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Agglomeration and Growth: A Study of the Cambridge Hi-Tech Cluster

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AGGLOMERATION AND GROWTH: A STUDY OF THE CAMBRIDGE HI-TECH CLUSTER*

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ABSTRACT:

This chapter is an empirical study of the growth and change in the Cambridge high technology cluster. Cambridge shows the paradoxical co-existence of vastly smaller scale outcomes but many qualitative similarities to Silicon Valley. Our main questions from the empirical enquiry in this chapter are broad: First, how has the Cambridge hi-technology cluster changed and grown overtime? Secondly, we are interested in what sorts of microeconomic factors explain these bigger changes. With an understanding of these two questions we draw some implications of the Cambridge story for our understanding of what kinds of agglomeration economies and externalities were important to the growth of the Cambridge cluster. The failure of Cambridge to globalise to the same degree as Silicon Valley, we argue, accounts for the dissimilarities in the two experiences.

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1. The Cambridge phenomenon: Is it Silicon Fen?

The "Cambridge Phenomenon" was a term coined by Segal, Quince and Wicksteed (SQW) in 1986 to describe the mushrooming of over 300 high technology firms in the Cambridge area, after the Cambridge Science Park received its first occupant in 1976. This number has increased steadily through the decade of the nineties and had more than tripled in 1999. By the end of 1999, the number of hi-tech establishments had grown to 959 in all employing over 31,000 people. In terms of its economic impact on the region, the Cambridge area accounted for 60% of all hi-tech establishments and over 70% of all hi-tech employment in Cambridgeshire County.

Cambridge has also developed an array of institutions, university-industry links and local technology venture capital that have favoured and sought to nurture entrepreneurship in science based industries. In these institutional developments, Cambridge is unique of all the other IT clusters that followed in the wake of Silicon Valley's success. No other European region has shown the same scale of entrepreneurial activity in science-based sectors as Cambridge or can boast the emergence of similar institutions without any state intervention. Furthermore the University of Cambridge has been a key player in these institutional developments. These qualitative features of the growth of Cambridge have prompted several comparisons with Silicon Valley.

Despite these similarities, growth and change within the Cambridge cluster has not produced the same sort of economic outcomes as Silicon Valley. The differences that stand out most markedly are the smaller scale of Cambridge (whether measured by population size or regional GDP) and the absence of large firms based on product market successes. Estimates suggest that though Cambridgeshire County and Silicon Valley (Santa Clara county) encompass a similar geographical area, their economic scale is vastly different.[1] Thus Cambridgeshire County (without Peterborough) has a population of 543,000 compared with 1.6 million people in Silicon Valley.

Average earnings are £20,000 in contrast with £31,000 in Silicon Valley. Most tellingly, the regional GDP of the Silicon Valley at £42 million is 6 times that of Cambridgeshire County.

A second difference in economic outcomes is that Cambridge has not produced a large number of outstandingly successful firms that have grown to large sizes in the manner of Silicon Valley successes like Hewlett Packard or Intel. This has not changed very much in the recent past. Though there are impressive stock market successes the average rate of growth for Cambridge firms continues to be low, and the faster growing firms have not shown a great growth of employment. As we show later in the paper, the growth of employment in the area comes predominantly from the growth in the numbers of establishments.

Lastly, unlike Silicon Valley the Cambridge area is not regionally specialised in hi-technology production in the UK. Regional specialisation is inferred from the higher than average proportion of employment in any industry or group of industries, with the average being defined by the national average. Recent computations of relative specialisation indices of different UK regions in knowledge based businesses[2] by Huggins (2000) shows that Cambridge showed roughly the same proportion of knowledge-based businesses as the UK average: thus, Cambridgeshire county shows a specialisation index of 105.5 and is ranked 20th among UK regions with high values for specialisation in knowledge based services. The areas that were regionally specialised in knowledge based businesses lay around London, and included areas like Bracknell, Wokingham, Surrey, and Reading. An earlier estimate by Begg (1991) covering the 1981-89, showed that Cambridge ranked 18th among UK urban areas that were relatively specialised in hi-technology activity.[3] The regions ranked higher than Cambridge included Bracknell, Stevenage, and Welwyn – all areas that lay outside London.

Thus, while Cambridge has succeeded in getting a significant amount of science-based entrepreneurship, some local network effects among the scientists, there is not much in the way of success in a firm-growth sense or even in the number of firms to start making a big national contribution, as is confirmed by regional specialisation indices. This paradox of vastly smaller scale outcomes but qualitative similarities frames the study of growth and change in the Cambridge hi-tech cluster in this chapter.

In this chapter, we define the Cambridge area as comprising Cambridge City, South Cambridgeshire district, East Cambridgeshire and the Fenlands area.[4] Our main questions from the empirical enquiry are broad: First, how has the Cambridge hi-technology [5] cluster changed and grown overtime? This is specially interesting when we consider that compared with all the other clusters studied in this book, Cambridge has been recognised as a cluster for the longest. Secondly, we are interested in what sorts of microeconomic factors explain these bigger changes. With an understanding of these two questions we draw some implications of the Cambridge story for our understanding of agglomeration economies and externalities in the growth of clusters. The chapter is empirical and draws on two main sources of data, which are detailed in Appendix 1.

The remainder of the chapter is organized in the following way: Section 2 describes the features of change and growth of the Cambridge hi-tech cluster between 1988-2000. Section 3 highlights the main microeconomic processes that appear to lie behind these changes. Section 4 examines the some implications of these dynamics – particularly the relative unimportance of Marshallian agglomeration economies, but the importance of the mobility of personnel and small Olsonian groups that have played a crucial role in linking university and industry and in the development of institutions to nurture entrepreneurship. Section 5 concludes with some lessons that comparing Cambridge with Silicon Valley allows us to draw.

2. Growth and change in the Cambridge hi-tech cluster

2.1: Growth in the Cambridge area

Figures 1 and 2 document the growth in numbers of firms and in employment in the Cambridge area. In the absence of data on the value of sales of firms, we rely upon the growth in employment to give us a measure of growth for the region as a whole. The growth of employment and establishments shows a steady rather than explosive growth.

{Figure 1 & 2 here}

Decomposing the changes in the stock of firms over the period 1988-98 into gains and losses due to various reasons as shown in Table 1 reveals that it is the high rate of new firm formation that has sustained the gains in the stock of firms since 1988. This is not a new trend. Keeble (1988) showed that rates of new firm formation in the Cambridge area had consistently been far above national averages even in earlier periods.

(Table 1 here)

The category of new firms in Table 1 does not distinguish between indigenous new firms and firms from outside that are moving into Cambridge. Other studies however have shown that the proportion of independent firms in the region is remarkably high. Thus, SQW in 1986 estimated that 75% of firms were independent and later estimates by Garnsey put this figure at 66%. Thus, it is the independent start-ups of new firms, rather than the set-up of branch plants of national firms or subsidiaries of large international firms, which explain the high rates of new firm formation in the Cambridge area.

The proportion of firms that emerged as new start-up, or as a spin-off from other firms, in the Cambridge area has increased overtime (Table 2a). This proportion was high at 73% in SQW's 1984 study, and the later SQW (1998) puts this figure at a higher 79%, but the CBR (1996) study found the proportion of new firms and start-ups to be even higher (88%).

{Table 2a-c here}

The more interesting aspect of new firm formation revealed by the CBR survey is that more than one third of these new firms were spin-offs from other firms and the University. The SQW study had noted that about two-thirds of all hi-tech businesses (244 out of a total of 355 known firms) were interconnected. This is strikingly evident in their "family tree" of enterprises. The CBR survey does not draw a similar family tree but reveals nonetheless that linkages between firms due to common origins are very prevalent. Thus they show that an overwhelmingly large proportion of the founders of new companies (start-ups and spin offs) come from local firms, followed by University departments (Table 2b). Further, nearly half the surveyed local firms report staff leaving to set up a new firms (Table 2c) and a large majority of the "parent" firms had formal and informal links with firms so set up.

