The Global Evolution of Cambridge's Crossover Model of Innovation

Philip Cooke, Centre for Innovation, Bergen University College

Contents List

0. Executive Summary

1. Cambridge science park was set up in 1970 with the aim to attract existing science-based industry. This was fulfilled by academic entrepreneurship based on funded research. It gave rise to an ecosystem in the form of new science and technology-based business that has been growing ever since, with a strong acceleration in the 1990s.

2. Knowledge arising from the research conducted in Cambridge is of world-class and pathbreaking, meaning that the alumni and staff have an initial advantage in publishing, being awarded Nobel Prizes and, for academic entrepreneurs, being early or first in the market with commercial innovations, innovative processes or new business models.

3. Cambridge is a collaborative enterprise complex. It has a high rate of networking among technology entrepreneurs, university researchers and government or military representatives and clients. It is not a top-down hierarchical system in any meaningful way.

4. Government intervention has been more indirect than direct although the UK has been slow until recently in promoting the idea of "innovation systems" of any kind. Accordingly there was always "arm's length" government funding for scientific research supplemented by industry and charitable trust-funding, assisted until 2016 (Post-Brexit) by the EU Framework Programme (Horizon 2020).

5. The internationalisation actors in the Cambridge cluster-platform are; first, the University leaders and professors who are the guardians of the research ethics of a world-class knowledge-intensive research institution, second, the academic and other entrepreneurs that meet the challenge of translating research discoveries into world-beating commercial innovations, and third the support infrastructure of research, partnership and entrepreneurial financing and services.

6. There is no formal strategy, nor has there been. The main driver has been incremental, evolutionary, sometimes rapid, change. The UK is an open not a managed economy and there is no present, recognisable industrial strategy in place.

7. Internationalisation has been based on scientific and technological expertise, knowledge and excellence. Thus globally important discoveries have been made ranging from the splitting of the atom, to the discovery of DNA and the science of low energy microprocessor design software and cybersecurity.

8. There is plenty of outsourcing to global leader firms like Apple, Samsung, Google, Microsoft and so on, as testified by the existence of research institutes of many of these being found in Cambridge.

9. The local-global interaction is complex but works well. Cambridge products and services are in demand globally in diverse product and service niches. Cambridge is understood to be an innovative culture with many exploited and exploitable ideas for foreign buyers. These also invest long-term (FDI) in the Cambridge cluster-platform.

10. Technological inspiration emerges from large cluster-platforms like Silicon Valley and lesser ones like Cambridge. New innovation models have emerged like that discussed regarding “crossover” innovations from microelectronics to advanced combustion engines and healthcare.

Main Report:

The Global Evolution of Cambridge's Crossover Model of Innovation

Philip Cooke

1.0 Introduction

1.1 This contribution reports on the drivers of the UK's Cambridge "cluster". The data show 4,330 technology companies (ICT, biotech and KIBS) which employed some 59,102 people and generated £11.1bn revenues in 2015. There are five firms worth more than £1bn and the area has one of the highest concentrations of Nobel prizewinners in the world (some 92 historically). The reported research identifies the main drivers of the cluster process, especially in respect of the international forces that have contributed to cluster growth. As part of the background analysis there is, early on in this report, a focus on the economic geography of corporate learning and knowledge flows. We place emphasis on the perspective that shows the "origins of wealth" lying in a combination (Beinhocker, 2006) of these related capabilities of international value networks. In the first section, the report identifies some milestones of corporate and regional learning.

1.2 In the second section, knowledge flows in clusters (after Michael Porter) are in focus, drawing upon key instances of research on both geographical and business literature. Here, perhaps economic geography and regional development economics were at the forefront. In the third section, we begin asking who drives internationalisation. Fourth, there follows a section on Cambridge ICT which explains a key transition point whereby corporate control of knowledge flows was "learned" by small and medium-sized enterprises (SMEs). From global supply chains and networks these have, through "outsourcing", "global innovation networks" and "open innovation," taken over from large firms.

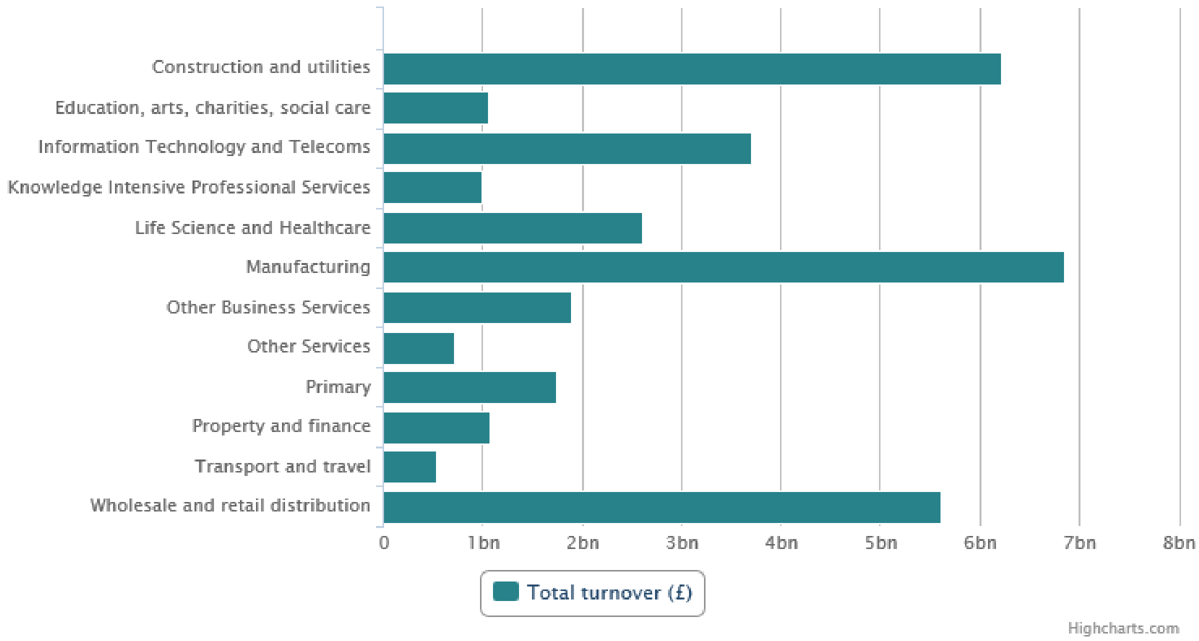
Table 1: Cambridge Cluster Indicators

All Cambridge Companies	***Total Turnover***	***Total Employees***
21,861	£33bn (7%)	196,625 (7%)

All data shown are for 2014-15 and % figures are for the change from the previous year. Last update: June 2016.

