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

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December 2000

NUMBER 29

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This series is registered under
ISSN 1753-2590 (Print)
ISSN 1753-2604 (Online)

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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 growth and change in the Cambridge hi-technology cluster, and the mechanisms that underlie this growth. Despite high rates of new firm formation that explain the sustained growth of employment in the region, this growth has not been spectacular. Further, these high levels of entrepreneurship are motivated more by inertia of founders and quality of life factors than agglomeration advantages. The chapter highlights some significant changes that have taken place in the area's economy, their impact on firm growth and explores the importance of traditional sources of agglomeration economies. It finds that the main mechanisms creating knowledge spillovers are the movement of personnel between firms and the spinout of new firms from parent firms, rather than dense and proximate local links. We explore the role of the University in this process, and draw attention to the importance of a small group of individuals who have been instrumental in various kinds of information transfer and the creation of institutions that encourage the transfer of knowledge from the university to firms. We conclude that though Cambridge displays cluster like characteristics it is not an example of a classic cluster and shows evidence of different mechanisms that achieve collective efficiency.

*The study was financed by a grant from the Stanford Institute for Economic Policy Research under its project "Silicon Valley and its imitators". I am very grateful to David Keeble and Clive Lawson for numerous discussions, suggestions for further reading and for having generously made available published and unpublished data from the CBR survey. Jill Tuffnell generously helped with data related queries and suggestions for improvement of the paper. The paper benefited from discussions with Lilach Nachum and Elizabeth Garnsey. An earlier draft received very constructive suggestions from Alfonso Gambardella and Tim Bresnahan. The usual disclaimer applies.

1 Agglomeration, clustering and collective efficiency

The agglomeration of firms has attracted the attention of both theorists and policy makers. Economists, since Marshall, have been particularly fascinated by the observation that the actions of one firm may have advantages in production and innovation activities, for all firms in such agglomerations. This can happen because the concentration of firms in an area magnifies initial local advantages through a variety of ways. Marshall himself described three sources of collective efficiency or agglomeration economies as helping the growth of firms located in the agglomeration, 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.

Economists often use agglomeration and clustering synonymously, defining agglomerations and clusters in a specific way: they are a geographical and sectoral concentration of enterprises and firms. Thus, by this definition a region shows agglomeration when it specialises in a particular industrial sector relative to other regions in the economy. This definition has been used in empirical descriptions of regional specialisation (Huggins 2000, Begg 1991) and also by economic theorists explaining agglomeration (Arthur 1994, Krugman 1991).

In contrast to economists, economic geographers have long believed that dispersion of economic activity over regions is the norm and clustering is an unusual occurrence. They have instead drawn attention to the unique features of clusters: the synergy created by firms that have cooperative linkages with each other (Saxenian, 1994), the regional milieu that encourages some agglomerations to become more innovative. The focus of this literature has been much more on the mechanisms that give rise to synergies between firms and understanding the institutional and economic features that promote these mechanisms. Traded and input-output type of advantages is given much lesser prominence. Thus, an alternative definition of clusters used in some recent empirical work is based on the extent of inter-firm linkages in clusters. (Keeble and Nachum, 2000).

These alternative definitions differ in the precedence they give to the source of collective economies and the nature of the mechanisms that generate them.[1] Thus, a definition of agglomeration based upon geographical and sectoral concentration gives equal importance to proximity and specialisation as the sources of collective efficiency. Backward and forward linkages, resource pooling and involuntary knowledge spillovers through inter-firm linkages become the mechanisms by which collective efficiency is generated. A definition of cluster based on the strength of inter-firm linkages also gives precedence to proximity but stresses the competencies that are transferred in largely voluntary inter-firm exchanges. These are often a result of a region's history, and "embedded" in the development of socio-economic relationships and institutional arrangements in the region.

While agglomeration economies and institutional networks may explain the growth of a cluster and the competitive advantages of firms in the cluster, they do not explain why an agglomeration or cluster emerges in the first place. This initial advantage may depend upon some unique feature of the regional location that is advantageous to a new industry. Thus, university towns may encourage the establishment of technology-based clusters. Arthur (1994) showed that idiosyncratic events too, may give rise to a cluster through path-dependence. An important example he considers is the role of spin-offs from a parent firm, which will tend to favour the location the parent came from. Once a large enough mass of firms develops agglomeration economies will explain further growth of the cluster. But the initial choice of industry location depends upon where the first founders located. Later entrants into the industry are attracted to the presence of these first firms.