2.2 The growth of firms

The region does not boast of a large number of outstandingly successful firms that grew to large sizes. Even now, though there are firms that have a high stock market capitalisation, firms that a large sized are few. Thus, the size distribution of firms reported in Table 3 reveals very small numbers of large firms. In part this could be explained by the large presence of service firms or consultancies (where 50 employees indicate a reasonably large size) but the slow growth of firms is undoubtedly a factor.

{Table 3 here}

Gonzalez -Benito et al (1997) showed that the growth of sales varied across industrial sectors and years, but was about 5.5 % per annum for firms in the region.[6] Their figures are reported in Table 4. The trends for 1988-96 also show that the recession of 1991 hit most firms and average rates of growth fell between 1991-93.

{Table 4 here}

Despite the preponderance of small firms computations suggest that the rate of failure amongst small hi-tech firms in Cambridge was low. Table 5 suggests a ratio of firm closure to new firms close to 1 for South Cambridgeshire but about 0.5 for Cambridge city. It is a ratio that appears to increase through time, but surprisingly falls in the recession years of 1991-93 for both Cambridge city and South Cambridgeshire.

{Table 5 here}

2.3: Industrial diversity and change in the bases of growth

The region retains an industrial diversity. This in turn is probably related to the fact that its industrial production comprises intermediate rather than final goods. Table 6 shows that the two big sub-regions of Cambridge city and South Cambridgeshire show different but related specialisations. While R&D strengths are common to both regions, manufacturing and engineering are South Cambridgeshire strengths, while computer services and telecommunications seem to be strengths of the Cambridge city firms. Together South Cambridgeshire and Cambridge city show a functional specialisation of the region around generic R&D strengths in new technologies that could be spread over a large number of industrial sectors.

{Table 6 here}

The industrial composition of the cluster also changed in the late 80s, and the relative concentrations of employment in instrumentation and electrical and electronic engineering have been replaced over time by a concentration in R&D services, computer services and telecommunications. The last decade has also seen the growth in importance of biotechnology firms in numbers of establishments and in employment. It is estimated that employment in biotechnology (in the Cambridge area) grew rapidly from 4819 employees in 1990 to over 8,000 employees at the end of 1999. Biotech firms are also increasingly concentrated in the Cambridge area of Cambridgeshire county: at the end of 1999 the Cambridge area accounted for just under 90% of total biotech employment in Cambridgeshire county.[7]

A diversified industrial base has also contributed to maintaining a steady growth of employment in hi-tech industry in the Cambridge region. As noted earlier the gains in employment between 1988-97 were largely due the setting up of new establishments. These gains are concentrated in computer services, telecommunications and R&D services and have more than offset the losses in employment, which have been concentrated Instrument and Electronic and electrical engineering.[8] The R&D sector has continued to be a major source of employment gains amidst the shifting specialisation from related manufacturing sectors to the service-intensive sectors of telecommunications and software.

These changes in the industrial bases of growth mask an underlying continuity in functional specialisation. Cambridge has always had strong R&D strengths that earlier drove the scientific instrumentation and a less successful electronics industry in the region in the late 70s and early 80s. These strengths have in recent years been leveraged in R&D services and consultancy services.

2.4 Institutional developments

The period since the late 80s has been marked by a growing thickness of institutions in the Cambridge area. Activities like corporate venturing which were earlier carried out within particular firms now spawn a separate and specialised economic activity, viz. local technology venture capital firms. Another development has been the more institutionalised relationships between the University research and industry on one hand, and the involvement of the university and local administration in providing a congenial environment for the growth of hi-technology firms, on the other.

These developments have also imparted the Cambridge region with an image of a place that is outward looking and ready for change - thus adding to its reputation and credibility as a hi-technology centre - an image that in turn, has some force in attracting new hi-technology businesses to locate in the Cambridge region.

2.4.1 Corporate venturing and technology venture capital

Cambridge firms like Cambridge Consultants Ltd. had started corporate venturing activities as early as 1984, though in those days its activities were not termed as corporate venturing. In their report, SQW (1986: 18) note that CCL had always encouraged their employees to do their own thing making it a prolific source of spinout companies. These companies were assisted in a variety of ways including commercialisation of technological ideas and finance being provided in return for license fees, royalties or equity participation. A notable feature of the late 80s has been the involvement of employees from Cambridge firms, and sometimes entrepreneurs from the earlier generation in managing venture capital funds that have flowed into Cambridge.

There are several prominent examples of this. The directors involved with Cambridge Consultants have set up other successful venture capital firms: Robert Hook went on to set up Prelude Technology Investments in 1984 and Gordon Edge (also from CCL) went on to set up Generics Asset Management Ltd. in 1987. Sinclair Research, another entrepreneurial start-up of the 1980s, which also had strong business links with Cambridge Consultants, brought John Lee to Cambridge. John Lee stayed on as a business angel and was involved in several prominent start-ups such as Xaar, Cantab Pharma, and Ionica. He became Chariman of the Cambridge Quantum Fund, established in 1990 with investment from the University of Cambridge and 3i Plc. In Jan 2000 he set up Odessey- a new venture capital fund. Similarly, one of the founders of Acorn, Hermann Hauser has been involved in the set-up of Amadeus, a venture capital fund with has capital from Microsoft. Another successful entrepreneur managing venture capital funds is Chris Evans, founder of Chiroscience, who has been a key person in the setting up of the new Gateway venture capital fund in 1999 and plans to bring his own biotechnology venture capital firm, Merlin Ventures from London to Cambridge.

It is estimated that the known venture capital funding in Cambridge exceeds £300 million.[9] The proportion of applications funded by venture capital firms is however small (~4%) in comparison to the applications made to them. Still there are signs that a virtuous circle is emerging. Not only have local venture capital firms emerged and benefited from the management expertise of some of the prominent entrepreneurs from the region, the presence of local venture capital firms also help the emergence of new technology based enterprises in the region. Thus, Lumme et al (1994) estimated that a larger proportion of Cambridge technology-based firms (19-21% of all firms) drew their initial capital from venture capital when compared to their Finnish counterparts, where only 3% of all firms resorted to venture capital as a source of start-up capital. Similarly, Keeble et al (1999: 329) based upon the CBR survey reported that 20% of the surveyed firms had used local venture capital and two-thirds of those had used local venture capital for more than 50% of their capital needs.

2.4.2 University-industry links

The period since 1986 has also seen the prominent growth of industry-university linkages through a variety of means. Both the involvement of Cambridge alumni, and the beneficial effect of the setting up of some important public sector research centres have been crucial to the development of these linkages. New research labs have been funded in collaboration with some large national and international firms. These have often been inter-disciplinary in nature- itself a recognition of the University's uniformly good strengths in several of its departments.

The first such collaboration was the setting up of the Olivetti and Oracle research laboratory by Dr. Andy Hopper, who had completed his Ph.D with Profs. Wilkes and Wheeler at the Computer laboratory in Cambridge. This research lab has spun out companies like Virata, Telemedia, and Adaptive Broadband. The lab has in 1999 been taken over by AT&T. The success of the CAD centre, set up as a public sector research lab in 1964, but privatised in 1983, no doubt inspired this venture. The University has also benefited from public sector research laboratories such as the medical research centre (MRC), and more recently the establishment of the Sanger Research Centre and the Human Genome project just outside of Cambridge in 1996.

The spring and summer of 1998 saw a spate of research collaborations. Unilever gave £13 million to the department of Chemistry for the setting up of a new Centre for Molecular Science Informatics; British Petroleum gave the University £21 million to set up an interdisciplinary centre to create a focus for research on multiphase fluid flow; Bill Gates donated £12 million to set up a computer laboratory; Hutchinson Whompoa gave £5 million to fund a research centre which would comprise a unit for cancer research and another in molecular and cellular biology. In March 2000 this year Marconi donated £40 million towards a the setting up of the a telecom research centre to develop new technology for internet and data transmission.[10] Leading firms in all three of the major industries of the region have now invested in research in the University.

There have also been other institutional developments to strengthen university-industry links in 1997-98. Hermann Hauser and David Cleevely have been instrumental in setting up the Cambridge Network to raise global profile and increase local networking by Cambridge IT firms. The Network has set up a website Cambridge Connect (modelled along the lines of San Diego connect) which aims to publicise the business support facilities available for the Cambridge region. St. John's Innovation Centre on the science park has been set up to provide incubation and support facilities for technology hi-technology firms. There are also plans to add a bioscience park to the St. John's Science Park, and to set up another new Science park for biotechnology at Hinxton Hall near the Sanger Centre/Wellcome Trust.