Source: CA Cambridge Ahead

Fig. 1 Cambridge Business Sectors (Source: Cambridge Cluster Map)



1.3 In the fourth section global shift of value chains and production networks towards global *innovation* networks of supplier platforms in Cambridge biotechnology is briefly explored. Of importance here is the plural “industries” connotation as Cambridge once relied on ICT but has now spawned a “platform” of ICT, systems design, biotechnology and clean technology (“cleantech”). In the fifth section the chapter moves to an understanding of the consolidation of SME supplier networks. This section focuses on the now important Software and Systems Design outgrowth from ICT in Cambridge. These open up for later comparison and contrast, in Section 9, two types of SME sub-system that have become “associative” institutions in the management of corporate buyer-supplier relations, namely regional innovation systems and enterprise ecosystems. In the sixth main section we account for the rise of a Cleantech cluster accompanying the others in Cambridge. There follows a brief exegesis of the deeper structure of economic learning and knowledge flow management emphasising – importantly as the chapter clearly implies – the importance of the shift in the nature of innovation to corporate and SME supplier interactions.

1.4 In this, the form of innovation in the corporate sphere ceased being mainly linear and evolved interactively in a realisation that much innovative potential is exploitable through “crossover” or “transversal” knowledge exchange among diverse industries and services. Pipeline connections designed to be secretive are now “glass pipelines” while agglomeration “buzz” became more encrypted in “dark pools” on the “dark web”. Military knowledge underpins the cybersecurity industry as aerospace informs automotives, hydrological algorithms inform structured finance and fine chemistry informs cuisine. No single corporate actor can control this but, without it, advanced economy capital accumulation is significantly arrested. Section 7 explores the limited role of the public sector in Cambridge’s technology-led growth. There follows, in section 8 an assessment of new roles for Government in the era of “Big Data”, encryption, privacy and exploitation by new market and non-market actors. Section 9 addresses the role of “associational governance” of the Cambridge cluster. It also makes a clear distinction between Cambridge’s near-market “enterprise ecosystems” and nearer research regional innovation system (RIS). Section 10 explores the question of strategy in the evolution of the cluster. Section 11 broaches questions of internationalisation, while section 12 relates processes of internationalisation and cluster localisation in corporate learning and knowledge flows. Finally section 13 marks the Conclusions of the report.

2.0 Cambridge Cluster: Post Porter Perspective

2.1 Problems with Porter's Definition

As a point of conceptual departure it is usual to note Porter's (1998) definition of clusters as: 'a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities'. There is nothing conceptually wrong with this definition except that it is static whereas the key feature of clusters is that they are *dynamic*. Hence we prefer that the following factors should be taken into account:

- A cluster displays a shared identity and future vision. This arises from the associational activities of such organisations (e.g. in Cambridge ICT cluster) as the (private) Cambridge Network Ltd, modelled on San Diego's CONNECT network
- A dynamic cluster is characterised by 'turbulence' as firms spin-off, spin-out and start-up from other firms or institutions.
- A cluster is an arena of dense and changing vertical input-output linkages, supply chains and horizontal inter-firm networks.
- It is likely to have developed localised, third party representative governance associations that provide common services but also lobby government for change (e.g. in Cambridge biotechnology, St John's Incubator (private), Babraham bioincubator, Sanger Genomics research and incubator, Eastern Region Biotechnology Initiative [ERBI: an important public agency, now replaced by Local Enterprise Partnership (public-private)] and, active 1999-2010 - specific services of the East of England Development Agency (EEDA)
- A cluster may have caused governments to develop policies to assist cluster development, especially where market-failures are present. ERBI began in such a manner to integrate shared knowledge, information and innovation interests of Cambridge's biotechnology businesses).

- Over time, clusters can reveal features of emergence, dominance and decline.

2.2 This is a more rigorous definition of clusters than Porter's because of its sensitivity to *process,* and it is more meaningful than the econometric objects catalogued in DTI (2001) which consist of regional sub-sectors with marginally above-average location quotients. The latter lack spatial identity, even in terms of localisation economies, or agglomeration, and they absolutely lack a sense of human agency supplied by the concept of *governance.* So we prefer to define clusters as: *geographically proximate firms in vertical and horizontal relationships, involving a localised enterprise support infrastructure with a shared developmental vision for business growth, based on competition and co-operation in a specific market field*.

2.3 Furthermore, we agree with findings expressed at the British Association for the Advancement of Science reported by Cookson & Pilling (1999) that states:

- Looser groupings of firms in clusters have better, more efficient knowledge transfer than stand-alone hierarchical corporations.
- Clusters (e.g. Silicon Valley) combine higher turnover of scientists and engineers with extraordinary openness about technical information.
- Clusters kill-off unproductive projects through insolvencies while large firms have weak mechanisms for ceasing them.

2.4 Returning to Porter (1998), we are in agreement that a number of advantages are derived from clusters. In particular, productivity gains arise from access to early use of better quality and lower cost specialised inputs from components or services suppliers in the cluster. Local sourcing can be cheaper because of minimal inventory requirements and transaction costs generally can be lower because of the existence of high trust relations and the importance of reputation-based trading. Common purchasing can lower costs where external sourcing is necessary. Serendipitous information trading is more likely in contexts where formal or informal face-to-face contact is possible. Complementarities between firms can help joint bidding and scale benefits on contract tenders, or joint marketing of products and services. Access to public goods from research or standards bodies located in proximity can be advantageous. Diverse types of knowledge, especially opportunities to exchange tacit knowledge are readily available in the cluster setting. They may not be 'untraded', although some kinds and levels may be; it is likely most trades are trust-based but conducted through the medium of monetary exchange

2.5 Also, innovation gains come from proximity between customers and suppliers where the interaction between the two may lead to innovative specifications and responses. User-led innovation impulses are recognised as crucial to the innovation process and their discovery has led to a better understanding of the interactive rather than linear processes of innovation. Proximity to knowledge centres makes the interaction processes concerning design, testing and prototype development physically easier, especially where much of the necessary knowledge is partly or wholly tacit rather than codified. Localised benchmarking among firms on organisational as well as product and process innovation is facilitated in clusters. Qualified personnel are more easily recruited and are of key importance to knowledge-transfer. Furthermore, informal know-how trading is easier in clusters than through more distant relationships. These points are largely concurred with in the now rather dated study of computer and biotechnology clustering in Swann, Prevezer and Stout (1998).