The difference between the two types of arguments as Arthur (1994) explains, is not trivial. In the context of Silicon Valley, he explains, a regional advantages view would explain the relative concentration of electronics industry in California as driven by proximity to Pacific sources of supply and because it has better access than other places to airports, skilled labour and advances in academic engineering research. A history dependent view would however, ascribe these developments to chance. If the key persons – the Packards, Shockelys and Varians had decided to set up in another place in the 1940s and 1950s, they would have created local expertise and markets that would have attracted subsequent entrepreneurs to another location.

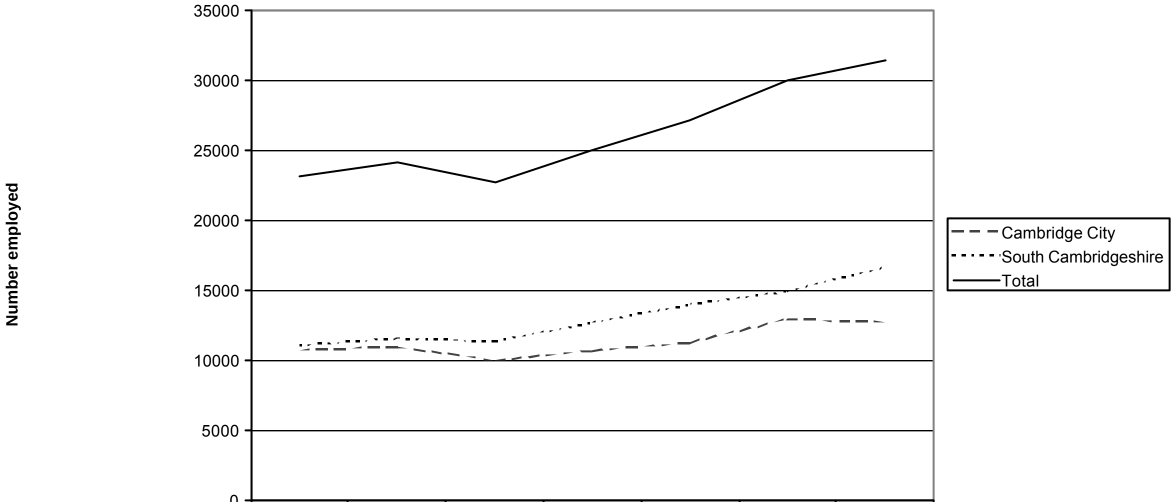
This chapter studies growth and change in the Cambridge hi-tech cluster.[2] In this paper we define the Cambridge area as comprising Cambridge City, South Cambridgeshire district, East Cambridgeshire and the Fenlands area.[3] We are principally concerned with two questions. How has the Cambridge cluster changed overtime? What socio-economic mechanisms contribute to its growth and collective efficiency? Two sources of data have been tapped in our study and these are detailed in Appendix 1.

The remainder of the chapter is organized in the following way: Section 2 describes the "Cambridge phenomenon", its scale and growth and compares it to Silicon Valley. Section 3 describes qualitative and quantitative features of change and growth of the Cambridge hi-tech cluster between 1988–2000. Section 4 examines the importance of different mechanisms that underlie agglomeration economies. Section 5 concludes.

2 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 more than tripled in 1999. Figures 1 & 2 show the steady growth in the number of hi-tech establishments and of employment in the hi-tech sector in the Cambridge area. It is estimated that at the end of 1999, the number of hi-tech establishments had grown to 959 in all employing over 31,000 people. The Cambridge area accounted for 60% of all hi-tech establishments and over 70% of all hi-tech employment in Cambridgeshire County.

