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When High Tech ceases to be High Growth: The Loss of Dynamism of the Cambridgeshire Region

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When High Tech ceases to be High Growth: The Loss of Dynamism of the Cambridgeshire Region

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Abstract
This paper analyses mechanisms of decline and renewal in high-tech regions, illustrated with empirical evidence on the Cambridgeshire high-tech region in the UK. The paper contributes to ecological (‘carrying capacity’) and evolutionary (path dependence) theories of regional development. It provides a longitudinal, multilevel analysis of invention, firm, and industry dynamics and change in the supply and costs of resources in order to explain the decline of high-tech regions. While expansion of the Cambridgeshire high-tech region has been sustained over time, recently forces of decline have been stronger than those of renewal. Decline in employment has been most marked in the local telecommunications and biotech sectors, while the creation of variety by new firms has fallen off most strongly in the local IT software & services industry. Increasing diseconomies of agglomeration are in evidence, together with a contraction of finance that may have been a harbinger of financial stringency to come.

Keywords: high-tech regions, industrial dynamics, innovation, entrepreneurship, cluster decline

JEL classification: L22; M13; O31; R11

When High Tech Ceases to be High Growth:

The Loss of Dynamism of the Cambridgeshire Region

1. Introduction

Regional concentrations of related economic activities (clusters) have received considerable attention in a number of academic disciplines. Most studies have focused on the success of particular clusters (Saxenian 1994; Tallman et al. 2004; Glasson et al. 2006), and some on their emergence (Garnsey 1998; Braunerhjelm and Feldman 2006). While there has been particular attention to the decline of old industrial areas (Grabher 1993; Boschma and Lambooy 1999; Potter and Watts 2011) we know very little about the mechanisms and processes that lead to the decline and possible renewal of high-tech regions. High-tech regions are not immune from decline: they are subject to limits to growth like any other regional economic system. An understanding of these issues begins with analysis of industrial and corporate dynamics in regions. The long-term growth of a region depends on the emergence of new industries that compensate for the decline of previously strong sectors, that is, on processes of adaptation, conversion and replacement.

Two contrasting propositions regarding the emergence of new industries can be derived from the literature. The first is the argument that new industries are unlikely to emerge in existing ('old') clusters, mainly because of the congestion and 'negative lock-in' effects (Martin and Sunley 2006) that are likely to arise after a cluster has reached maturation (or what might be called 'negative path-dependency'). This proposition connects to geographical economic agglomeration theories (Brezis and Krugman 1997; Maggioni 2006; Potter and Watts 2011), and to economic geography theories on ‘myopia’ in clusters (Maskell and Malmberg 2007). A second, contrasting, proposition is that new industries are in fact more likely to emerge in existing clusters precisely because new industries build on the knowledge and skills that have been accumulated within more mature industries within these localities (‘positive path-dependency’). This proposition connects to theories on organizational birth and heredity (Audia et al. 2006; Klepper 2007; Brenner and Fornahl 2008) and cognitive theories of recombination (Nooteboom 2000), and reflects a process of techno-industrial diversification (Best 2002; Frenken et al. 2007; Frenken and Boschma 2007).

Which of these accounts is correct may of course depend on the specific context concerned, on the nature of the existing industries in a cluster, on the stage of their development, on the resource base inherited from those sectors, on the technological complementarities and needs of new activities, and a host of other factors. The basic point, however, is that the continued successful development of a cluster is by no means assured, but is the outcome of a balance of forces, some making for growth and renewal, some for slowdown, stasis or even decline. Clusters are obviously not static phenomena but evolutionary systems, and they can and do undergo slowdown and decline: indeed, the economic landscape is littered with examples of the remnants of once highly successful clusters, industrial districts and regional specialisms. This paper aims to provide new insights into the decline and renewal of high-tech clusters and regions through an analysis of the mechanisms bringing about their decline. The paper contributes to ecological (‘carrying capacity’) and evolutionary (‘path dependence’) theories of regional development. It provides a longitudinal, multilevel analysis of invention, firm, and industry dynamics and change in the supply and costs of regional resources in order to explain the decline of high-tech clusters and regions. The latter aspects provide empirical indicators of the 'carrying capacity' of regions affecting all high-tech firms, while the former aspects are more direct indicators of path dependent trajectories of industries within the region. Drawing on these ideas, we explore explanations for and implications of the decline of high-tech regions with special reference to evidence on the Cambridgeshire high-tech economy, one of the leading regions in Europe in terms of R&D, patenting, and venture capital investment. The concluding section raises some implications from this empirical case study.

2. Theories about the decline of high-tech regions

To what extent and how does the history of a region enable or constrain its further development? Industrial history is embodied in the present. Choices made in the past - technologies embodied in machinery and product design, firm assets gained as patents or specific competencies, or labour skills acquired through learning - influence subsequent choices of method, designs, and practices (Walker 2000). Regional (and cluster) development is a path-dependent process (see Martin and Sunley 2006; 2011). Once a particular specialism or group of interlinked industries becomes established in a locality, various external economies and increasing return effects emerge which act to reinforce the further local development of that specialism, and - for a while - provide the momentum for continued local economic growth. We know, however, from numerous empirical examples, that sooner or later this growth momentum slows and may even turn into decline. The path dependence literature typically attributes this slowing down to various 'lock-in' effects, whether technological, cultural, cognitive, institutional or some other kind, that weaken or even undermine the external economies associated with localised specialisation and clustering. Once ‘positive’ path dependence then turns into ‘negative path dependence’. Some authors see this evolutionary pattern of the rise and (relative or absolute) decline of clusters and regions in ‘life-cycle’ terms (see Audretsch and Feldman 1996; Brezis and Krugman 1997; Audretsch, et al. 2008; Potter and Watts 2011).

Whether or not the standard life cycle model is a valid depiction is open to question (see, for example, Menzel and Fornahl 2010; Martin and Sunley 2011). But in any case, such a perspective of itself tells us little about why, when a particular industrial cluster or localised specialism begins to lose its growth momentum, other local industries fail to emerge to take the place of the activity that is waning. The economic history literature, however, provides several arguments as to why new industries tend typically to develop in areas different from the old industrial concentrations. For example, Checkland (1976) suggested that a long-standing concentration of an old, mature industry in a locality could actively undermine the conditions needed for the emergence of new sectors there, what he called a ‘Upas tree effect’ (cf Van Stel and Storey 2004). Using this idea, he argued that Glasgow’s economic decline occurred because its specialised concentration on custom shipbuilding deterred the development of new industries such as vehicles or aircraft. This ‘overshadowing’ of other local firms is more likely in regions with oligopolistic domination (Chinitz 1961; Markusen 1985) than in diversified economies with relatively many small firms (Dicken and Lloyd 1978). Similarly, Hall (1985) argued that each new Kondratieff wave establishes a new geography in which ‘tomorrow’s industries’ tend not to be attracted to ‘yesterday’s regions’, because the patterns of activity, skills, infrastructures and socio-cultural conditions in the latter tend to be inimical to the development of new technologies and sectors.

Likewise, Brezis and Krugman (1997) have argued that new industries are more likely to emerge outside existing centres of industry than within, because "for the new technologies the accumulated experience of existing industry concentrations may be of little value; meanwhile, existing industry concentrations present difficulties for new firms. Precisely because of their previous success, they are likely to be characterized by high land rents, prices, and wages" (Brezis and Krugman 1997: p. 370). The latter situation might reflect that in fact the local 'carrying capacity' is reached (cf. Maggioni 2006). The concept 'carrying capacity' is well known in ecological studies, where it reflects the notion that a limit on resources implies a limit on the size of a particular population an ecosystem or environment can sustain (see for example Dewar 1984). The term has acquired a specific meaning within organizational ecology studies, where it is defined as the ability of the environment to support a population of particular organizations. The carrying capacity of environments is presumed to be of central importance in explaining organizational failure (Hannan and Freeman 1977). In economic terms, the notion might be used to convey the idea that factor endowments become constrained, or impose some sort of limit on activity or growth.

