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Technology and Knowledge Based Business in the

Cambridge Area; A review of evidence

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No: 2002/01, May 2002

I.S.B.N. 1-902546-27-X

Abstract

The area around the city of Cambridge (the Cambridge Sub-Region) was the first centre of high-tech activity to emerge around a university in Europe and remains one of the most active. It is seen both as a model for others to follow and as a source of increasing prosperity for the region and country as a whole. From a handful of technology-based firms in the 1970s, by 2000 there were around 1200 firms that can be described as 'high tech' employing over 38,000 people with a combined turnover of £3.7bn. In March 2002, following the recent stock market correction, those companies with UK public company status had a combined market capitalisation of £4.3bn.

Growth had eased somewhat by the end of the 1990s, though firm numbers grew by 14% and employment by 26% over the decade. Beneath the aggregate figures, however, there was significant churn as new firms were created while others were closed, acquired or moved out of the area. There are also significant differences between sectors.

Survival rates were generally better than the national average, and better than those commonly quoted in the literature, typically 55% survived the first 10 years. Despite this, there are few large firms in the area to act as hubs for development, though there are a number of globally significant firms and some industrial clusters.

The development of high-tech activity in the Cambridge area was largely self-organising. However, congestion effects such as skills shortages, house prices and excess pressure on the local infrastructure, point to the need for improved co-ordination between central and local government and between the university, civic and business communities if the success of the last two decades is to be sustained.

Keywords

Cambridge Phenomenon; Technology-based Firms; Growth; Employment; Turnover; Market Capitalisation; Regional Development; Clusters

Introduction

The University of Cambridge is surrounded by one of Europe's most active centres of high-tech activity. Recent studies have emphasised the need to encourage continued growth of the region's industrial base with a target of becoming one of the top ten regions in Europe in terms of GDP per capita by 2010.[1] The significance of Cambridge has been recognised at national level:

'If Cambridge can continue leading the new industrial revolution, the rewards will be massive. It can be a springboard for a new prosperous future not just for the City, but for the whole economy'

Rt. Hon. Tony Blair, 1999

The "Cambridge Phenomenon" which emerged in the 1980s involved the rapid growth of high-tech industry around the city. The population is relatively small (city population: 100,000; county population: 700,000), but at its heart is Cambridge University, which exemplifies the extent to which knowledge provides an impetus to new forms of activity. The university's links with other leading centres throughout the world have encouraged global activities among firms spinning out from it.

A new analysis of high tech enterprise in the Cambridge area is presented here, drawing on a database derived from public and commercial sources to augment the Cambridgeshire County Council employment survey[2]. We depict growth in the number of firms and the employment they provide during the 1990s, and the scale of high tech activity on the eve of the Millennium.

The sphere of influence of high-tech activity in Cambridge is difficult to define and studies employ a variety of definitions depending on objectives and the availability of data sources. Whilst it is evident that the influence extends well beyond the city and the South Cambridgeshire district in which it lies, attempts to spread the perceived benefits across the East Anglia region have met with only limited success. For the purposes of this analysis, the "Cambridge area" is taken to be the County of Cambridgeshire (Figure 1) the definition used in the County Council's employment surveys[3].

We would like to thank the Hauser Rasp Foundation for supporting this research and Hermann Hauser for initiating it. We continue to value our association with the Cambridge County Council Research Group. At a time when many local authorities have been downgrading their research facilities, their expertise built up over many years is an invaluable resource. We also thank Andrea Pasquill, Goh Kuan Tan, Ben Deacon and Tristan Fletcher of the Institute for Manufacturing for their help.

[1] Cambridge Sub-Regional Study, 2001, SQW, 2000
[2] The County Council have kindly provided access to survey records dating back to 1988.
[3] Data sources and the definition of "high-tech" are discussed in the appendices.

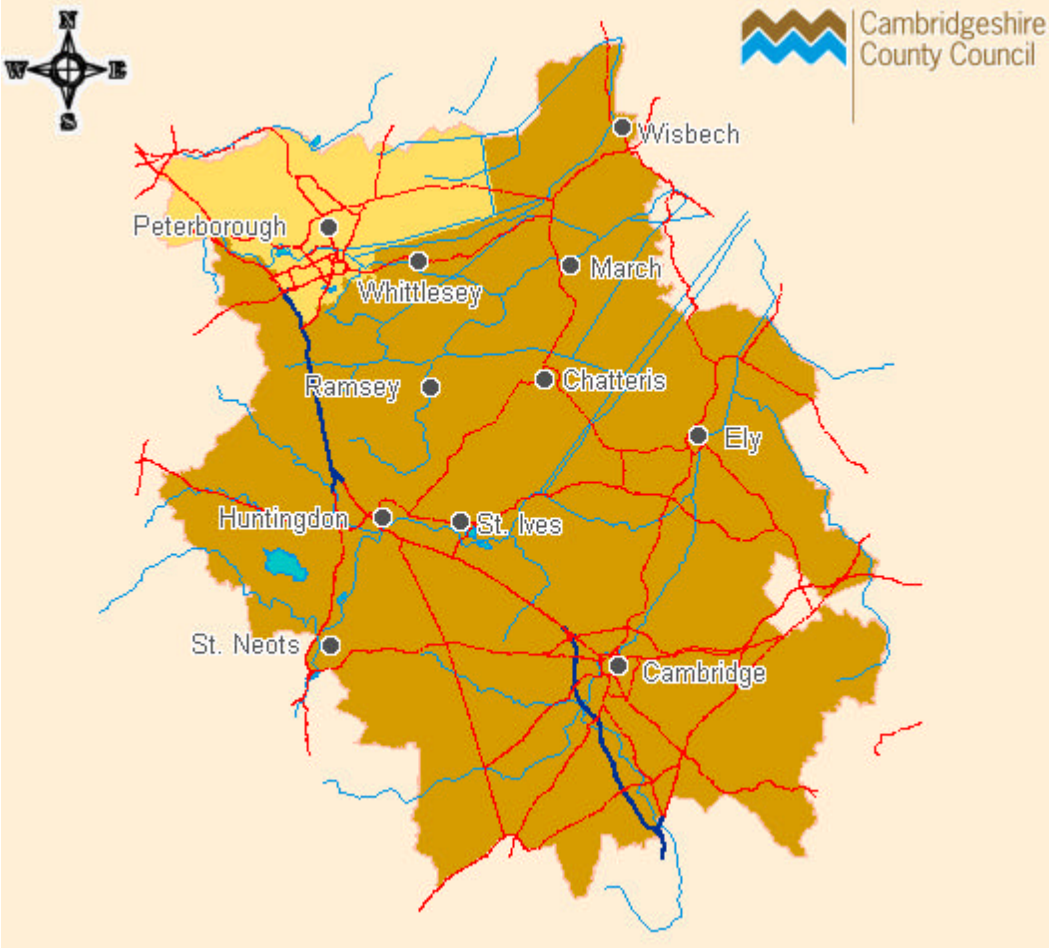


Figure 1 - The County of Cambridgeshire

Cambridge at the Start of the New Millennium

By the end of the 1990s, Cambridge was recognised as a significant centre of high-tech activity. Around 38,000 people were employed in technology-based firms, of which there were around 1,160 in Cambridgeshire. Yet more people were employed in organisations providing services to these firms and their employees.

Figure 2 shows the distribution of firms and employment across the high tech sectors. IT Software firms are by far the largest single group, but they are mainly small, the large number probably reflecting the ease with which such firms can be established. Instrumentation, and Research and Development are also important sectors, the latter being the largest employer, reflecting the presence of the University[4]. Biotechnology is also important in the Cambridge area but comprises firms classified under other codes, e.g. Research and Development or Chemical. Biotechnology-related firms account for 13% of firms and 23% of employment.

[4] Research and Development includes contract research organisations, but, due to the SIC 92 coding restrictions, also includes firms such as ARM which are involved in design but not manufacture.

