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Entrepreneurship, innovation and the triple helix model: evidence from Oxfordshire and Cambridgeshire

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Abstract

This paper focuses on how regions become entrepreneurial and the extent to which the actors in the triple helix model are dominant at particular stages in development. It uses the case studies of Oxfordshire and Cambridgeshire in the UK to explore this theme. Both can now be described as 'regional triple helix spaces' (Etzkowitz 2008), and form two points of the Golden Triangle of Oxford, Cambridge and London universities. As entrepreneurial regions, however, they differ in a number of respects. This is not surprising given their differing geo-historical contexts. However, by comparing the two similar counties but which have their own distinctive features we are able to explore different dynamics which lead to the inception, implementation, consolidation and renewal (Etzkowitz and Klofsten 2005) of regions characterised by very high levels of technology-based entrepreneurship.

Keywords: Entrepreneurship, Oxfordshire, Cambridgeshire, triple helix regions, innovating regions

JEL codes: 018, 038, R58

1. Introduction

Not only does the technological basis of each entrepreneurial region's growth trajectory make them different from each other, but their performance also differs: some are better than others in creating firms and jobs. Silicon Valley is often seen as the epitome of success because of its sheer scale and technological diversity of activity. It remains unique: it is the home of companies which are changing our lives: Google, Apple, Facebook, and so on. These are companies with total revenues equivalent to some countries' GDPs.

This paper focuses on two smaller entrepreneurial regions in the UK, Oxfordshire and the Cambridge sub-region. Both regions are dominated by historic universities, Oxford and Cambridge, (often referred to collectively as Oxbridge), two of the world's leading research universities. The paper addresses the research questions: how different are these apparently very similar sub-regions, in other words, how unique are they, and how successful are they?

The paper shows that they are both leading locations of multiple clusters of high-tech firms, and in this respect they are not unique. However, they could have been more successful in creating more and bigger firms. The thesis of the paper is that part of the explanation lies in the relative lack of engagement of their major assets (the universities) in leading economic development and thus in their regions becoming 'regional triple helix spaces' (Etkowitz 2008). Other factors include planning constraints which are related to their status as heritage cities.

The paper draws on a series of studies on the growth of Oxfordshire's and Cambridgeshire's high-tech economy since the mid-1980s (Lawton Smith 1990, Garnsey and Lawton Smith 1998, Waters and Lawton Smith 2002, Mohr and Garnsey 2010, Breznitz 2011, Lawton Smith and Waters 2011). These studies provide an historical perspective on the growth of the two economies, and points of comparison with other similar places such as Grenoble in France. However, it is important that these two regions should be seen in their own terms as smaller centres of technology-based enterprise and with populations well short of one million, rather than in comparison with metropolitan regions such as London which have very different urban economies. Moreover, the actions of the Oxbridge universities should also be considered both in the light of the political importance of universities in playing leading roles in economic development (Lawton Smith 2006) and in the universities' own interests in maintaining their global research positions. The focus is therefore on process as well as performance in economic development.

The paper proceeds by providing the framework for the discussion of Oxfordshire and the Cambridgeshire sub-regions as entrepreneurial regions. This is followed by an assessment of the qualities of the two regions and the extent of their being entrepreneurial using this framework. Finally, some conclusions are drawn.

2. Entrepreneurial and innovating regions

Centres of high technology industry including university city-regions such as Oxford and Cambridge are distinctive because of their high rates of entrepreneurship and innovation. The dynamism of such regions also reflects the ability and willingness of local actors (firms and organisations such as universities) to adapt to changing political and economic environments. This paper is concerned with how or how much the different elements which comprise an entrepreneurial region interact to create that dynamism. To explore this theme, a distinction is made between actions and their consequences from those of interconnected, systemic processes which have a localised impact through a series of what might be relatively exclusive networks and consequences operating at varying geographical scales. Conceptually a distinction can made between two kinds of analysis of regional development.

The first is the less frequent interpretation of a non-systematic approach. Conceptualisations such as the triple helix model (Leydesdorff and Ektzowitz 1995) do not presume a geographically delineated system but provide a framework for analysis of systemness (and allow for mismatches between institutional arrangements and social functions within the model) (Leydesdorff and Zawdie 2010). This allows for the specificities of political and institutional/organisational environments. The second is where the analysis is couched in terms of stages or continuous evolution. There actions are taken systemically through a variety of interactions and whose consequences occur within a region. The dynamism of such places can be seen as resulting from path dependence, increasing returns and the lock-in phenomenon (Arthur 1992), systemic and contextual variables from non-systemic actions and agency. These include regional innovation systems approach and evolutionary economic geography (see Boschma and Frenken 2006). Clark et al (2002), however, point out the problems associated with assumptions of path dependence. They argue that there 'is ample evidence of unrelated economic activities co-existing with core elements of successful industry-region complexes' (p.162).

The approach in this paper therefore is not to rely on systems thinking but to identify six key elements in a local economy related to its dynamism and where there are mismatches and events that do not have direct systemic effects (Table 1). These elements are drawn from three conceptualisations of dynamic regions: Feldman and Francis's (2006) three stage process model in which entrepreneurs are the agents who drive the formation and shaping of clusters, 'the innovating region' (Etzkowitz and Klosten 2005) and 'regional triple helix spaces' (Etzkowitz 2008). These are supplemented by elements missing or underplayed in those three.

Entrepreneurs	New firms, clusters, anchor firms
Labour markets	Skill profiles, mobility
Universities and research instutitions	source of new firms by staff and students sources of knowledge attracting foreign science-based industry engagement in regional development
Infrastructure	Science parks and incubators
Social interaction	Formal and informal networks
Government	National and local

Table 1 Core elements in framework for analysis

Entrepreneurs, sectoral specialisations and anchor firms

Entrepreneurs, in Feldman and Francis' (2006) model and neglected in the triple helix model (Lawton Smith and Bagchi-Sen 2010), are at the heart of innovation-led economic development. This approach is placed within an adaptive systems model, one which is complementary to the triple helix model of cluster formation (Etzkowitz 2000). Their three stages are: emergence, self-organisation, and a mature stage characterised by a well functioning system.

The approach recognises that factors which promote a new cluster of firms in similar or related markets are different from those that encourage its growth. It is also evolutionary with its view that cluster development is path dependent or heavily influenced by chance historical events. Feldman (2003) earlier noted that a further factor that encouraging growth is that of larger firms (anchor firms) which provide stability in a local economy and generate multiple effects such as adding skills to the local labour market, providing markets for specialised intermediate industries as well as knowledge spillovers.