Cambridge Futures, an academic and business alliance has been set up with private sector funding to explore different scenarios for accommodating anticipated growth in the region. The Greater Cambridge Partnership was established in 1998 to develop a consensus between local business, government (county and districts) and the university on the future of economic strategy for the Cambridge region. Firms in the region wishing to expand face numerous difficulties due to traffic congestion and the non-availability of land for industrial expansion. As the major landlord in the region, the cooperation of the University and its Colleges are key to the region's development.

3 Explaining changes in the region: some microeconomic forces

In this section we try to assess what lies behind some of the main changes outlined in Section 2: why has there been so much start-up activity, why the shift in the industrial base towards high technology services, and why the slower growth of firms in Cambridge? We also argue that some of these changes are linked.

3.1 The emergence and location of new firms in the Cambridge area

The strongly local character of new firm formation revealed earlier in Table 2b begs the question of motives. What sorts of factors favour entrepreneurial activity in the Cambridge area? A number of factors may lie behind new firm formation. Founders may face actual or threatened unemployment. Entrepreneurship may also be preferred for quality of life reasons. Many employees may achieve job satisfaction only when they have the independence to try out different ideas and ways of working. These may not be possible in another person's firm. Desire for independence is an important motive for many founders that want to set up a new business. Founders or employees of the university may sight an important technological and market opportunity. In Cambridge, which has long had a liberal tradition in the usage of the results of science, this motivation might especially be important.

Table 7a reports the importance of the motives that influenced the founders of new firms. The motives scored very important by firms in the sample were: the desire to be independent, to make money and to exploit research possibilities. Technological motives are important but not overwhelmingly so. Table 7b shows that 58% of the firms (29 of 50 firms) were established primarily to exploit a technological idea or innovation. In the majority of the cases this idea originated with the founder. The university was not an important source of hi-tech firms based on technological innovations alone.

{Table 7a & 7b here}

The motivations of the founders does not inform us about the particular regional advantages that Cambridge possesses that makes firms want to locate there. Firms in the CBR survey were asked an open question about why they located in Cambridge and their responses coded. An overwhelming 86% of the new start-ups (i.e. 38 out of 44 firms) answered that they located in Cambridge because they were already living there. In their study, SQW (1986) report a similarly high percentage of firms (73%), which located in the Cambridge area because the founder was already living there. Even more compelling is the observation in SQW (2000) that 20% of start-up firms in Cambridge that had relocated from elsewhere had Cambridge founders.

Keeble et al (1999) also report on the importance of various regional factors in the decision of new start-up firms to locate in Cambridge. Table 8 below reproduces their findings; the seven most important factors from a list of 19 are reported. The attractiveness of the local living environment for staff and directors and the credibility, reputation and prestige of a Cambridge address for hi-tech firms were the factors most frequently cited as important for locating in Cambridge. Local availability of research staff, their quality and also the possibility of *informal* access to innovative people ideas and technologies follow these two main pull factors (emphasis mine).

{Table 8 here}

Precisely what lies behind this inertia and pull of Cambridge is difficult to pin down. Entrepreneurs may want the familiarity of known surroundings and environments in the initial risky stages of a business. This geographical inertia is reportedly an important characteristic of new firm formation in other regions of the world. [11] In a situation where new firm formation is frequently due to spin-off activity, this is more likely to be the case, as the newly set-up firm will have several formal and informal links with their parent firm that proximity can help to retain. Cambridge alumni might value their links with their old university much more than in other universities - a factor possibly facilitated by the college structure of Cambridge. The existence of an University and the proximity of London may present spouses with more varied job options and this may prompt several young couples to want to stay in Cambridge. Whatever the reason, the inertia that kept several dynamic entrepreneurs in Cambridge has also probably contributed to the institutional developments in the area, a subject we discuss in more detail in Section4.

3.2 Changes in the growth strategies pursued by leading firms: the Acorn-ARM story

A different business model has become common among Cambridge firms in the late 80s and 90s. Vertically integrated hi-technology manufacturing has been eschewed in favour of revenues from the direct licensing of R&D services and products, often with an investment in overseas subsidiaries to promote overseas markets. The demise of Acorn and the rise of ARM epitomises this trend and this section describes this in some detail. Acorn is an interesting firm to consider here for another reason. It has often been compared to Silicon Valley's Fairchild.[12] Though Acorn itself failed it has given rise directly or indirectly to more than thirty start-ups including ARM, just as Fairchild gave rise to Intel and other start-ups in Silicon Valley. The business strategies of ARM were different from those of Acorn, and had in fact learnt from the failures of Acorn.

Acorn Computers was started in 1978 by Hermann Hauser and Chris Curry, and supported on a part-time basis by Andy Hopper.[13] Its business objectives were broad rather than narrow. The company wanted to conceptualise and design microcomputers for home, educational and business purposes, local area networks, and the associated hardware and software. There was an early decision to concentrate on developing an in-house excellence in computing research, development and design, with the company undertaking no large-scale manufacture and assembly. These activities were contracted out to other companies elsewhere in the UK. However, the company sold a product (the micro-computer) that embodied its research expertise rather than its research development and design services.

After an initial period when the company produced and sold (by mail order) home computer kits, the company enjoyed a period of rapid growth because it won an exclusive contract from the BBC for supplying microcomputers, which was renewed and followed by a contract with the Government of India to introduce computers in schools. The company entered the business computing market by its acquisition and development of IBM compatible products. It invested in complementary hardware and software companies and entered into joint ventures with companies like ICL and Racal.

This strategy of broad diversification into all related areas had advantages and disadvantages. On one hand the company built up an enviable research competence in several frontier areas, and created a pool of labour that was able to recognise and encourage the use of such research strengths. On the other hand, Acorn itself became an unwieldy organisation, and we can do no better than quote Stan Boland who presided over the ultimate break-up of Acorn into ARM and Element 14 in 1999:[14]

"Acorn had unreal ideas of how business was done. It had no real model of how it was going to earn money. It had a larder full of amazing technologies that were not being sold. It was engaged in 'Martini' marketing. It would do anything, anytime, any place for anyone. It had no focus. The breakthrough for any company is when you achieve leadership in your particular space".

In a recent interview, Herman Hauser reflected on the several factors that contributed to Acorn's demise.[15] He believed that though the BBC Micro had a real lead over its nearest rivals, Apple II and Sinclair Spectrum both in terms of speed, price and expansion slots, Acorn did not go around the world persuading people to adopt its products as the industry standard. Instead when it received offers to license its technology (as from Commodore to use its Econet networking system) it refused. At the same time the company had wanted to sell in the US and spent roughly $20 million in getting regulatory approval for the BBC Micro's several devices. This large cost associated with the company's US operations eventually contributed to its cash-flow problems of 1983-85 causing Olivetti to bail it out and take the majority stake. Though the company had subcontracted most of its manufacture of its machines the contracts were not flexible enough causing delays in the launch of new products like Acorn Electron. Research and development spending were too high and often the company appointed senior managers that were more interested in technology than in the day-to-day mechanics of running a business.

Acorn's demise was probably not all a question of its poor management strategy. Similar stories may be told of other promising firms of the 1980s: Sinclair Research, Amstrad, and Apricot all of whom were unable to beat off the competition from the US giants, Apple and IBM. Saxenian (1988) pointed out that Cambridge firms in the mid 80s suffered from deficiencies that were common to all new enterprises in Britain, viz. a dearth of markets, managers and manufacturing experience. British manufacturing had shown signs of decline for a long time. The industrial base of the economy had atrophied, with poor standards of living and successive governments tried to cash in on the low wages of British labour. The home market for intermediate high technology products was small making the new firms dependent upon exports and marketing strengths in new markets. Saxenian(1988) also points out that in several cases UK firms were bought out by their overseas distributors. Lastly, despite a world-class science a poor manufacturing ability that required the coupling of science with the technology of production hampered the ability of firms to undertake manufacture of science-based products.