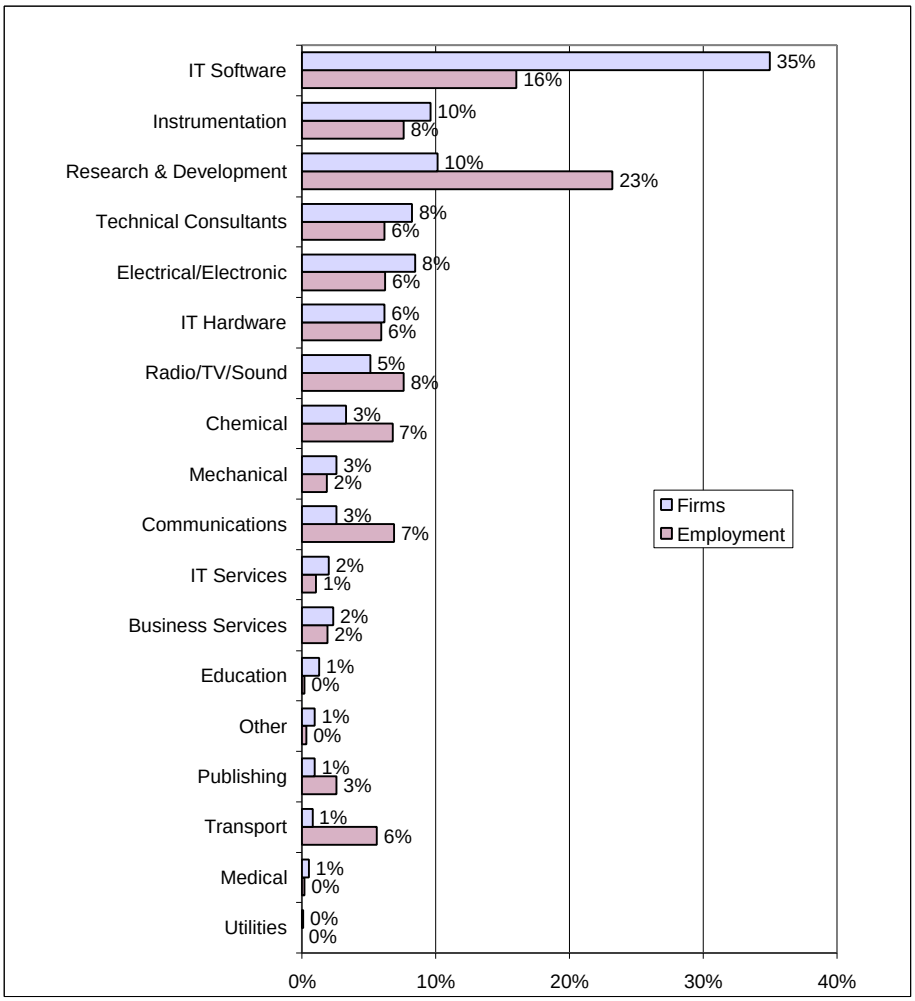


Figure 2 – Technology Sector Prevalence by Number of Firms and Employment in Cambridgeshire 2000

But employment is not the only measure of growth and it does not necessarily reflect the scale of the economic activity in which firms are engaged. This is particularly pertinent with respect to knowledge-based firms and those employing licensing business models, where high turnover and market value are generated by a relatively small number of staff. Determination of total turnover and market value is not at all straightforward. For this reason data have not thus far been available on this subject. The following estimates give some indication of the scale activity among high tech firms and the market value of public companies based in the area.

Turnover

The value of sales is an important indicator of firms' activity which has not been analysed in previous studies of high tech Cambridge.[5] The following estimates use actual turnover data where available, adjusted using employment to reflect Cambridge-based activity and estimates based on government statistics[6].

[5] Companies operating in the UK are required to submit reports on their activities to Companies House. However, smaller firms are granted exemption from Profit and Loss reporting and the smallest firms are granted complete exemption from financial reporting making estimates necessary for some categories.
[6] The methodology is described in more detail in the appendices.

By this method, total turnover for technology-based firms in Cambridgeshire in 2000 was calculated as £3.72bn, the sectoral distribution of which is shown in Figure 3.

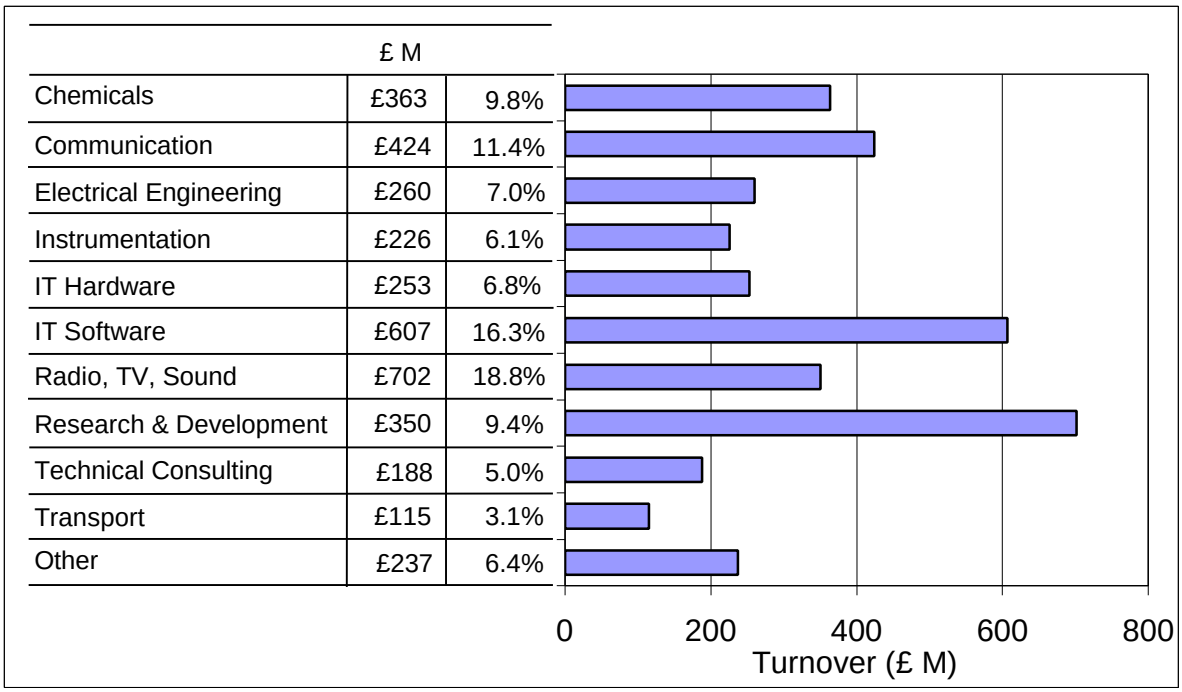


Figure 3 - Sectoral Distribution of Turnover for Technology-based Firms in Cambridgeshire in 2000

The Software, and Research and Development sectors predominate, accounting for over 35% of total turnover. Although the proportion of turnover generated by software firms is approximately equal to their contribution to employment, Research and Development firms account for 4% less (a relative difference of 18%). Communications and Chemicals firms, on the other hand, account for considerably higher proportion of turnover than employment (4% and 3% higher respectively). This serves to illustrate the effect of different measures, though the variations are not of a scale which would call into question the validity of analyses which use only employment data.

Market Value

The number of Cambridge companies that have become public quoted companies rose rapidly during the 1990s. Market value is difficult to establish since the majority of firms are privately owned (95%). We have estimated the Market Value of Cambridge companies that are publicly quoted at £4.30bn in 2002, reduced from around £9bn during the stock market boom in 2000.[7] If the capitalisation of entire companies on all sites is used, the total in 2002 is £11.41bn.

[7] The Cambridge Evening News list of share prices without the firms that are not technology-based was taken as a basis for establishing "Cambridge" companies, corrected for Cambridge employment for multi-site companies.

	Company £m	Cambridge based £m
Acambis	318.00	262.81
Alizyme	42.36	42.36
ARM Holdings	3,328.35	1075.40
Autonomy Corporation	440.75	181.49
Aveva	65.80	53.11
AWG	1,703.34	67.98
Cambridge Antibody Technology	568.07	529.26
Celltech Chiroscience	2,004.34	177.87
Celsis International	13.37	1.37
Cenes Pharmaceuticals	11.47	5.74
Domino Printing Sciences	142.69	142.69
Ferraris Group	65.40	65.40
Generics Group	91.54	87.60
Globespan Virata	1,196.39	562.30
Linx Printing Technologies	40.49	40.49
Medical Marketing	17.90	17.90
NCipher	120.31	24.72
Netcentric	1.21	1.21
NXT	80.95	16.19
Pharmagene	49.70	49.70
Phytopharm	221.83	221.83
Plasmon	26.30	6.31
Pursuit Dynamics	12.40	12.40
Roxboro	144.70	0.62
Tadpole Technology	23.56	5.52
TTP Communications	325.58	325.58
Vocalis Group	6.95	6.95
Weston Medical	214.18	214.18
Xaar	46.18	46.18
Xenova	84.80	54.13

Table 1 - Market Capitalisation of technology-based firms in Cambridgeshire in 2002

A number of other PLCs operate in the Cambridge area and a proportion of the market value of these could be added to the totals referred to above. Since the quoted companies are a small proportion (numerically 2.5%) of the total of technology-based firms, estimates based on this group represent a very conservative estimate of the net worth of technology based firms in Cambridgeshire.