However, the concept is somewhat ambiguous since local economic 'carrying capacity' is not fixed. The 'carrying capacity' of a cluster will be a function of both locationally-fixed and spatially-mobile local factors, as applies for example to the supply of labour. If the region attracts a rising number of skilled workers from outside (e.g. by 'magnet organisations' (Harrison et al. 2004) or 'anchor firms' (Feldman 2003) attracting talent), without a similar increasing outflow of workers, this is likely to increase the 'carrying capacity' of the region. In contrast, if an increasing number of graduates and workers is drawn away to other regions, without an increasing inflow of workers, this is likely to lower the 'carrying capacity' of the region. Easing planning restrictions could also increase the supply of real estate, and in that way enlarge the 'carrying capacity' of the region (cf. Healey 2006), just as investments in infrastructure could lower congestion costs. The limits of the 'carrying capacity' of a region reflect constraints in the supply of particular resources including labour, real estate, and venture capital. Among the symptoms of this constrained supply are a lack of growth of incumbent firms and start-ups, and out-migration of incumbents – the collective effects of which are seen in trends in overall regional growth and decline. The overheating of a region could lead to cost-based competition between regions. With the growth of a region's high-tech economy, the labour market may tighten, wages will rise, and land costs could be driven upwards with increased pressures on the housing stock. This diminishes the attractiveness of the region as a place to live, work and produce. Porter (1998: 245) is optimistic that market forces will correct such imbalances: "Rising local wages and profits reflect economic success. This means that less skilled and less productive activities should move to other locations". However, if these firms are labour intensive this could lead to an overall decline of employment in the region. And the outward movement of capital and labour from a region can work not to restore a region's growth dynamic, but serve instead to intensify its decline.

The 'carrying capacity' argument holds that as the number of firms located in a cluster (or region) increases, gross agglomeration benefits increase only initially, sometimes after a particular critical mass is reached. This occurs because of agglomeration economies, resulting from such factors as productive specialization, knowledge spillovers, access to specialized labour and reduced transaction costs. However, with further expansion the increase in benefits from agglomeration may slow and disadvantages may begin to appear and outweigh the benefits, as the negative effects of increased congestion (high land rents, prices, wages, and increased transportation costs) exceed agglomeration economies. Potter and Watts (2011) invoke the idea of the 'life cycle' to capture this evolutionary path of agglomeration economies. In fact, agglomeration has been formally described as a concave non-monotonic function of the number of firms already established in a cluster (Maggioni, 2006). The point at which the agglomeration benefits decline is assumed in this approach to reflect the threshold of the 'carrying capacity' of a cluster (and the region in which it is located). When the 'carrying capacity' is reached, every new entrant is contributing to a lower average net benefit available to the firms located in the cluster, reflected in a decreasing average performance of the firms in the cluster (and region) concerned. Thus while the (claimed) benefits of cluster growth are well known (higher innovation and productivity levels, higher new firm formation rates), a number of disadvantages may develop over time, related to either the nature of local techno-industrial knowledge or to increased resource costs (Martin and Sunley 2003).

In brief, two propositions regarding the emergence of new industries – and renewal of high-tech regions - can be derived from the literature. First, new industries are unlikely to emerge in existing high-tech regions, because of the congestion effects and techno-industrial lock-in that are likely to arise after a cluster has reached maturation ('negative path-dependency'). The congestion effects constrain profitable exploitation due to increasing costs of resources, while techno-industrial lock-in refers to constrained exploration of new possibilities. Second, new industries are more likely to emerge in existing high-tech regions because new industries build on knowledge built up in older industries that is more likely to be accumulated within high-tech regions than outside ('positive path-dependency'). It remains an empirical question whether positive or negative path-dependency will dominate in regional industrial dynamics: path dependency can have self-reinforcing positive effects (high local growth, high invention and innovation levels, high entry rates), but can also induce self-reinforcing negative effects, including technological lock-in (local growth decline, low inventive and innovative activity, low entry rates, increasing exit rates). In what follows, we seek to identify what role these mechanisms might play in the evolution of regional industrial dynamics in term of the specific case of the Cambridgeshire high-tech economy. This high-tech cluster, which first began to develop in the 1960s, has until recently been one of the fastest growing and most innovative regions in the UK. But in a recent period it seems to have lost its former growth dynamic, a development that has attracted increasing concern from local policy makers, and indeed from the local high-tech community itself.

3. Dynamics in the Cambridge high-tech economy[1]

3.1 Historical background

Although the origins of Cambridge's high-tech economy are often traced back to the 1960s, and especially to the establishment of Cambridge Consultants, a research-based technology spinout from the University, in 1960, it was not until the early-1970s, and the setting up of the first science park, that the region's high-tech development began to crystallise, and even then for much of the 1970s growth was

[1] See Appendix 1 for research design and data.

slow and uncertain (Gould and Keeble 1984; Keeble 1989; Garnsey and Cannon-Brookes 1993). The real take-off of the Cambridgeshire high-tech economy - often referred to as the 'Cambridge Phenomenon' - took place from the early-1980s onwards (see Figure 1) (Garnsey and Lawton-Smith 1997; Druilhe and Garnsey 2000). Until the mid-1980s high-tech activities consisted mainly of instrumentation, electrical engineering and some IT. The second half of the 1980s saw the rapid growth of computer services and the emergence of the biotech sector, mainly from the University and other research institutes. In this period, an increasing number of multinational subsidiaries were attracted to the area, mainly focusing on R&D. This chiefly took the form of implant sites (e.g. Napp Pharmaceutics, Schlumberger, IBM, Marconi, Siemens, Microsoft, Toshiba, AT&T), but also involved the takeover of indigenous Cambridge firms, as when Arthur D Little took over CCL (founded in 1960) in 1971, Olivetti took over Acorn Computers (founded in 1979) in 1985, and McDonnell Douglas took over Applied Research of Cambridge (founded in 1969) in 1985. The latter trend continues, notably with the takeover of promising biotech firms, which has intensified since the late 1990s (see Mohr and Garnsey 2009).[2]

[2] This might be harmful for the new firm formation rate in the region: research on the Canadian biotech industry (Hennessy 2009) showed that the presence of acquisitions in the region tends to dampen entrepreneurial entry.

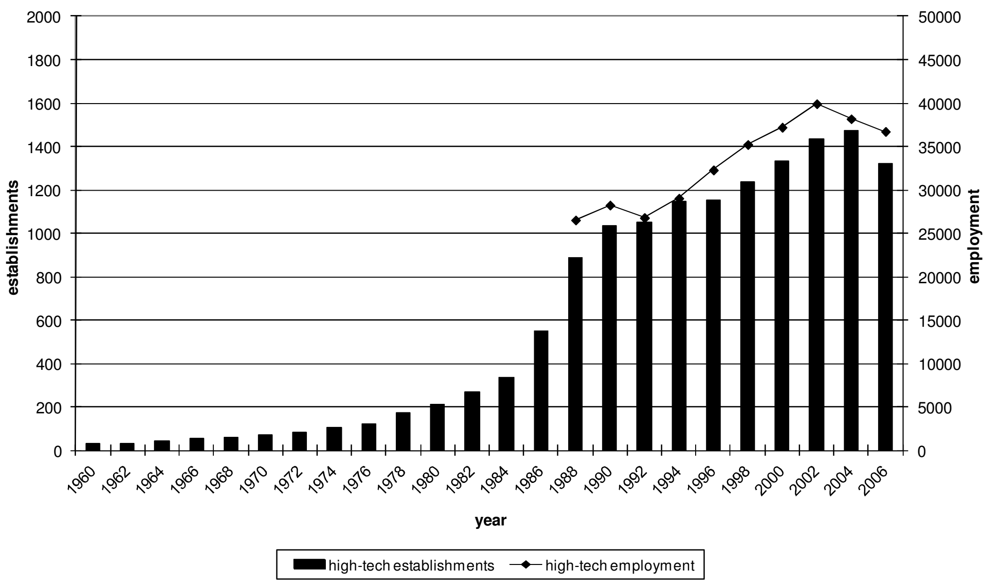

Figure 1. High-tech establishments and employment in Cambridgeshire 1960-2006 (Sources: Keeble 1989; Segal et al. 1985; Garnsey and Cannon-Brookes 1993; CUED database)

The development of the IT software and services sector in Cambridgeshire is very similar to the development of this sector in the UK more generally (SIC 722), with the difference that there was no decline in 2005-6 in the UK as a whole. However, the biotech sector has grown much faster in Cambridgeshire than in the UK overall (a growth of 101 percent over the period 1988-2002 compared to 12 percent for the UK). The location coefficient for this sector has been around 5.0 in the period 1994-2006, indicating a distinct regional specialization of Cambridgeshire in biotech activities. The growth of biotech and IT in the 1990s compensated for the gradual decline in the electrical engineering and the instrumentation industries.

By the end of the 1980s, high-tech activity in the locality reached critical mass through a set of virtuous cycles as firms created value for customers, which fed back into the area, benefiting other firms and attracting in yet others, as well as inflows of scientific and technical workers. A small set of start-ups developed into industry leaders in technology consulting (CCL) and computing (Acorn), and spun-off a larger set of industry leaders in IT hardware (Domino, ARM, CDT, CSR) and software (Cambridge Interactive Systems, Autonomy). This critical mass of high-tech activity also led to the emergence of an informal investors' community in the local area and the attraction of venture capital funds, together with the spontaneous emergence of an institutional support system of local organisations and social capital (Keeble et al. 1999; Myint et al. 2005). A number of significant serial entrepreneurs and informal investors emerged as role models and sources of knowledge and financial resources for high growth start-ups in the region.