A promising area, which Acorn invested in, was the design and manufacture of RISC (reduced instruction set chips), which could be embedded in various products. Acorn pioneered the use of these chips in its Archimedes range of microcomputers, partly because Intel would not allow Acorn to license its 286 core chip. Acorn RISC Manufactures was set up in 1983 as a subsidiary of Acorn computers. Apple wanted to use the ARM in its Newton handheld so ARM was spun off as an independent subsidiary (Advanced RISC Manufactures) with Acorn holding a stake in the company and Apple as the other major shareholder. By 1999, Acorn's 25% stake in ARM was worth more in the stock market than Acorn itself. Acorn was formally dissolved in 1999, and Element 14, the non-ARM part of Acorn has recently been bought by Broadcom, an US chip design company.

ARM worked to a business model that showed that it had learnt from several of Acorn's failures. ARM was specialised in the design of chips. The company eschewed manufacturing altogether. Instead of subcontracting the manufacturing of chips they chose the licensing route to selling their technology. RISC could be embedded in any technology product, for which the US had by far the largest markets. They tapped external markets by setting up a subsidiary firm in the US. The ARM chip was quickly established as the industry standard. Over its lifetime the company has made and shipped 175 million units. Its size however is modest and it employs about 250 employees.

The important features of the ARM business model were its decision to sell technology rather than products and its use of subsidiary operations to gain credibility with foreign customers. High technology manufacturing relationships are based on trust in quality and often success in the US market and listing on the NASDAQ/EASDAQ stock exchanges has been the way that Cambridge firms have chosen to signal this the world. Listing on the second tier stock exchanges also paved the way for the exit of the original founders by the divesting of their equity or through acquisition by a bigger company (as happened to Element 14 the other part of Acorn).

Interestingly the one hi-technology firm that tried to go into providing a service product in this period (1997) - Ionica, with its wireless telephone technology - failed spectacularly. Even with a product that did not require manufacturing, the lack of a sound marketing strategy caused the collapse of what was most analysts agreed a good idea. Possibly this failure has added further credibility to the ARM business model based on licensing.

Growth via the licensing route creates several problems for the growth of the licensor. If the company grows by developing its own market then R&D costs can become very high, especially if it does not find a product that it can embed the technology in. Often the market for the technology may be thin and firms may find it difficult to develop their own independent markets. In this case, a technology based firm's marketing strategy can be entirely determined, or confounded from its initial objectives, by the preferences of the big licensors. [16] The long-term growth and viability of licensing firms is difficult when markets for the technologies are not well developed and they are also vulnerable to takeovers. Original entrepreneurs may have little choice but to exit the founding firm.

The ARM model was followed by other hi-technology successes in the 90s, notably Autonomy, Zeus, Vocalis, and Virata. In 2001, two of these firms, Autonomy and Vocalis are reported to be facing problems. Autonomy was one of the more successful firms, which enjoyed considerable stock market success in the mid nineties, and managed to grow into a globalised technology company employing about 160 people.[17] Autonomy's software can search, retrieve and index data from a host of sources including unstructured data such as e-mails. Its software can be embedded in any information search retrieval products of large companies. Two-thirds of Autonomy's sales come from the US, and recently it has signed over 40 OEM contracts, which will allow other firms to embed Autonomy software in their products. Competition for Autonomy's main product from US companies, Vignette, Inktomi and Broadband is intense. More damaging is the threat that rivals like Microsoft are moving into the company's main markets. A product from Microsoft's Cambridge based research centre's Tahoe project is now out and is reported to look a lot like Autonomy but is targeted to small and medium businesses. Following a poor performance at the stock market the board of directors is reported to be in favour of inducting fresh management to be an independent Chairman of the company and pave way for its faster growth. Currently Autonomy's founder Mike Lynch holds both the positions of Chief executive and Chairman of the company.

Vocalis, a speech recognition company, has posted profit warnings after undertaking a heavy second round of R&D spending, which have contributed to losses though their sales have been stable. The sorts of applications that the company expected with its speech recognition software have not really taken off. The judgement of financial analysts on this company is that it is still a product waiting for a market.

3.3 Explaining the slow growth of Cambridge firms

The shift of the dominant business model away from products to licensing implied a slower associated growth of employment. While this model avoided some of the pitfalls that Acorn faced in its growth, it didn't actually help to overcome the obstacles to that had prevented that growth in the first place. The obstacles to Acorn's growth came principally from being unable to meet the competitive challenge of IBM and Apple and in carving out a large, possibly global market for its product. Licensing as a strategy avoided the problem of having to define markets and aggressively compete in them. To the extent that most new technologies when developed are unique, licensing avoids competition. Firm growth depends upon growing the market for the licensor and avoiding imitative competition. ARM was fortunate that its chip became the industry standard. But the technologies of Autonomy and Vocalis have not had the same scope and so the old problems (growing markets, and facing competition) have returned to haunt the stock market successes of the 90s.

Few studies have systematically investigated the causes of the slow growth of firms in the Cambridge area. However the recently concluded SQW (2000) provides some clues. Based on a statistical analysis of the determinants of sales and employment growth across 137 academic and industry start-ups, they find that while age and membership of the chemicals and pharmaceuticals sectors, always exercised a positive influence upon growth, somewhat different influences govern the growth of sales and employment among start-up firms.[18] In addition they found that a greater share of R&D expenditures exercised a significant negative effect on growth measured in terms of employment, while owner managers negatively influenced sales growth. The academic or industry origin of the start-ups did not however explain their subsequent growth, when factors such as industrial sector, age and dominant activity were controlled for.

These factors are in line with what we have argued so far. The shift to a business model based on technology licensing should imply a slower growth of employment but a proportionately larger growth of R&D expenditures. Of the important start-up sectors, only chemicals and pharmaceuticals has an explicitly "product focus" that makes for rapid market growth. The other important start-up sectors such as consultancy, software, telecom are essentially service sectors, where market growth is slower and more dependent on a few customers.

More evidence of this is provided by the CBR survey, where Cambridge firms rated their main competitive strengths, reported in Table 9. Relatively few firms felt competitive advantages like price, marketing and R&D – crucial to the success of hi-technology products in mass markets - were their important competitive advantages. Instead the majority of firms scored factors such as attention and responsiveness to client needs, technological innovation, specialised expertise, established reputation and quality aspects of their product or service as their most important competitive strengths. These are likely to be the important competitive strengths in markets with a few prominent customers, which is often the case of niche technology (service) markets.

{Table 9 here}

Thus, in Cambridge, there is an incredibly high rate of technology transfer in the form of entrepreneurial high technology start-ups but this has been accompanied by somewhat muted growth because of a singular absence of large-scale product markets that would go with that technology transfer. Indeed it may even be a Cambridge spin to an old cliché about Britain: it is good at invention but not innovation.

4. *What sorts of externalities?*

The story we have told about growth in the Cambridge area is one of slow but steady growth based on increased levels of entrepreneurship. Slow growth and low failure rates of firms have also meant the absence of any big firms in the economy, whether indigenously grown or pulled into the regional economy from outside. Public policy has been absent. What has emerged instead is a slow self-organisation based on the development of institutions that have sought to foster and maintain what the region is perceived to be good at, viz. generating new ideas and commercialising them. This self organising process has in fact encompassed all the main actors in the region - the local firms, the local administration, finance and the university. It has also been the consequence of the activities of a small group of academics and entrepreneurs that have stayed in Cambridge for a long time. Not surprisingly then it is also a story that reveals the unimportance of traditional agglomeration economies and the importance of other socio-economic mechanisms that share information and create opportunities for other firms.

4.1 The relative unimportance of Marhsallian agglomeration economies

Traditionally, agglomeration economies promoting growth in clusters are thought to centre around the three sources of collective efficiency described by Marshall, viz. backward and forward linkages associated with a large local market, advantages derived from a “thick” labour market with specialised labour skills and knowledge spillovers. Firms may specialise more finely in intermediate stages of production, because agglomeration can result in a sizeable demand from local firms. The existence of a large number of similar firms may encourage the concentration of supplies of skilled labour. Information on new technologies and methods may be shared in informal meetings between employees of different firms. Firms may observe the better business practices of other firms and learn from this.