The Cambridge Phenomenon and Beyond

The Cambridge cluster is relatively young, emerging only in the last 3 decades of the last century. In that short time, technology-based industry in the Cambridge area has developed from virtually nothing to the significant economic centre described above. Its continued growth relies on an understanding of the dynamics underlying its development to date. Trends in growth, survival, and industry evolution provide a useful input to analyses of future demands and challenges.

Growth in Firms and Employment

In 1985 the Cambridge Phenomenon report found almost 300 firms, employing 16,000 people, in new high tech industries, most of which had indirect links with the university [SQW, 1985],. Figure 4 traces the expansion in the number of firms identified as high tech and having Cambridge connections from the early 1960s through to 1984 [SQW 1985]. It can be seen that the start up of new firms was very rapid, numbers more than doubling in the years 1964-74 from around fifty to over a hundred, and tripling in the years 1974 to 1984 to around 350.

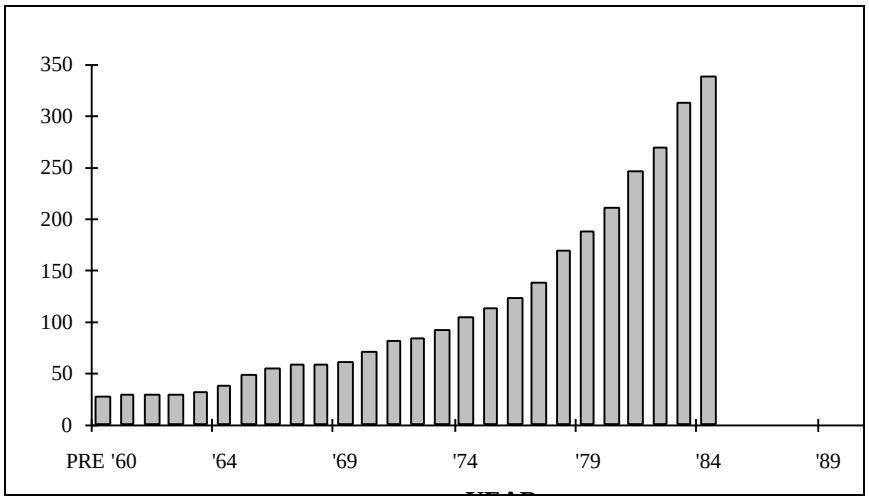


Figure 4 - Growth in Technology-based firms 1960-1984 [Garnsey and Cannon-Brookes 1993]

In the late 1980s, over 100 new firms were formed annually. Because there were changes in data collection methods, the graphics in Figure 4 extend only to 1984, and analysis resumes in 1988 for the data discussed below. Major changes include a decline in the proportion of manufacturing firms from about two thirds of the total of high-tech firms in 1984 to about a third in 1996. [Garnsey and Cannon Brookes 1993; Gonzales et al 1996]

During the 1990s the creation of new enterprises continued. On average, 90 new firms were created in the high-tech sector each year, while employment increased by around 800. By 1997 there were 36,500 people employed in high-tech firms representing 10.4% of the total employment of Cambridgeshire.[8]

By 1999 there were 1,160 technology-related firms in Cambridge, employing 38,000 people. Figure 5 shows the variation in growth rate during the decade, and clearly shows the impact of the recession of early 1990s. The main impact was on employment rather than numbers of firms, reflecting the shedding of labour by firms facing a downturn. However, the mean size of firms in

[8] Total employment 351,170, based on 1997 Employment census, adjusted by CCRU.

1999/2000 (33) was very similar to that in 1988 (32) having dropped to 28 in 1991/92 (the median remained between 7 and 8).

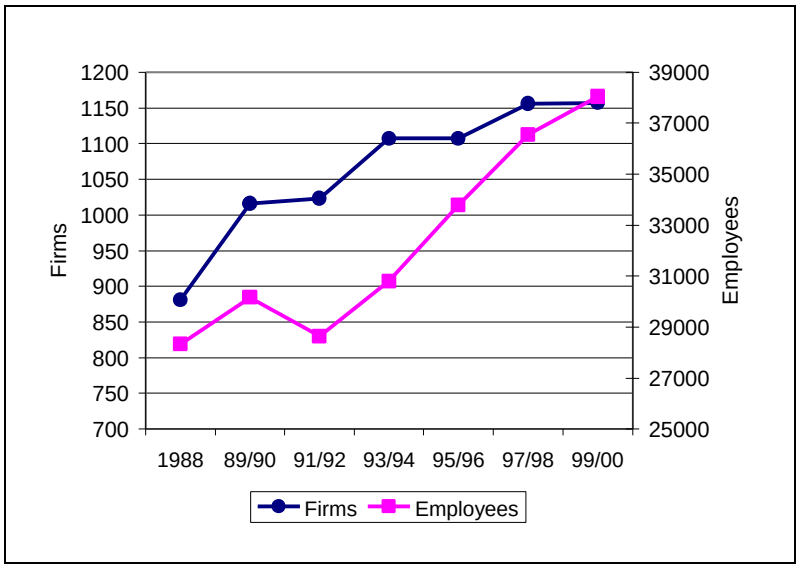


Figure 5 - Growth in Technology-based Employment and Number of Firms 1988-2000

Underlying the relatively modest growth in firm numbers is a great deal of turbulence or "churn" with the emergence of new firms being offset by the loss of existing enterprises through closure, consolidation and relocation (Figure 6). As stated above, on average, 90 new high tech firms appeared in Cambridge each year, but 30 firms moved away from Cambridge and around 50 firms closed. Although the closures remained steady at between 7 and 10 %, the proportion of firms leaving Cambridge increased by around 28% from around 2.8% per biennial period at the beginning of the 1990s to 3.6% at the end of them[9]. Again, the effect of the recession can be seen, but a similar reduction in activity is evident in 1995/96 and again in 1999/2000 and it is not clear why this apparently cyclical effect should be present.

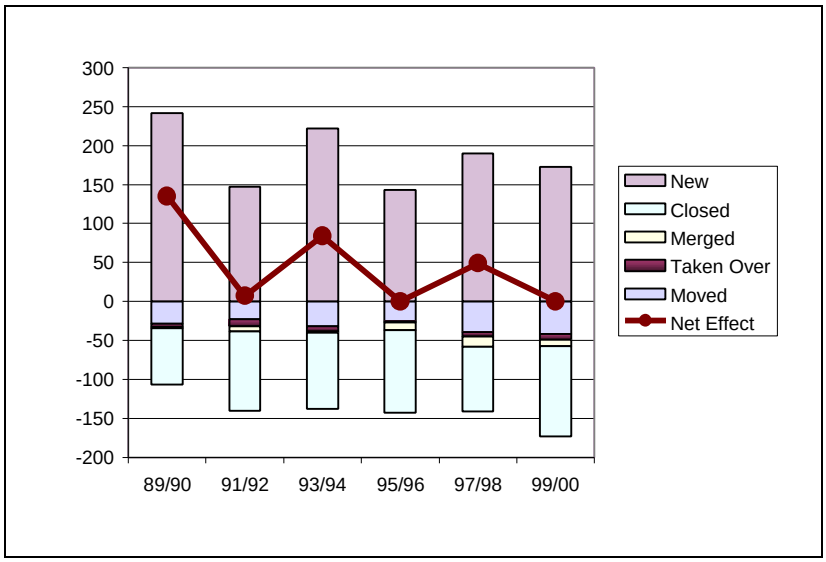


Figure 6 – Breakdown of Biennial Change in Number of Firms 1989-2000

[9] The number leaving is relatively small, but the change represents an increase of nearly 29%.

Snijders and van Elk [1998] report a high level of turbulence[10] for UK industry as a whole between 1990-94 of 24.9, compared with 20.2 for the USA and 9.4 for Japan. Over the same period the high tech sector in Cambridge saw an average turbulence of 14.5. Hence, although there is considerable turbulence in the sector, it is actually lower than that reported for the UK as a whole.

When closures and firms moving out of the area are taken into account, the annual growth rate was under 1.5%, compared with 15% between 1980 and 1984 when the base was much smaller and proportionate growth larger. The rate of growth (i.e. emergence) of new high tech enterprises exhibited a downward trend from 1990 to 2000 (Figure 7). Despite the reduced rate of growth in firm numbers, employment continued to grow at a steady rate throughout the decade, other than during the recession of 1991/1992 (Figure 7).

