoble and its *département*, the Isère, with a larger population than Oxfordshire, had some 23 400 people employed in 950 high-tech firms compared to 547 high-tech firms in Oxfordshire which employed 15 500. Although Cambridgeshire had 200 more firms, the average size of firm was smaller than in Oxfordshire (Garnsey and Lawton Smith, 1998). Both Oxfordshire and Cambridgeshire are now characterized by a high density of high-tech firms and their associated employment. Cambridge is ranked third on the UK's percentage of firms and first on employment in the UK, Oxford sixth and fifth, with the South-East (Oxfordshire) ranked as the top UK region and the East (Cambridgeshire) ranked second (Waters and Lawton Smith, 2011).

Oxfordshire's high-tech roots can be dated to the 1940s and 1950s. The first recorded high-tech firm (Penlon) was established in 1943. It is a medical equipment firm, originally named the Longworth Scientific Instrument Co. Ltd. It was a spin-off from Oxford University's Department of Anaesthetics. This was followedby two other university spin-offs: in 1953 Littlemore Scientific Engineering Ltd and in 1959 Oxford Instruments.

It was in the late 1970s that the high-tech economy began to take root and contribute to the changing industrial structure of the county. 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 whereas in 1979, 7731 were employed in some 50 high-tech firms (Lawton Smith, 1990).

Growth in the number of start-ups was slow until the mid-1980s. The 182 R&D-intensive advanced technology firms in existence in 1987 collectively employed 10 659 people. Of the 182, the majority were in manufacturing (125), followed by R&D/consultancy (32) and software (25). The early sectoral specialization reflects national trends and local conditions. 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 (Keeble and Kelly, 1986).

The early high-tech economy in Oxfordshire was dominated by manufacturing firms. Larger firms included Oxford Instruments and Research Machines (RM), established in 1973. At that time RM manufactured its computers used in education locally. Many smaller manufacturing firms were in the field of instrumentation, especially for medicine such as diagnostics. The concentration of R&D consultancy firms reflected the strength of the science base in the universities and government laboratories. Nationally, both computer sectors (hardware and software) showed significant job and firm formation increases over a similar period (Keeble and Kelly, 1986). This pattern continued into the 1990s and was associated with high levels of investment by small business in personal computers. This in turn created a demand for hardware and software (Bitler, 2002). Oxfordshire and Cambridgeshire were both in the van of those developments.

3.4 Increasing Maturity

Over time, the Oxfordshire high-tech cluster has grown to be services dominated. The relative balance between manufacturing and services in 2001

Table 2.2 Numbers of high-tech companies and employees in Oxfordshire, analysed by sector – end of 2001

Sector	Number of companies, end of 2001	As % of all high-tech companies	Number of employees, end of 2001	As % of all high-tech companies
Manufacturing				
Publishing – specialist electronic only	9	0.6	93	0.3
Biotech, pharmaceuticals and medical diagnostics	73	5.2	3257	8.9
Computer equipment	23	1.6	1825	5.0
Electrical equipment (Butchart categories)	14	1.0	657	1.8
Electronic and telecoms equipment	46	3.3	1550	4.2
Instruments, medical and optical equipment	112	7.9	5026	13.7
Motorsport and automotive engineering/design	24	1.7	2503	6.8
Aerospace and related services	12	0.9	840	2.3
Other manufacturing	70	5.0	1498	4.1
Services				
Telecommunications	30	2.1	2335	6.4
Software, Web/Internet and other computer services	635	45.1	7899	21.6
Other R&D activities (not included above)	44	3.1	5907	16.1
Technical consultancy and technical testing	317	22.5	3257	8.9
Other/not classified	8	–	35	–
Total: all sectors	1417	100.0	36 682	100.0

Source: Chadwick et al. (2003).

is shown in Table 2.2. In manufacturing, the early specialization in instrumentation in the number of firms and employment, including that in the biotech sector, continued. The largest manufacturing sector was instruments, medical and optical equipment, followed by biotech/pharmaceuticals. Oxfordshire was part of the South-East of England's specialization in small manufacturing firms. In the mid-1990s the region was the UK's leading location for manufacturing small firms of fewer than 50 employees (around a quarter of all firms in the UK), having over twice the percentage of firms than in the East of England (Hart and McGuinness, 2003).