Local regional markets have always been relatively unimportant for Cambridge firms. The CBR survey estimated that on an average a Cambridge hi-tech firm exported 36% of their output in 1995, and that just under half the sample (46% of firms) exported more than 40% of their output. The CBR survey asked firms what proportion of their outputs were sold locally and what percentage of their purchases of intermediate goods and services were made locally. Table 10a & 10b summarise the results.

{Tables 10a and 10b here}

Local markets absorb less than 10% of sales for most of the sample of firms. Only about 6% of all firms surveyed sell more than half of their output locally. The table also indicates that sales to local markets have become marginally more important in 1995 than they were in 1990. Local markets seem more important for purchases of intermediate products and services than they are for final goods. In 1990, 48% of all firms purchased up to half of their materials components and services requirements locally. This proportion rose to 70% in 1995. Nevertheless all these firms still bought an equal amount of their requirements from outside the local economy. These figures suggest that though local markets in sales are not important to most firms, local purchases are becoming more important.

Labour market advantages did not constitute the most important factor attracting firms to locate in the Cambridge area, as we noted in Section 3. Direct recruitment by firms also suggests the low importance of local labour markets. Less than half the surveyed firms in Cambridge (24 of 50) reported a conscious policy to recruit locally. Firms were also asked to report where at least one of their last three research or management staff came from. The firm could tick different boxes, local university, local firms, other UK universities and UK firms, or overseas universities and firms. Table 12 summarises the results obtained. The responses reveal that Cambridge firms mostly recruit from other UK universities and firms, for managerial and research staff.

{Table 12 here}

These results on the relatively modest importance of local labour markets should not be surprising. Despite the presence of a large university, the size of the local labour market is small. Furthermore, a large proportion of the Cambridge population is migrant. Overseas students return home or move to other locations. Students from other universities come to Cambridge. It is also relatively easy for Cambridge firms to dip into the neighbouring Greater London labour market, which is larger and almost as diversified.

The evidence on inter-firm links echoes the conclusions about local market linkages. Table 11 reports the importance of local and non-local inter-firm links, from the CBR survey. The types of inter-firm links in the local area that were rated as important by most firms were those with suppliers/subcontractors and with firms providing services. The types of inter-firm links outside the local economy that were rated as important by Cambridge firms were links with customers, followed by suppliers and subcontractors. It is also worth noting that a larger proportion of firms reported non-local than local inter-firm linkages. Further firms felt that geographical proximity was not an important factor for many of the links.

Notably inter-firm links did not benefit firms in access to new research findings. Few firms thought that proximity would benefit the firm by more effective or innovative R&D. Instead the main benefits for the Cambridge firms of the links lay in improving the amount and quality of information about new products, assuring timely and satisfactory delivery of supplies and the greater responsiveness it gave the firm to changing market requirements. Not surprisingly all of these were categories where firms felt the links would be improved if they were within the region, suggesting that some of these benefits presently came from outside the region.[19]

4.2 Other mechanisms creating externalities

In the remainder of this section, we draw upon the available information on other socio-economic mechanisms that underlie information sharing and spillovers in the Cambridge area. For convenience we discuss these under the following three headings:

1. The university as a source of knowledge transfer
2. Information sharing due to the movement of personnel and spin-offs
3. Self organising institutions and information sharing generated by a small group

4.2.1 The university as a source of knowledge transfer

The University was clearly an important source of knowledge transfer in the early years of the Cambridge cluster as SQW showed. The CBR survey measures several directly observable ways in which the University could influence knowledge transfer to hi-tech firms. One kind of direct impact could be that academics could set up hi-technology establishments to commercialise technological inventions. Table 2b tells us one in five spin-offs is still attributable to academics previously employed by the university, though only 4% of firms set up to exploit technological innovations attributed the source of the innovation to the University. SQW (2000) estimate the proportion of university spin offs to be somewhat higher at 31%.

The University may also offer other kinds of free technological advice through various formal and informal links that could be important to firms. 42 of the 50 firms surveyed reported these links though only 14 of the 42 firms thought that such links were crucial to the success of the firm. Table 13 reports the incidence of different types of interaction between Cambridge firms, Cambridge University and other Universities. It is noteworthy that the links with external universities are more important in the aggregate than interactions with Cambridge University for seven out of the eight categories considered. The most frequent forms of interaction with Cambridge University were in the form of collaborative projects and University staff acting as consultants to the firm.

{Table 13 here}

This evidence that points to a low direct impact of the University on businesses in the area. However, academic spin-offs tend to be concentrated in science based sectors like software, instrumentation engineering, chemicals and pharmaceuticals, and biotechnology, while industry spin-offs are concentrated in the engineering based sectors of electronics and audio and R&D consultancy.[20] Secondly, even though the direct impact of the university is not large, the firms that spinout from the University and the researchers that do get employed in local firms, may have a disproportionate impact on the cluster as it developed. Certainly the most important firms in the Cambridge area, like Acorn, Sinclair Research and Cambridge Consultants have had university roots.

Focussing on the University alone obscures the role of the powerful and wealthy Cambridge colleges that have long seen themselves as producing a fellowship of academics. Students who knew each other as graduates or post-graduates have got together to set up new firms. The interdisciplinary nature of college interaction and the lifelong membership it gives to its graduates has been an important factor in keeping the University linked to industry. As we earlier, former alumni have played an important part in many of the visible industry-university links of recent times.

The independent resources and the relative autonomy of the colleges also mean that they have the ability to initiate and support schemes that may not emerge due to consensus. Thus, the early experiment of the Science parks were initiated by Trinity College and St. John's- two of the wealthiest colleges in Cambridge, on land that belonged to them. Though the science park is often seen as an indication of the vision of Cambridge University, the university's role in it was minimal. Indeed it could be argued that all the risks were borne by Trinity College and its fellowship.[21]

4.2.2: Information sharing due to movement of personnel and spin-offs

Knowledge spillovers and information sharing also take place because of the movement of people between firms. Each person carries information about a firm's production and technology and could potentially utilise it in whichever way she likes. Firms may also have links with each of these former employees, which might facilitate problem solving in an environment within a collective of firms. The CBR survey estimated that 46% of Cambridge firms reported links with other firms because of personnel that had moved between firms. Further, 77% of these firms said that these links were important or crucial to the firm's development. Table 2c showed that a large proportion of firms spun out by former employees continued to retain formal and informal links with the parent firm. Both of these types of links make use of previously existing personal relationships that are in turn an important source of information transfer and information sharing.

4.2.3 Self organising institutions and information sharing generated by a small group

A striking feature of the catalogue of changes in Section 3 is how often a few names crop up in the catalogue of institutional developments in the Cambridge area. Other scholars have noted that a small set of key individuals has been important in the many transformations that have made for the continuing success of Cambridge. Thus, Garnsey (1998) draws attention to the role of key individuals in the context of defining the main concepts needed for an understanding innovative milieu, Lawson (1998) ascribes such structured interactions to be a feature of "regional competence", and Keeble et al suggest that such key persons and their associated networks of relationships are a unique feature of a historical process of regional development. Less admiringly, Saxenian (1988) has also remarked on the old boys' club that dominates in the explanation of the Cambridge successes.

There appear to be two or three nodes in a network of relationships that spawn both the IT and biotechnology sectors. Chief among the IT node are the names of Maurice Wilkes, and Charles Sinclair. Prof. Maurice Wilkes had been involved with the ENVIAC project and was something of a visionary in being able to recognise very early on the potential for software. He was involved in the race to find a solution to the network problem, which Ethernet finally won. Nevertheless the "Cambridge ring" solution on which he worked with Andy Hopper for the latter's Ph.D was a close second and the computer laboratory had an outstanding competence in that area. Andy Hopper teamed up with Hermann Hauser to found Orbis and Acorn, with the latter being a prolific source of other spin-off firms. Both Hermann Hauser and later John Lee worked for Sinclair, and as they set up their own companies with various other people. Of these Hermann Hauser and Andy Hopper had already studied in Cambridge, but Charles Sinclair came to Cambridge because Sinclair Research started in partnership with Cambridge Consultants. A similar but smaller network of individuals dominates the biotechnology sector and centres on Chris Evans, the founder of Chiroscience.