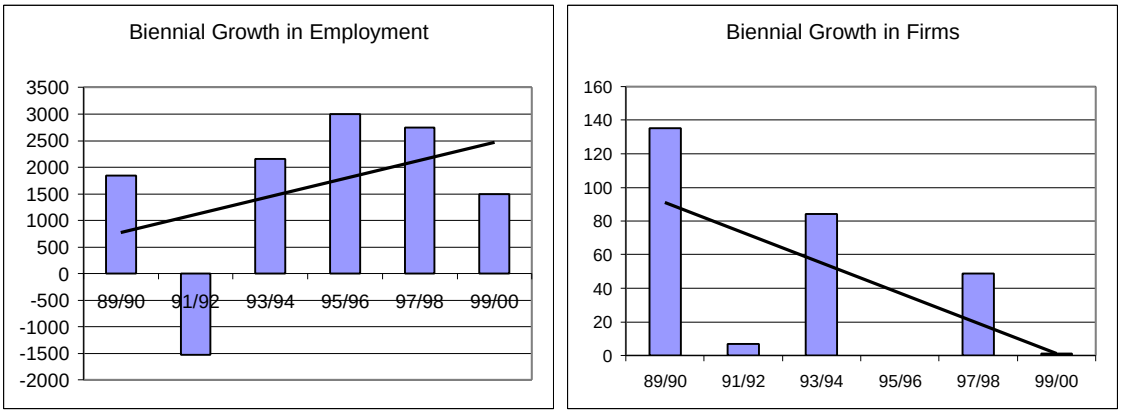


Figure 7 - Trends in Employment and Firm Number Growth 1989-2000

The patterns of firm formation and departure are particularly interesting (Figure 8). Although there was a significant decline in the net growth of firm numbers through the decade, the generation of new firms declined much less. The reduced rate of increase was due to increasing numbers of closures and relocations out of the area[11].

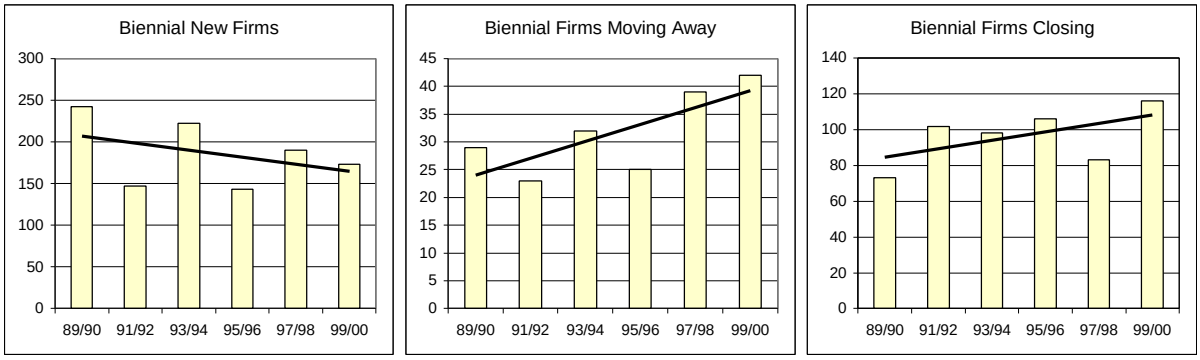


Figure 8 - Trends in Changes in Number of Tech-based Firms in Cambridgeshire 1989-2000

[10] Defined here as % of entering (new) firms plus % of exiting firms.
[11] Since the CCRU database is concerned only with firms operating in Cambridgeshire, firms moving out of the county, event to adjacent towns, are not tracked.

Survival

Although data are not available for UK firms over more than 3 years, high-tech firms in Cambridgeshire appear to survive better than average. In Figure 9 and Figure 10 it can be seen that the trajectory of survival over time for all firms in the East of England and the UK as a whole are quite different to those for Cambridge High-tech enterprises[12].

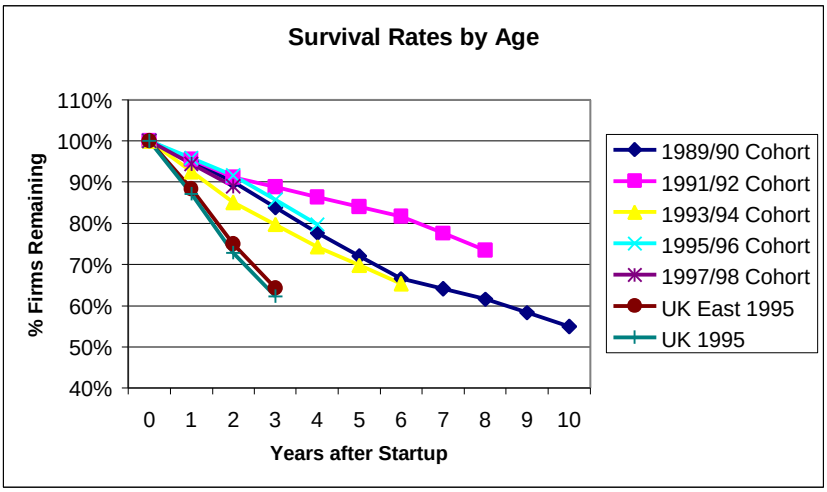


Figure 9 – Survival Rates for Cohorts of Tech-based Firms in Cambridgeshire, the UK and East England

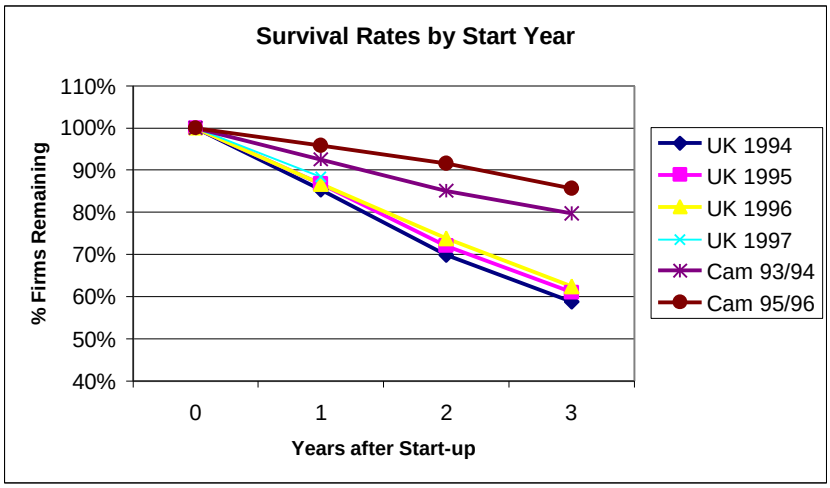


Figure 10 - 3-Year Survival Rates for Tech-based Firms in Cambridgeshire and UK firms in general

Survival rates for Cambridge firms are consistently higher despite variations in survival by start year (Figure 10)

As would be expected, however, there are significant differences in the survival rates of firms in different sectors. Figure 11 shows the breakdown for the cohort of firms first appearing in Cambridge between 1989 and 1990.

[12] Firms in the East of England have a better survival rate than the national average.

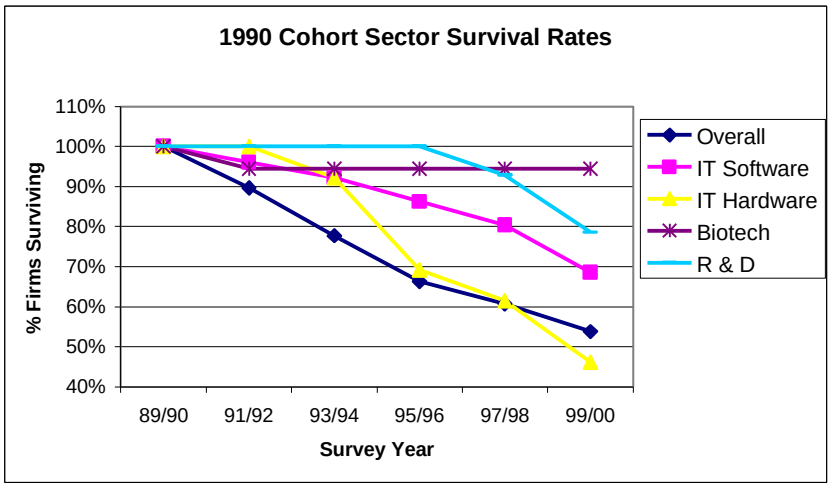


Figure 11 – A Sample of Survival Rates by Sector for Firms in the 1989/1990 Cohort

Firm Size

Over all sectors, small firms continue to dominate, though to a lesser extent than is found across the UK as a whole. Since UK data include small retailers, tradesmen etc., the charts shown in Figure 13 include only firms with industry classification codes matching those in the Cambridgeshire high-tech group. With no very large enterprises in the area, the proportion of firms of between 10 and 250 employees is significantly higher than the UK average and they provide over half of all employment.