2.6 Local networking means new businesses are more readily formed where better information about innovative potential and market opportunities are locally available. Barriers to entry for new firms can be lower because of a clearer perception of unfulfilled needs, product or service gaps, or anticipated demand. Locally available inputs and skills further reduce barriers to entry. A cluster in itself can be an important initial market. Familiarity with local public, venture capital or business angel funding sources may speed up the investment process and minimise risk premiums for new start-ups and growing businesses. Clusters attract outside firms and foreign direct investors who perceive benefits from being in a specialised, leading-edge business location. These may also be a further source of corporate spin-off businesses. Finally, especially important are the *international* processes, networks and knowledge flows that underpin the successful cluster or growing and diversifying “cluster-platform” as with Cambridge, which combines ICT, systems, biotechnology and cleantech.

3.0 Cambridge Cluster: Who are the actors for internationalization?

3.1 The Emergence of Cambridge ICT hardware and software: Some examples

3.2 Three key features are crucial here. First, in high-tech it is essential that research is both world-class and within that category, high-grade. This means the knowledge flows of cognitive raw material are at the leading edge of problem definition and suitable teams of researchers exist in dedicated research centres capable of solving problems early or, preferably, first.

3.3 Second, the presence of global corporations with specific needs mean that long-term preferred knowledge suppliers have access to needed financial resources that also foster evolving research capabilities. Many Cambridge SMEs in software, for example, are quite small – up to ten employees, mainly serving a global customer or possibly two or three maximum.

3.4 Third, internationalisation involves not just UK global corporate clients but foreign ones for whom the world market is highly competitive. ARM is an excellent case of a Cambridge firm that started in hardware making Acorn computers in the 1980s-1990s but was able to access software design capabilities from private, local firms (e.g. Cambridge Consultants, PA Consulting) and develop the “fabless” non-hardware aspect of its targeted business. Learning from Silicon Valley’s RISC chip architecture, ARM became expert in learning of Asian silicon “foundries” where the designs could be realised. Flagship clients like Dell, Hewlett-Packard and Apple then contracted to Taiwanese “foundry” suppliers networked to their transplants on the Chinese mainland then discovered the network advantages of this model. It aggregated excellence at each point of the network. The ARM designs were instantly transferred electronically to the systems integrator (E.g. Mediatek), the logistics worked on a 98/2 schedule. This meant 98% of any chip consignment was delivered in maximum two days for assembly. Taiwanese transplant Foxconn and others met “flagship” quality and reliability standards. Accordingly, Apple’s Silicon Valley neighbour and leading chip designer-producer Intel was deemed too slow by comparison (Isaacson, 2014).

3.5 We have seen how for ARM (in 2016 acquired by Japan's SoftBank) like its smaller 4G, Bluetooth and "Internet of Everything" chip designer Cambridge Silicon Radio (CSR, in 2015 acquired by leading US communications firm Qualcomm of San Diego) dominated the world in specific chip system design. For this both firms managed knowledge flows in "fabless construction" of specialist chip technologies, e.g. low energy designs in the case of ARM that are highly desired by smartphone firms for their low energy capabilities in products for which short battery-life is an unsolved problem. They became so dominant that ARM controls over 98% of global smartphone chip demand because of their quality, reliability and innovativeness.

3.6 So, we focus in the next paragraphs, upon key mechanisms of internationalization such as work or employment, start-up business activity, financing, research etc. Next we inquire about positive and negative effects for both SMEs and MNCs (multinationals). Outsourcing is also conjectured to be important to the Cambridge businesses by amount and share of outsourcing firms involved. To start with the relative weight of internationalization mechanisms, especially workforce and employment (including skills), start-up profiles, finance and research the following factors are key:

- Regarding future priorities, Segal Quince Wicksteed (2011) noted the following key priorities for the future cluster. Listed first was *migration.* The meaning of this is skill shortages which demand inward migration of – generally – very high skilled employees from the relevant global labour markets. This emphasised recruitment from outside the EU because favoured graduate and doctoral skills pools are especially valued in Asian and some other non-European countries where, for example it is easier to major immediately in, for example, biotechnology. In Europe most universities still adopt classical pedagogies starting with biology and botany. Similarly, "design engineering" models of interdisciplinary team learning based on the MIT engineering syllabus are more common in Asia than Europe (e.g. at Singapore University of Technology and Design (SUTD); MAEER-MIT, Pune, India; MIT Malaysia Supply Chain Management Engineering; MIT-SUTD-Zheijang University.

- Second emphasis is placed (SQW, 2011) on the need for reform to *fiscal regimes.* This indicates official recognition of need to increase volumes of early-stage investment finance (noting lack of finance has been a real constraint on growth in the high-tech sector) and support for research, commercialisation and innovation. The global financial crisis dried up many sources of risk finance although low interest rates and quantitative easing moderated this over the 2011-2016 period. Nevertheless global expansion in advanced technologies and the prodigious amounts of investment capital required meant EU scale coffers were insufficient for the likes of ARM (bought by SoftBank), CSR (bought by Qualcomm) and Cambridge Consultants (CCL; bought 2002) by Altran. In the last case, CCL has also acquired US high-tech firms like Synapse (2016).
- Finally, emphasis for future growth was placed on continued acquisition of research funding, understood as the key knowledge core of – especially – ICT and biotechnology innovation excellence. Further the identification of *flexible research funding* that furthers and fosters "knowledge at interfaces" types of interdisciplinary research profile to evolve along multiple crossover research pathways. A new development bolstering research at Cambridge University has occurred as follows. Because of UK (and EU) financial weakness so-called "quantitative easing" more commonly known as "printing money" is practised by the Bank of England (and in the Eurozone, the European Central Bank). In the UK the Bank of England currently buys bonds issued by some universities, including Cambridge. The largest university bond was a £350 million issue from Cambridge in 2012 with a maturity date of 2052. Such bonds are sold to finance university research and teaching – deemed officially to make a material contribution to the UK economy. Accordingly, the Bank now also has a contributory role in funding long-term Cambridge University research (Wilson, 2016).