However, integral to understanding these processes are firm level factors such who they entrepreneurs are and what roles they play in shaping business strategy compared the inventors and to managers. This is important because it matters to relationships and interactions between actors within a local cluster. Schumpeter (1934) clearly distinguished these roles: the entrepreneur is as innovator is the pioneer of change by capitalising on new combinations of knowledge, rather than being an inventor or a manager.

Labour markets

Related to high levels of entrepreneurship and innovation is the presence of a highly skilled labour market. This serves both as a source of entrepreneurs (Fritsch and Schindele 2012) and through inter-firm mobility particularly by the highly-skilled is a mechanism for technology transfer and fostering of inter-firm links (Breschi and Lissoni 2009, Faggian et al 2009). Other studies have also suggested an association between high levels of in-migrant workers and entrepreneurship and innovation as is the case in Silicon Valley (Saxenian 2006). It is, however, important not to make a causal link between the presence of universities and that of a highly skilled labour market as other factors will also be at work in creating stocks and flows of the highly skilled such as employment in the private sector with people being attracted into the county to work in the high tech firms as well the public sector (see Waters and Lawton Smith 2011).

Universities

In the 'innovating region' concept (Etzkowitz and Klosten 2005, 246) the university is placed at 'the root of virtually any high tech region'. The focus in this 'assisted linear model' is on collective entrepreneurship, through outcomes of collaboration among business, government and academic actors. This approach, like that of Feldman and Francis (2006), emphasises changes from self-organising systems to more formal and intentional interactions between agents (see also Garnsey and Lawton Smith 1998).

Infrastructure

In some contexts, a major economic contribution to the local environment of high-tech firms is the provision of incubators and science parks. This is one of a number of means by which universities might stimulate regional economic development (Goldstein 2009). Mostly this is a passive activity but in some cases, science parks and incubators are proactive in a number of the other six ways this can occur including transfer of know-how and technological innovation.

Social interaction and networks

Increases in formal networking are associated with the rise of high tech economies demonstrating a demand for local resources such as information and also economic transactions (see Lawton Smith et al 2012). These can also be seen as a proxy for the rise of informal networks – but which unlike formal networking activity cannot be measured. Both formal and informal networks are argued to be key mechanisms through which external economies benefit local firms and are ultimately responsible for the emergence, growth and success of a cluster of innovative firms (Breschi and Malerba 2005, see also Lawton Smith and Romeo 2012).

Governance

The concept of a regional innovation organiser (ROI) (Etkzowitz and Klosten 2005) is a governance model. Governance is co-ordinated though a group of people or an organisation which draws in other key stakeholders. Sometimes universities may be the ROI in formulating a knowledge-based regional economic development strategy, for example SUNY Stoneybrook in New York State in the US and Linkoping in Sweden (Ektzowitz and Klofsten 2008). More often the university is part of a broader configuration of actors in a regional system of governance.

In the later development of the innovating regions approach, that of 'regional triple helix spaces' (Etzkowitz 2008, 82), governance systems consist of the set of political organisations, industrial entities, and academic institutions that work together to improve the local conditions for innovation, forming 'the regional triple helix'. This interpretation unlike the innovating regions approach is non-linear: actions are taken in any order with any one used as a basis for the development of the others. It is similarly a phased approach during which institutional roles and relationships may change. Three phases are identified: creation of a knowledge space – collaboration among different actors to improve local conditions for innovation; creation of a consensus space, ideas are generated in a triple helix of multiple reciprocal relationships among institutional sectors (academic, public, private) involving localised formal and informal networking or what can be termed 'social agglomeration'); and creation of an innovation space – attempts at realising the goals articulated in the previous phase and attracting venture capital.

A number of caveats to assumptions of seamless interconnections between the above and path dependent localised economic development need to be introduced before discussion of Oxfordshire and Cambridgeshire. Firstly, there is limited evidence of the importance of universities as a source of entrepreneurs in a region. Entrepreneurs from other backgrounds, even in such sectors as biotechnology, are far more numerous. Moreover, the focus on systems ignores the peculiarities and leverage of independent actors (individuals, organisations).

Secondly, the impact of universities relies on a match between the university and regional conditions. This is contingent on factors such as the type of university and its academic research, and the local industrial structure (Lawton Smith and Bagchi-Sen 2010). Thirdly, regions can be relatively successful without key organisations working together. For example, in the case of premier universities such as Oxbridge, strategic science (Rip 2002) always has a local or contextualised component. It contributes to the "glocalisation" of the region with the effect of universities becoming internationally recognised attraction poles for research and commercial activities rather than because of systemic local engagement. Fourthly, when organisations do collaborate, their actions do not necessarily lead to successful (systemic) outcomes over the longer term. Finally, it is necessary to separate events from general processes, some of which may be driven by 'top down' initiatives by national governments which may not have strong local outcomes.

Next, the rise of the Oxfordshire and Cambridgeshire entrepreneurial regions are described using the framework above. In doing so, agency of individuals and organisations and their consequences are explored.

3. Oxfordshire and the Cambridgeshire sub-region as entrepreneurial regions

3.1 Context

Oxfordshire and the Cambridgeshire sub-region are two of a small number of places, such as Silicon Valley and Route 128 in the USA where there is a local impact of research universities (Lendel 2010). Both are located some 60 miles from London: Oxford to the west and Cambridge to the north. As well as their premier universities, each city-region has a post-1992 university (former polytechnics) (Oxford Brookes and Anglia Ruskin University). They qualify as triple helix regions because of their concentrations of university, public and private sector research, high tech entrepreneurship and the highly-skilled. Both locations are relatively new centres of high technology industry in predominately rural counties. Neither was in the top 19 counties of high technology industry in 1981 (Hall 1985) and R&D did not feature in the list of key sectors in the City of Oxford in that year. As is shown, they have similar but diverging growth trajectories.

In this paper, early data, up to 2010 is used to compare the counties of Oxfordshire and Cambridgeshire. More recent data compares the county of Oxfordshire with the

Cambridge Sub-region which comprises (Cambridgeshire, South Cambs, Huntingdonshire, Forest Heath, North Herts and Uttlesford). It should therefore be born in mind that while the counties of Oxfordshire and Cambridgeshire have similar populations, the Cambridgeshire sub-region is larger (792,200) compared to 653,900 (2011).