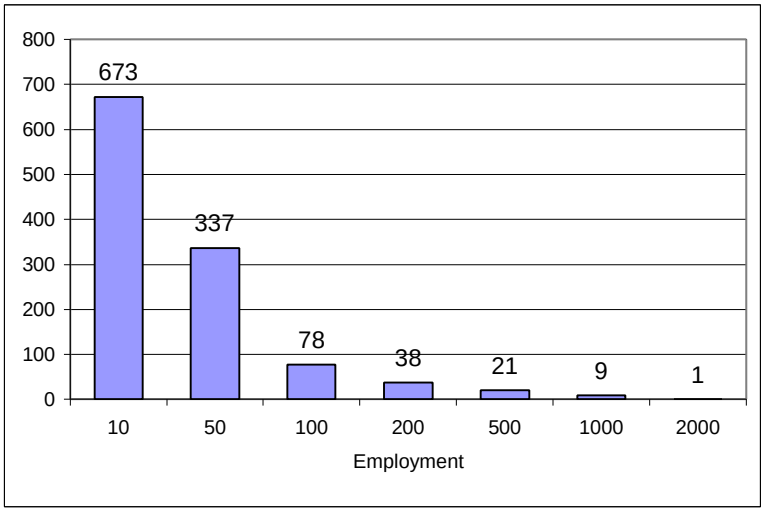
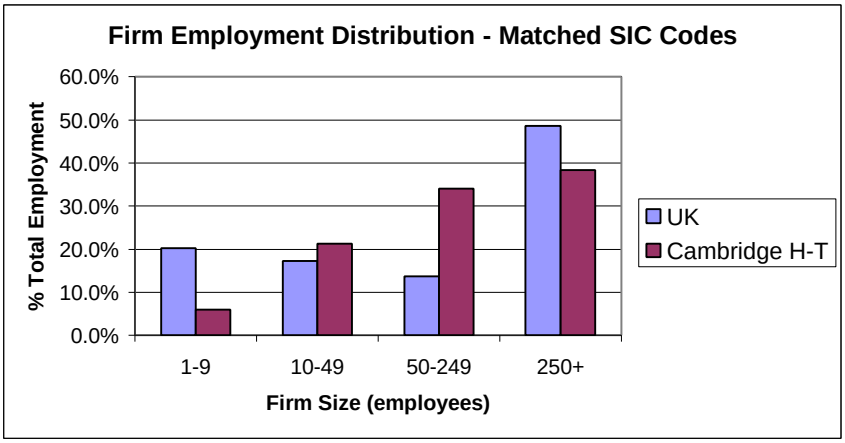


Figure 12 - Cambridge Technology-based Firm Size Distribution in 2000

The "10 or less" category includes 116 firms employing only one person and 341 firms employing between 2 and 5. Few Cambridge-based firms have achieved global scale[13] and some of these have adopted licensing strategies which result in limited local employment.

[13] Firms such as ARM, Virata, Domino and Autonomy are notable exceptions.



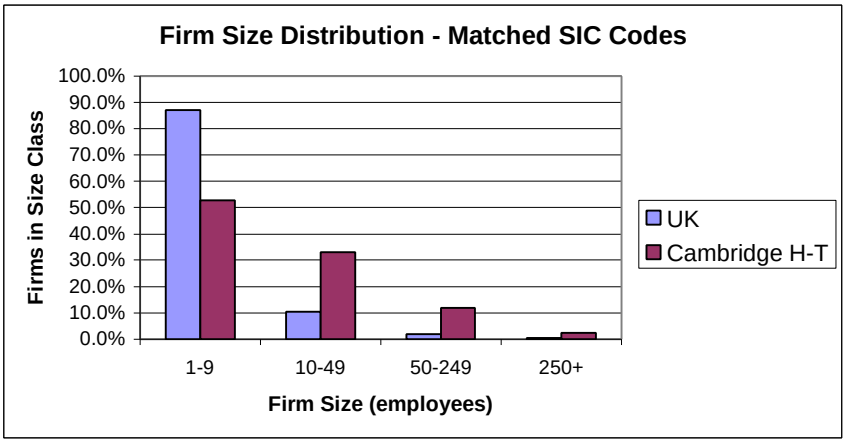


Figure 13 - Technology-based Firm Size Distribution in Cambridgeshire and in the UK as a whole 2000

Small firms dominate some sectors in particular. Firms employing 10 or less people represent 74% of the IT Services sector (20% of employment) and 70% of the IT Software sector (19% of employment). In others, a few large firms provide a very large proportion of the employment. In the Communications sector 3 firms (10% of the total) provide 75% of the employment, while in Transport 1 firm (9%), provides 92%.

Although firm survival rates for technology-based firms in Cambridge (55% over 10 years[14]) compare well with survival rates reported in other studies [cf. Kirchoff, 1994; Slatter, 1992; Storey; 1994], firms tend to remain relatively small, with 58% employing less than 10 people and less than 1% employing 1000 or more [Garnsey and Heffernan, 2001].

The problem was recognised in the UK government's Competitiveness White Paper[15]:

The UK has more people who want to start a business than many other countries. We have talented entrepreneurs who have created world-class businesses. However, compared to the US,

[14] This figure is for firms started between 1989 and 1990. Cohort analysis of firms starting in 1993/94 and 1995/96 show similar patterns, while firms starting between 1991 and 1992 show a better survival rate (analysis based on data from CCRU, 2000).

[15] Storey [1994] made a similar point: "It is the failure of UK small enterprises to grow into large enterprises that may be at the heart of the country's long-term poor economic performance"

too few of these businesses achieve high growth. They lack a competitive edge and their founders often lack the ambition or capabilities to manage growth.

[DTI, 1998, p14]

Industry Sectors

Aggregate measures mask very different patterns in particular sectors. The drop in employment evident in 91/92 mainly affected established industries such as electrical engineering, and instrumentation, though IT Services was also affected. The software sector continued to grow throughout. Mature industries would be expected to suffer in a recession, but for both instrumentation and IT services, the reduction in employment appears to be part of a long-term decline at the national level. The rise of Software is consistent with increasing activity in the industry as a whole. Nationally, the Software and Services sector grew by between 10 and 20% per annum from 1993-1998 [Holway, 1999]. The Biotech and Research and Development sectors also experienced significant growth (Figure 14).