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

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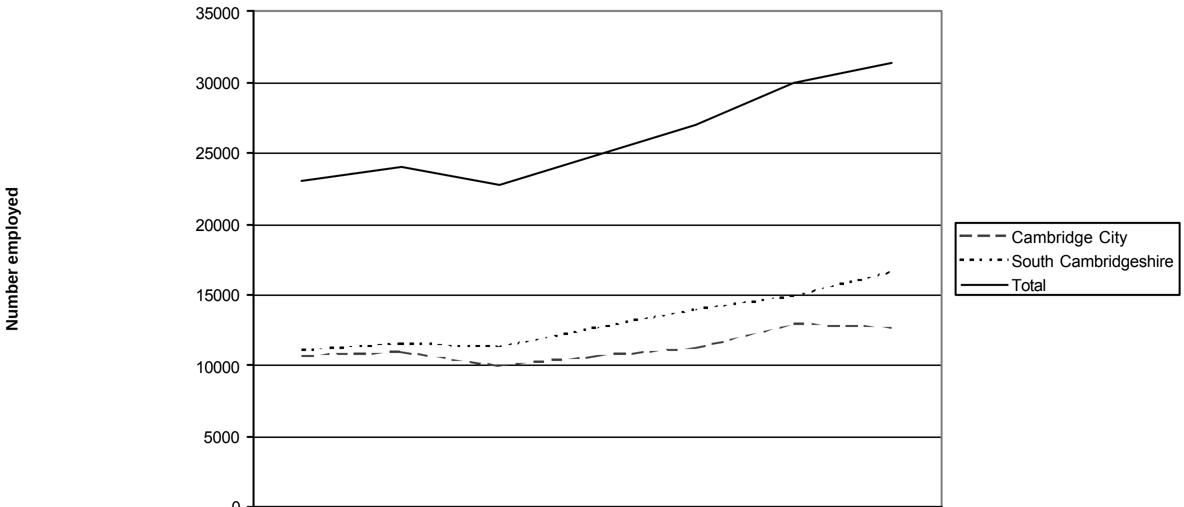

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Year

Firms in the Cambridge area are not specialised in any one sector of industrial activity, and the region as a whole is diversified in its industrial sectors of activity. This diversity was noted by the SQW report in 1984, which first drew attention to the agglomeration of firms around the Cambridge Science Park. Though the sectors of industrial specialisation have changed (see Section 3.2 below) industrial diversity rather than specialisation remains a feature of the Cambridge hi-technology cluster. This may however be a feature of clusters that specialise in the provision of intermediate goods rather than final goods, and it may be more appropriate to consider all hi-technology goods and services together as a sector.

Though the numbers of hi-tech establishments and hi-tech employment have increased overtime, and the Cambridge area accounts for most of the regions' hi-tech employment, it is not regionally specialised in hi-technology production in the UK. A recent computation of relative specialisation of different UK regions in knowledge based businesses[4] 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 the highest value 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.[5] The regions ranked higher than Cambridge included Bracknell, Stevenage, and Welwyn – all areas that lay outside London.

Thus by indices of industrial specialisation or regional specialisation in hi-technology, Cambridge does not seem to be an agglomeration. This is probably related to the fact that there are few large firms in Cambridge – domestic or foreign. One finds cluster like behaviour only in the high incidence of inter firm linkages among Cambridge firms – a high prevalence of such linkage relationships has been reported in the work of Keeble *et al* (1999).

The Cambridge cluster shows two remarkable differences when compared to "successful" clusters like Silicon Valley. The first is the smaller scale of the Cambridge cluster. Estimates suggest that though Cambridgeshire County and Silicon Valley (Santa Clara county) encompass a similar geographical area, their economic scale is vastly different.[6] 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.

These low average earnings figures are in turn related to the second difference, which 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.

The magnitude of difference in the size and scale of success between the two clusters nevertheless mask some qualitative similarities. Economic activity in both regions appears to have benefited from the presence of and interaction with a reputed university. In their 1986 report, SQW drew a family tree showing the common origins of several of the new firms, due to a process of spin-offs from fourteen Cambridge University departments and the role of the Cambridge Science Park in making these developments possible. Spin-offs from the university continue to be important. A second area of similarity is the industrial diversification rather than specialisation of the two clusters. Lastly, the supporting institutions that are emerging in Cambridge, especially those surrounding venture capital and interactions with the university show some similarities with what was observed in Silicon Valley in the 1980s.

Thus, compared to Silicon Valley Cambridge is a "partial success" as a cluster. It has succeeded in getting a significant amount of science-based entrepreneurship, some local network effects among the scientists, but 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.