In Oxfordshire, manufacturing firms were on average larger by employment than the other firms. For example, the average size of motorsport and automotive engineering design firms, which includes racing car manufacturers such as Williams FI, was 104 and for computer equipment firms it was 79. The motorsport sector accounts for less than 2 per cent of the county's high-tech firms but 7 per cent of its high-tech jobs. In instrumentation, average firm size was 45, about the same for the biotech, pharmaceuticals and medical diagnostics sector. The emerging biotech sector had 73 firms and only 5 per cent of the county's employment high-tech firms. The biotech and medtech sectors are now supported by the Oxfordshire Bioscience Network (a not-for-profit business network) and Diagnox (a network and incubator for firms in the diagnostics sector). Over time these and other networks have been established as demand has increased, thus adding to the favourable environment.

However, even by the end of 2001, service sectors dwarfed those of manufacturing in the number of firms and total employment, but firms on average were much smaller. For example, the software, Web/Internet and other computer services accounted for nearly half of the firms, but only a quarter of employment. The average size of firm was 12 employees. This sector had twice as many companies as technical consultancy and technical testing (22.5 per cent), which were also on average small firms. In contrast, the 30 firms in the telecoms sector were on average much larger (78 employees).

The mid-1990s saw a rapid expansion of the high-tech economy, including the number of university spin-offs (see below). Table 2.3 shows that the take-off period of growth began in the period 1991–95, but accelerated from the middle of the 1990s. This is significantly faster than in neighbouring Berkshire, which has the highest absolute number of high-tech jobs, many of which are in multinational companies (Chadwick et al., 2003).

3.5 Mature Stages

More recent data show that the rate of new firm formation in the Oxfordshire high-tech economy continues to increase. In the absence of local data, the Office of National Statistics data show that in 2005 Oxfordshire had some 3500 high-tech firms employing 45 000 people, around 14 per cent of the county's workforce[1] in 12 per cent of businesses in Oxfordshire (Glasson et al., 2006). Using these figures, the county has

Table 2.3 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
2001–02	29	3.1
1996–2000	357	38.1
1991–95	233	24.8
1986–90	139	14.8
1981–85	92	9.8
1980 and earlier	88	9.4
Year not known or company not registered	479	–
Total	1417	100.0

Source: Chadwick et al. (2003).

the third-largest high-tech employment among UK counties (high-tech as a percentage of total employment). The county is characterized by 'diverse specialization' with high-tech services, including software consultancies and biotechnology, as the largest employers. The larger businesses were still in high-tech manufacturing, including pharmaceuticals, medical instruments and computers.

In 2007, the numbers of firms and employees had increased further. Using Glasson et al.'s (2006, 507) definition of high-technology industry, there were 37 300 employees in 3600 high-technology firms in Cambridgeshire in 2007 compared to 35 500 in 3800 in Oxfordshire (Table 2.4). With 13.6 per cent of all employment being in high-technology industry, Cambridgeshire ranked first of all county council areas in England, with Oxfordshire ranking fifth (Waters and Lawton Smith, 2011).

Oxfordshire was outperformed by Cambridgeshire but was still well above the national average and above that of the leading high-tech regions of the East and South-East. The main differences appear to be the dominance of the city of Cambridge in the high-tech economy compared to that of Oxford, and the superior performance of South Cambridgeshire (in which Cambridge is located) compared to Oxfordshire's Vale of the White Horse, where most of the research laboratories are located.