As a final and recent indication of the financing prowess of the UK's leading seats of academic entrepreneurship in the country's changing circumstances, the following report is indicative. A comparison of University venture funds shows the UK at the global top of the league (Table 2). Within the KAUST (King Abdullah University of Science & Technology of Saudi Arabia) University Venture Fund data for the UK,

Country	Magnitude
UK	$5 billion
US	$4.5 billion
China	$2 billion
France	$1.1 billion
Japan	$0.6 billion

Table 2: University Venture Funds

Source: KAUST Innovation Fund (2016)

Cambridge Innovation Capital (a private investor) was a key investor in intellectual property, raising £75 million. From 2011 to 2016 University of Cambridge Enterprise (public knowledge transfer office of the university) 11 companies were sold or stock exchange listed with a combined value of £1.3 billion. These spinouts oen their own IP and were incubated in the university with regular peer-review of progress before coming to market. As hinted earlier, much of this initial investment capital comes from the Gulf and Asia (Frean, 2016).

3.7 Many of the effects of the global financial crisis, and some or all these listed key priorities, will also be affected by the UK exit from the EU with its negative and positive effects upon the cluster-platform. Access to high skilled migrant labour from the EU is also affected by migration policy from the UK state. It is less a driver of negative effects than non-EU talent recruitment which, as we saw, is seen as more modern in its curriculum than EU labour. Thus it may in different ways happen to EU and non-EU talent recruitment. As SQW (2011) say, the cluster:

> "...must recruit workers they need, recognising a particular shortage of top quality management and marketing skills but also the imperative to attract internationally excellent professionals from all spheres" (SQW, 2011, vi).

This means EU-start-ups, management and research leaders may continue to be sought while non-EU trained medical diagnosticians and analysts and technologists in medical and ICT fields will remain in demand. Finance will remain an imperative if high-tech growth occurs while the UK’s declining currency makes acquisitions from abroad more likely and attractive. However, Cambridge foreign acquisitions still occur as noted with CCL’s recent acquisition of US firm Synapse. This is part of its strategy to evolve a track record of creating high-value organisations built around disruptive technology, developed by its staff. Four of Cambridge's $15 billion capitalisation firms - Cambridge Silicon Radio (CSR), Xaar, Vectura and Domino Printing Sciences - are among those spun off by the company. Other spin-offs include Alphamosaic and Inca, who were subsequently acquired by Broadcom for $123m and Japan’s Dainippon Screen for $60m. With the expansion of its US presence, it will also be bringing its venturing activity to the US. Finally, there is great uncertainty about basic and applied research funding that hitherto came to Cambridge research from programmes such as Horizon 2020. The UK government has given some reassurance that substitution of such funding will occur short-term, but the final arrangement awaits the results of BRExit negotiations. By contrast as shown, long-term uncertainty is in part insured against by the issuing of Cambridge University bonds that are currently available for purchase by the UK central bank’s quantitative easing policy.

3.8 Outsourcing is the fundamental core management capability of the Cambridge cluster-platform. We can say this relationship between Cambridge firms to the outside world and from the outside world into Cambridge takes at least five main forms:

- Partnership – where firms like CCL partner start-ups, consult to them leading to spin-off and continued contractual market relationships
- Commissions – one-off contracts for specific knowledge and expertise
- Ownership – purchase of desired firm capabilities from home or abroad
- Acquisition – sale of Cambridge-originated firm to overseas or domestic buyer (e.g. ARM-SoftBank; CSR-Qualcomm; CCL-Altran)
- Alliances – regular local or global agreements jointly to design, develop or market innovations

From 1985 (SQW, 1985) to 2011 (SQW, 2011) the number of high-tech firms in Cambridge grew from 300 to 1,400. High-tech employment grew from 31,000 to 48,000 over the same period. As SQW (2011) puts it:

> "From a very early stage in their development, these high tech businesses are frequently global operations in terms of the customers they serve, ownership structures, investment decisions and the specialist labour markets on which they draw" (SQW, 2011, 8).

Cambridge's firm size structure is mainly composed of SMEs topped by four –to-seven larger native enterprises. It is noteworthy that some larger firms and many SMEs are in fact consultancies:

- In the Partnership category - of the major Cambridge consultancies by turnover, (CCL; PA; TPP; and Sagentia the average overseas work represents 70 per cent of their total projects with 42 per cent from North America.
- In the Commissions category including the some smaller but increasingly influential consultancies, the average figure for overseas business is 49 per cent with 30 per cent coming from across the Atlantic
- Among Ownership (including "sticky" FDI category) firms are: CCL (acqurer of Synapse (US); "sticky FDI" include Evi attracting Amazon R&D to Cambridge; Deep Mind attracted Google artificial intelligence (AI) R&D facility to Cambridge (Kirk & Cotton, 2016)
- In the Acquisition category are - Domino (2000 employees worldwide - inkjet printing); ARM (now SoftBank, 1,700 worldwide; chip design); Autonomy (now MicroFocus, 4,500 worldwide; enterprise software); and CSR (now Qualcomm, 1,400 worldwide; bluetooth chips); Cambridge Antibody Technologies (550 employees in CAT-Medimmune-AstraZeneca, biotechnology); Chiroscience (2,300 employees; Medeva, biotechnology)
- In the Alliances category are included international agreements among – ARM- Apple, Google, Samsung, Qualcomm (systems-on-a-chip, SoC); AstraZeneca with Labcyte, HighRes Solutions and Genedata (Biorobotics; gene discovery and diagnostics); 42 Technology & Design Triangle (automotive design)

4.0 The Emergence of Some Cambridge Biotechnology Firms

4.1 This process of foreign acquisition has occurred historically and not only in ICT but also biotechnology. A comparable case is Cambridge Antibody Technologies founded in Cambridge as a spin-out from the UK Medical Research Council's