3 Growth and change in the Cambridge hi-tech cluster

The late 80s have seen important within the Cambridge hi-tech cluster. This change has measurable quantitative aspects, i.e. the growth in the number of establishments, growth in employment, and the rate of growth of firms. The more important changes, however, have been qualitative: the emergence of a new business model based on technology licensing, a related shift in the aggregate industrial structure and the emergence of an array of supporting institutions strengthening university-industry links and providing venture finance. Indeed it is the emergence of some of these qualitative changes, without any government intervention, that has led analysts to focus upon Cambridge as a cluster, despite its lack of cluster like qualities noted in the previous section. We detail each of these in turn.

3.1 The growth of hi-tech establishments in the Cambridge area

3.1.1 The importance of new firm formation

Figures 1 and 2 have documented the growth in numbers of firms and in employment in the Cambridge area. We can decompose the changes in the stock of firms over a period of time into gains and losses due to the various reasons shown in Table 1. What Table 1 shows remarkably 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.

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

The category of new firms in Table 1 does not distinguish between indigenous new firms and firms from outside that are moving into Cambridge. Neither does it distinguish between the wide varieties of ways through which new firms come into existence. They can emerge due to entrepreneurial activity, due to spinouts from an existing large firm, due to spin-offs from University labs and departments or due to new subsidiaries being set up by existing firms. Of these, new start-ups and spin-offs (from other firms and University Departments) represent entrepreneurial activity. Other studies 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, which explain the high rates of new firm formation in the Cambridge area.

Table 2a shows the proportions of firms that have emerged as new start-up or as a spin-off from other firms in the Cambridge area in the CBR (1996) survey. 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 higher (88%). We can conclude from these figures that the importance of new-start ups has been rising through the late 80s and 90s.

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?"

	Type of firm /organisation				
Location	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.

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. The prevalence of such links constitutes an important mechanism by which technological and market information is shared and exchanged between firms in the region – a point we return to in a later section.

3.1.2 Factors favouring the emergence and location of new firms in the Cambridge area

The strongly local character of new firm formation revealed in Table 2b still begs the question of motives. What sorts of factors favour entrepreneurial activity in this 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 3a 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. Distress entrepreneurship due to threatened unemployment is very low in importance. Technological motives are important but not overwhelmingly so. Table 3b 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 3a 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 3b 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

The motivations of the founders does not inform us about the particular regional advantages that Cambridge possesses that makes firms want to locate there. The regional advantages of Cambridge derive from several factors. The links that firms can have with the university, the pool of specialised labour that might favour hi-technology start-ups, are some of the economic advantages that come to mind. Cambridge has also been a prosperous area for a long period of time and this has meant it has a good infrastructure, good schools and an attractive local environment.

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 (1998) that 20% of start-up firms in Cambridge that had relocated from elsewhere had Cambridge founders.

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.[7] 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.

Keeble, *et al* (1999) report on the importance of regional factors in the decision of new start-up firms to locate in Cambridge. Table 4 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). It is also interesting that "links with the university" does not figure in this list of the seven most important factors.

Table 4 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.

3.2 The growth of firms

Figure 2 showed that employment has seen a steady growth since the late 80s. This growth could come about due to an increase in the number of establishments or due to increased employment within existing firms (firm growth). In Cambridge the former processes has dominated, and firms have experienced slow rates of growth, but with a low incidence of failure. The more remarkable change over the last few years is however, a marked change in the business model that has become dominant among hi-tech firms in the region.

3.2.1 Rates of growth and incidence of failure

The growth of firms in the region does not boast of a large number of outstandingly successful firms. Even now, though there are firms that have a high stock market capitalisation, firms that a large sized are few. The size distribution of firms reported in Table 5 reveals very small numbers of large firms. While in part this could be explained by the large presence of service firms or consultancies (where 50 employees indicate a reasonably large size), the slow growth of firms is undoubtedly a factor.

Table 5 Size distribution of hi-tech firms in the Cambridge area, 1998.

Size Class (Employees)	Cambridge City N	(%)	South Cambs (ex City) N	(%)
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)

Most hi-tech firms in Cambridge experience low rates of growth. Most recent figures are unavailable, but 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 the region.[8] Their figures are reported in Table 6. 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 6 Growth Index by sector and period, 1988 -1995

Year	Biotech	Hard-ware	Elec. Engg	Instrument-ation	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.

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

Despite the preponderance of small firms the rate of failure amongst small hi-tech firms in Cambridge is low. Table 7 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 7 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.