The rationale for the difference in unit of analysis is that Oxfordshire's high-tech economy falls within an administrative entity (the county). In contrast, as high tech activity in Cambridgeshire high tech activity has grown, it has spilled over into in a number of districts that include those in neighbouring counties, largely through planning decisions to protect the green belt around the city of Cambridge. Land ownership and planning restrictions have also played a part in where activity can be located in both university cities.

3.2 Entrepreneurs, clusters and anchor firms

Measuring the number of new high tech firms and monitoring their survival over time, is problematic. In Oxfordshire, the criterion used in the original study (Lawton Smith 1990) was that firms were undertaking research and development (R&D) in one or more of science, computer science and engineering. This definition was compatible that used for the Institute for Manufacturing's database of high tech firms, a collaboration between Cambridgeshire County Council and Garnsey which has lasted over 20 years (see Mohr and Garnsey 2010). Maintaining such a database was not possible in Oxfordshire. Since 2003 Oxfordshire data have been compiled on Butchart-based definitions by the Oxfordshire Economic Observatory (OEO). The most recent comparisons of the two locations here are made using official national statistics. These use two definitions of high-tech industry one narrow (Eurostat) and one wider (Eurostat +) (Appendix A) which are equivalent to standard industrial classifications. The use of the latter serves to provide a more inclusive picture of high-tech activity which includes medium-tech manufacturing and therefore better reflects the broader range of technology-based entrepreneurship in each locations.

From the early 1980s both locations emerged as high tech clusters because they generated new firms (Feldman and Francis 2006, Etzkowitz and Klofsten 2005). Some grew to major technology-based companies (see Garnsey and Lawton Smith 1998, Mohr and Garnsey 2010) but nothing on the scale of firms in Silicon Valley, or even . The publication of *Cambridge Phenomenon: the growth of a university town* (Segal Quince and Partners 1985) in part led to Cambridgeshire's profile as a leading cluster of high tech firms or 'knowledge space', but was not, as was suggested in the report, outperforming Oxford. In 1987 Oxfordshire had 182 high tech firms employing 10,695 compared to 200 employing a similar number in Cambridge (see Lawton Smith 1990). A recent update of the original Oxfordshire study (Lawton Smith and Romeo 2012) has found around two-thirds of the companies still operate, many of them university spin-offs (see below). Nearly 40 percent are under the same ownership. By 1997, Oxfordshire had 543 firms employing 19,465 compared to Cambridge where there were 736 firms employing 20,792.

A difference in their economies at that time was that Oxfordshire, unlike the Cambridge sub-region was still a centre of food manufacture, blankets and particularly in the post-war period, automobile manufacture). Until the late 1960s, Oxfordshire's dominant sector was the automotive industry with some 28,000 employees, but was contracting rapidly in the 1980s. In contrast, Cambridgeshire's economy until the 20^{th} century was linked to its importance as a market town. Oxford is still the home of the BMW Mini plant which employs some 4000 people. The importance of the automotive industry to the early high tech economy was that there was a supply of precision engineering firms available to the early high tech manufacturing firms such as Oxford Instruments. There is, however, no evidence of interchange of personnel between the high-tech and automobile sectors. Instead, it was the national laboratories that were (and still are) a source of technicians for the high tech firms (Lawton Smith 1990).

It was in the 1990s that both high tech economies grew very quickly. Where they differed in the late 1990s was that Oxfordshire had twice the proportion of firms with over 100 employees than did Cambridgeshire, mainly engineering firms (see Garnsey and Lawton Smith 1998). At that time the larger Grenoble region (1m people) had 950 companies employing 23,400 (Lawton Smith 2003), showing that proportionally the two English counties were outperforming the longer established cluster in France.

By the end of 2001, the number of Oxfordshire's high-tech firms had risen nearly threefold to contribute around 12% of all employees working in the county (Chadwick et al 2003). At this 'consolidation' or 'self-organisation' stage (Feldman and Francis 2006) the county had the fastest rate of employment growth in high-tech sectors in the UK. Over the decade 1991-2000, particularly between 1996 and 2000 high tech employment increased by 82%, the fastest of any of the 46 English counties. This was mostly in service sectors, often neglected in analyses of high tech economies, while manufacturing growth was concentrated in a few high-tech sectors such as cryogenics and instrumentation more generally, and motorsport. In Cambridge similar developments in the cluster were shaped by waves of firms entering into various sectors (Mohr and Garnsey 2010). Early waves of electronics and manufacturing were followed by waves of firms in instrumentation, IT, biology, telecommunication and R&D.

The two regions now differ in the extent and diversity of clustering, hence of the degrees of technologically related variety (Boschma 2011), hence degree of dependence on particular sectors. It is likely to be an advantage to have high LQs in fastest growing sectors with the potential for knowledge spillovers from related variety for example through recruitment (see Breschi and Lissoni 2003, Faggian et al 2009).

Oxfordshire specialises in a small range of sectors. A total of six high LQ sectors account for 65% of wider-defined high-tech employment. Sectors with the highest LQs are Computers and peripheral equipment (11.4) compared to the still high 4.6 in the Cambridge sub-region, Irradiation/electromedical equipment (6.7) (related to the presence of the national laboratories, see below) and scientific research & development (3.9). Oxfordshire also has a lower percentage of employment in high-tech sectors than the (larger) Cambridge sub-region (6.4% compared with 9.1%), but higher than the national average of 4.8% (Table 2). Publishing activities, publishing of and software publishing for example are important to the economy. In 2011, some 5,500 people were employed in these sectors, many of them in Oxford University Press which dates back to 1586 when the university was given the right to print books.

It is a department of Oxford University, is its earliest spin-off company and is the largest university publishing company in the world**.**

Number of Employees	*Oxfordshire*	*Cambridge*	*England*
High & Medium High-Tech Manufacturing	13,500	16,900	695,600
High-Tech & Selected Other KI Services	29,400	36,300	1,414,200
Total: Wider High-Tech Sectors	42,900	53,200	2,109,800
Total Employees (All Sectors)	311,900	343,700	22,490,000
As % of Total Employees	Oxfordshire	Cambridge	England
High & Medium High-Tech Manufacturing	4.3	4.9	3.1
High-Tech & Selected Other KI Services	9.4	10.6	6.3
Total: Wider High-Tech Sectors	13.8	15.5	9.4

Table 2 - Employees in High-Tech Sectors (Wider Definition), Oxfordshire & Comparators, 2010

Source: ONS, Business Register & Employment Survey (NOMIS). High-tech & medium high-tech manufacturing: 2007 SIC 20-21, 25.4, 26-29, 30 (except 30.1), 32.5. High-tech & selected other knowledge intensive services: 2007 SIC 58-63, 71-72, 74.1, 74.9. Figures for total employees exclude farm-based agriculture (2007 SIC class 01000). All figures are rounded to the nearest hundred employees.