This small group has played an important role in information transfers and in the development of the self organising institutions in the Cambridge area.[22] Understanding their role in information transfers is straightforward. As we have seen, the same people are entrepreneurs, have links with colleges and the university labs and later also advised financial venture capitalists. The role of this group in information transfer from one institution to another is effective in the same way as the movement of personnel from one company to another results in a transfer of information. The downsides of this arrangement are two-fold: they could become too closed and not let in any outsiders and secondly, the informational transfers between institutions may not survive beyond the lifetime of the existing (common) members.

In a seminal work, Olson (1965) had suggested that small groups are often capable of better organisation and investment in collective goods than larger groups. In later work he extended this analysis to encompass the provision of collective goods to a larger group through the activities of a small group of "imaginative political entrepreneurs" who have selective incentives to undertake this task. The activities of the small group of Cambridge individuals discussed above resembles that of an Olsonian group. Their role was crucial to the involvement of the University and its colleges in the activities of industry in the region. More recently, the establishment of formal partnerships with the university have involved many of the same individuals. This successful interface with the University is a collective good for other hi-tech firms in the region. It gives the Cambridge area an image of being forward looking and entrepreneur- friendly, which we saw is important to the continuing establishment of new firms and the growth of the region.[23]

5. *In conclusion*

We started this chapter by noting the similarities and differences in outcomes that a comparison between Cambridge and Silicon Valley revealed. In conclusion, we would like to suggest some reasons for the observed similarities and the differences.

Like Silicon Valley, Cambridge shows a case of successful entrepreneurial activity without any enabling government policies. Given the longer time of its existence as a cluster (relative to the other nascent clusters studied in this book) it also shows the slow development of some similar local institutions – notably technology venture capital and university-industry linkages. In both Silicon Valley and in Cambridge these developments are the outcome of a self-organising behaviour whereby groups of local entrepreneurs and the university recognised their mutual advantages for each other. This strong organic development of working set of institutions and institutional relationships that encourage entrepreneurial activity is one of the main successes of Cambridge.

Cambridge however, did not 'globalise' to the same degree as Silicon Valley. There are two aspects to this globalisation. First is the obvious one of firms developing global markets. While it is certainly true that most Cambridge firms export, they have not created global markets that rely on their exports alone. Put differently, the leading firms of the early 80s did not capture global markets in any one product/technology space. There were at least two reasons why it did not happen. First, they were unable to cope with the competition from US firms when after all the largest market for their products was in the US. Second, the lack of good marketing and management skills, which seem to be endemic to the growth of British industry.

The absence of globalisation in this first sense meant that there were no large firms that could act as markets for smaller ancilliary firms in the same region. This is why we find few of the traditional agglomeration economies important in the Cambridge case. This is also the reason why Cambridge doesn't show up as regionally specialised in hi-technology activity in England.

The second sense in which Cambridge did not globalise is that it did not pull other regions of the world to integrate with its production. This is clearly a function of the first but is still a distinct second step. Immigrants and students did not stay to set up start-ups in Cambridge in the way they do in Silicon Valley. Unlike Silicon Valley, Cambridge remains a quaint English university town, and further more would like to remain so. A consequence of this lower degree of globalisation is in fact the smaller scale of the cluster whether measured by population or by regional GDP.

Of the clusters studied in this book Cambridge is in many respects the closest to Silicon Valley. With no government policies to help, Cambridge tried to manufacture technology products based initially on commercialising science from the university laboratories. It tried to produce technology products that were general rather than specific. But in the mid seventies when it started Silicon Valley had already got there first. Perhaps this is why history did not repeat itself.

Notes:

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[1] Estimates are taken from *Guardian*, 15 April 2000, "Where talent and ideas meet money" by James Meek.
[2] The OECD definition of Knowledge based business adopted in the Huggins study includes all hi-technology manufacturing and service sector activities such as IT, computer technology and telecommunications, financial and business services, media and broadcasting.
[3] This study adopted a definition of high technology based on Butchart (1987).
[4] The area defined as encompassing the Cambridge Phenomenon has varied in different studies depending upon the availability of data. Thus, it could encompass Cambridge City alone - the area around the university and its colleges. Alternatively, it could comprise the fifteen-mile radius around the university including all of Cambridgeshire County but excluding Huntingdon and Peterborough as used in the CBR study and detailed in Keeble et al (1999). Lastly, media reports using CCC data often define Cambridge to mean Cambridgeshire county. Some studies also use the employment service area for Cambridge, which is the labour market for Cambridge employers as defined by commuter patterns. In general this latter definition encompasses all of Cambridgeshire County and regions further south and east.
[5] The definition of hi-tech has remained reassuringly consistent in all the work. It is based on some additions to the Butchart (1987) classification and described in Appendix 1.
[6] Their definition of Cambridge region is much vaster than that employed in this paper.
[7] These figures are based on revised data that were generously made available by Jill Tuffnell of the Research Group, Cambridgeshire County Council. Detailed figures are in Table A2.1 in Appendix 2.
[8] Appendix 2 contains the Tables A2.2-3 that charts the sectors of gains and losses in employment.
[9] Estimates from "Cambridge set to take UK venture capital lead" *Cambridge Evening News*, 2 March 1999.
[10] This information has been collated from different volumes of the *Cambridge Reporter*.
[11] See for example studies by Galbraith (1985), Oakey and Cooper (1989) and Haug (1991).
[12] See for example 'From the BBC Micro, little Acorns grew' by Joia Shillingford, *The Guardian*, March 8 2001.
[13] This sketch of Acorn Computers is based on several secondary sources and newspaper clippings.
[14] This quote is taken from an article on Stan Boland in the *Cambridge Evening News* (May 18, 1999) by Jenny Chapman titled "Branching out to build on Acorn's success".
[15] 'From the BBC Micro, little Acorns grew' by Joia Shillingford, *The Guardian*, March 8 2001.
[16] See for example the Garnsey and Wilkinson (1994) case study of Amartec, a Cambridge silicon chip design company.
[17] This report on Autonomy is based on the following newspaper reports: 'Autonomy is no longer master of its destiny' by Rick Wray, *The Industry Standard Europe*, March 26,2001 & 'Trading places' by Jon Cassy, *The Guardian* June 8, 2001.
[18] The results of the regression analysis are reported in SQW(2000), Tables 12.9 & 12.10.
[19] See Appendix 2 for table on which this inference is based.

[20] See SQW(2000), Table 12.7.

[21] It is rumoured that the Science Park experiment had a plan B- to convert the buildings into a restaurant if the Science Park became financially unviable!

[22] I have seen this argument first made in Schwerin, J. (1999) on the Clyde shipbuilding industry in the 19th century. He notes that a small group of individuals served in multiple institutions that they helped set up and acted as the mechanism of information transfer between these institutions and to the extent that this information was shared outside the group, these individuals were a source of information externalities.

[23] The causes of the attachment of these people to the Cambridge area are less well understood. Not all of them are in academia nor do they all hold positions in the colleges and universities.

Tables and Figures

Table 1: Decomposing the gains and losses in establishments

Cambridge City							
Year	New firms	Moved in	Total New	Closures	Moved out	Takeovers	Total lost
1988-90	31	4	35	26	15	4	47
1991-92	41	10	51	20	23	2	50
1993-95	34	7	41	36	20	2	58
1996-97	50	12	65	26	26	5	59
1998-99	61	5	75	36	13	6	73
South Cambridgeshire							
Year	New firms	Moved in	Total New	Closures	Moved out	Takeovers	Total lost
1988-90	33	9	41	24	14	3	41
1991-92	48	22	70	22	13		35
1993-95	28	11	39	28	15	4	47
1996-97	16	10	27	26	25	5	57
1998-99	42	22	75	31	14	7	67

Note: 1. Cambridge City and South Cambridgeshire have the most significant proportions of the total growth of establishments. See Figure 1.
2. "Moved in" category includes firms that have moved in from other regions of Cambridgeshire.

Source: Research Group, CCC.