There have been few studies that have systematically investigated the causes of this slow growth. 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.[9] 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. Though the study does not explain these findings, we think they are significant and important findings because they could represent logical outcomes of important qualitative changes that have taken place in the Cambridge economy in the 90s. We will return to a discussion the findings at the end of our sections detailing the qualitative changes.

3.2.2 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. Not only were the business strategies of ARM different from those of Acorn, ARM was a spin-off from the research activities of Acorn. Since ARM the original founders of Acorn have been involved in many more similar start-ups and successes.

Acorn Computers was started in 1978 by Hermann Hauser and Chris Curry, and supported on a part-time basis by Andy Hopper.[10] 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:[11]

> 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.

Acorn's demise was not all a question of poor management strategy. A similar story may be told of other promising firms of the 1980s: Sinclair Research, Amstrad, and Apricot. 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. 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. Acorn RISC Manufactures was set up in 1983 as a subsidiary of Acorn computers. Later, it was spun off as an independent subsidiary (Advanced RISC Manufactures) with Acorn holding a stake in the company. By 1999, Acorn's stake in ARM was worth more in the stock market than Acorn itself.

The new 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 subcontract manufacturing they chose the licensing route to selling their technology. They tapped external markets by setting up a subsidiary firm in the US. Not only is the US itself a large market for such chips, but also it was a market where managerial skills for market development are widely available. The ARM chip was quickly established as the industry standard. Over its lifetime the company has made and shipped 175 million units and helped to create as many as 30 millionaires. 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 manufactured 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. Many Cambridge entrepreneurs have used this exit route to set up other new companies, thus, making serial entrepreneurship more common in the region now.

These features of the ARM model have been followed by other hi-technology successes in the area, notably Autonomy, Zeus, Vocalis, Virata to name a few. Interestingly the one hi-technology firm that tried to go into providing a service product in this period- 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 arguably a good idea. Possibly this failure has added further credibility to the ARM business model based on licensing. However, as the Garnsey and Wilkinson (1994) case study of Amartec, a Cambridge silicon chip design company showed it is not a strategy without its pitfalls. Growth via the licensing route creates several problems for the growth of the licensor. In particular, a technology based firm's marketing strategy can be entirely determined, or confounded from its initial objectives, by the preferences of the big licensors. This in turn makes the long-term growth and viability of such firms difficult and also makes them vulnerable to takeovers. Original entrepreneurs may have little choice but to exit the founding firm.

3.3 Other qualitative changes

3.3.1 Industrial diversity and change in the bases of growth

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 has 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.[12]

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 8 also 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.

Table 4 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.

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. It is hard to deny the role of the University in creating and sustaining these strengths.

A diversified industrial base has contributed to maintaining a steady growth of employment in hi-tech industry in the Cambridge region. 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.[13] 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.

It is significant that R&D services, telecommunication, computer services, aero and electronic engineering also comprise a set of related industries that are technologically convergent, or share similar bases of generic knowledge for their production activities. Indeed Cambridge firms particularly favour interdisciplinary research products: the use of databases on gene sequences, applying set theory to search engine software and embedded software. Despite the absence of fine specialisation within a single production filiere, the technologically related nature of the diversity could be an important source of externality for firms that operate within these related sectors.

The technologically related nature of production (and therefore interlinkage of) producers' activities is a potential source of knowledge externality. It is less clear that the mechanisms through which this knowledge externality is realised needs the geographical proximity of other regional firms. It may only require the reasonable proximity of consistently good research departments and labs. While it is tempting here to attribute good research departments and labs to Cambridge University alone, it would not be true. The South east economy which Cambridge borders on, has several important public and private sector laboratories, and has consistently received more public R&D funding than any other region in the UK. The premier institution for basic scientific research in the country is the Imperial College in London, which is also barely an hour away, by train from Cambridge.

3.3.2 Institutional developments

Another significant change in the late eighties and nineties is the emergence of venture capital and a proliferation of visible links with the University. In this section we discuss briefly these developments.

3.3.2.1 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. The directors involved with Cambridge Consultants have set up other successful venture capital firms. Thus, Robert Hook went on to set up Prelude Technology Investments in 1984 and Gordon Edge from Cambridge Consultants 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 Chairman 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.[14] 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 205 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.