The Cambridge sub-region is more diversified having a larger number of high LQ high-tech sectors (11 out of the 20 high-tech SIC categories have an LQ of 1.5 or above). Other specialisations with a LQ of over 4 include consumer electronics, communication equipment and optical instruments. With the addition of medium high-tech manufacturing sectors and selected other knowledge intensive services to the Eurostat high-tech sectors, total employment in high-tech sectors in Oxfordshire is more than doubled to just under 43,000. Although the percentage of employment in wider-defined high-tech sectors is lower than in the Cambridgeshire sub-region the relative differential is much smaller than with the narrower Eurostat definition (13.8% compared with 15.5%). This narrower differential reflects the inclusion of important Oxfordshire sectors such as motor vehicle manufacture, medical instruments and publishing in the wider high-tech definition.

In biotechnology Oxford, Cambridge and London were identified in the Report on 'Biotechnology Clusters' by Lord Sainsbury, Minister for Science, published in August 1999. By 2011 the number of Oxfordshire’s firms had risen to some 84 companies. Cambridge has also maintained its position as one of the largest UK clusters of biotech firms (Breznitz 2011, Mohr and Garnsey 2010) with a LQ of 6.7 compared to only 1.59 in Oxfordshire. However, in neither case are home grown biotech companies of any major size, but this is also the case for UK biotech companies as a whole (Lawton Smith and Bagchi-Sen 2010). The relationship between the failure of this sector to growth and the universities in both locations is discussed in 3.5 below.

The dynamics of growth of firms and the percentage of employment in larger, anchor firms is similar. In both locations, high growth firms were small in number until the mid-1990s. Thereafter, their contribution rose sharply, and some, although not very many (in Cambridge, 39 or 3% of the total number of high-tech firms which account for 24% of jobs created between 1988 and 2008) (Mohr and Garnsey 2012). In Cambridge, four local start-ups have achieved considerable growth to employ more than 1000 employees: Domino (ink jet printing), Autonomy (search engines), ARM (chip design) and Cambridge Silicon Radio (semi-conductors). At their peak they employed 6000 and had a combined turnover on £1.4bn. Although each went through periods of setback in 2002-2008, they showed less volatile growth than smaller ones, and provided stability to the high tech economies as 'anchor firms' as did Oxfordshire's largest high tech firms.

In Oxfordshire, the impact of Oxford University on the local economy is evident because the largest high-tech firms originated in Oxford University, formed by staff or former students, mainly from departments of Engineering Science and Metallurgy but with some from medical research and life sciences (see below).

In both locations, merger and acquisition (M&A) has changed the locus of agency with non-local ownership affecting the potential for local engagement by the acquiring firms in any 'regional triple helix space'. In Oxfordshire as well as Cambridgeshire foreign firms, often from the US and mainland Europe, particularly in the biotech sector (DTI, 2005; Lawton Smith and Bagchi-Sen 2010) is common. In Cambridge half of acquisition of indigenous firms was by foreign firms, a trend which intensified in the 1990s (Mohr and Garnsey 2010). In Oxfordshire, a quarter of firms that existed in the 1980s had been so acquired by 2010 (Lawton Smith and Romeo 2012).

3.3 Labour markets

An indicator of the potential for high levels of entrepreneurship is the profile of educational attainment of the workforce compared to national levels. The locations are unique in the UK in that both have a significantly higher proportion of well-qualified residents than most of the rest of England & Wales. This is particularly the case in Oxfordshire, which has a higher rate of degree level attainment than any county council or Local Enterprise Partnership; 55 per cent of residents hold degrees in Oxford which ranks 5^{th} of all 380 local authority districts in England, two other districts rank in the top 50. In the Cambridge sub-region, over half (52 per cent) of working age residents hold degree level qualifications leading to ranking $12^{th,}$ but no other district is ranked in the top 50.

This pattern in part reflects the relatively high proportions of Oxbridge graduates, and those of Oxford Brookes, who stay in their respective local areas post-graduation. London is the second most popular destination for graduates both as well as for other universities. Oxfordshire and the South East are popular destinations for graduates from across the UK but this is not the case for the East of England which includes Cambridge. Assessing impact on the local labour market, however, is not straight forward: there is a lack of evidence on the differences in the extent to which students to stay and work in occupations outside academia in a region after graduation (Waters and Lawton Smith 2011).

A further important aspect of the labour market which relates to the locations' economic dynamism is the level of overseas workers employed in the localities and in the student bodies and academic staff in the Oxbridge universities. Both have been found to be associated with levels of entrepreneurship (Breschi and Lissoni 2009). For example, nearly 24 percent of people working in Oxford city have come from abroad, making it the 8th highest English borough with in-migrant workers. Oxbridge universities are highly international, but more so in Oxford than Cambridge (40% compared to 25% of staff are citizens of foreign countries, coming from almost 100 different countries and territories).

3.4 Entrepreneurial universities and research institutions

Like Silicon Valley, the two locations have multiple knowledge bases (Etzkowitz and Klofsten 2005): prestigious universities with similar patterns of university spin-offs and public and private research laboratories. Their impact on the dynamism of the economies varies. In each there are elements of systemic features shaping the trajectory of each region but some events have non-linear effects and do not contribute directly to regional triple helix spaces (Etzkowitz 2008) in either place.

3.4.1 The universities

The historic universities Oxford and Cambridge dominate their respective cities. Oxford can be dated back to the 11th century, with Cambridge rather younger, being formed 1209 when a group of Oxford University academics went to Cambridge after disputes between students and townspeople. There they established what became the University of Cambridge. A distinctive feature of both is their collegiate systems (over 40 in each). Each college is an independent institution with its own property and income. Many of them are wealthy. They appoint their own staff and are responsible for selecting students, in accordance with University regulations. The teaching of students is shared between the Colleges and University departments. Degrees are awarded by the University.