Molecular Microbiology Research Centre (MMRC) in 1989. Cambridge Antibody Technologies (CAT) was a biotechnology company. Its core focus was on antibody therapeutics, primarily using phage display and ribosome display technology. It discovered the successful treatment Humira. CAT was acquired by UK/Swedish corporation AstraZeneca for £702m in 2006. AstraZeneca subsequently acquired US biotech firm MedImmune which it combined with CAT to form a global biologics division called MedImmune. CAT was often described as the 'jewel in the crown' of the British biotechnology industry and during the latter years of its existence was the subject of frequent acquisition speculation. In the case of adalimumab (Humira), the process started in 1993, when BASF Pharma commissioned CAT to make a TNF neutralizing human antibody, using the newly described phage display technology. Within 2 years, the lead compound that became adalimumab (Humira) had been identified and the drug candidate passed onto a new journey. The expertise of many hundreds of professionals steered the candidate drug through pre-clinical and clinical testing, manufacturing, regulatory affairs, approval and marketing. The smaller companies involved at the outset were swallowed up into larger organizations. Many thousands of patients participated in clinical trials leading to the approval of this drug in 2002.

4.2 More recently Cambridge has been responsible for producing companies such as Astex Pharmaceuticals, Chroma Therapeutics and Funxional Therapeutics. This combined with world leading companies such as AstraZeneca and Gilead has ensured that Cambridge has remained one of the world's leading biotech clusters. In 2016 AstraZeneca moved its HQ to Cambridge from London. Cambridge Biomedical Campus currently employs over 7000 industry professionals. Spin outs from Cambridge University are supported by the University of Cambridge Enterprise agency which provides seed capital, consultancy and IP advice. Spin outs in Cambridge have also been well supported by a number of venture capital firms and biotechnology incubators. Venture capital companies such as ET Capital, Total Medical Ventures and IQ Capital partners are located in the cluster. Cambridge has a long and highly successful history in angel investments. Cambridge Angels is a group of investors who typically invest £50,000 to £500,000 in early stage ventures such as Phico Therapeutics and Oval Medical. Cambridge Angels have invested over £20m in over 40 companies in a variety of technology areas including biotechnology.

4.3 Cambridge Science Park, established in 1969, has traditionally been home to spin out companies and has also seen a number of global pharmaceutical companies set up operations in the park. Amgen, Genzyme, Mundipharma and Takeda are nestled alongside small innovative companies such as Sentinal Oncology, Novus Biologicals and Celldex. This park is just one of the many business parks that surround Cambridge, with Granta Park also highly prominent within the life sciences sector hosting companies like F-Star, Bicycle Therapeutics, Kymab, Vernalis, Gilead Sciences, MedImmune and Pfizer Regenerative Medicine. It also houses One Nucleus, the organisation established to tie together the various aspects of the cluster. One Nucleus, formally known as ERBI (see above, p. 2-30) is a not-for profit membership organisation which aims to maximise the global competitiveness of its members. The organisation has recently expanded to include the London Biotechnology Network (LBN) which has significantly boosted business-to-business interactions and elevated the cluster to a global level. One Nucleus now has over 500 members in fields such as pharma, biotech and medical devices. One Nucleus runs events and provides networking opportunities for it members. Of these, the Genesis conference attracts a global audience. One Nucleus is fundamentally a public representational agency (membership organisation), a first stop for any information seeker, networker or entrepreneur to be able to access signposts or other indications of what associational services the Cambridge biotechnology cluster offers. The Cambridge Network has had a similar history, but with more of a private-sector flavour in the past, with its origins in the early years of the ICT cluster trajectory. Organisations like, for example the Babraham Bioincubator will have membership of One Nucleus and events, services and opportunities that it offers to incubatee start-ups and so on, will be available from One Nucleus. But for specific commercial, entrepreneurial or innovation requirements of candidate occupants of Babraham or other bioincubators or science and technology parks customers will primarily receive their expertise requirements directly from the incubator. This also includes making successful networking and learning relationships with domestic and foreign membership associations like nearby Stevenage Bioscience Catalyst (SBC) which is the UK's first "open innovation" biomedical catalyst and, for example, BioVentureHub, AstraZeneca's bioincubator initiative in Gothenburg. Here, One Nucleus identifies business incubation models from which members can learn and various members potentially apply new and interesting practices.

4.4 One Nucleus organises an annual promotional event ON Helix, which focuses on Translational Research, and compliments their more industry-focused annual event called Genesis. One Nucleus is a not-for-profit organisation, which has its largest footprint of members in the Cambridge and London "corridor". This is considered the largest healthcare biocluster in Europe. One Nucleus is also a leading European Healthcare Network that helps maximise the global competitiveness of One Nucleus members through group purchasing initiatives, events, training and other support. One Nucleus promotes its growing international membership, and its focus on developing international collaborations with other leading membership organisations such as MassBIO, BIOCOM and BayBIO. Before merger, One Nucleus' Cambridge predecessor organisation had some 200 members. The London Biotechnology Network, more than 500 members, includes pharmaceutical, biotech, medical device and diagnostic companies and associated technical and commercial service providers. One Nucleus's mission is to maximise the global competitiveness of our members. For our science and technology-based members, that means being global leaders in the research, development and commercialisation of healthcare innovations that radically improve the quality of people's lives around the world. For our business and professional services members, it means delivering exceptional services that significantly enhance the business performance of their clients.

4.5 As noted, One Nucleus was formed in April 2010 by the merger of two regional lifescience networks – Cambridge-based ERBI and the London Biotechnology Network (LBN). Together we form a commercial, clinical and academic powerhouse. London and Cambridge are home to at least 60% of the UK's life science industry base, four of the UK's five Academic Health Science Centres and three of the world's top six universities. The merger of ERBI and LBN recognises that the Cambridge-London network is an international life science "super cluster". One Nucleus offers several member benefits including:

- A large pool of companies to support business-to-business interaction
- Membership of a cluster of international size, relevance and visibility

- One membership providing discounted entry to events in London and Cambridge
- Economies of scale supporting our group purchasing scheme
- An expanded training programme focused on the needs of members.