The Cambridge Phenomenon continued to grow, despite recessions in the early 1980s and early 1990s, and even the bursting of the 'dot.com' bubble in 2000 had little immediate impact on the cluster. The recessions even heralded the rise of new industries: the IT hardware in the early 1980s and the telecoms in the early 1990s. A trend towards clustered diversity of the local high-tech economy is in evidence (Figure 2). In practice the boundaries between the sub-clusters are fuzzy and they often overlap. In organizational ecology terms, the Cambridge high-tech economy is a regionally bounded community of related populations of high-tech activities (cf. Aldrich 1999; Audia et al. 2006). By 2002, it is estimated that the high-tech cluster comprised over 1400 establishments employing as many as 40,000 workers.

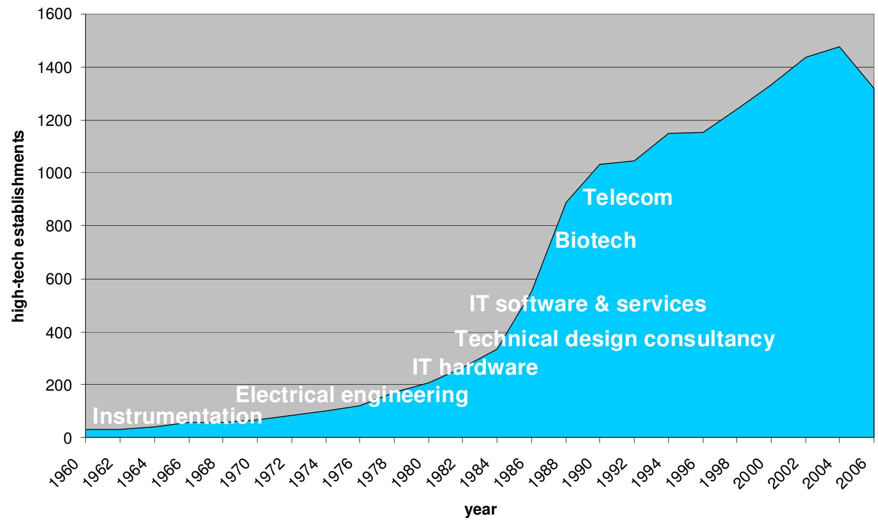

Figure 2. The cumulative diversification of the Cambridge high-tech economy

From around 2002, growth has stalled with decreasing high-tech employment, and a decrease of 10 percent in the number of all high tech establishments since 2004 (Figure 1). Related figures on Gross Value Added (per capita) in Cambridgeshire reveal a similar pattern with considerable growth in the late 1990s, but a slowing down of growth in the early 2000s (Simmie et al. 2006). However, the Cambridgeshire economy as a whole did not see a decline in the number of firms of all types in the early 2000s, which grew steadily from 19,900 firms in 2000 to 22,335 firms in 2006 (VAT statistics BERR).

3.2.1 Recent industry dynamics

The decline of high-tech manufacturing activity in the last two decades was offset by the rise of IT software & services and biotech, and R&D activities more broadly. Though trends in other local industries also affect aggregate numbers, these influences are overshadowed by the dynamics in the more numerous biotech and IT software & services firms. The technological specialization of the Cambridgeshire high-tech economy is also revealed by data showing that in 2004, East Anglia had the second highest number of patent applications per million working population of Europe in both ICT and biotech (OECD 2007; see also Sunley and Martin 2007). But competitive advantage in knowledge production in ICT and biotech did not afford the region market leadership in ICT (Bresnahan and Malerba 1999) or biotech as compared with other regions (Casper 2007).

Employment

Figure 3 shows that high-tech employment in Cambridgeshire faced a net decline in the early 1990s recession. However, the decline in the period 2003-2004 was greater, and continued in the subsequent period. This decline involved a decrease in employment by start-ups (from 2614 jobs in 2001-2 to 1452 jobs in 2003-4) and a decrease in employment by growing incumbents (from 6030 jobs in 2001-2 to 3978 jobs in 2003-4). While it is possible that reduced job creation by start-ups results from the attraction of local entrepreneurial talent to incumbent firms, the growth of such firms also declined in the early 2000s. This was accompanied by a somewhat less dramatic increase in jobs lost by exits (especially in 2003-4) and the shrinking size of incumbent firms.

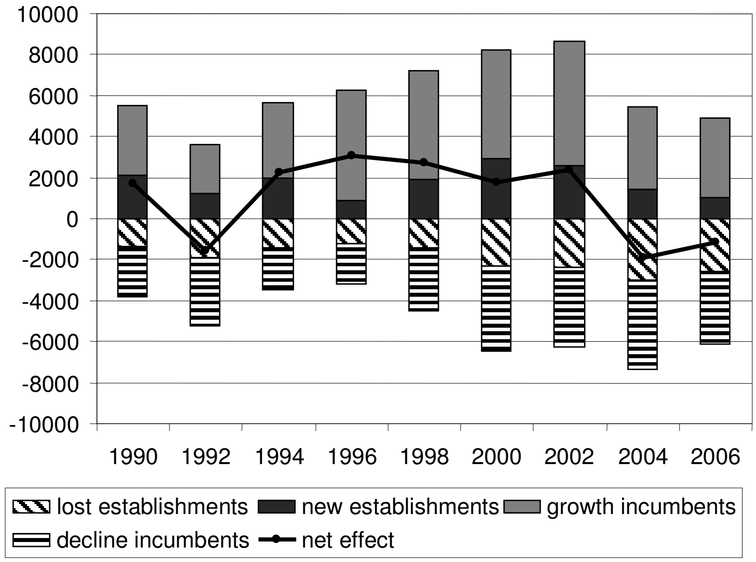

Figure 3. Employment dynamics in firms

The 51 percent increase in employment in the 1987-2002 period was mainly driven by the IT software & services and biotech sectors, which increased their share in total employment from about 25 percent in the last ten years to almost half of all employment at the end of the period. In contrast, the telecommunication sector lost almost half of the maximum level of employment it reached in 1998 (see Figure 4). Most of the 3,186 jobs lost (8 percent decline in the 2002-2006 period) were eliminated in telecommunications (858) and biotech (783), with very few job losses in IT software & services, and net job growth in R&D and technical design.

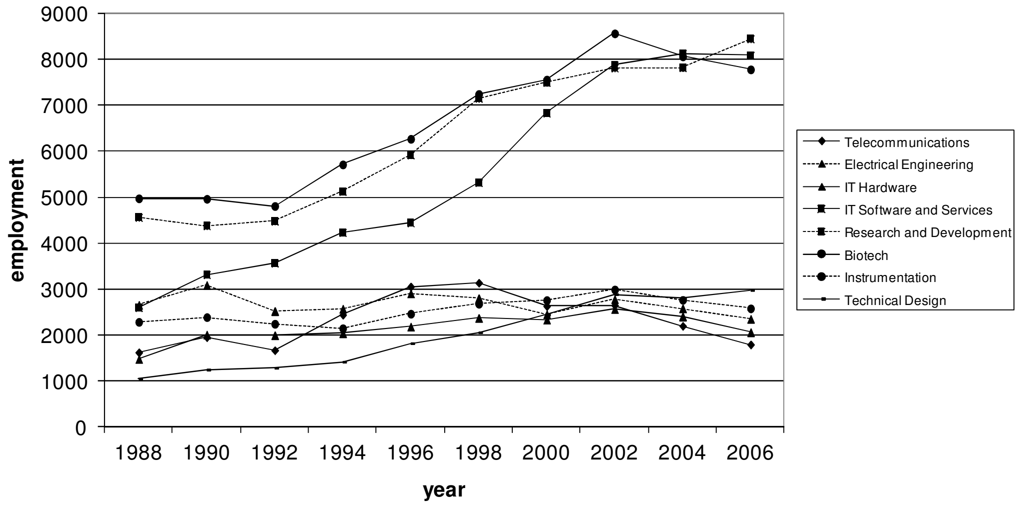

Figure 4. Employment dynamics in sectors

Employment in the biotech industry is dominated by a few large research institutes receiving industrial as well as pubic sector funding, including Bayer, Sanger Centre and the Babraham Institute, all having more than 400 employees. These three large organizations have gone through contrasting development paths: Bayer (owning a local agri-business firm subject to serial acquisition) has shrunk from 700 employees (1988) to only 100 employees in 2006, the Sanger Centre has grown from 53 employees (1994) to 797 employees (2006), while the employment of the Babraham Institute more or less stabilized around 400 employees.