Oxfordshire is one of the UK's four leading locations of biotechnology, the others being Cambridge, London and the Edinburgh/Dundee area of Scotland. Over time, Oxfordshire has been the home of some of the UK's largest biotech firms: most but not all were spin-offs from Oxford University. In 2002, biotech spin-offs from Oxford University

Table 2.4 High technology in Oxfordshire and Cambridgeshire, 2007

	Firms			Employment		
	No	%	Rank	No	%	Rank
Cambridgeshire	**3657**	**13.6**	**3**	**37278**	**13.6**	**1**
Cambridge	891	15.6	15	11579	13.7	30
East Cambridgeshire	394	11.3	104	1813	7.5	137
Fenland	255	7.5	308	1080	3.4	350
Huntingdonshire	959	13.0	58	6674	9.4	89
South Cambridgeshire	1158	16.7	8	16141	26.0	3
Oxfordshire	**3866**	**12.3**	**6**	**35523**	**11.2**	**5**
Cherwell	723	11.1	111	6068	9.0	101
Oxford	644	11.1	112	8075	7.9	124
South Oxfordshire	1033	13.5	44	5647	10.4	60
Vale of White Horse	843	14.8	23	11376	21.1	7
West Oxfordshire	623	10.9	122	4361	11.4	48
East	**27110**	**11.2**	**2**	**194068**	**8.2**	**2**
South-East	**48423**	**12.5**	**1**	**392266**	**10.6**	**1**
Great Britain	**243240**	**10.2**	–	**1984733**	**7.5**	–

Source: Lawton Smith and Waters (2011).

included PowderJect, established in 1984, employed 984; Medisense 1151, and Evotec/OAI 358 (Lawton Smith and Glasson, 2005). Studies by the Oxfordshire Bioscience Network (OBN, 2008) have found that the number of bioscience firms is increasing. By 2008, Oxfordshire had some 142 biotech and healthcare firms. Two-thirds were more than six years old and 13 per cent had been formed between 2007 and 2008. Estimates of employment rose from 1000 in 2002 to just under 2000 in 2005 and 5000 in 2008.

3.6 Empirical Findings

Against this background we now examine the growth and performance of the firms that were in existence in the mid-1980s.

3.6.1 Status, active and inactive firms

The companies have been grouped into three categories: dissolved (they have ceased trading); changed status (they have been acquired or they have merged with other companies); and active (they still operate in the market as independent companies). Figure 2.2 shows the breakdown of the companies by status.

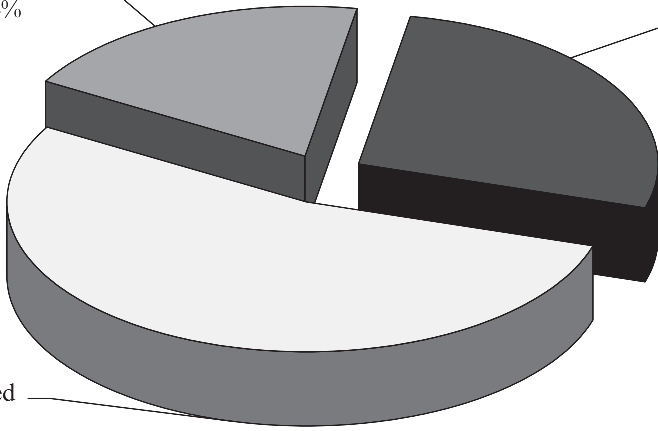

Figure 2.2 Current status of Oxfordshire high-tech companies from original sample

The study found a very high survival rate of firms. Over two-thirds of firms (118) are more than 25 years old, some a great deal older than that. Many date back to the 1950s, 1970s and 1980s. A significant majority are independent firms. Nearly 30 per cent are still active and under the same ownership. A quarter have changed status (Figure 2.2).