The One Nucleus strategy is to be non-regional, although ON remains London and Cambridge-centric in its activities. The growing membership base from outside the founding regions is testament to the greater value critical mass and economies of scale offer. The quality and depth of membership of the consolidated group provides much greater leverage in attracting high quality speakers and delegates to ON events, negotiating power with third parties on services and collaborations and enhanced opportunities to profile ON members to their target audience – all of which enable ON to deliver greater return on investment to members on their engagement. Examples already coming through are the recent deal ON announced to collaborate with World Business Research on the January 2011 BioBusiness Conference. The deal saves ON members up to £1100 on the cost of accessing a premier bio-partnering and thought leadership event.

4.6 Cambridge is known globally as a centre for research excellence. This has drawn the attention of global pharmaceutical companies and innovative biotechs. In order to maximise this potential The Cambridge cluster is part of the Health Axis Europe (HAE). HAE links three key European clusters: Cambridge (UK), Leuven (Belgium) and Heidelberg (Germany). The combined expertise of these clusters focuses on the development of regenerative medicine including stem cells, medical electronics, nanotechnology, personalized medicine and cancer research. Alongside One Nucleus and HAE the 2015 launch of the UK Golden Triangle (London, Cambridge, Oxford) Partnership will allow for the UK biotech clusters to work closely and ultimately compete and collaborate with other leading global biotech clusters. The aim of the partnership is to develop international biopartnering and investment activities.

5.0 Recent Important Events in Internationalisation of Systems and software design firms

5.1 Operating from China, a small "Asian tiger" economy like Taiwan has been associated not just with "global production chains and networks" but emergent "global *innovation* networks". This occurred through the aspects of the global value chain for ICT that they dominate – as with flat screen technology – now colonised by Korea's giants Samsung and LG and "chipsets" for which Taiwan's Mediatek has been a leader. Judicious national innovation system (NIS) actors like the innovation agency ITRI have been key intermediaries between Taiwanese suppliers and global corporations, even facilitating FDI acquisitions (e.g. from IBM) amongst other actions. Such firms systems-integrate knowledge emanating overwhelmingly from Cambridge (UK) software and systems design firms – so-called "fabless" design requiring no domestic "chip" or semiconductor manufacturing in-house. Even a putative leader in such systems design, Apple's neighbour in Silicon Valley, Intel buys its "fab" designs from ARM (Advanced RISC Microprocessors) while the latter outsources the fabrication ("fab") to a specialized manufacturer called a semiconductor "foundry".

5.2 Such foundries are typically, but not exclusively, located in China and Taiwan. One of ARM's attractions to its 2016 acquirer, Japan's SoftBank, is that it has evolved the design of low energy chips that are crucial in computers, tablets and smartphones that suffer short-life battery capacity. SoftBank's attraction for ARM is limitless research investment for next generation designs (e.g. "Internet-of Things"). ARM thus followed its neighbour Cambridge Silicon Radio (CSR), a specialist Bluetooth chip designer ("Internet-of-Everything" and automated vehicles, especially) into foreign ownership in 2015, on this occasion acquired by Qualcomm, the San Diego mobile communication company. In passing, other recent Cambridge acquisition targets have included Datanomic, a leading provider of customer risk and compliance data screening acquired in 2011 by Oracle for just $80 million. Then, later that year data-mining software flagship Autonomy was purchased for $10 *billion* by Hewlett Packard (HP) and seen as an indicator of HP's then policy of seeking to develop as a software and systems services firm. In 2016 UK firm MicroFocus of Newbury; Berkshire in the M4 corridor then acquired the enterprise software assets the former Autonomy, now called Hewlett Packard Enterprise in an $8 billion-plus deal. Other South East UK knowledge businesses recently acquired by US buyers have included artificial intelligence firm DeepMind, acquired by Google for $600 million, Tweetdeck a customer data analyst for $40 million by Twitter and SwiftKey a keyboard software designer bought by Microsoft for $250 million. The “knowledge flow” conveyor belts inter-connecting these agglomeration platforms are a notable feature of contemporary globalisation.

6.0 Recent Events in the Cambridge Cleantech Cluster

6.1 In 2014 Cambridge celebrated the opening of a business incubation centre set to bolster the social enterprise and cleantech clusters. The Future Business Centre hosts a new wave of entrepreneurs finding profit generating solutions to social and environmental issues and testing new business models. The Centre opened its doors in 2014 after securing final funding at the end of 2013. Awarded BREEAM (UK green energy approval) standard for environmental design excellence, the centre showcases local energy efficient technologies as it establishes itself as the UK’s hub for ambitious organisations that want to create positive social and environmental impact.

6.2 As an indication of the manner Cambridge Cleantech operates internationally, the following *Business Weekly: Cambridge Business, Innovation & Technology* Newsletter is instructive.

> “.....Clean technology companies from across the Cambridge region and the UK have just returned from a major and successful trade mission to China and Hong Kong.
>
> The mission, which was led by Cambridge Cleantech as the official UKTrade International approved organiser of the British Pavilion at the trade fair event, included 15 companies exhibiting at and attending the largest building technologies convention in China with 3,000 attendees. The event took place in Beijing over three days and was organised by the Chinese Government’s Housing and Urban Development Department.
>
> A number of the UK companies travelled on to Hong Kong and attended and spoke at a full day cleantech seminar at the Hong Kong Science and Technology Parks – which was the first international partner to join Cambridge Cleantech 18 months ago.
>
> UK exports to China doubled in 2015 and with the new Chinese 5-Year Plan incorporating a major section on achieving an improved environment, the opportunities for Cambridge and UK cleantech companies are immense.

Companies attending the mission included: The David Ball Group PLC, Cyan Technology Ltd, Stramit, Cambridge Architectural Research, Cambridge Environment and Technology, the Building Research Establishment, the Chartered Institute of Builders, ADAPT UEA, Fielden Clegg, Space Syntax, NDTSL, Space Syntax and Studio LK.......”

6.3 Cambridge CleanTech (CCT) has well over 300 members as of 2016. The organisation provides a range of services, from access to finance to contract opportunities for members, and coaching for start-up companies. In the forthcoming two years CCT’s plan includes helping member companies to grow to be international scale competitors, and then further explore the international agenda. CCT has signed a Memorandum of Understanding with an equivalent membership organisation in China. Inward investment to Cambridge also occurs. As an example, Solar Cloth Co. a UK start-up with £1 million in crowdfunding began making solar cloth to generate energy from yacht sails after the America’s Cup race was staged in Valencia in Spain. CCT persuaded the firm to move from Valencia to Cambridge and actually set up and use its services. Why? Mainly because there is a huge educational benefit being located in Cambridge, with the University, and the environment and the cluster which meant it made commercial sense.