The IT software & services sector is dominated by a large number of small firms. In the whole regional high-tech economy, there were only 7 establishments with more than 500 employees and 81 establishments (5.1 %) with 100 or more employees in 2006. This reveals the lack of large anchor firms (cf. Feldman 2003), which could have made the high-tech region more robust against external shocks, as smaller firms are more likely to exit in unfavourable economic circumstances (either via bankruptcy or by acquisition) than these large anchor firms.

Establishments

The number of establishments in the manufacturing oriented sectors electrical engineering and IT hardware has declined considerably over the period 1987-2006 (see Figure 5). Both have also seen their share in the total population reduced by 50 percent during the period. In contrast, both IT software & services, and biotech have seen their share considerably increased, and the absolute number of establishments in these sectors has more than doubled. The technical design sector shows a different pattern: almost doubling in size over the period 1988-1998 (57 to 106), followed by a steady decline from 106 to 81 firms in 2006. A similar, but lesser development can be found in the older instrumentation industry, with a growth from 78 to 111 firms in 2000, and a slow decline to 100 firms in 2006.

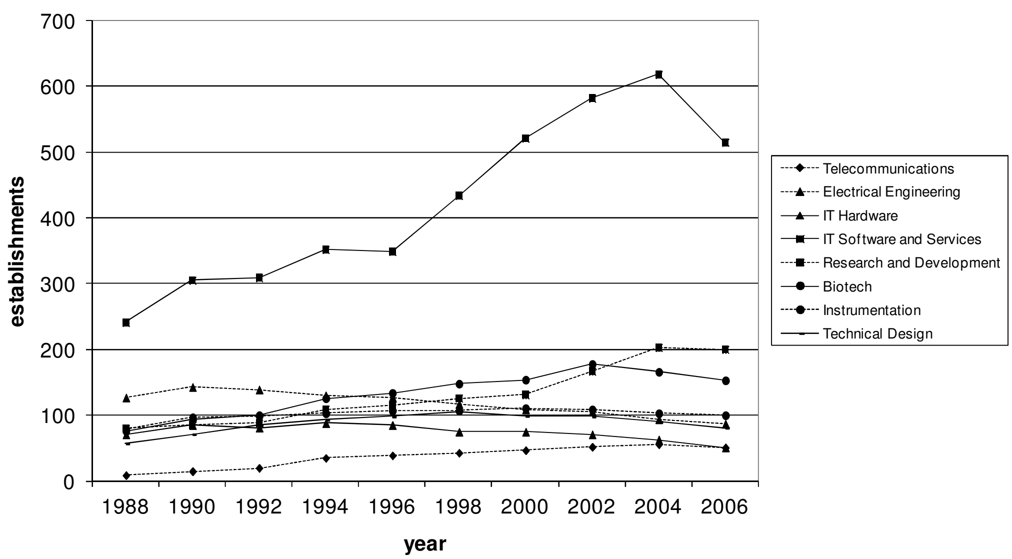

Figure 5. Business dynamics in sectors

Two potential sources of techno-industrial diversification whose expansion has come to a halt recently are inventions (patents) and new firm formation. These two sources are discussed next.

3.2.2 Patents

Inventive activity, and its codification in patents, is one of the most commonly used indicators of new economic variety. The number of patents increased dramatically in the period 1987-2001. Both in the US (USPTO) and the UK (UKIPO) the number of patents doubled in this period, while the number of patents in Cambridgeshire – which was already three times higher (per capita) than in the UK in 1987 - has more than quadrupled (see Figure 6). The majority of patents belong to the biotech or ICT patent classes. The number of patent applications has stagnated in Cambridgeshire in the early 2000s, with a continuing decline in the number of biotech patents (in line with national and global trends) and ICT patents (in line with the national trend, but not with the stagnation in number of ICT patents globally). With respect to the relation of patenting with employment growth, we have to take into account that there is a time-lag of about three years between inventions and subsequent firm growth (see Ernst 2001). On the other hand, a shortage of cash - which is also likely to negatively affect firm size – is likely to have a negative effect on the number of patent applications directly, as is reflected in the immediate decline of the number of patents with the dot.com bust in 2001.

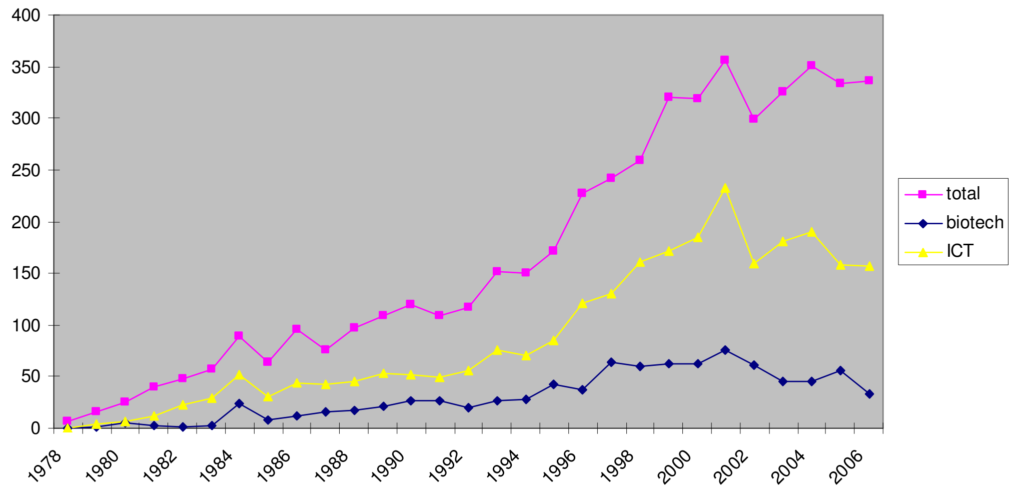

Figure 6. EPO patents in Cambridgeshire (total nr, biotech, and ICT; period 1978-2006)

3.2.3 New firm formation

Another indicator of the creation of variation can be found in the number of new establishments. Figure 7 shows that the most dramatic decline in the number of entrants was in the period 2005-6 in which only 92 establishments entered, in comparison to 249 establishments entering in the previous two year period. The decline in number of entrants is much more dramatic than the increase in the number of exits (see Figure 11), suggesting that the reduction in firm start-up numbers was a more important component of decline in the high-tech economy than the increase of the number of exits. During the boom years the number of start-ups was unprecedented.

The sector leading employment growth from 1987 to 2006 – IT software & services – produced the lowest number of new establishments during the period 2003-6 after a period of enormous growth. The number of start-ups in biotech also decreased in this period, but did not reach a historical low. If these once leading sectors have ceased to be sources of variety, it is not yet clear whether new sectors will emerge as creators of variety.

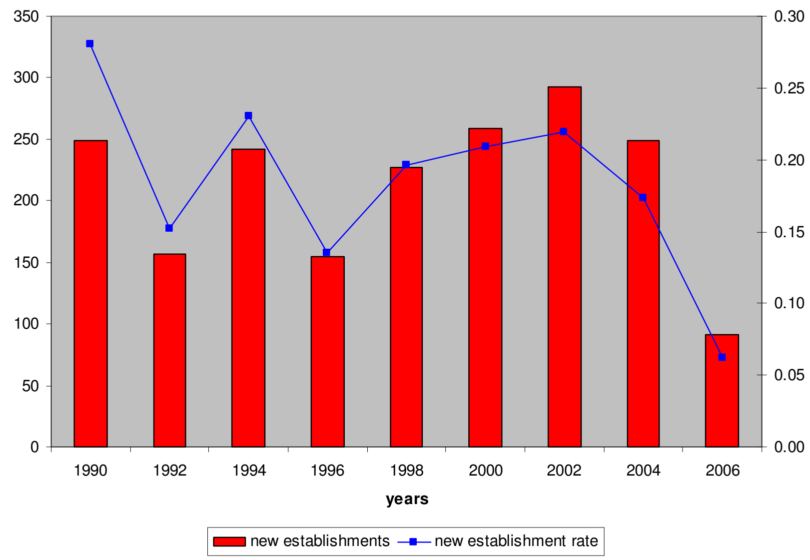

Figure 7. New establishments

The number of spin-offs is a more specific indicator of local variety creation than the total number of new establishments. It is clear that spin-offs from the university and the technical design consultancies were very responsive to the technology boom of the late 20th century, reaching unprecedented levels at its height and falling back to levels found before the boom after 2002 (see Figure 8). The decline of the number of spin-offs is even more pronounced than the decline of the total number of high-tech entrants.[3]

[3] Figure 8 suggests that it is unlikely that the decline of new firms – especially in IT software & services – has been driven by changes in intellectual property rights regulations of the University of Cambridge (as Breznitz (2011) claims) since this pattern is also found in the technical design consultancies spin outs. In 2005 the university introduced intellectual property rights (IPR) regulations,