The Oxfordshire high-tech economy is therefore dominated by a few very large and long-established firms. Examples of larger companies and their employment in 2009 are: Oxford Instruments (1522), Sophos, formed in 1987 (1339) and RM, formerly Research Machines (2000). Some indications of the local impact of the 'Active' group are employment and revenues. The 'Active' group includes 46 companies. The total number of employees for 2009 was 8233 and total revenues were £10 270 billion. Using figures for 2008 as a baseline, the active and older companies employ more than a third of employees in the high-tech sector. They remain a lower percentage of the total of high-tech firms (1.6 per cent) as at 2007. This is consistent with studies (e.g. Cressy, 2008; Mason et al., 2009) that have found that a minority of firms create the majority of jobs.

The county's favourable environment for older firms, particularly in manufacturing, is illustrated by the study. Employment growth is most marked in the manufacturing firms, which are the largest. This is also the largest group for surviving firms. However, the impact of some of these anchor firms has been diluted; much of the manufacturing is now overseas. For example, RM no longer manufactures in the UK.

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3.6.2 Breakdown of companies by sector

We next examine in more detail the sectoral profile of these firms by status. The current status of the companies by sector is shown in Figure 2.3. In the 'Active' group, that is, those that have remained under the same ownership, is the 'Manufacturing and engineering' subset.

The Biotech group has survived remarkably well. The group has the lowest death rate but the highest change of status, mainly through acquisition, consistent with general trends (see Lawton Smith and Glasson, 2005). Over four-fifths of the biotech companies have survived in one form or another. Some which have been acquired of those are university spin-offs. With some exceptions, M&A is associated with stability in some cases and growth in others. Examples of employment change spin-offs from Oxford University and date of acquisition are shown in Table 2.5.

Others that did not survive following acquisition include PowderJect and British Biotech. PowderJect was bought by Chiron in 2003 and then in turn by Novartis in 2006, and effectively closed down after the vaccines business was relocated. A notable failure, not a university spin-off, was British Biotechnology Ltd, which at one time was the UK's largest biotech company. British Biotechnology Ltd was founded in 1986 and was the first British biotechnology company to be publicly listed when it was floated on

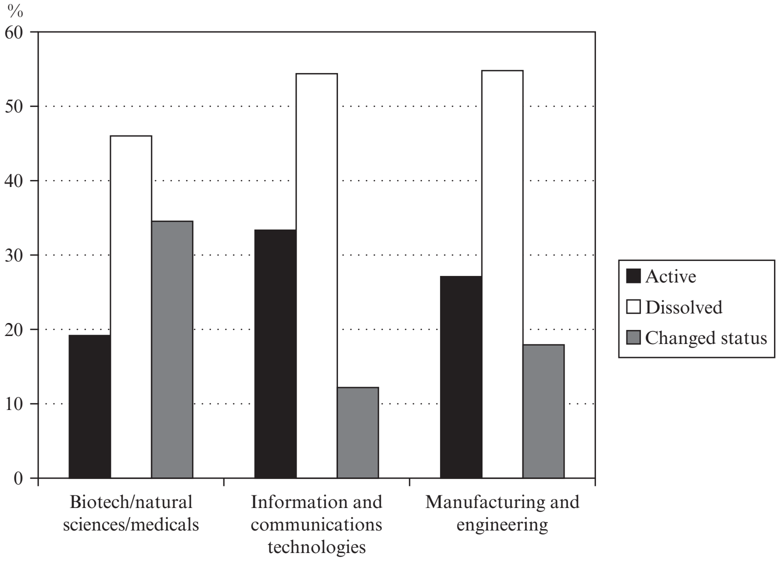

Figure 2.3 Current status of the Oxfordshire high-tech companies from original sample by sector

Table 2.5 Examples of employment change in Oxford University spin-offs

Company acquired	Date of acquisition	Employees (time of acquisition)	Employees (2009)
Evotec (UK) Ltd	2000	198	205
Medisense Ltd	1996	448	640
Haemocell Ltd	2001	21	63
Avidex Ltd	2006	39	36

Source: Chadwick et al. (2003).

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 were integrated into the Vernalis organization in neighbouring Berkshire.