Hence the question of agency and assumptions about the workings of a regional triple helix model (Etzkowitz 2008) is not as simple as if the two 'universities' were coherent entities. The formal rather than the informal process by which both have become entrepreneurial universities (Etzkowitz 1983) followed different routes. Both formal systems have recent their problems which appear to have limited their impact on the growth of their respective high tech economies.

The university spin-off process from Oxford University has a long history. Some spin-offs were established in the 1940s and early 1950s but in the 1970s and 1980s the number of university start-ups increased. By the mid-1980s, some 40 firms had been established broadly defined as spin-offs (see Lawton Smith and Ho 2006). They include Oxford Instruments (scientific, industrial and medical devices) which employs nearly 2000 people worldwide; Research Machines, the UK's leading educational computer manufacturer (1973); and Sophos (1981) (antivirus software) which by 2012 employed 1682.

Internal pressures on Oxford University to capitalise on the growing number of spin-outs rather than just the entrepreneurs becoming rich resulted in important events. The first was the establishment of its wholly-owned technology transfer company in 1987 as Oxford University Research and Development Ltd and renamed it as Isis Innovation in 1988. Its main activities at formation were the Isis Angels Network which provides a vehicle for the introduction of private individuals and companies with potential interest in investing in university spin-out companies, and the Oxford Innovation Society, set up in 1990 provided networking events for scientists and potential funders/acquirers of university research. It was not then geared up to promoting the formation of spin-offs.

The second was the *Review of Technology Transfer Arrangements* in 1994 (Report published 1995). This was a response by the University to internal pressures to review its policies as well as a response to the national political agenda. The Report recommended that the University assert its rights to the IP of academics, students and visitors (Lawton Smith 2003), with a consequence that a more professional commercialisation organisation was required. From 1997 onwards there were opportunities for academic staff to form their spin-outs through Isis Innovation who were obliged by their contracts of employment to do so. The first CEO was a locally well-known serial entrepreneur. Under his leadership, by the mid-2000s, Isis Innovation grew to having the largest number of commercialisation staff of any UK university (Minshall and Wicksteed 2005).

Isis now employs more than 60 people, in three main parts: Isis Innovation, the main organisation, Oxford University Consulting (OUC) and Isis Enterprise – a consultancy company which focuses on technology transfer. In 2008, Isis Innovation established Oxford Spin-out Equity Management to manage the University's interests in its spin-out companies. In 2012 Isis returned £5.3m to the university and its researchers on a turnover of £10.2m, hence for Oxford University is a successful operation. Isis Innovation has been responsible for creating over 70 spin-out companies based on academic research generated within and owned by the University of Oxford, and has spun-out a new company every two months on average with five formed in 2012. Since 2000 over £266 million in external investment has been raised by Isis spin-out companies, and in 2013 five were currently listed on London's AIM market.[1]

While the rate of spin-off has not slowed, there is evidence of relatively poor recent performance with fewer surviving, more becoming inactive, no spin-off has yet reached the magic £bn turnover figure. Many, usually biotech companies, have been acquired by overseas, usually US companies. Moreover, there has been no biotech IPO since 2006 (Lawton Smith 2012). Hence, there is little evidence that the formalisation of the technology transfer process created the kinds of large firms that were established in the past.

[1] http://isis-innovation.com/documents/IsisAnnualReport2012.pdf accessed January 13 2013

During the 1990s Cambridge University also took steps to simplify the technology transfer system ‘to ensure greater efficiency and professionalism’ (Breznitz 2011). However, like Oxford in recent years, the outcome was far from effective, resulting in negative attitudes towards the technology transfer office (TTO) and a reduced number of spinouts. The creation of the Cambridge-MIT institute in 1999 was followed by restructuring of technology transfer units. In 1983 the Wolfson Industrial Liaison Unit (WILO) established by the Department of Engineering in 1970 as its own technology transfer unit, became responsible for the commercialisation of university research as a whole. In 2000, the WILO merged with Research Grants and Contracts Office to form the Research Services Division, which operated several divisions dealing with sponsored research from research councils, charities and industry, including the WILO which became the TTO. In 2002 with HEIF Funding, a new unit called Cambridge Enterprise, the Isis Innovation equivalent, was founded as an independent unit but it went into the RSD in 2003, and following changes to the university’s IPR policy in 2005 the merged body became a single organisation. Cambridge adopted a very similar set of rules to those which existed at Oxford: it would receive all control over inventions regardless of the source of funding. In principle this would encourage entrepreneurship, licensing and other forms of commercialisation because of the greater academic freedom to place their inventions in the public domain.

Breznitz (2011) instead finds that the changes have had a negative effect on industry’s ability to negotiate with the current technology transfer system which has not been fully integrated because of the volume of changes and key individuals were less visible. In the past, high profile individuals such as the head of St John’s College Innovation centre, the former director of the WILO were well known inside and outside of the university. Moreover, the formula for sharing income favours licensing over spinouts. Breznitz argues that far from the changes enabling Cambridge to be more integrated into regional innovation systems (local, regional), they were one sided and not made in consideration of the impact of the relationships with industry. Therefore assumptions associated with regional innovation systems approaches, including relationships with actors in the region, sharing information, knowledge flow, social capital and social networks were absent, leading to antagonism, for example, on the part of the local biotech industry, entrepreneurs and venture capitalists. This arguably has limited the impact of the university on local economic development through technology transfer, predicted in both the innovating regions (Ektowitz and Klofsten 2005) and the regional triple helix model (Etzkowitz 2008).

As in Oxfordshire, in Cambridge, Mohr and Garnsey (2010) show that unofficial start-ups by members of the university (staff and graduates) outnumbered official start-ups in which the university held a stake, both types of firms have provided a continuous supply of technology-based firms to the local economy. Moreover, the authors identified further spin-offs from previous university spin-offs providing evidence of the impact of serial entrepreneurship. In Oxfordshire seriality appears to be primarily related to angel investors, recruitment of senior managers and multiple board memberships (Lawton Smith 2008).