Table 2a: Original basis of establishment of Cambridge firms

SQW study, 1984 N=261	%	CBR study, 1996 N=50	%
Independent new firm	73	Independent start-up	56
Relocation of existing enterprise	9	Spin-off	32
New branch	2	By another firm	12
New subsidiary	16		

Source: SQW (1990); page 19. Keeble et al (1998): page 234

Table 2b: Firm origins: founder's previous employment

"For new start-ups and spin-offs only, where was the chief founder employed immediately previously?"

Location	Type of firm / organisation: Self-employed / Unemployed	University	Govt. Research lab	Another firm	Total
Cambridge area	2	8	1	24	35
Rest of the UK and abroad	0	2	0	6	8
Total	2	10	1	30	43

Table 2c: New Cambridge region start-us by former employees and inter-firm links

	Number (Total of 50 firms)
New start-ups by former employees	24
Located in Cambridge, of which:	24
Continuing links with parent firm	18
Both formal and informal links	15
Only informal	3

Source for Tables 2b & 2c: Keeble et al (1998) page 234.

Table 3: Size distribution of hi-tech firms in the Cambridge area, 1998.

Size Class (Employees)	Cambridge City N	Cambridge City (%)	South Cambs (ex City) N	South Cambs (ex City) (%)
0 to 5	117	(33.1)	136	(39)
6 to 10	72	(20.4)	55	(15.8)
11 to 24	58	(16.4)	57	(16.3)
25 to 49	54	(15.3)	44	(12.6)
50 to 99	24	(6.8)	24	(6.9)
100 to 199	20	(5.7)	15	(4.3)
200 to 499	4	(1.1)	14	(4)
500 +	4	(1.1)	4	(1.1)
Total firms	353	(100)	349	(100)

Source: Research group, CCC (1998)

Table 4:Growth Index by sector and period, 1988 -1995

Year	Biotech	Hardware	Elec. Engg	Instrumentation	Consultancy	Software	R&D	Others	Total
1988-89	0.37	0.38	0.33	0.28	0.27	0.42	0.19	0.34	0.33
1990-91	0.44	0.24	0.03	0.16	0.06	0.20	0.11	0.18	0.14
1992-93	0.26	0.15	0.15	0.17	0.06	0.25	0.22	0.12	0.18
1994-95	0.05	0.43	0.22	0.19	0.12	0.38	0.33	0.31	0.29

Source: Gonzales-Benito et al (1997) pages 16-17.

Notes: 1. Index includes only those establishments that were known to be trading and remaining in the Cambridge TEC region.

2. The Growth index (GI) for any firm is = (number of employees (t+2)- number of employees (t))/ number of employees (t).

Growth Index of a sector = n (GI)/N, where N=total number of establishments in the region and n=number of establishments in the sector.

3. Annual rate of growth (g)= $\sqrt{1+GI}$

Table 5: Ratio of closures to new establishments

Period	Cambridge city	South Cambridgeshire (ex city)
1988-90	0.84	0.73
1991-93	0.49	0.46
1993-95	1.06	1
1995-97	0.52	1.63

Source: Computations from Table 1.

Table 6: Industrial diversity in the Cambridge area (% of employment), 1984 and 1998

Industrial sector	Cambridge Area 1984	Cambridge Area 1998	Camb city 1998	South Cambs 1998
Chemicals	9	9.7	0.4	18.3
Specialist mechanical engg	-	3.8	4.8	2.9
Computer hardware	7	13.3	20.0	7.2
Electrical and Electronic Engg	33	8.6	8.1	9.0
Instrument Engg	22	7.2	0.3	13.5
Aero Engg	-	0.3	0.4	0.2
Specialist distribution	-	2.5	1.6	3.4
Specialist retailing	-	0.7	0.9	0.4
Technical services	-	3.2	4.3	2.0
Computer Services	8 [1]	12.3	17.0	7.8
Business Services	-	1.1	0.3	1.8
R&D	7	26.7	33.4	20.4
Telecomm	-	6.5	7.9	5.3
Others	-	4.2	0.5	7.7
Total	100	100.00	100.00	100.00

Notes: 1. Includes software.

Source: SQW (1990) for column 2, Research Group, CCC (1998), for columns 3-5.

Table 7a: Founder's motives in setting up the firm

Motive	% Of firms ranking motives as important or very important
Desire for independence/ be own boss	60
To make money	52
Stimulated by research possibilities, urge to innovate	46
Identified new market opportunity	44
Threatened or actual unemployment	15

Table 7b: Technological innovation and new firm formation

Was your firm formed primarily to develop or exploit a technological idea or innovation?

% YES
58

What was the source of the innovation?

Source	% (of what?) Firms
The founder	40
The university	4
Existing technology	4
Founder's previous employer	6

Source: CBR survey, unpublished summary

Table 8: Region specific advantages for firm development in the Cambridge region.

" How important have the following been for your firm's development?"

	% Of all firms reporting 4 or 5
Attractive local living environment for staff/directors	46
Credibility, reputation and prestige of a Cambridge address	42
Local availability of research staff	30
Quality of local research staff	28
Informal local access to innovative people, ideas and technologies	28
Availability of appropriate premises	22
Access to London	20

Source: Keeble et al (1999); page 325.

Table 9: Competitive advantages of Cambridge firms: frequencies of extreme scores

Nature of competitive advantage	% Of firms reporting extreme scores
Product/ service quality	86
Attention and responsiveness to client needs	80
Specialised expertise	72
Technological innovation	70
Established reputation	70
Product and service design	68
Flair and creativity	58
R&D	46
Marketing and promotion	36
Price	30

Notes: 1. Firms were asked to rank each source of competitive advantage on a scale 1(not important) to 5 (crucially important).

2. N=50.

Table 10a: Importance of local markets in sales: % of sales to own area by Cambridge firms

	1990		1995	
	N=50	%	N=50	%
Not applicable	15	30	3	3.3
Less than 10%	29	58	37	76.7
11 to 50%	4	8	7	14
Over 51%	2	4	3	6

Table 10b: Importance of local markets in purchases: % of purchases in own area by Cambridge firms

	1990		1995	
	N=50	%	N=50	%
Not applicable	22	44	11	22
Less than 10%	17	34	22	44
11 to 50%	7	14	13	26
Over 51%	4	8	4	8

Table 11: Importance of inter-firm linkages inside and outside the Cambridge area

Type of link	Within Cambridge		Outside Cambridge		Importance of proximity	
	N	%	N	%	N	%
Customers	8	21	32	84	6	16
Suppliers / Sub-contractors	17	45	17	45	15	39
Firms providing services	12	32	4	11	10	26
Research Collaborators	4	11	9	24	5	13
Firms in own line of business	4	11	7	18	3	8
Others	1	3	0	0	1	3
Total	25	66	34	89	23	61

Notes: 1. N refers to the number of firms that rated the particular link 4 or 5 on a scale 1(not important) to 5 (crucially important).

2. % is N as a percentage of all firms reporting links. 38 firms in all (of 50) reported having any inter-firm links. Source: CBR survey, unpublished summary