The 'Information and communications technologies' group has the highest active rate. It is also the second-highest growing group, moving from 20.5 per cent at the time of the first study to the current 29.0 per cent of high-tech firms in the county. Both this and the Biotech group are important sectors in the maturing high-tech economy.

3.6.3 University and laboratory spin-offs

The impact of Oxford University on the Oxfordshire high-tech economy has been significant over its history. Even in the mid-1980s Oxford University had contributed to over a fifth of Oxfordshire's high-tech companies. Some 40 firms had been established by academics, technicians and former students, and are broadly defined as spin-offs (see Lawton Smith and Ho, 2006). These spin-offs[2] were not associated with any mechanisms for entrepreneurial support in Oxford University pre-existing the establishment of Oxford University's technology transfer company, Isis Innovation, in 1988.

Early university and research laboratory spin-offs were in manufacturing sectors. 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. Examples of academic spin-offs have already been mentioned: Penlon, Littlemore Scientific Engineering and the largest of all spin-offs, Oxford Instruments.

Oxford Instruments 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). As an anchor firm, from its formation it has subcontracted locally (Lawton Smith, 1990).

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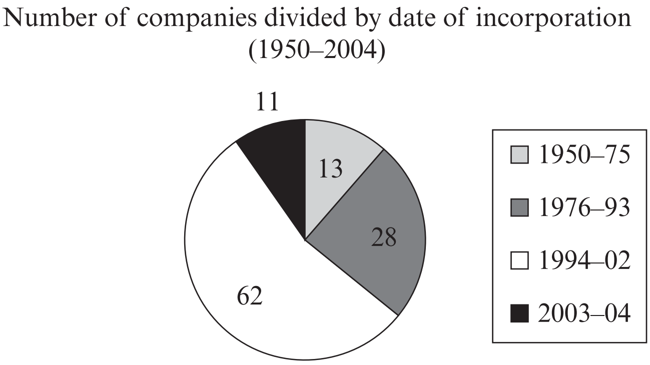


Source: Lawton Smith and Glasson (2005).

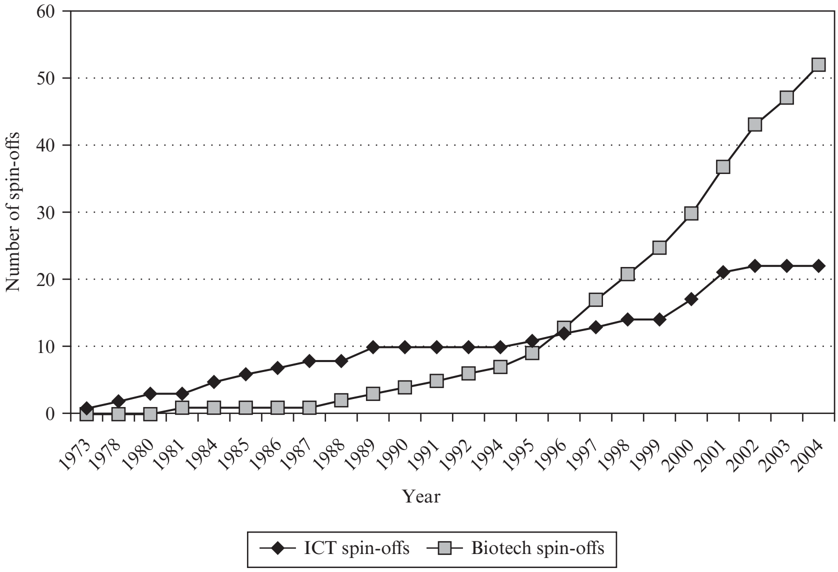
Figure 2.4 Spin-offs from Oxford University

By 2002, the available data (Lawton Smith and Glasson, 2005) showed that spin-offs accounted for over 3 per cent 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. Most have stayed within Oxfordshire, thus contributing to the growth in the county's high-tech cluster. Figure 2.4 shows the number of spin-offs formed between 1950 and 2004.