3.3.2.2. 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 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 Professors Wilkes and Wheeler at the Computer laboratory in Cambridge. This research lab has spun out companies like Virata, Telemedia, and Adaptive Broadband. This 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 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.[15] 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 co-operation of the University and its Colleges are key to the region's development.

All 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. Table 4 suggests that this image has some force in attracting new hi-technology businesses to locate in the Cambridge region.

3.4 Qualitative changes and their impact on the growth of Cambridge firms

In this section we return to the findings on growth reported by the SQW(2000) study. We think their findings are significant in light of the qualitative changes that have taken place in the Cambridgeshire regional economy, as their findings are in line with what one would expect as a consequence of those changes. Our discussion also highlights the nature of the paradox about growth Cambridge: by the standards of qualitative indicators it is a “happening” cluster. Yet as one measures its aggregate impact, for example in national indices of regional specialisation nothing significant has really happened. The clue to this paradox we suggest lies in the increasingly service orientation of the Cambridge economy at the micro and macro level. This service orientation is primarily a result of the uncompetitive manufacturing base of the national economy but this disadvantage has been reinforced by planning restrictions in Cambridge that favour service firms rather than manufacturing firms.

The shift to a business model based on technology licensing (discussed in section 3.2.2 above) should imply a slower growth of employment but a proportionately larger growth of R&D expenditures. An extremely important role of outside capital is in selecting professional management that will orient firms towards market growth. The use of outside capital and professional management has been spurred by the growing importance of corporate venturing and venture capital in the region, which we discussed in Section 3.3.2.1. Venture capital often intervenes directly in this process of greater market growth by putting the right scientists in touch with the right managers. For this type of intervention, in turn, venture capitalists may need more local information, and the local emergence of corporate venturing and venture capital shows the utilisation of this kind of information.

Lastly, of the important start-up sectors (detailed in section 3.3.1 below), 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 were their important competitive advantages. Instead the majority of firms scored factors such as attention and responsiveness to client need, technological innovation, specalised 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 technology service markets.

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.

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. Nevertheless the regional economy of Cambridge has thrived as a consequence of this kind of hi-tech entrepreneurial activity. For this reason, it also an exceptional place to look for the mechanisms that create collective efficiency and cluster-like growth. We turn to a consideration of these mechanisms next.

4 Mechanisms of growth in the Cambridge hi-tech cluster

The previous section documented the important changes in the Cambridge hi-technology cluster. In this section we will discuss the relative importance of various mechanisms that could contribute to collective efficiency of firms in the Cambridge area. We do not propose to investigate or assess the contribution of each mechanism to the growth of firms in the Cambridge area. The section first discusses the importance of the three sources of Marshallian collective economies, and subsequent sections discuss other mechanisms that may give rise to collective economies.

4.1 Importance of agglomeration economies

4.1.1 Local markets, backward and forward linkages

Cambridge firms have always depended in an important way on export markets for their growth. This is not a surprising fact when we consider the intermediate good nature of firms' economic activity in Cambridge. 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. Both these statistics suggest the unimportance of local markets as source of demand for final products.

We can assess the importance of local markets for Cambridge hi-tech firms more directly. 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.

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

	1990 N=50	%	1995 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 N=50	%	1995 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

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 significantly more important.

4.1.2 Advantages of "thick" labour markets

Thick labour markets are attractive to firms as they imply the easy availability of specialised labour skills. Their importance should be reflected in the decisions of firms to locate in the Cambridge area. However, as we saw in Section 3, labour market advantages did not constitute the most important factor attracting firms to locate in the Cambridge area. In this section we look at the direct recruitment by firms to understand the importance that local labour markets have.

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. Local recruitment is however greater than overseas recruitment.

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)

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.