Table 12: Research and Managerial staff recruitment

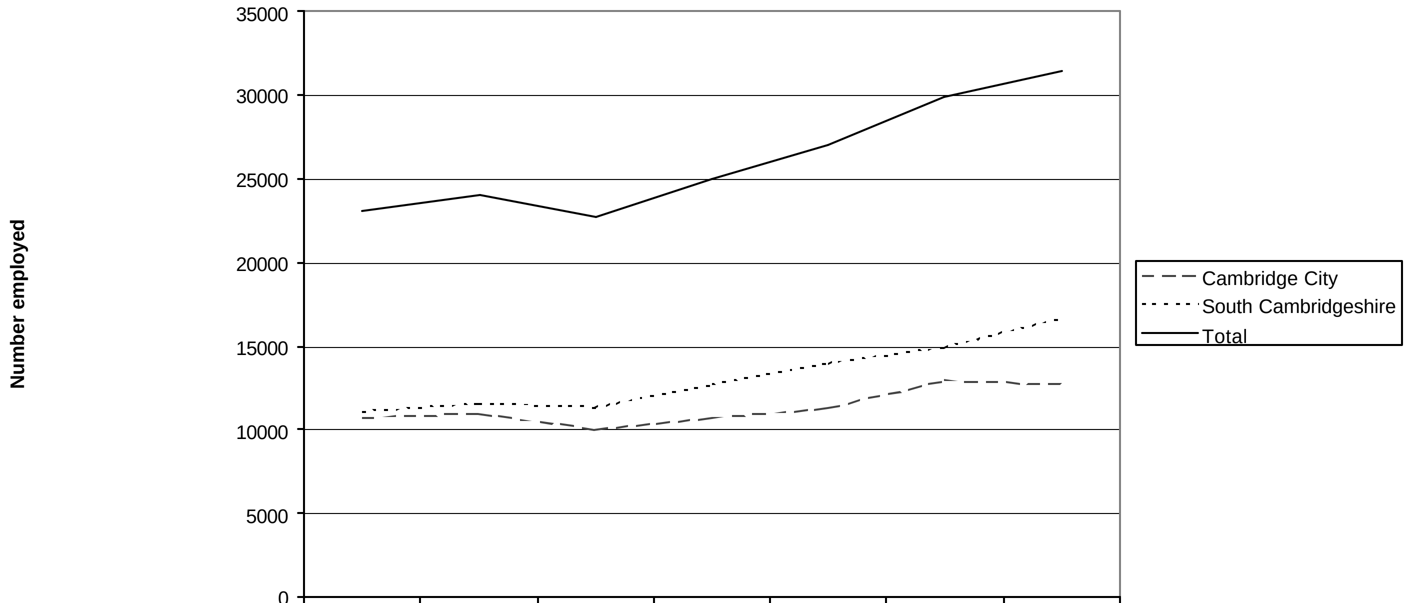
	Research Staff		Managerial staff	
	N	%	N	%
University of Cambridge	7	19	2	6
Other Cambridge firms / organisations	13	35	12	39
Other UK universities	10	27	3	10
Other UK firms / organisations	15	41	18	58
Overseas universities	4	11	1	3
Overseas firms / organisations	3	8	7	23

Source: Keeble et al (1998)

Table 13: Interaction of Cambridge hi-tech firms with Universities (Number and % of all firms)

Type of formal interaction	Cambridge University	Other universities
Academics on board	6 (12)	1 (2)
Collaborative projects with universities	14 (28)	18 (36)
Collaborative projects with government research establishments	3 (6)	7 (14)
Part-time secondment by academics	7 (14)	8 (16)
Research consortia or clubs	5 (10)	8 (16)
University staff acting as consultants	12 (24)	13 (26)
Licensing or patenting of university inventions	2 (4)	5 (10)
Training programmes run by the university	2 (4)	3 (6)
Total (includes others)	19 (38)	24 (48)

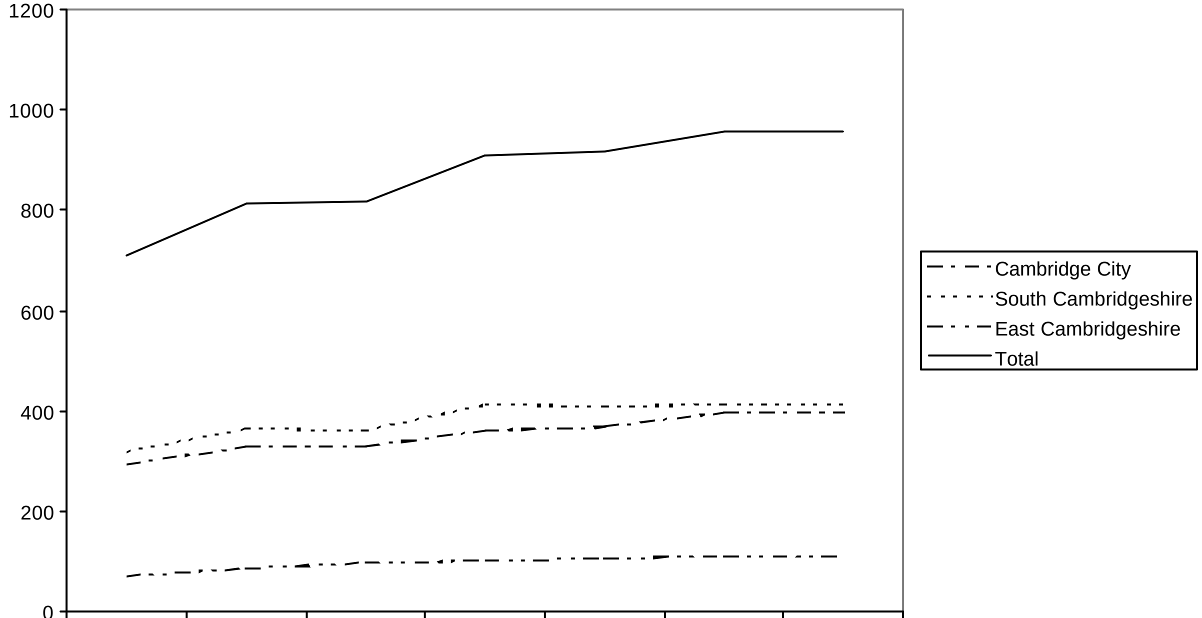
Figure 1: Employment in hi-tech industry (1988-99)



	1988	1990	1991	1993	1995	1997	1999
Cambridge City	10714	10960	9996	10689	11265	12944	12699
South Cambridgeshire	11085	11579	11331	12700	13981	14935	16650
Total	23087	24068	22763	24950	27062	29924	31399

Year

Figure 2: Growth in hi-tech establishments (1988-98)



	1988	1990	1991	1993	1995	1997	1999
Cambridge City	294	328	329	361	367	397	398
South Cambridgeshire	318	365	360	412	409	412	414
East Cambridgeshire	70	86	96	101	105	110	108
Total	710	812	818	909	918	957	959

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Appendix 2: Other tables

Table A2.1: Growth of employment in biotechnology in the Cambridge Area

Year	Total employment in Biotechnology in the Cambridge Area	% of Biotechnology employment in all of Cambridgeshire county
1988	4816	80
1990	4819	80
1991	4687	80
1993	5703	82.8
1995	6128	82.2
1997	7554	84.6
1999	8133	89.3

Source: Research Group, CCC.

Table A2.2: Gains and losses in employment in hi-tech industries (1988-98) by industrial sector: Cambridge city

Industrial sector	1988-90	1991-93	1993-95	1995-97
Chemicals	+17	+3	+4	+26
Computer hardware	+35	-122	-49	289
Electrical and Electronic Engg	+30	+319	+66	-114
Instrument Engg	-451	-51	-89	+2
Aero Engg				+14
Specialist distribution		+52	+25	+27
Specialist retailing	-17	+13	+6	-8
Technical services	-17	-29	-27	+72
Computer Services	-106	+26	+135	+371
Business Services	+9	+67	-135	+5
R&D	+553	+222	-32	+570
Telecomm	-	+162	+689	+530
Total	+43		+616	+1792

Source: Research Group, Cambridgeshire County Council, various volumes.

Table A2.3: Gains and losses in employment in hi-tech industries (1988-98) by industrial sector: South Cambridge (excluding Cambridge city)

Industrial sector	1988-90	1991-93	1993-95	1995-97
Chemicals	-298	-55	-94	80
Specialist mechanical engg	+83	-48	-41	+171
Computer hardware	+70	+153	-36	-229
Electrical and Electronic Engg	+221	+105	+142	+137
Instrument Engg	-82	-97	+158	-101
Aero Engg		-49	-157	+141
Specialist distribution	+11	+21	+25	-70
Technical services	+22	+5	-27	+20
Computer Services	+300	+352	+135	-68
Business Services	+18	+2	-135	+52
R&D	-24	+201	+496	+548
Telecomm	-	300	-262	+48
Total	+306	+931	+600	+678

Source: Research Group, Cambridgeshire County Council, various volumes.

Table A2.4: The benefits from inter-firm links (N of firms ranking 4 or 5)

Type of benefit	No. of firms reporting importance	Proximity increases usefulness
Improving amount of information about new products	20	12
Improving quality of information about new products	20	13
Improving access to research findings	9	10
Assuring a satisfactory quality of supplies	19	14
Assuring a timely delivery of supplies	15	14
Greater responsiveness to market requirements	20	6
More effective or innovative R&D	18	12
Other	2	2

Source: CBR survey, unpublished summary.