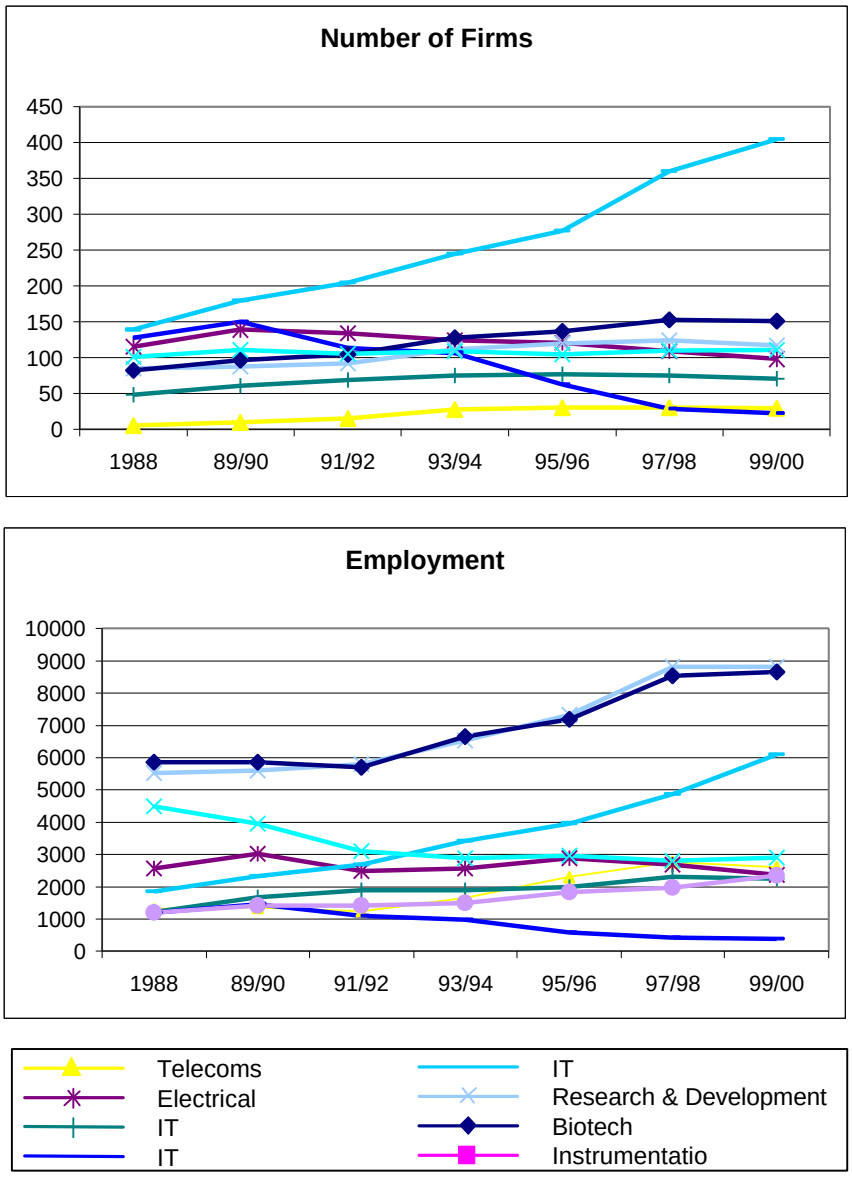


Figure 14 - Growth and Decline of Selected Technology-based Sectors 1988-2000

The diversity of high tech activity in Cambridge gives the area some protection against slow down or recession in any one sector. But critical mass within distinctive individual sectors is also beneficial in a local economy [Porter 1998]. In a number of sectors in Cambridge, clusters are in evidence. These are of two types: groups of related supplier and customer firms, and, more commonly, groups of firms that are not in a common production chain but are engaged in related activities in which there is a pool of competence in the area. The most interesting feature of the development of clusters concerns closely related firms, so the following discussion focuses on clusters of particular interest in this respect.

The original cluster of firms was in scientific instrumentation, the first to develop in the region in order to meet local needs associated with the rise of the science departments of Cambridge University in the 19th century. This cluster has been subject to considerable technological change and uncertainty, with invading products, new technologies, and improvements of existing products influencing developments [Garnsey 2000]. Response to these changes was not particularly successful; the larger firms were worse hit by the early-1990s recession than other high tech firms in the area. The industry now includes around 100 firms in the Cambridge region, with very diverse products, and has experienced a high level of spin-outs. There has been attraction of international capital and considerable acquisition activity, while interaction with the university appears to change as firms age. With maturation, research links between local instrumentation firms and Cambridge University have declined, being replaced by new relations with university departments and laboratories as customers. Training links have declined because of national institutional changes, particularly through a decline in local apprenticeships. These firms trained technicians for the whole area and their decline has created a severe shortage of skilled labour, and an urgent need to regenerate training schemes locally. The sector reveals the powerful influence of leading firms over a period as long as a century. Large numbers of managers and technicians in more recently founded firms were trained by Cambridge Instruments and UniCam (and also in the established electronics companies, Pye and Philips). The most successful instrumentation firms have addressed the new and expanding markets for automating biotechnology labs and production processes, showing the benefits of innovation. A special unit supporting the instrumentation industry has been set up in the university's engineering department (Appendix).

By the late 1980's further clusters of firms had emerged. In software, Computer Aided Design emerged early, as a result of the location of the government founded CADCentre in 1967, since privatised. Small firms specialising in geographic information systems (GIS) emerged early. Software remains an important cluster, though it is not a production network but is linked by mobile staff and ideas. Software innovation has been more widespread than use of the Internet to provide standard services in retailing etc, as occurred elsewhere. This has made the Cambridge software sector less volatile than one dominated by Internet based ventures. The impact of the US downturn is now being felt, but the software firms in the area have survived earlier recessions.

The industrial ink jet printing firms illustrate the self reinforcing impact of an emerging production network. This cluster of Cambridge firms has achieved major world market share in industrial ink jet printing. These firms have achieved external economies by helping to develop common supply networks. They employed 3000 directly and provided many more jobs in supplier firms extending into the Eastern region. They had achieved revenues of £500m by the end of the 1990s, with international offices and acquisitions.[16] The firms had common origins in the Engineering Department of the University, from which spun out Cambridge Consultants Ltd

[16] Calculations by Alan Barrell, former CEO of Domino and Willetts.

(CCL) in 1960. All the industrial ink jet printing firms originated in CCL which supported spin-out activity by its employees.

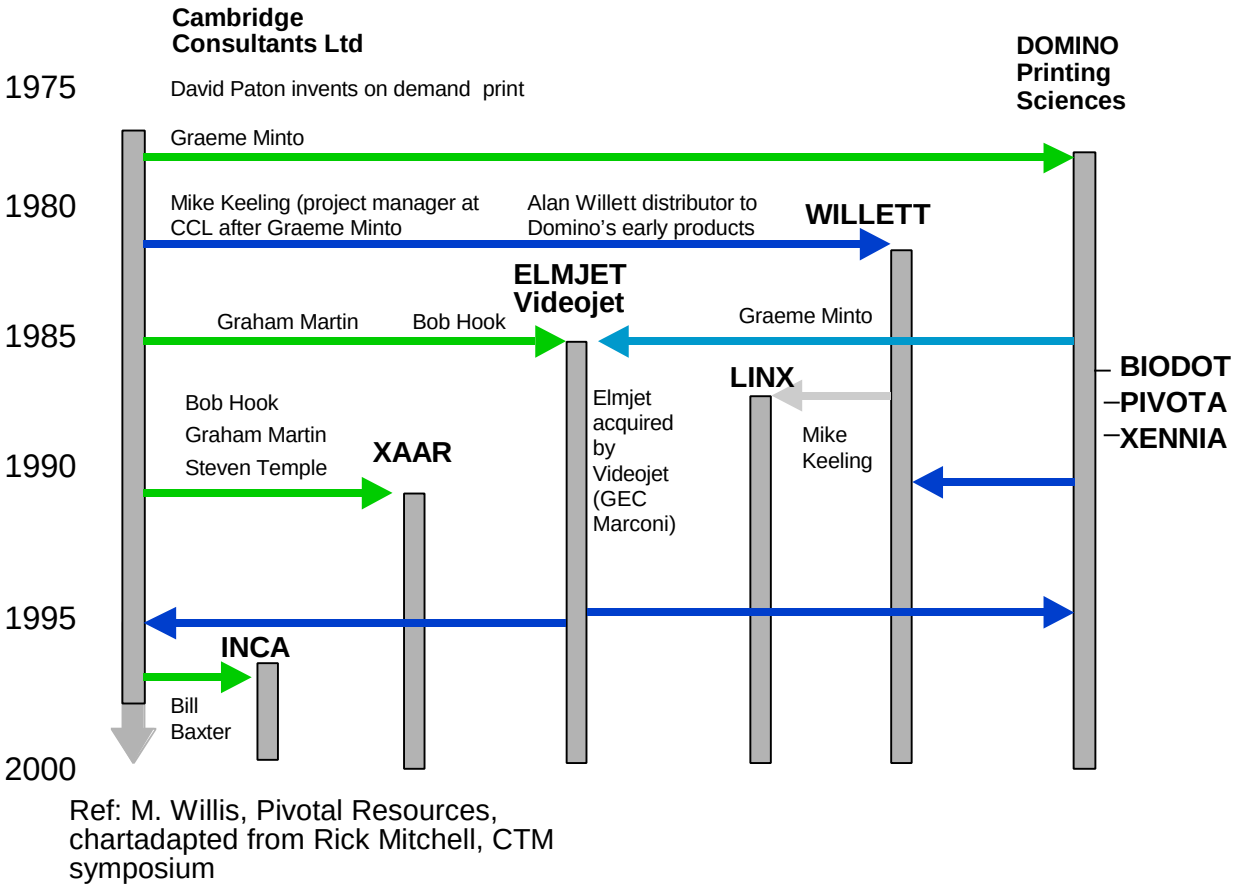
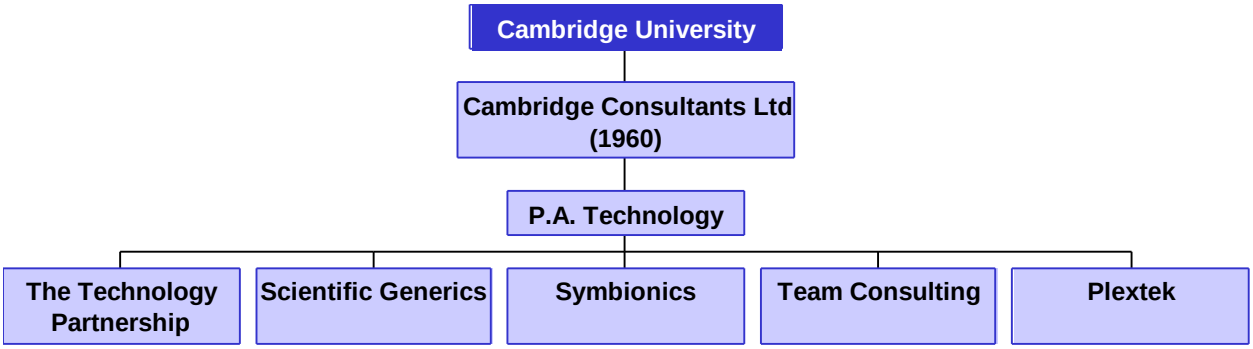


Figure 15 - The cluster of Industrial Ink-jet Printing Firms in Cambridge

Another important cluster consisted of technical design consultancies, which have been particularly active in spinning out new ventures. Some of these are illustrated in figure 16, but more such firms have sprung up recently. These technical design houses engage in prototype production as well as advisory consultancy, and diffuse technical and business expertise among local firms through open seminars. There was movement of research and technical staff between them and they actively stimulated local spin-outs.