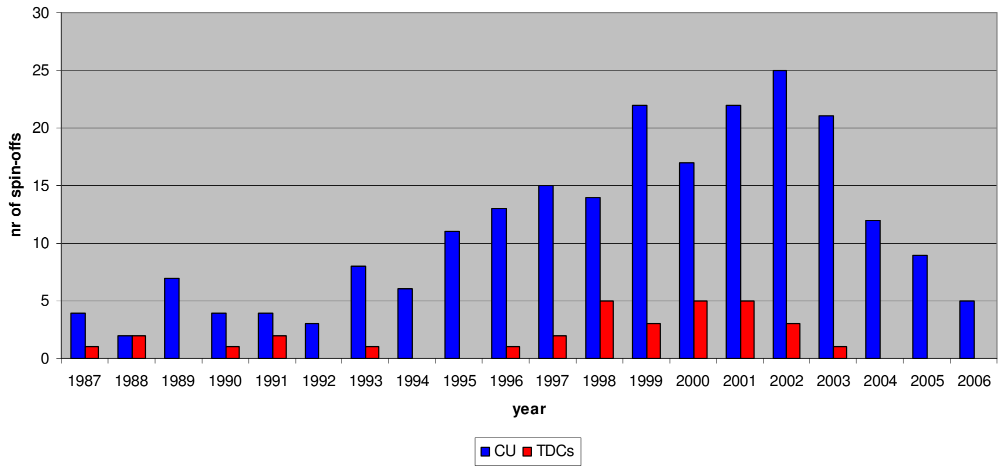

Figure 8. Spin-off firms from the University of Cambridge and three leading technical design consultancies

3.2.4 New firm growth

It has been said that one of the problems of the Cambridgeshire high-tech economy is that it has relatively few new firms that reach a substantial size (Athreye 2004). But in other places too, longitudinal cohort studies of new firms have shown that only very small portions of a cohort reach a substantial size within six years after start-up: about 1 to 8 percent grow to a size of 20 employees or more, and less than 1 percent grows to a size of 100 employees or more (Storey 1997; Stam et al. 2008; Anyadike-Danes et al. 2009). We traced the number of firms in the cohorts from 1990 to 2000 that had grown to a size of at least 20 or 100 employees. Figure 9 shows that about 12 percent of the entrants reached a size of at least 20 employees, and about 2 percent reached a size of at least 100 employees within six years after formation. These numbers are

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ending a period of relatively liberal 'laissez-faire' IPR policies. This new IPR regulation makes the university the owner of any new invention: the university has the initial right to apply for a patent, with revenue sharing arrangements between the university, the inventor and the department from the exploitation of these inventions.

thus relatively high in comparison to other cohort studies on populations of new firms.[4] In contrast to the survival rates (see Figure 11), the shares of high-impact entrants as a percentage of the cohort of entrants remained fairly stable over time. The absolute number of high-impact entrants is as volatile as the total number of entrants (as in Figure 7).

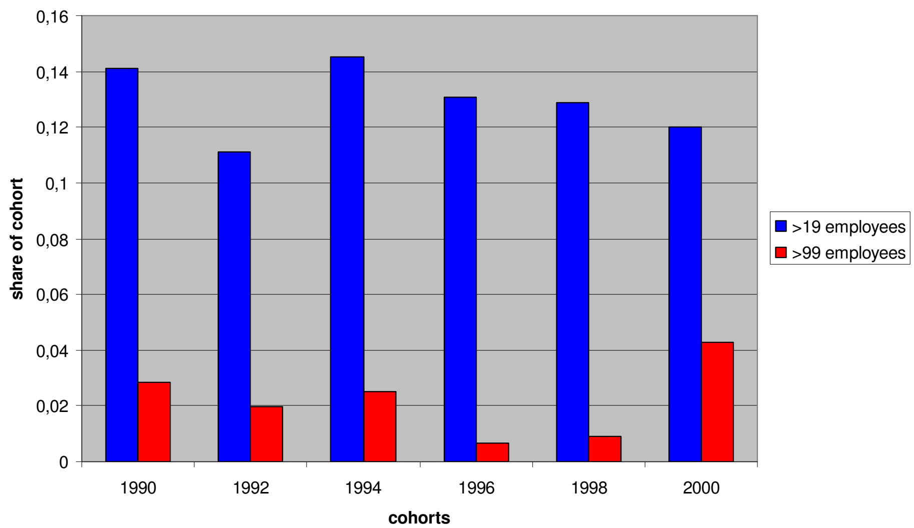

Figure 9. Size of establishments six years after formation, cohorts 1990-2000

There is even more dynamics when we disaggregate the group of high-impact entrants into specific sectors (see Figure 10). Only the electrical engineering, IT software & services, R&D, and biotech produced more than five high-impact entrants in at least one period. The number of high-impact electrical engineering entrants drops very quickly from 9 in the 1990 cohort to (almost) zero in the subsequent cohorts. The number of high-impact entrants in the other three sectors is highly volatile, with the

[4] One disclaimer might apply here, since the studies by Stam et al. (2008) and Anyadike-Danes et al. (2009) contain all industries, the number of high-growth start-ups in a population of high-tech establishments might be expected to be higher. However, other studies found that in general high-growth firms are not overrepresented in high-tech industries (see Henrekson and Johanson 2010).

number of biotech high-impact entrants remaining relatively low after the 1994 cohort (i.e. since 2000).

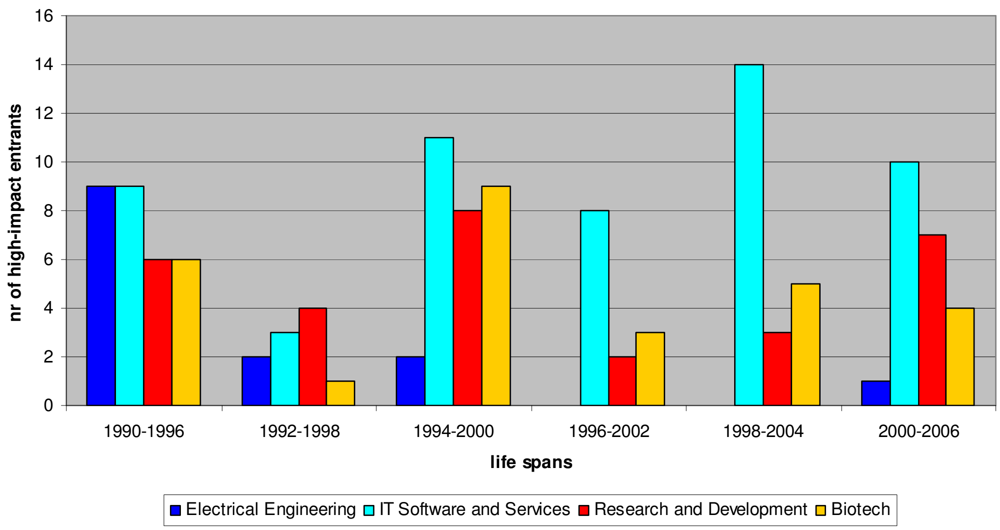

Figure 10. The number of high-impact entrants in electrical engineering, IT software and services, R&D, and biotech.

Although there are few large high-tech firms in the area, it is also relevant to examine the proportion of such firms emerging from a pool of local start ups. In comparative terms, available data show that more start-ups in the Cambridgeshire high tech region grow into medium-sized businesses than occurs in other regions (see above).

In the next section we will explore another possible explanation of the recent decline of the Cambridgeshire high-tech economy, namely the limits of the carrying capacity of the regional ecology.

3.3 Carrying capacity

'In many ways, the Cambridge sub-region has reached a major crossroads in its development. It's imperative that its growth is not held back by inadequate roads, lack of housing, traffic congestion, limited cultural facilities, and a deterioration in its quality of life. That's why it's crucial that all of the interested parties, all those who have a stake – to use that term – in the place, must work together to solve the constraints and barriers. That's why a common sense of strategic purpose is so vital. I'm glad to say that this appears to be emerging. Though the problems remain immense. But at least most of us agree on what the problems are, so that's a crucial step forward. And a consensus on what we need to do is, I believe, beginning to take shape. And a number of key developments are now in train. Given the Government's plans for the sub-region – as part of a Growth Area, growth corridor, including all those new houses planned for the area, there is added impetus to moving forward strategically. The city is too important for the region, for the national economy, for us not to find solutions' (interview: Simmie et al. 2006: 146-147).

Pressures on the carrying capacity are indicated by stabilizing or declining employment numbers, and an increase in the number of exits and especially relocations out of the region. If firms no longer expand efficiently within the region they are likely to forego further employment growth, or realize employment growth in other regions.