6.4 CCT’s guide to members lists the following seventy core cleantech firm in the Cambridge local postal area. Some twelve (24%; identified with asterisks *) of the cleantech firms in the UK’s top fifty as judged by CCT and accountants KPMG were located in Cambridge in 2016. Because of its relatively recent evolution and to give a clear impression of the numerical scale of the CCT cluster we provide a simple list of players that may, if so desired, be inspected by interested readers from their websites. Firms in the CCT cluster located in Cambridge include Adiabatic Logic, Aideas, Alquist, Amantys Ltd, AmeyCespa, Anther Investments, AppNearMe, Archipelago Technology, Ardenham Energy, ArmadilloLED, Arriba Cooltech, Aveillant Ltd*, Azuri Technologies*, Bactest, BDO, Beach Energy, Breathing Buildings*, Cambond, Cambridge Architectural Research Ltd, Cambridge Carbon Capture, Cambridge cmos Sensors Ltd*, Cambridge Energy Partners, Cambridge Environment & Technology Ltd, Cambridge Nanosystems*, Cambridge Solar Ltd, Cambridge Water, Cambustion Ltd*, Camfridge, Camrow, Carbon 2050 Ltd, Cernunnos Homes, Citrecycle, Cognima, Coheat, Cube Clean Tech, Cyan

Technology*, DZP Technologies Ltd, Educe, Energy Communications, Epicam Ltd, Evonet, Fauna & Flora International, First Ascent, Foca Energy Ltd, Futureneering Ltd, Green Energy Options*, Green Heat Ltd, Green-Tide Turbines, H2GO Power, Instinctively Green, iSotera, Kinetic Renewable Energy, KisanHub, Kition Research Ltd, Ocean Array Systems, Origami Energy*, Polydax, Polysolar Ltd*, Pulsar Light*, Reduse the Unprinter, Sagentia, SensorHut Ltd, Sentec*, Solar Cloth Company, Transition Energy, Viridian Solar, XMMO.

6.5 The Cambridge CleanTech (CCT) Plan

Greater Cambridge Action Plan

An array of themes and emerging opportunities for the Greater Cambridge sub-region are detailed in the following action plan. These themes with potential actions were discussed and tested by the stakeholders and included in the action when it was felt they contributed to developing Greater Cambridge as a world leader in the Cleantech sector and supported the development of a genuine low carbon economy in the sub-region.

In summary planning themes are to:

1. Create investment vehicles for early stage finance and link to R&D/prototyping capability.
2. Link academics to the private sector to facilitate the development of practical, commercially viable products and find innovative solutions to market problems.
3. Work with public sector partners or SMEs on procurement innovation initiatives or training.
4. Work with all new property developments in the Greater Cambridge area to create ‘living laboratories’ to test and prove new building technologies, products and methods.
5. Designate an area for a retro-fit initiative to install and trial energy-efficiency measures – ideally incorporating some of Greater Cambridge’s heritage or listed buildings.
6. Develop exemplar low carbon initiatives based on the outcomes of the Living Laboratory trials, including establishing a cleantech incubator to provide start-up space, business support and network space to help the sector develop.
7. Build on best practice examples in planning across the sub-region and showcase nationally.

8. Form local strategic alliances such as the adoption of the ‘Green Triangle’ idea : Greater Cambridge, Peterborough and Norwich, to benefit from complementary skills, and strengthen funding applications.
9. Form international alliances with an EU region such as Munich, to open up opportunities for EU funded projects, and international trade links.
10. Form worldwide international alliances with regions such as Cambridge MIT, USA or San Diego, USA for knowledge transfer opportunities, international marketing and inward investment.
11. Showcase skills capability in sustainable construction and sustainability in both higher-level innovation and lower-level skills.
12. Inward Investment – showcase region to the globe leveraging the additional benefits from local partnerships and strategic alliances.
13. Raise the profile of the GCP area aside from academia by showcasing practical Cleantech projects and highlighting the advanced manufacturing and engineering skills that also exist in the sub-region.
14. Establish sector focused business leaders groups.
15. Leverage Cambridge’s reputation and links to central government for lobbying and influencing policy at national level.
16. Identify specific sub-sector market failures and create corresponding sector initiatives and support.

7.0 The Role of the Public Sector.

7.1 It is clear that the direct role of the public sector in the evolution of the Cambridge “cluster-platform” has been very limited. The earliest initiatives to encourage agglomeration on the foundations of scientific and engineering research were made independently. The Mott Report (1967) was set up by Cambridge University to investigate science based industry and academic entrepreneurship in the town. Cambridge City Council supported this report as it was frustrated by the County Council's limits on housing and employment expansion and consequent limitation on local taxation. Local employers also supported it as they faced serious recruitment problems due to the lack of housing. The report took over a year to compile, with extensive consultation and debate, but represented a consensus. The report recommended careful relaxation of policies and in particular the establishment of a science park on the edge of Cambridge. This idea was influenced by Stanford University’s pioneering Science Park initiated by Frederick Terman, which opened successfully in 1949. In Cambridge the report was responded to by Trinity College, Cambridge investing its own resources (real estate and building costs) in 1969 with the establishment and opening in 1970 of the Cambridge Science Park.

7.2 The Cambridge Phenomenon

7.3 This was reported upon by a Cambridge business consultancy (Segal, Quince, Wicksteed, 1985) reviewing progress since the foundation of the science park. They deemed it a success due to the presence in and around Cambridge of many high-technology companies (computing, biotechnology, electronics & scientific instruments at that time). The authors attributed this success to:

- very high proportion of young, small, independent and indigenous companies and a corresponding low proportion of subsidiaries of large companies based elsewhere;
- a history of high-technology company formation such as; Pye (TV production), Marshalls (aerospace) and Sinclair and Acorn (personal computers)
- a tendency for high-technology companies to concentrate on research, design and development rather than production;
- numerous complex direct and indirect links between the companies and Cambridge University.