Oxbridge universities’ business schools have established programmes and societies to encourage academic and student entrepreneurship. In 2001 central government funding enabled Oxford to set up the Oxford Science Enterprise Centre (OxSEC) in the Said Business School with the central tenet of promoting entrepreneurship within the university. The Said Business School has sought to add value through entrepreneurship education in three specific areas: Teaching Entrepreneurship, Knowledge Transfer, and Links to Business. All programmes are open to Oxford-based entrepreneurs, high-tech companies as well as to university members. The number of people being trained is rising steeply, with over 3000 people attending an event each year (Lawton Smith and Bagchi-Sen 2012). The Cambridge equivalent is Judge Institute of Management's Cambridge University Centre for Entrepreneurial Learning[2]. This 'aims to spread the spirit of enterprise through the creation and delivery of educational activities that inspire and build skills in the practice of entrepreneurship'. From the evidence above, training provided by the universities to local and national high-tech economies is likely to be more significant in the future than university spin-offs.

Student entrepreneurs clubs are symbolic of a rise in interest in entrepreneurship within student communities but their direct impact is less obvious. *Oxford Entrepreneurs,* a network for students and alumni of the University of Oxford, aimed at encouraging and supporting student entrepreneurship followed in 2002, now has over 7000 members, the largest student entrepreneurship society in Europe. Cambridge University Entrepreneurs was started in 1999 as a society for student entrepreneurs. By 2012 it had awarded £500k in prize money to more than 40 start-ups which have a very small impact on the local economy creating only some 110 full time jobs[3].

3.4.2 research laboratories

Oxfordshire has more government-funded research laboratories, with specialisms in physics than Cambridgeshire (Table 3). Its research laboratories were established post-World War II, firstly to service the UK's nuclear energy programme (UK Atomic Energy Authority, UKAEA, first nuclear fission and now only fusion research), making it more similar to its twin town Grenoble in France than the Cambridge sub-region (Lawton Smith 2003). Over time, the composition of this scientific research, its ownership and orientation has changed. It was always 'big science' but has developed into a more of a 'regional triple helix space', with an emphasis on commercial activity as well as pure science.

[2] http://www.enforbusiness.com/focus/education-and-training/centre-entrepreneurial-learning-cfel-university-cambridge?page=1 accessed January 13 2013
[3] http://www.cue.org.uk/about/

Harwell	**Organisation**
RAL (Rutherford Appleton Laboratory) materials and structures, light sources, astronomy and particle physics. - Space science - Diamond Light Source Facility (Synchrotron Radiation) - ISIS (physical and life sciences)	STFC
ESA UK Harwell Centre (space research)	European Space Agency (ESA)
NRPB laboratory	National Radiological Protection Board
Radiation And Genome Stability Unit	Medical Research Council
MRC Harwell (Mouse genetics)	Medical Research Council
Centre for Ecology and Hydrology	NERC (National Environment Research Council)
Culham	
Culham	UKAEA
JET (Joint European Torus)	EU - European Fusion Development Agreement

Table 3 Public sector research laboratories

The Harwell site now operates as the Harwell Science and Innovation Campus, one of the UK's two National Science and Innovation Campuses. It is a public-private partnership, and operates as a combined research and innovation park which in 2013 hosted 150 organisations and companies, employing over 4,500[4]. In a neighbouring district are two nuclear fusion research laboratories. The campus forms part of a sub-region to the south of the county known as Science Vale UK, a collaboration between Harwell, Milton Park (the largest business/science park in the county), two local district councils (Vale of White Horse and South Oxfordshire)[5], the Oxfordshire Local Economic Partnership, Oxfordshire County Council and the Science and Technology Facilities Council (STFC). While the atomic energy laboratories have contracted, the activities of RAL have continued to expand in both basic science, for example in skills training and technology transfer, while other laboratories have located onto the site.

Reflecting this concentration of science, the Vale of White Horse district, the location of Milton Park and the Harwell Science and Innovation campus, has three times the national average (4.3%) of the percentage of employment in high-tech sectors, at 14.3%, and reflects particular strengths in the district in computer, electronic and optical products, computer related activities and scientific research and development. In absolute terms, the district accounts for 39% of Oxfordshire's high-tech employment on the narrow definition and 29% on the Eurostat + definition. In this respect the Science Vale UK initiative shows how the policy involvement is being attracted to both private and public sector excellence and represents the potential of this scientific 'regional triple helix space'. This potential is being reinforced by central government funding since its award in 2011 of Enterprise Zone status under

[4] http://harwelloxford.com/business-directory accessed 13 January 2013
[5] http://www.sciencevale.com/ accessed 13 January 2013

which businesses are eligible for a business rates discount of up to £55,000 a year for five years.[6] In Cambridgeshire a former airfield, Alconbury, located 24 miles west of Cambridge has been given the Enterprise Zone status but is in a remote location rather than being embedded in a regional triple helix space.

In contrast, Cambridgeshire has a stronger private sector research base than Oxfordshire, which may have an impact on the future trajectory of the region. Examples are shown in Table 4. In both, the 1980s and 1990s was marked by the arrival of a number of high-tech firms from other parts of the UK and R&D departments of overseas companies. A notable closure in Cambridge was that of AT&T's European laboratory in April 2002. Pfizer is partnering with the Cardiovascular Epidemiology Unit (CEU) at the University of Cambridge in the U.K. to establish an embedded collaboration.

Cambridge	**Oxford**
Toshiba Research Europe Limited 1991	Sharp European Laboratory 1990
Microsoft Research Cambridge 1997	Infineum (petrol additives) formerly Esso Research Centre
The Nokia Research Centre	
Philips Research laboratory (Home Healthcare initiatives)	
Kodak European Research	

Table 4 Examples of private sector research laboratories

Both have a number of world leading research laboratories mainly specialising in biomedical science, supported by charities and government funded research councils, sometimes in association with the universities (Table 5). Although, these concentrations of expertise have not led to the formation of major biotech companies, that is not necessarily the most appropriate indicator of their societal importance. More telling is presence in Cambridge (and absence in Oxford) of big pharma which suggests that co-location is crucial to the technology transfer process and that in this respect, Cambridge is a stronger triple helix space than Oxford.

Consequences of the growth and change of the science base are twofold. First, the different organisations' presence and changing orientation contribute to a greater or lesser degree to all of Etzkowitz and Kloftsten's (2005) four stages of the growth of an innovating region. Where those organisations become innovating institutions as well as scientific research institutions, this has a knock on effect on the dynamics of the localities becoming 'innovating regions' characterised by technological renewal. Second, they have a changing impact on the supply of and demand for skills within the local labour market.