3.3.1 Firm exit

There has been a slow but steady increase in the number of exits since the end of the 1990s, increasing from 142 in 1997-8 to 247 in 2005-6 (see Figure 10). This is strongly driven by an increase in exits in both IT software & services, and biotech. There is also a clear decrease in the survival rate of new firms over time: the survival rates of the cohorts started in the 1990s (dotted lines in Figure 11) are considerably higher than those started in the 2000s, with a 2 year-survival rate of around 90% for the 1990s cohorts, and less than 85% for the 2000s cohorts (Figure 11).

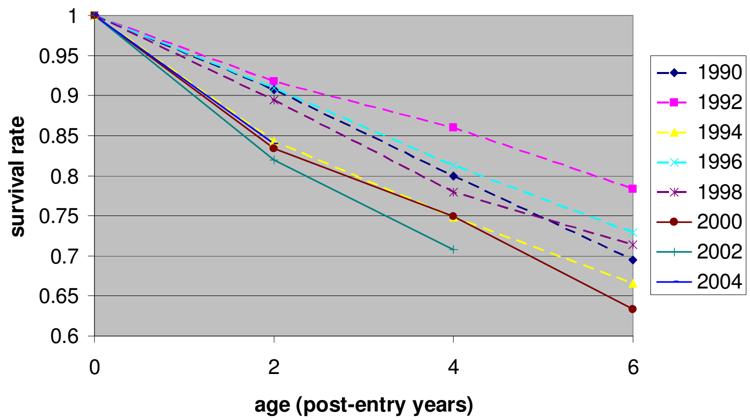

Figure 11. Survival rates per cohort

The biannual number of firms that moved out of the region has more than doubled in the period 1996-2006: from 25 firms in the period 1995-6 to 64 in the period 2005-6 (see Figure 12). Though opportunities to grow may not be constrained in an economic sense (i.e. international demand remained high), an increasing number of firms experienced spatial limits of the regional high-tech economy. Outmigration as a percentage of the total population fluctuated at around 2-3 percent until 2004, but increased to almost 5 percent in the period 2005-6.[5] The percentage of exits due to relocation out of the region fluctuated at around 20 to 25 percent.

[5] With about 41% IT software & services establishments and 14% biotech establishments, this resembles their share in the total population of establishments.

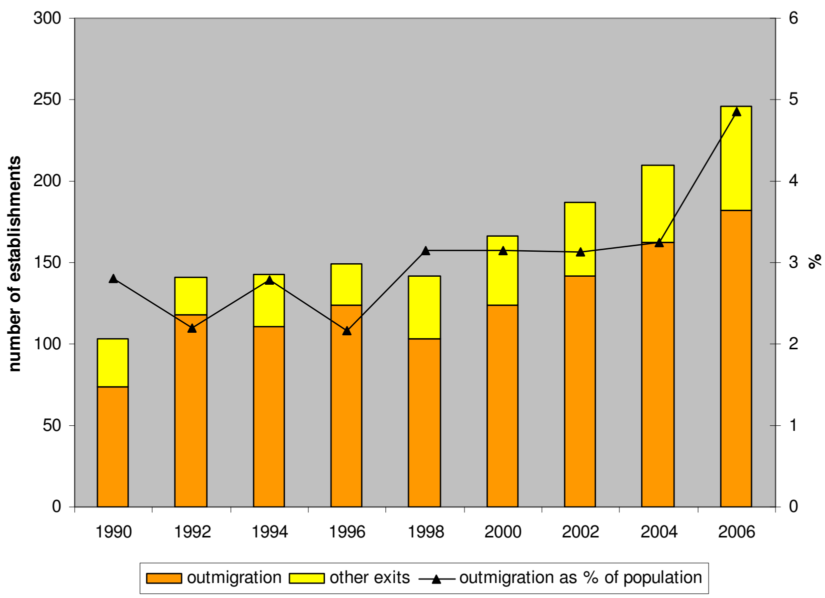

Figure 12. Outmigration of firms

The numbers on the outmigration of establishments underestimates the loss of jobs (and of job growth potential). Many firms in the Cambridgeshire high-tech economy have opened offices and divisions and even headquarters in the US. Examples of Cambridgeshire start-ups that have transferred their headquarters to the US east or west coast recently are leading firms like CCL (2007), Virata-Globespan (2004), DisplayLink (2006) and Artimi (2004). The latter two relocated just a few years after start-up. Even though these firms often maintain a branch in the Cambridgeshire area, their employment generation potential for the region declines (cf. Stam 2007). In particular, the relocation of headquarters of high-growth start-ups is likely to represent opportunity costs, reducing future employment growth in the region. These figures point to increasing spatial constraints in the Cambridgeshire region. There may be a decline of the relative attractiveness of the Cambridgeshire region from a broader business development perspective, in comparison to its competing regions Boston and Silicon Valley (cf. Bresnahan et al. 2005).

Thus a number of resource constraints may be at work underlying the stalled growth of the Cambridgeshire high-tech economy. Two of them – constrained supply of land (spatial planning constraints) and constrained supply of venture capital – will be discussed in the next sections.

3.3.3 Resource constraints

Among the most location-specific resources are land and housing. There have been spatial planning constraints ever since the emergence of the Cambridge Phenomenon. It could even be said that the emergence was triggered by these constraints: the development of science parks by colleges of Cambridge University reflected a reaction to a national decision in 1968 to refuse permission to IBM to set up its European headquarters in Cambridge (Healey 2006). Even though the national government eased its planning restrictions with respect to science-based industries in Cambridge in the 1970s, planning policies have ever since reflected the tension between protecting the historic and rural character of Cambridge (a legacy and tourist attraction) and encouraging high-tech economic development (Healey 2006; cf. Oxfordshire: Glasson et al. 2006). There were already severe pressures in the housing market and increasing traffic congestion when the high-tech economy took off in the 1980s.[6] There have been dramatic increases in house prices in Cambridge, tripling in the period 1996-2006. The median house price in Cambridge was 30 percent higher than the England median in 1996, but was 52 percent higher in 2001 and remained 36 percent higher in 2006 (see Figure 13), showing that house prices were a greater constraint in Cambridge than in other regions. In contrast to the housing prices, the labour costs (median annual pay) did not increase more in Cambridge than it did in

[6] This was similar to the situation in Silicon Valley in the late 1970s: at that time it was expected that Silicon Valley would stop growing because of too high housing prices, transportation congestion and environmental degradation (Saxenian 1980).

England as a whole in the period 1999-2006. Thus in Cambridge the ratio of house price to local salaries has increased considerably. Traffic congestion contributed to erosion in quality of life factors (especially housing) which had earlier given Cambridge a comparative advantage.

This trend is likely to have a net detrimental effect on new firm formation, since the nature and size of the residential workforce is a key determinant of the size of the population that is willing to start a new firm (cf. Bönte et al. 2009). On the one hand increasing house prices could provide larger collateral for loans to start up a business. On the other hand, many potential newcomers to the region and recently graduated students will not be able to live in the area. The latter effect is likely to be stronger than the former, as especially young and higher-educated individuals have the highest probability to start (high-growth) start-ups (Bosma 2009). This effect is stronger for Cambridge city than the larger Cambridgeshire county, which is also reflected in the stagnation of the overall number of new firm registrations in Cambridge city in contrast to the growth of new registrations in Cambridgeshire county in the 1996-2006 period (VAT statistics BERR). In addition, the relatively high rise of housing prices also makes it more difficult for incumbent firms to attract labour from outside the region, and might be one of the factors triggering relocation out of the Cambridge area.

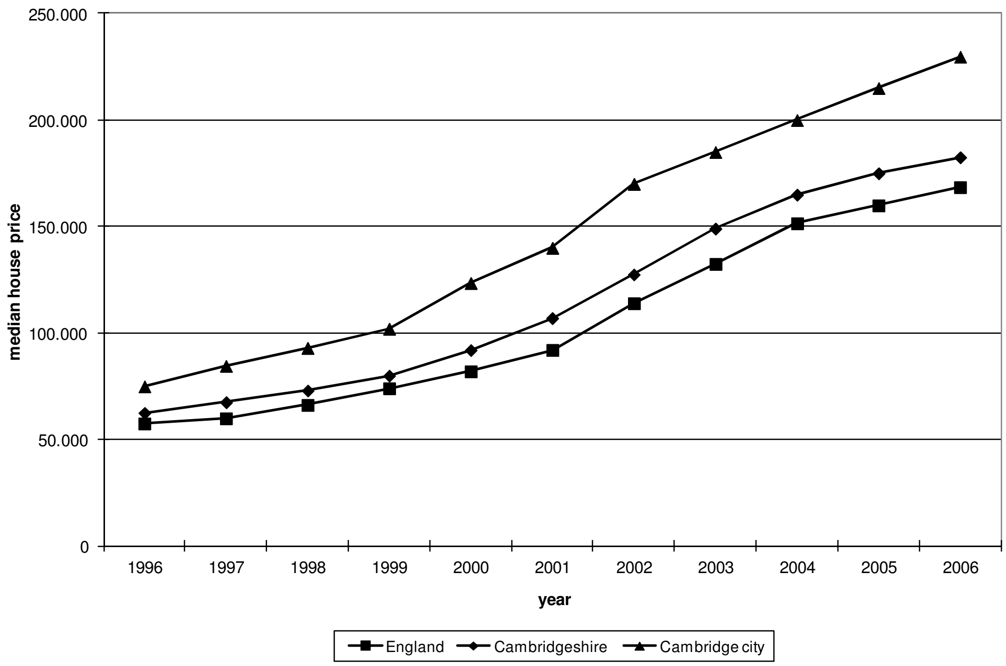

Figure 13. Median house price in England, Cambridgeshire and Cambridge.