The Lawton Smith and Glasson (2005) report 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 were biotech and 16 were pharmaceuticals companies. Until 2001, the ICT group had more employees than the biomedical group and enjoyed sharp employment growth between 1994 and 1996, when 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 2.5).

Six biotech spin-off companies employ more than 200, the largest being Medisense formed in 1990 (640). This company's fortunes have fluctuated, having employed 1175 in 2005, but since then badly hit by the recession. Others have had more stable patterns of employment, while yet others have started to grow; and another set of firms remained small. There is, therefore, little clear pattern.

The stability and growth of the county's university and research laboratory spin-offs is a vitally important component of the Oxfordshire high-tech economy. Their impact is twofold. First, they comprise some of the



Source: Lawton Smith and Glasson (2005).

Figure 2.5 Comparison of numbers of ICT and biotech spin-offs

county's largest high-tech firms and as such can be described as anchor firms, providing stability to the county's economy. Second, they have contributed to the county's specializations in manufacturing, ICT and the biotech sector.

4. CONCLUSIONS

The context to this study was a series of reports and studies of Oxfordshire's high-tech economy dating back to the mid-1980s. The main features that characterize Oxfordshire as a favourable environment for innovation-led entrepreneurship as well as attractive locational attributes are its dense concentration of world-leading research institutions and the associated highly skilled labour market. These, when interconnected, are predicted in the literature to provide the conditions under which entrepreneurship levels are high (Audretsch and Keilbach, 2005; Fritsch and Schindele, 2011). There also appears to be an association between quality of the environment and growth and survival of high-quality firms.

In Oxfordshire nearly two-thirds of the 182 firms identified as advanced technology are still operating. They account for a third of high-tech employment as at 2007 (Waters and Lawton Smith, 2011). Although the largest share of employment in the high-tech sector has been generated by newer firms, that statistic alone underestimates the overall impact of the older firms, for example through multiplier effects of employment generation through subcontracting, local spend of employees and a general contribution to the stability of the economy. Directly these firms have replaced employment in the previously dominant automobile sector. Moreover, much of the early growth was in manufacturing, which both benefited from the history of manufacturing in the county – skills and subcontractors – and continued that tradition. These have important role as anchor firms (Feldman, 2003). There are more large firms than in Cambridgeshire (Stam and Martin, 2011) and they tend also to employ more people.

At the same time, the county was in the van of national and international developments in ICT and biotech and associated medical instrumentation such as diagnostics. While the largest firms in manufacturing tend to be independent firms, in biotech, there is more M&A activity consistent with national trends. In some cases this has a negative impact on employment but generally the effect is positive (consistent with the arguments made by Weitzel and McCarthy, 2009).

What does all this tell us about the region and regional change? It tells us that the county is one of the fastest-growing high-tech economies in Europe (whereas in Cambridgeshire growth has slowed: Stam and Martin, 2011). It appears that Oxfordshire does have a positive impact in encouraging ambitious entrepreneurs (and possibly, making entrepreneurs more ambitious) (Levie et al., 2009). Regional change and stability are here two associated concepts.

The next stage of this research is to survey the 170 firms to establish how they have grown and the extent to which their interaction with the regional economy has changed over the 25 years. This will provide evidence of association of factors that can only be speculative at present. In particular, the work of Arbaugh and Camp (2000), work on the resource-based view (Barney, 1991), on mastering innovation (Deloitte, 2004), and on optimal firm size (Smart, 2008) provide the foundations for exploring those interrelationships.

NOTES

1. ONS uses data from the annual Business Inquiry, which uses a more comprehensive data set with a less restrictive definition of high-tech and includes higher numbers of businesses in IT and computer-related services.

2. The definition of spin-offs used in this study is broadly consistent with that used in the Higher Education Business-Interaction (HEBI) surveys for the 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 businesses started by recent graduates (within two years) regardless of where any IP resides. HEBI surveys show that the number of spin-offs with some HEI ownership older than three years is increasing. In 2003–04, 2004–05 and 2005–06 there were 521, 529 and 669 respectively.

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