4.1.3 Knowledge Spillovers due to proximity

Proximity and inter-firm links can be important sources of knowledge spillovers. Firms may observe each other's ways of doing business and learn from it. Where backward linkages are important one firm can transmit considerable information about markets, products and new opportunities. 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- a prime candidate if a process of knowledge spillover was underway. 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.[16]

4.2 Other mechanisms causing knowledge spillovers

In the remainder of this section, we draw upon the available information on other mechanisms that underlie knowledge spillovers in the Cambridge area. For convenience we discuss other mechanisms generating knowledge spillovers under the following three headings:

1 The university as a source of knowledge spillover
2 Knowledge spillovers due to the movement of personnel and due to spin-offs
3 Knowledge externalities generated by a small group

4.2.1 The university as a source of knowledge spillovers

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 be responsible for a high level of human capital in firms in the area, but as Table 9 shows that recruitment of the local labour is often from other parts of the UK, though the local labour market is also used. 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 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)

This evidence that points to a low direct impact of the University, it is difficult to conclude that the University is not important to knowledge spillovers. The main evidence to consider here is the nature of industry specialisation in the Cambridge area and the relatively high proportion of academic start-ups. As Table 8 indicated this has been around generic R&D strengths, which must somehow come from the numerous science laboratories of the University. SQW (2000) point out that 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.[17]

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. In their more recent analysis SQW (2000) point to interesting differences between industry and academic spin-offs: academic spin-offs are older, larger in terms of size and employment, have a larger portion of revenues coming from exports, have larger shares of R&D expenditure, are less likely to be owner managed and have a much larger involvement of external finance.[18] From this evidence we can conclude that though academic spin-offs are a smaller proportion of all spin-offs, they are also the more efficient firms.

Lastly, 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 noted in Section 3.2.3, 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.[19]

4.2.2 Knowledge spillovers due to movement of personnel and spin-offs

Knowledge spillovers may 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 Knowledge externalities generated by a small group

A striking feature of the catalogue of changes in Section 3 is how often a few names crop up. 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.
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.

We wish to draw attention to the role that this small group has played in information transfers and in the generation of externalities.[20] 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, was crucial to the involvement of the University and its colleges in 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.

5 In conclusion

In this study of the hi-tech cluster in the Cambridge area we try to highlight the fact that Cambridge is not a classic cluster. Though it has cluster like elements in the high rates of science based entrepreneurship, a sustained growth of employment and in the emergence of networking relationships and institutions promoting entrepreneurship in the region, the growth of the region as a whole has been muted rather than spectacular.

The chapter then documented the changes in the cluster between 1988–2000, and to study the mechanisms that underlie collective efficiency in the Cambridge area. There are unusual features of the Cambridge cluster. High rates of new firm formation explain the growth of employment in the region. These high levels of entrepreneurship are however motivated more by inertia of founders and quality of life factors than agglomeration advantages. Significant changes have taken place in the regional economy of the Cambridge area at the micro and macro levels. A new business model based on technology licensing has accompanied the growth of firms in the last decade. This has seen a corresponding shift in the aggregate industrial structure from hi-technology manufacturing to hi-technology R&D services in technologically related sectors. This relatedness is a source of technological externality in growth. There has also been a noticeable growth in institutions and institutional participation in the area with the emergence of technology venture capital and more visible industry-university participation. However, the technology service orientation of the cluster, though the best way to leverage the region's unique technological advantages, is also the main reason for its more muted growth. The rapid growth that accompanies the development of a new technology product market has so far eluded Cambridge.

In exploring the mechanisms that underlie growth in the cluster are also different from those in classic clusters. We find traditional sources of agglomeration economies are less important to firms. Local markets are less important than national and overseas markets in the sales of goods. Local supply side linkages are also weak though there is some evidence that the importance of local purchases is increasing. Proximity is not very important in inter-firm links and Cambridge firms report more non-local than local links. There are however other mechanisms that have created knowledge spillovers. These are the movement of personnel between firms and the spinout of new firms from parent firms, rather than dense and proximate local inter-firm links. There is evidence that firms benefit from the links created by the movement of personnel, and by firms that spin-out of parent firms, and that these links are widespread.

It is not easy to assess the role of the University as a source of knowledge transfers to industry. While the direct measurable impact of University knowledge spillovers is small, the colleges of the university and the role of a genuine fellowship of academics cannot be overstated. We have also drawn attention to the importance of a small group of individuals who have been instrumental in various kinds of information transfer and the creation of institutions that encourage the transfer of knowledge from the university to firms.

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Appendix 1

This appendix details the data sources used to generate the tables that appear in this paper.