3.3.4 Venture capital investments

The Cambridgeshire area was for a period the area with the highest level of venture capital invested per capita in Europe (Hugo et al. 2007). The majority of the venture-backed firms in the region in 2006 were formed at the turn of the millennium (Hugo et al. 2007) when investment levels were on a historical high. Before the mid 1990s the supply of venture capital was marginal in comparison with other sources of funding to new firms.[7] Investments in the region reached an historical high in 2001 (just over £300 million), declined very strongly afterwards, and remained fairly stable around £150 million a year since 2003 (Figure 14).[8]

[7] For example, the total supply of venture capital in the somewhat larger region of East Anglia developed from £38m in 1988 to £41m in 1995, and only really taking off to £165m in 1998 (BVCA 2001).

[8] This decline and stagnation of venture capital investments might be compensated to some extent by the increase of business angel investing since the early 2000s (see Pierrakis and Mason 2008).

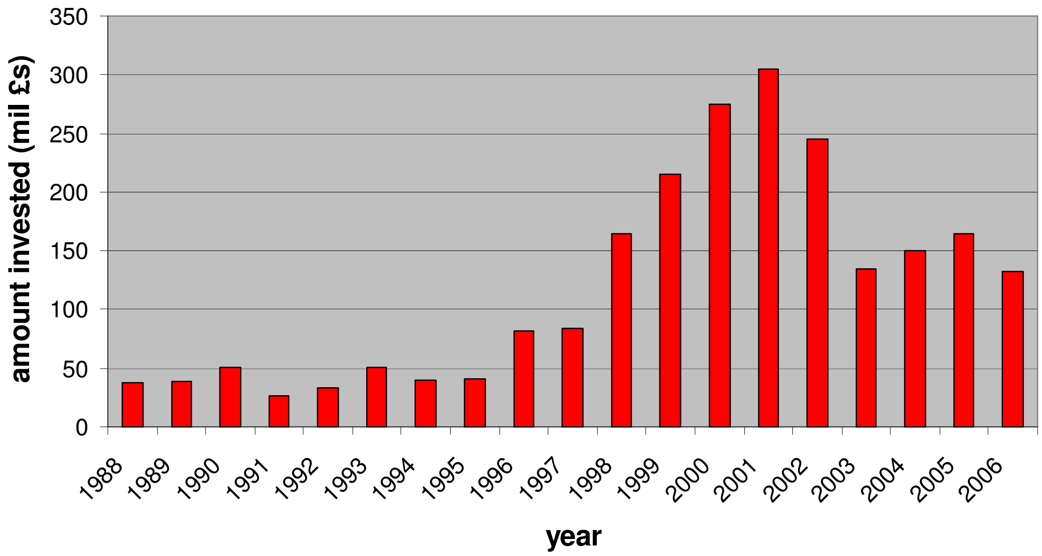

Figure 14. Funding raised by Cambridge Cluster firms 1988-2006

From the late 1980s until the mid 1990s the region contained less than 1,000 VC induced jobs, while from the mid 1990s the number of VC induced jobs grew very fast to almost 6,000 VC induced jobs in 2000, and then decreasing to around 2,800 in 2004 and 2006 (see Figure 15 in Appendix 2). This estimation suggests that the enormous job growth in the late 1990s has largely been fuelled by VC investments, and similarly that the job decline in the 2000s was largely driven by the decline in VC investments. In the early 2000s VC induced jobs even crowded out endogenous jobs, which was caused by for example VC induced spin-offs that attracted employees of existing (non-VC backed) organizations.

It seems unlikely that the supply of venture capital investments to Cambridgeshire high-tech firms has declined due to a decrease in 'investment-ready' technology firms (Mason and Harrison 2001), as the number of entries only began to decrease strongly since 2004. A more likely cause of the decline of technology investments are the relatively low returns on VC investment in technology firms (cf. Pisano 2006), close to 0% in the 2006 in comparison to a return of almost 16% on investment in non-technology firms, in contrast with the double digit returns in technology investments in the boom period of the turn of the millennium (BVCA 2006).

Even the decline of biotech jobs from 8564 in 2002 to 7781 in 2006: a net loss of 783 jobs, is relatively modest compared to the decrease of venture capital funding in healthcare in the region from £230 million in 2001 (the largest category then) to £50 million in 2005 (Library House 2006). Minus £180 million reflects a loss of about 3600 jobs of £50,000 per annum. A similar situation occurred a few years earlier in the telecommunications industry, which saw VC investments decline from £55 million in 2000 to close to £0 in 2002 and 2003 (Library House 2006), reflecting about 1100 jobs of £50,000 per annum. The telecommunications industry in Cambridgeshire had a net loss of 1343 jobs over the period 1998-2006. Estimations of the effect of VC induced job creation and loss in the region are given in Appendix 2. VC induced jobs were a major component in the rapid job growth and decline over the last decade. In addition to job losses, the decline of VC is also likely to constrain the financial resources available for investing in new knowledge creation and the subsequent patenting.

4. Conclusions

High-tech regions like Silicon Valley, Route 128 and Cambridgeshire are prominent centres of innovation showing impressive growth in numbers of high-tech firms and employment. This growth is not without limits. The Cambridgeshire high-tech economy has been seen as a harbinger for the future of the UK economy, and a leading example of success in nurturing the information technology, telecommunication and biotech industries. It was particularly well-placed to gain from and even co-create the rise of these industries worldwide. It has not remained successful in gaining from and co-creating the rise of new industries recently.

How can we explain the decline of high-tech regions, and the difficulties of the Cambridge high-tech region in particular? Two propositions, reflecting three explanations of industrial cluster growth and decline have been formulated in the start of this article. First, geographical economics emphasizes the rise of resource costs in growing clusters due to increased congestion as an explanation of cluster decline. This is a relevant factor in our analyses, with house prices growing much more rapidly in Cambridge than nationally. Wage costs do not seem to have risen more rapidly in Cambridge, making housing even more unaffordable for employees in the area. These increasing costs may be an important driver of the increasing number of high-tech establishments that have relocated out of the cluster, and the decline of the number of new high-tech establishments (especially in Cambridge city).

Second, economic geography emphasises processes of myopia and technological lock-in as causes of cluster decline. A relevant factor here includes the vast decline in the number of start-ups and stagnation in the number of patent applications which shows that the sources of variety have become constrained. Both start-up rates and patent applications have been reduced most dramatically in ICT and biotech. If these once leading sectors have ceased to be sources of variety, it is not yet clear whether new sectors will emerge as creators of variety.

These explanations are not mutually exclusive. For example, the supply of skilled labour is relevant for both explanations of decline. The carrying capacity is not a given, but can be changed by exogenous shocks or local developments. If the demand for skilled labour is not matched by continuing suitable supplies, the carrying capacity of the region is lowered. A shortage of skilled labour will also constrain the possibilities for renewal since a labour pool of engineers and technologists is needed to convert innovative ideas into production capabilities. A strong skill base is the most important source of long run cluster growth (Audretsch and Feldman 1996; Glaeser 2005). Venture capital also plays a role in both types of explanations, as an increase in the supply of venture capital can offset high resource costs in the cluster, and venture capital can accelerate the emergence and growth of new technology-based industries.

We have found dominant explanations of cluster decline to be over-simplified since many important factors are at work that have not been recognised in the literature. Traditionally, location-specific factors have been emphasized, at the expense of not only firm level, but also economy wide factors. A factor of major importance neglected by the cluster literature is the boom and bust pattern of venture capital in high-tech regions, which hardly coincides with the business cycle. This is especially relevant in regions that depend to a large extent on the supply of venture capital, instead of retained earnings gained by large scale production. There was hardly any venture capital in the area before 1996. The rapid expansion of the Cambridge Phenomenon around the turn of the millennium appears to have been fuelled by the exceptionally high levels of venture capital for technology based start-ups. In that respect, this boom period may be regarded as an anomaly, with the levels of high tech activity returning to the trend of the late 1990s after 2004. The decline in the numbers of IT firms in particular may reflect the elimination of non-viable Cambridge IT ventures started up in the IT boom years of 1999-2002. However, the very low levels of new establishment formation and the strong increase in the number of outmigrating establishments are signs that more has been going on than just a return to the trend after the boom period.