Source: Alan Barrell, Gateway Fund

Figure 16 - The Cluster of Technical Consultancy Firms in the Cambridge Area

Spin-out provides a major source of connections between Cambridge firms in related activities. The development of inter-firm production networks was limited by the specialisation of Cambridge firms and the relatively few firms of any significant size, since leading firms play an important role in such networks. Other kinds of linkages between firms are nevertheless in evidence, for example through the mobility of employees moving from one company to another [Lawson, 1997]. The role of leading firms in production networks is confirmed by the experience of Domino Printing Sciences, whose above average growth to over 1000 employees has generated considerable ancillary activity among local suppliers. In Cambridge biotechnology and health related firms are highly specialised and case study evidence suggests that these firms had their major linkages with large pharmaceutical corporations. Nevertheless there are close connections in terms of job mobility and common origins among firms in the biotechnology cluster. Increasing numbers of new firms providing services to reduce the length of the drug discovery to production process are emerging to meet the needs of biopharmaceutical companies in the area. Developments in bioinformatics have been accelerated by the location of the Human Genome project in the Cambridge area.

Ownership

The previous section focused primarily on the growth of indigenous firms within local clusters. However, external investments have also played an important part in the development of the area's industrial and research base, whether through commercial operations or embedded labs.

A number of well-known Cambridge firms have achieved substantial success while remaining independent, but significant number have been acquired by national or international enterprises, while still others have been set up as subsidiaries of existing companies. The independence or otherwise of local industry may influence the continuing development of the local economy, not only through the inflow of capital, but through the transfer of strategic decisions from local to corporate headquarters.

Our initial study investigated the ownership of all firms in our database having 10 or more employees (600 firms). Ownership data was obtained for 79% of the firms and is summarised in Figure 17.

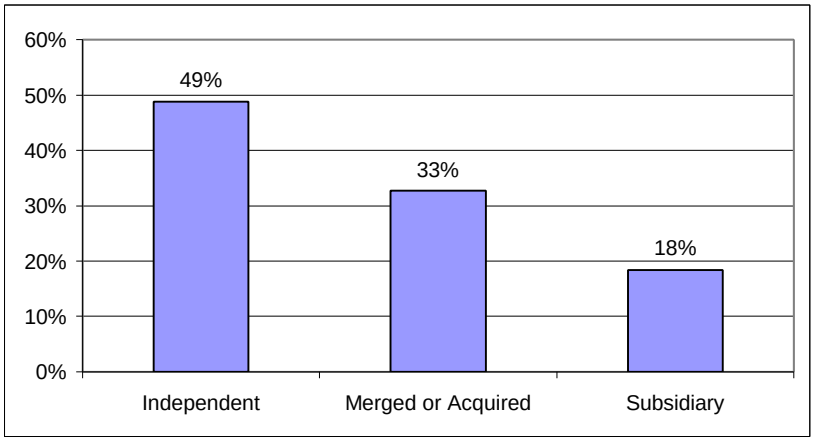


Figure 17 - Ownership of Technology-based Cambridgeshire Firms with 10 or more employees 2002

A more detailed analysis was undertaken of the cohort of firms which started operations in Cambridgeshire in 1989/1990 and remained in the county in 2000, including firms with less than 10 employees (94 firms). Information was obtained on all but 17 firms, of which 14 employed

less than 7 people and were therefore assumed to be independent. The results of the analysis are summarised in Figure 18.

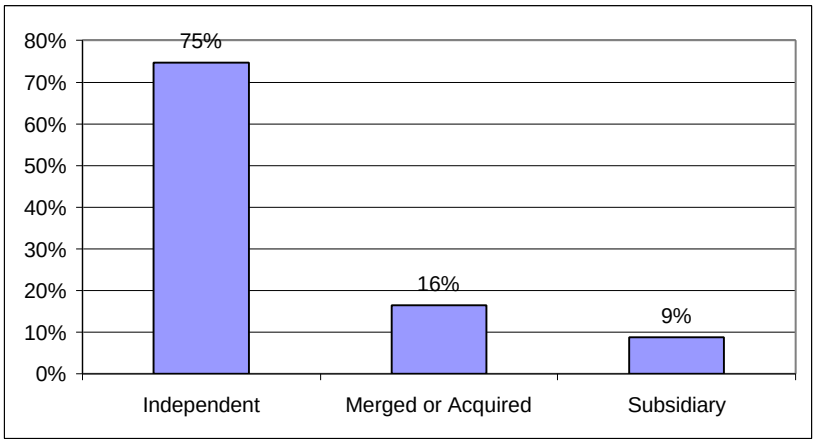


Figure 18 - Ownership of Firms in the 1989/1990 Cohort in 2002

The nationality of parent organisations was established for firms in the 1989/1990 cohort known to have been acquired or merged. The sample size is relatively small (16 firms), but it suggests that the majority of parents are foreign, and mostly from the USA (Figure 19).

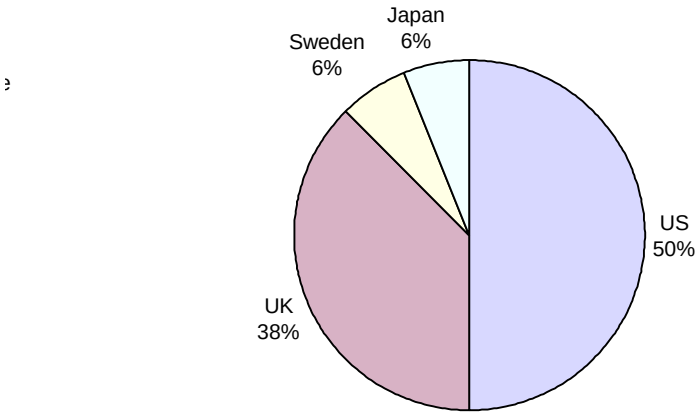


Figure 19 - Country of Origin of Acquiring Firm - 1989/1990 Cohort

Among subsidiaries established by existing organisations, the US and UK accounted for 3 each, with Austria and Germany providing another 2. Such subsidiaries made up 8.5% of the firms surviving 10 years or more.

Growth Factors

The reason why the Cambridge Phenomenon firms have "failed to grow" is often raised. In fact the size distribution of these firms reflects the national size distribution of firms in the UK. There are many causes at work, but the absence of significant growth in individual firms can be attributed to a cycle of managerial inexperience, low growth aspirations affected by funding provision, with consequences for performance which affect high-tech enterprise generally in Europe. The shortage of technical and management expertise may be the single most important obstacle facing Cambridge technology-based firms, like other such firms in the UK.

A number of new developments are now in evidence, as experienced entrepreneurs create a new generation of firms

Inter-firm linkages

The recent CBR comparative study of 100 high-tech firms showed a much higher incidence of inter-firm linkages in Cambridgeshire than in Oxfordshire [Keeble 1997]. This study found that just over three-quarters of the 50 firms in Cambridgeshire claimed to have close links with other local firms, compared with slightly less than half of the firms in Oxfordshire. The most frequent inter-firm linkages were to be found in the manufacturing sector in Cambridgeshire, where 80% (17) of surveyed firms had links with other firms, while the least frequent linkages are among firms in the service sector in Oxfordshire were 39% (9) had close inter-firm links. Research collaboration between organisations in this sample was higher among Oxfordshire firms (39%) compared with the Cambridgeshire sample (11%) [Lawson, 1997].[17]

Importance of larger enterprises for ancillary activity

Limited growth of individual firms has an impact on the rate of emergence of inter-firm production networks, since focal firms play an important role in such networks [Miles and Snow 1986]. Case study work on the Cambridgeshire inkjet printing firms confirmed that a single large firm, such as Domino Printing Sciences, can generate considerable ancillary activity around itself and spin out its own competition [Garnsey and Alford 1996]. The deficit of larger firms capable of generating local supplier activity is likely to reduce positive clustering effects. The establishment of a critical mass of firms engaged in similar activities promotes the density of interactions associated with productive linkages.