Bi-annual reports published by the Research Group of Cambridgeshire County Council (CCC)

Tables 1, 5, 7 & 8, and Figures 1 & 2 in the paper are based upon estimates published by the Research Group of Cambridgeshire County Council (CCC). These estimates are contained in bi-annual reports available since 1988, of all hi-tech establishments in the region. The CCC reports are invaluable in outlining the trends in the growth of hi-technology in the region as they are based on census surveys of hi-technology firms, their employment and distribution across industrial sectors in the region. Figures 1 &2 are based on the latest revised figures made available by Jill Tufnell, CCC.

The definition of high-tech adopted by the CCC is a modification of the Butchart (1987) classification (detailed in Table A1.1 below). Though the Butchart definition forms the starting point firms are evaluated for the hi-tech content of their activities on an individual basis. Thus, R&D activities in non-high tech fields (e.g. market research) are not included. On the other hand, specialist computer retailers and publishers of hi-tech CD-Rom, internet page developers etc. are included. The categories of special firms included or excluded are described in each report.

Survey of 50 hi-technology firms conducted by the Centre for Business Research
A second valuable set of data is the published findings of a survey of 50 hi-technology firms conducted by the Centre for Business Research at the University of Cambridge in 1996. This second set of data has been utilised extensively to assess the importance of different mechanisms of collective efficiency in the cluster and form the basis for Tables 2, 3, 4, 9, 10, 11 &12.

Details about the survey and how it was conducted may be found in Lawson *et al* (1999). Here, we note that the distribution of the sample of firms was differed in some respects with that of the underlying population. In particular, firms with a larger size (greater than 100 employees) were over-sampled in the survey, partly because the response rate for this size class was higher than that for others. Table A1.2 contains the size distribution of firms in the Cambridge survey sample, with that published by the CCC for end-1995.
Newspaper clippings

Newspaper clippings over a long period (1989–2000) were a third important source of information on particular companies and on broad qualitative changes such as those of strategy. Local newspaper clippings were available in the Cambridgeshire Public Library. For clippings from the National press and business newspapers, the MaCarthy's database of newspaper clippings was used.

Table A1.1 Butchart's High technology industry definition

SIC 1980	Industry description
2514	Synthetic resins and plastics materials
2515	Synthetic rubber
2570	Pharmaceutical products
3301	Office machinery manufacture
3420	Electronic data processing equipment manufacture
3441	Basic electrical equipment
3442	Telegraph and telephone apparatus and equipment
3443	Electrical instruments and control systems
3444	Radio and electronic capital goods
3444	Components for electronic equipment
3453	Active components for electronic sub-assemblies
3640	Aerospace equipment manufacturing and repairing
3710	Measuring, checking and precision instruments and apparatus
3720	Medical and surgical equipment and orthopaedic appliances
3732	Optical precision instruments
3733	Photographic and cinematographic equipment
7902	Telecommunications
8394	Computing services
9400	Research and development

Table A1.2 Distribution of firms in sample and population (% of all firms)

Size (number of employees)	CBR sample (1996)	CCC census End-1995
0–5	36	40
6–10	18	20
11–24	4	18
25–49	4	10
50–99	6	6
100–199	6	3
200–499	14	2
500+	-	1

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.

[1] The sharp divergence between the views of the economists on one hand and the views of the economic geographers is summarised in a critical review by Martin, RL (1999).

[2] 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.

[3] 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.

[4] 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.

[5] This study adopted a definition of high technology based on Butchart (1987).

[6] Estimates are taken from *Guardian*, 15 April 2000, "Where talent and ideas meet money" by James Meek.

[7] See for example studies by Galbraith (1985), Oakey and Cooper (1989) and Haug (1991).

[8] Their definition of Cambridge region is much vaster than that employed in this paper.

[9] The results of the regression analysis are reported in SQW(2000), Tables 12.9 & 12.10.

[10] This sketch of Acorn Computers is based on several secondary sources and newspaper clippings.

[11] 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".

[12] 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.

[13] Appendix 2 contains the Tables A2.2-3 that charts the sectors of gains and losses in employment.

[14] Estimates from "Cambridge set to take UK venture capital lead" *Cambridge Evening News*, 2 March 1999.

[15] This information has been collated from different volumes of the *Cambridge Reporter*.

[16] See Appendix 2 for table on which this inference is based.

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

[18] All differences are statistically significant. See SQW (2000), table 12.8.

[19] 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!

[20] I have seen this argument first made in Schwerin, J. (2000) 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.

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