In contrast, the growth of jobs in Silicon Valley has recently resumed. Silicon Valley has been going through periods of boom and bust over 40 years, and recent expansions follow a period of decline (16% in the period 2001-2004) (Joint Venture Silicon Valley 2008). Route 128 has gone through a similar boom-bust and revival, with major job losses in the 2002-2006 period, but with a recovery afterwards. Both Silicon Valley and Route 128 have shown that they are able to 'reinvent' themselves over time (Saxenian 1994; Glaeser 2005; Best 2001; Joint Venture Silicon Valley 2008). The great diversity of activities and the dominance of small firms should make the Cambridgeshire high-tech economy relatively insensitive to the dangers of lock-in entailed by vertical integration and asset specificity (cf. Storper 1992). The Cambridgeshire high-tech economy is not dominated by a few large firms or a few industries and so is less liable to a cognitive lock-in. But, lack of robust anchor firms beyond a certain size makes it vulnerable to setbacks (Bresnahan et al. 2005).

Moreover, start ups as sources of variety have recently been stemmed. The Cambridgeshire high-tech economy is much smaller than its American counterparts and recently has included many R&D based firms, vulnerable to withdrawal of venture capital funding and credit rationing.

Regarding the potential for cluster renewal, the geographical economics and economic geography explanations seem to diverge. Geographical economics emphasises that it is unlikely that new industries will emerge in an existing cluster, while economic geography is agnostic as to whether new industries will emerge in existing cluster: processes of myopia might prevent this, but new industries might also be built on knowledge accumulated in older industries. Within the Cambridgeshire high-tech economy diversification into related new industries may go hand in hand with indigenous (university-based) creation of new industries (cf. Martin and Sunley 2006). In Cambridgeshire these processes can be observed in the emergence of new industries such as display technology and renewable energy, together with the renewal of the communication technology industry, building on older technology based local industries and knowledge from local research institutes and the University of Cambridge. The emergence of these new industries may in the future compensate for the loss of jobs and firms in the IT and biotech industries.

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Appendix 1. Research design and data

Dynamics of high-tech regions theorised in terms of cluster myopia and carrying capacity have not been examined in relation to empirical evidence on high-tech regions. Here we test for supporting evidence, using case study research designed to include as much empirical evidence as possible (Yin 2003). Our aim is to examine trends in high-tech activity in the Cambridgeshire area to obtain pertinent evidence relevant to theoretical understanding of the causal mechanisms driving the dynamics of high-tech regions, including phases of downswing.

To achieve longitudinal evidence, we used data from several sources, covering partly overlapping geographical areas. The geographical units of analysis range from the city of Cambridge, to Cambridgeshire (county), East-Anglia (EU Nuts 2 region) and East of England (EU Nuts 1 region). The Cambridgeshire high-tech economy (with around 40,000 employees) is dwarfed by the Silicon Valley (251,000 employees) and Greater Boston (318,000 employees) high-tech economies (ITAC 2007), but is comparable to the size of the Oxfordshire high-tech economy (Glasson et al. 2006).

For this paper we use the CUED (Cambridge University Engineering Department) database on the population of high-tech organisations in Cambridgeshire from 1987 until 2006 (cf. Garnsey and Heffernan 2005). This database includes data on the establishment level (entry, employment, exit), which can be aggregated to the industry level. The database is derived from the Cambridgeshire County Council Employment Database which covers all employment numbers of individual high-tech organisations in the Cambridgeshire region in the period 1987-2006. The database contains information on 2802 high-tech organisations that have ever been active in the 1987-2006 period. High-tech refers to organisations with high-tech inputs, including (1) R&D budget, (2) above average proportion of science and technology employees, and (3) that by their activity description produce emerging and newly-diffusing technology. The organisations' self-description of activities is used to identify knowledge intensive ("high-tech") activity and to assign this to standard industrial categories (an overview of the SIC-codes of the firms in the specific high-tech industries is given in Table A.1). These data were refined to remove university departments, retailing and other units that were not directly relevant to the analysis of high-tech business. In addition to the entry, employment and exit data, we have been able to trace the origin of a subset of the organisations in the database which originated in the University of Cambridge (here the combined number of spin-offs from the Engineering Department, the Computer Lab, and the Biotech research groups) and the leading technical design consultancies. The latter type of organization has been very productive in spawning new firms (see Lawson 2003; Garnsey and Heffernan 2005 for Cambridgeshire; Brenner and Fornahl 2007 for Germany). For tracing the origin of firms we used multiple sources of information: interviews in incubating organizations and spin-off companies, the local press, websites and archives. Spin-offs are broadly defined as firms created by members of an incubating organization. This does not necessarily involve intellectual property, nor financial or other support of the incubating organization.

Table A.1. SIC codes of high-tech industries

Industry	SIC 1992
Electrical Engineering	31.1-31.6; 32.1; 45.31; 45.34; 52.72; and 33.30/1.

Instrumentation	33.2; 33.4
IT Hardware	30.01; 30.02; 72.1; 72.5
IT Software & Services	72.2; 72.6;
R&D Services	73.1
Technical Design	74.2; 74.3
Telecommunication	32.2; 64.2
Biotech	selection of: 24.2; 24.4; 29.2; 33.1; 33.2; 72.2; 73.1; 74.2; 74.3

Data on the overall business population (and specific industries) in Cambridgeshire and the UK are derived from VAT statistics of the UK Department for Business, Enterprise and Regulatory Reform (BERR). Data on earnings are derived from the annual survey of hours and earnings (UK Office of National Statistics), while data on housing prices are acquired from the UK Department of Communities and Local Government.

The information on venture capital is largely based on data reported by Library House (which monitors venture capital investments in the Cambridgeshire region) and on data provided by the British Venture Capital Association (BVCA), which excludes informal investors and investments by non-BVCA members. About 10% of the Cambridgeshire high tech firms are venture capital backed (Hugo et al. 2007), an unusually high percentage. The patent data is derived from the OECD RegPat database which is based on patent applications at the European Patent Office.

In order to triangulate and interpret our empirics, we also consulted local venture capitalists, incubator managers, entrepreneurs, and policy analysts.

Appendix 2. VC induced job creation and loss in the Cambridgeshire high-tech economy

Figure 15 represents an estimation of the Venture Capital induced job creation and loss in the region. The numbers are computed as follows: 50 percent of the annual amount of VC invested in the last two years (source: BVCA and Library House) divided by the average wage costs per employee in the last year (source: Office of National Statistics). For example in 2004 the average wage cost per employee was £50,500 per annum, and the VC invested in 2003 and 2004 was (£135 mil + £150 mil=) £285 mil: this amounts to 2822 VC induced jobs in 2004.

VC induced employment T_1 = [(VC T_0+VC T_1)/2]/ Average wage cost T_1

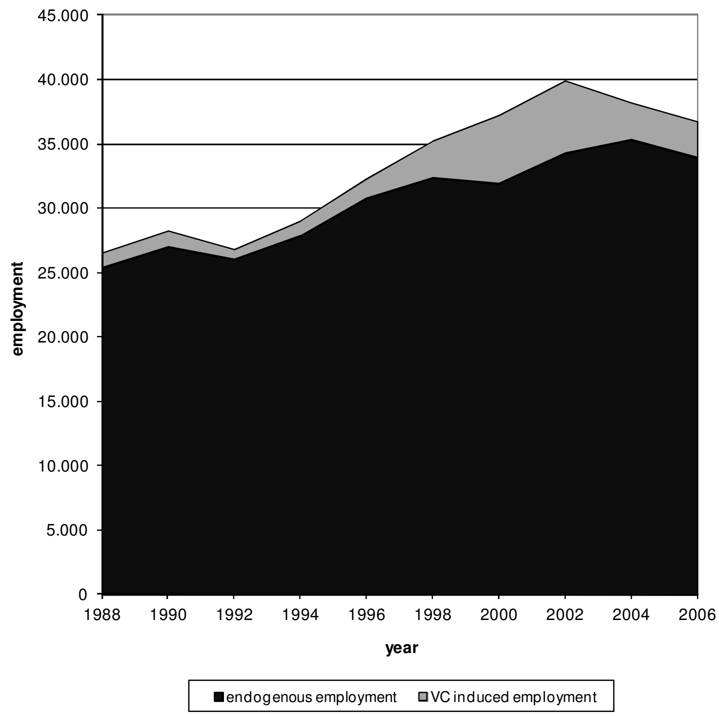

Figure 15. Estimation of VC induced employment in 1988-2006