[6] http://www.sciencevale.com/ accessed February 222 2013

Cambridge	Oxford
Strangeways Research Laboratory genetic epidemiology: independent charity, sole trustee is University of Cambridge. Laboratory houses the independent Foundation for Genomics and Population Health (PHG Foundation). Other research groups within the building are supported by the Medical Research Council and European Commission	Oxford Stem Cell Institute (Oxford University)
Institute of Public Health - Cambridge University, the MRC and the NHS	Oxford Biomedical Research Centre, partnership between the University of Oxford and Oxford Radcliffe Hospitals, funded by the National Institute of Health Research
Babraham Institute (healthcare and training) Biotechnology and Biological Sciences Research Council	Oxford Centre for Cancer Medicine
European Bioinformatics Institute	Institute of Biomedical Engineering
Laboratory of Molecular Biology	Jenner Institute (vaccines)
	Wellcome Centre for Human Genetics.

Table 5 Examples of charitable and other research labs

3.5 Infrastructure

The provision of space on university science parks and incubators is now a defining feature of both locations' high-tech entrepreneurship infrastructure. Both the Oxford Science Park (Magdalen College 1990) and Oxford University's own Science Park at Begbroke established in 2000 have incubators. Begbroke is several miles away from the city centre, and combines space with outreach and entrepreneurship activities including the Centre for Innovation and Enterprise, the Enterprise Fellowship scheme and the development of new courses with the Department of Continuing Professional Development. However, Milton Park has more firms including more university spin-offs than either of the two university parks (Lawton Smith and Glasson 2010).

The Cambridge Science Park (Trinity College 1970) was also developed by a university college rather than the university itself, but does not have an incubator. St John's College incubator provides that service (Breznitz 2011)[7]. Cambridge University was able to build a Bio-Medical Campus, one of the largest centres of heath science and medical research in Europe on land it owns in the city and therefore was not subject to the same planning restrictions as if it was on newly acquired land. At the time of writing, Oxford University is in the process of developing a much smaller incubator on land it owns on the edge of the city.

3.6 networks

An indicator of formal (and informal) interaction, between entrepreneurs in the two economies and hence of mature stages of high-tech based regional development

[7] http://www.stjohns.co.uk/

(Feldman and Francis 2006) is the rapid rise in the number of formal networks. By 2008 Oxfordshire had 65 and Cambridgeshire 59 formal networks, ranging from large and highly specialised networks to smaller networks, for example breakfast clubs. In Cambridge the largest network is the Cambridge Network which organises its own events and acts as an umbrella organization for other networks. Its members include One Nucleus, which is a membership organisation for international life science and healthcare companies, based in Cambridge and London [8]. In both, networking is particularly strong in the biotech sector. In Oxfordshire, Oxfordshire Bioscience Network (OBN) has replaced the Oxfordshire BiotechNet as the formal network for the sector.

Oxfordshire and Cambridgeshire each had focal points for formal networking in their incipient or emergent stages. Both provided incubator space and later supported business angel networks. In Oxfordshire networking began in 1985 when the Oxford Trust (now Science Oxford), was established by Sir Martin and Lady Audrey Wood (founders of Oxford Instruments). This is a charitable trust whose mission is 'encouraging the study, application and communication of science, technology and engineering'. Participants included university-based and national laboratory entrepreneurs but there was no formal tie to either of Oxford's universities.

Similar developments occurred in Cambridge somewhat later but this time based at a University of Cambridge college St John's College opened the St John's Innovation Centre in 1987 which does act as an incubator and as a focal point for networking and interfacing with regional, national and international technology transfer programmes (Waters and Lawton Smith 2002). Over time a different landscape with other actors taking the lead has emerged in both locations, with the Oxbridge universities becoming more active as sites for networking, especially in their business schools (see below).

3.7 Governance

Two aspects of the extent to which regional triple helix spaces exist relate to specific political and institutional/organisational environments and the degree to which the universities engage in them. First, decisions made at the national level on systems of government have profoundly changed key actors and their agency at local levels. Following the change of UK government in May 2010, the regional development agencies (RDAs) established in 1999 were abolished. They have been replaced by Local Economic Partnerships, 'joint local authority/business bodies that reflect genuine economic areas to promote local economic development'. They are intended to represent the core actors in a region. Those in the two regions differ in the scale: the Oxfordshire LEP is countywide but the equivalent in Cambridgeshire is the Greater Cambridge, Greater Peterborough Enterprise Partnership which covers a much wider area with a population of 1.3 million[9]. Cambridge University is represented on the board by the Cavendish Professor of Physics, also an experienced business man, at the University of Cambridge, and Anglia Ruskin by the Vice Chancellor. The two universities in the Oxford LEP are both represent at Pro-Vice Chancellor level.

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[8] http://www.cambridgenetwork.co.uk/directories/327/ (accessed 13 January 2013
[9] http://www.yourlocalenterprisepartnership.co.uk/ (accessed February 24th 201)

Second, neither Oxbridge university can be seen as an ROI. As a core actor, Oxford University's engagement in local economic development has been limited and has not changed in any major way from a position of not seeing the local hinterland as being of interest (Lawton Smith 1991). In 1999, however, the university appointed a Regional Liaison Director who was initially on secondment from Barclays Bank, but later funded under HEIF. The Regional Liaison Office was established under his leadership. At the time, the appointment, "underlines the University's commitment to play a more prominent part in local economic development". The office was absorbed into Isis Innovation in 2008. Until his retirement in September 2011, the post holder was the point of contact rather being someone in a position of authority.

This lack of engagement is in contrast with the efforts of leading figures within Cambridge University and its colleges, to pull together key stakeholders to consider the prospects for growth in the Cambridge sub-region. Two main initiatives are the *Cambridge Futures* and *Horizons*. Cambridge Futures, a private sector led organisation, was set up in 1996 to stimulate thinking about the future development of Cambridge, and to influence policy decisions. It was led by the Department of Architecture in the University of Cambridge, but involved a wide range of senior people in private, public and third sectors. *Horizons,* a company limited by guarantee was created in 2004 to manage the delivery of the growth strategy for Cambridgeshire. Its particular contribution to the development of the Structure Plan was through its remit to address issues of congestion and housing shortage which were identified as constraints to the growth of the high tech clusters in the second Cambridge Phenomenon report (SQW 2000). It was an outcome of collaboration between key local stakeholders (although it was disbanded in 2011 as a result of withdrawal of government funding, SQW 2011). Its board comprised a cross-section of partner representatives (elected members) and independent figures from different sectors, and was supported by the Joint Strategic Growth Implementation Committee (JSGIC). This involved all the local authorities but did not have statutory planning powers, which remained the preserve of the local authorities. Although these have been important actions, they do not in themselves suggest the existence of a formal 'innovation space' because as in Oxford, there is still fragmentation of effort both within the universities as well as between the universities and local government.