University policy

In the Cambridge case, technology transfer from the University to local firms has been encouraged by Trinity College's Cambridge Science Park (1974), St John's Innovation Centre (1987), and the University's own Wolfson Industrial Liaison and Technology Transfer Office, originally set up in 1970. This exists to help academics commercialise their research, and operates CUTS, the University's technology exploitation company. Cambridge Research and Innovation Ltd and Quantum Fund, in both of which the University is involved, are small local investment funds for university scientists seeking to commercialise their technology.

In Cambridge University the inventor has had the rights to intellectual property unless research is funded under a research council grant or an industrial contract. Cambridge University adopted a largely laissez-faire policy. A 1990 university report on relations with industry stated:

> "The university has for many years adopted a non-bureaucratic stance towards the exploitation by staff of inventions, software and other revenue-producing ideas. This policy has been considered to be the major factor in the development of the Cambridge Phenomenon [SQW 1985] and has also been of considerable advantage to the University. Encouragement to academic staff to pursue their own ideas and to develop the results of their research has been a key factor in the success of the Cambridge Science Park run by Trinity College and more recently the Innovation Centre run by St Johns College. It is not intended to change this policy in any major was, since the incentive that it

[17] However findings may be affected by the much higher response rate in the Oxford study and the unrepresentative size distribution of the samples.

> provides for members of staff has been found to produce substantial returns to the University." [*University Reporter* 11 July 1996]

This position has been criticised as based on "hearsay and assertion" and is being reconsidered in the light of the experience of successful technology transfer elsewhere. The benefits of taking out equity in spinout firms and supporting their growth are increasingly recognised and a more proactive policy is underway with the expansion of the university's industrial liaison offices.

Congestion effects

The wider implications of development are currently the focus of attention from the Greater Cambridge Partnership. Resources allocated to science at the national level have not been matched by local resources required to support new industry. Some of the limitations of the Phenomenon are emerging for public debate. So far, these industrial developments, favouring male professionals, have been highly uneven in their employment effects and have increased the polarisation of the labour market. It still remains to address problems of inequality, which, together with the ethical implications of military and biotechnical activity, have not yet been widely debated locally. Nor have agreed solutions been proposed to the environmental problems to which any high-tech boom gives rise. There are a number of university and business discussion groups in Cambridge, designed to bring together people from various parts of the community to address current issues. The Greater Cambridge Partnership represents the first focused task force set up to bring together business and local government. Consortia of this kind are needed to propose and press through solutions at the level of the region, as the experience of the *Joint Venture Silicon Valley* initiative also illustrates.

Further competition for skilled labour and for local housing from external firms may have negative consequences on indigenous activity in both centres unless countervailing measures are taken, e.g. dispersal of industry to surrounding small towns, improvements in transport and initiatives on training. There are already signs of ill effects of congestion, skill shortages, high house prices and pressure on amenities.

Individual and collective efforts

In Cambridge a variety of individuals have played a prominent part in promoting pioneering science-based industry. These came from a wide circle: entrepreneurs, scientists, former scientists, bankers and publicists. Successful entrepreneurs are now investing in other local ventures with good prospects. The Cambridge Phenomenon is often viewed as a triumph of individual enterprise, neither planned nor controlled. But high-tech development would not have occurred without extensive public investment in scientific research and teaching in Cambridge University and associated research institutes.

Conclusions

This paper has presented an overview of the scale and nature of the growth of technology-based industry during the 1990s. Growth in employment was strong throughout the decade, though growth in the number of firms was much less than that seen during the latter part of the 1980s. Beneath the aggregate figures for growth lay considerable "churn" as new firms were created and others lost, and there was some evidence of an increase in the proportion of firms moving out of the area. A few sectors predominate in terms of numbers, employment and turnover, with the research and development, biotech and software sectors experiencing particularly strong growth through the last decade. Although the geographical location of employment is not dealt with

here, it is stored in the CCRU database and has been used to great effect in their own publications[18].

Significant differences between Cambridgeshire technology-based firms and firms in the UK as a whole are evident in survival rates and size distributions. Local technology-based firms generally exhibit better survival rates, and there are fewer very small firms than reported in similar industry classes across the UK. However, the Cambridge area continues to have few large employers, despite the success of some high-profile indigenous enterprises. More than 50% of firms employ less than 10 people. Of the firms employing 10 or more, 49% remain independent, while around 18% are subsidiaries of firms based outside the area.

Employment and firm numbers provide measures of growth relevant to demands on the local infrastructure, but financial measures, hitherto neglected, must form part of a meaningful analysis. Ideally, turnover and market value would be analysed in a similar way to firm numbers and employment, but, although cross-sectional data is readily available, longitudinal analysis is difficult because of changes in ownership over time and reluctance to release sensitive data. Commercial, public domain and governmental sources have been used to estimate the combined turnover of firms active in Cambridge in 2000. The estimate could be improved through further research

A number of issues have been highlighted as threats to the continued health of technology-based firms in Cambridge. Shortages of technical and managerial skills are well recognised but the shortage of large employers to act as hubs and sources of training could exacerbate the problem. Infrastructure problems, particularly in transport and housing, also threaten to stifle further growth. The future of the "Cambridge Phenomenon" relies on co-ordinated action from business and civic leaders and the University.

Growth in new firms slowed considerably during the 1990s, though employment continued to grow. A few key sectors generate the bulk of employment and economic activity, but their continued development will rely upon a new approach to the resolution of infrastructural and human resource challenges. There is now a need for co-ordination and integration by members of the university and the civic and business communities working together if the new industrial ecology is to be sustainable[19]

[18] E.g. CCRU, 2000, "Employment in the Hi-tech 'Community' in Cambridgeshire".

[19] There are of course numerous economic and political factors at work which require study on a broader scale. Local economies are made up of a variety of systems of industrial activity, only some of which have been examined here. Collective purpose embodied in political action at various levels, together with the intended and unintended consequences of policy on the local milieu require a much more sustained analysis.

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Appendices

Notes on Data Sources

This analysis is based mainly on a dataset created by extracting and refining information from the database of high-tech firms constructed and maintained by Cambridgeshire County Research Unit (CCRU) and extending this with financial data. The CCRU undertake a survey every two years to establish the employment impact of high-tech activity in the county. The resulting dataset includes details of the number of people employed at each establishment, along with the location of the establishment, and the industry classification (using SIC 80 or SIC 92). The County Council has kindly granted our research team access to the data for the purposes of ongoing research[20].

The CCRU database has been augmented with turnover data purchased from ICC, industry data from the UK Government's "Statbase" website, and data drawn from corporate websites and Annual Reports, and other sources in the Public Domain.

The geographical area upon which this study is based is defined by county boundaries[21], but other studies employ different definitions of the "Cambridge area". Studies also vary with respect to their definitions of technology-related business[22], some including, for instance, firms which support technology-based business but are not themselves technology-based. Direct comparison of total employment, numbers of firms etc., is therefore not always possible, though overall findings are generally consistent.

[20] The dataset used in the current analysis excludes sales and distribution firms which means that totals will be lower than the equivalent measures reported in CCRU documents.
[21] In this case, Cambridgeshire includes Peterborough.
[22] This work uses a definition broadly based on Standard Industry Classification (SIC) codes, though in some classes not all firms are included.

Turnover Calculation - Methodology

Companies operating in the UK are required to report financial data to Companies House on a regular basis. However, smaller firms are not required to submit turnover and profit data, and very small firms are granted complete exemption from financial reporting. Certain types of larger firm are also exempted from financial reporting. Furthermore, many firms do not report to Companies House until some time after the period to which the data refer.

The determination of turnover figures, even for firms' entire UK operations, is therefore not at all straightforward. However, by reference to a variety of survey and individual firm reports, it has been possible to establish an estimate of the combined annual turnover of high-tech firms operating in Cambridgeshire. The methodology adopted was as follows:

All available 2000 turnover data for firms listed on the CCRU database was purchased from ICC, a commercial provider of data based on Companies House returns.

Where possible, total UK employment figures were obtained for each firm.

For these firms, the proportion of turnover for Cambridgeshire based operations was calculated on the basis of the proportion of employment based in the county.

Where ICC had not provided data for larger companies, Company Reports and websites were searched, and the relevant proportion of turnover determined as described above.

For small firms and others for which data could not be found, average turnover per head for the relevant sector and size of firm was taken from the UK Government "Statbase" and multiplied by the number of employees reported in the CCRU survey.