4. Conclusions

The paper addresses the research questions: how different are these apparently very similar sub-regions, in other words, how unique are they, and how successful are they? It is shown that they are examples of globally important knowledge spaces (Etzkowitz 2008), with high concentrations of strategic science (Rip 2002). As smaller centres of high technology, they are much smaller than Silicon Valley but are successful when the growth of the numbers of high tech firms and employees are used as the criteria. Although the composition of the two high tech economies differs in the number and sectoral composition of clusters, the scale of activity is not very different. Moreover, the two regions have a complement of incubators and science parks, although with a stronger orientation towards biomedical science in Cambridge compared to Oxford. The similarities between them suggest that they are not unique although they are inevitably different from places not dominated by world leading universities (see Lendel 2010).

Associated with the growth of the high-tech sector and key to each region's adaptability is the strength, depth and mobility of their highly skilled labour market. The universities play no small part in this through their contribution to being attractive places to live and work, and more recently through formal entrepreneurship programmes. Both entrepreneurship and labour markets are neglected in the innovating regions framework (Etzkowitz and Klofsten 2005) and the regional triple helix spaces concept (Etzkowitz 2008).

In both, stability has been provided by a small number of long-established, anchor firms. Also important as indicators of the dynamism of regions, an effect rather than a cause, is the presence of formal networks. Beyond the scope of the paper, however, is Schumpeterian analysis of the roles played by the entrepreneurs as the pioneers of change, compared with the inventors or a managers in the relationships and interactions between actors.

It might have been predicted by the 'innovating regions' and the 'regional triple helix spaces' models that the Oxbridge universities would inevitably be instrumental in the growth of the two high tech economies as a source of important firms and in processes involved in governing co-ordination of growth. This has been shown not to be the case. Instead there are mismatches in how the regions might from greater interaction on the part of universities, form 'regional triple spaces (see Leydesdorff and Zawdie 2010).

Mixed evidence of the importance of university institutional arrangements in spinning out new firms might be expected to be a key element in their role as 'entrepreneurial universities' is found in both (Etzkowitz 1983). While internal changes were important, their impact did not cause any significant systemic changes within the counties as might be predicted in the idea of an innovation space within the regional triple helix model. For example, while the largest Oxford University spin-offs (broadly defined) have contributed to Oxfordshire's changing industrial structure, it was the entrepreneurs who gave birth to the entrepreneurial region and not 'collective entrepreneurship' involving the university per se. Where the impact of the universities is most visible in both places is the establishment of incubators and science parks.

The paper has also highlighted the importance of specificities of political and institutional/organisational environments. In these two locations, coordination of high-tech economic development has taken place largely in the absence of public policy at the local level. National government has provided funding for business networks and for technology transfer activities, including specific funding for the creation spin-offs. Oxfordshire's Science Vale UK is an example of a nascent triple helix space similar to that developing in Grenoble, but this is not replicated at the level of the county. In Cambridge the university's presence has been felt though the actions of university-based individuals who have played a strategic role in driving change.

The analysis of this growth finds different kinds of systemic effects co-existing with events that are independent and in themselves do not bring about wider processes of change. The agency of individuals and of key organisations is fundamental to understanding the dynamism of regions. However, this has to be tempered by such realities as the planning process, which in historic cities such as Oxford and Cambridge really matters. More broadly, Oxbridge is still far from Silicon Valley and, perhaps by themselves they are not enough. A better unit of analysis is the university triangle region of Oxford-Cambridge-London, or more broadly the European scale as regions which might compete with Silicon Valley.

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Appendix A Eurostat definitions

Eurostat Definition:
The Eurostat definition is based on NACE Revision 2, which is identical to the UK 2007 SIC. Sectors are defined at the 3 digit SIC level for high-tech manufacturing and at the 2 digit level for high-tech knowledge intensive services.
High-tech manufacturing:
SIC 21.1: Basic pharmaceutical products
SIC 21.2: Pharmaceutical preparations
SIC 26.1: Electronic components & boards
SIC 26.2: Computers & peripheral equipment
SIC 26.3: Communication equipment
SIC 26.4: Consumer electronics
SIC 26.5: Instruments & appliances for measuring, testing & navigation; watches & clocks
SIC 26.6: Irradiation, electromedical & electrotherapetic equipment
SIC 26.7: Optical instruments & photographic equipment
SIC 26.8: Magnetic & optical media
SIC 30.3: Air & spacecraft & related machinery
High-tech knowledge intensive services:
SIC 59: Film & TV programme production, sound recording & music publishing
SIC 60: Programming & broadcasting activities
SIC 61: Telecommunications
SIC 62: Computer programming, consultancy & related activities
SIC 63: Information service activities
SIC 72: Scientific research & development

Appendix 1: High tech---narrower definition

The wider definition extends the Eurostat definition by adding in medium high-tech manufacturing sectors, as defined by Eurostat at the 3 digit SIC level. Selected additional knowledge intensive services are also included in the wider definition, again defined at the 3 digit SIC level (Table 3).

High-tech & medium high-tech manufacturing:
As above for Eurostat definition, plus:
SIC 20.1-20.6: Chemicals & chemical products
SIC 25.4: Weapons & ammunition
SIC 27.1-27.9: Electrical equipment
SIC 28.1-28.9: Machinery & equipment not elsewhere classified
SIC 29.1-29.3: Motor vehicles, parts & accessories
SIC 30.2: Railway locomotives & rolling stock
SIC 30.4: Military fighting vehicles
SIC 30.9: Other transport equipment
SIC 32.5: Medical & dental instruments & supplies

High-tech & selected other knowledge intensive services:
As above for Eurostat definition, plus:
SIC 58.1: Publishing of books, periodicals & other publishing activities
SIC 58.2: Software publishing
SIC 71.1: Architectural & engineering activities & related technical consultancy
SIC 71.2: Technical testing & analysis
SIC 74.1: Specialised design activities
SIC 74.9: Other professional, scientific & technical activities

Appendix 2 High-tech: wider definition