7.4 The Phenomenon Revisited: 1997

7.5 In 1997 it was reported that a second Cambridge Phenomenon, based largely around software and telecommunications systems and biotechnology, had evolved. A new report, Cambridge Phenomenon Report Mark II, was prepared by Segal Quince Wicksteed (1998), funded jointly by the European Commission, the Science Park, the St John's Innovation Centre, Cambridgeshire County Council and Cambridge Training & Enterprise Council. It criticised the lack of support from central Government to allow growth of high-tech business sector and in particular the lack of infrastructure developments, leading to planning pressures. 1,200 firms were surveyed to form the final part of the report, which was published in 2000. By then another Cambridge college had set up St John's Innovation Centre, founded in 1987. It provided active support for business development, and by 1999 having over 70 tenant start-up firms with a combined turnover of over £20 million. SJIC became the centre of a range of business support activities for high tech enterprise.

7.6 The Cambridge Phenomenon benefited from the university's approach to intellectual property as part of its liberal "open science" ethos. Unlike almost all other UK universities, Cambridge University did not claim title to the intellectual property created by its employees in the course of their duties. In practice, university research is largely funded by the Research Councils, charities and industry, all of which external sponsors require the university to manage the intellectual property output of their funding to the benefit of the inventors and the University. As a result the prevailing ethos is one in which the inventors were motivated to exploit their research and the university was able to facilitate this rather than compelling them to work with a potentially heavy-handed bureaucracy. The latter was then perceived as either driving commercialisation activities underground or stifling entrepreneurial initiative, both of which Cambridge then found unacceptable in its minutes of evidence to the UK Parliament's Science & Technology Committee (1999). By the late 2000s this policy was changed as universities everywhere tightened up their intellectual property management amid cuts to university budgets by successive governments.

7.7 Cambridge II

7.8 Hermann Hauser, co-founder of Acorn with Christopher Curry, was part of a *Cambridge II* initiative. His venture capital company Amadeus (with funding from the likes of software transplant Microsoft) was a leading actor in helping start-up companies. In agreement with Alec Broers (Vice-Chancellor of Cambridge University), spatial planner Marcial Echenique (Cambridge University School of Architecture and a transport planning specialist and David Cleevely (Analysys telecom consultant founder) decided to attempt to develop Cambridge's high-tech future. The initiative started around March 1997 and after a number of phases was due to conclude by the end of 1998. It looked at various issues such as land use, transport systems and telephony. The aim was to seek to accommodate growth through new Science Park development to permit expansion in collaboration between university and industry (Segal, Quince, Wicksteed, 1998).

7.9 Further emphasising the *non-governmental* support for investment in the Cambridge Phenomenon, the following is instructive. The funding requirements of new enterprises soon become increasingly recognised. The university saw very early the need for seedcorn finance and participated in seed capital funds, including the

Quantum Fund, and Cambridge Research and Innovation Ltd. Increasingly, successful entrepreneurs had become venture capitalists and making available further funding to start-up companies. These included Amadeus Capital (Hermann Hauser, a Cambridge graduate and founder of Acorn Computers), Merlin Ventures, a biotechnology fund (Chris Evans is not a Cambridge graduate but chose to set up Chiroscience etc in Cambridge) and the Gateway Fund founded by local financier Nigel Brown.The latest review of high-tech performance by the Cambridge cluster reveals, once again, that there is almost no role from the public sector in subsidising the Cambridge Phenomenon. Cambridge ranks in the top UK hotspots for growth of its digital economy and the role of the public sector in this has been minimal, The Tech Nation 2016 research survey-based report by Tech City UK and Nesta shows Cambridge as a thriving digital technology cluster based on incomes, density of businesses in the segment, international collaboration and economic payback. The report says turnover of digital tech businesses in Cambridge grew 46 per cent between 2010 and 2014.

Other key findings for Cambridge were:

- Average income in digital tech Industries of £47,194
- Digital Gross Value Added at £649 million represents growth of 12 per cent 2010-14
- Digital density (digital businesses as a percentage of total businesses) at 21 per cent
- Turnover growth for the sector of 46 per cent 2010-14 (Tech Nation Survey, 2016)

7.10 Since the Cambridge Phenomenon began being written about in the 1980s technology leadership has moved from hardware and computers to the then emergent software and systems design of smartphones and the Internet as part of the prodigious digital tech sector. As we showed, firms like ARM and CSC became world leaders in the digital systems design platform with Cambridge at its epicentre. Key sectors in Cambridge compared to the UK were in 2016 shown to be the Internet of Things (ARM), Internet of Everything (CSC) and connected devices, enterprise software (former Autonomy and Hewlett Packard Enterprise, now

MicroFocus) and cloud computing, apps and software development, data management and analytics (Alan Turing Institute; GCHQ; Intel).

7.11 The Alan Turing Institute (ATI) mission is to: undertake data science research at the intersection of computer science, mathematics, statistics and systems engineering; provide technically informed advice to policy makers on the wider implications of algorithms; enable researchers from industry and academia to work together to undertake research with practical applications; and act as a magnet for leaders in academia and industry from around the world to engage with the UK in data science and its applications. The online games sector in the region is booming along with digital healthcare technology. Key Cambridge cluster benefits are regarded as access to local networks (86 per cent), access to graduate-level talent (80 per cent) and business support (80 per cent).

7.12 Today, Cambridge has one of the best tech networking communities anywhere and it is a culture appreciated by local startups. As an example, Cambridge graduate Dr Jelena Aleksic is making genomic medicine more accessible as CEO and co-founder of GeneAdviser. GeneAdviser is an online marketplace for clinical genetic testing, making it easier for doctors to find and order lifesaving tests from accredited laboratories. Since 2015, she has secured a flagship National Health Service (NHS) laboratory as a customer, surveyed 1000+ clinicians, won awards and media attention, and attracted interest from clinicians across Europe as well as leading life sciences investors: “Having close working relationships with the local community of digital companies in Cambridge has been of huge benefit to GeneAdviser. The ability to share ideas and expertise across a collaborative cluster enables our business to grow faster and more sustainably. The digital tech ecosystem here is fantastic for starting and growing a digital tech business and Cambridge is rightly being recognised as a leading environment for entrepreneurs in the sector” observed Dr. Aleksic.

7.13 The Tech Nation (2016) report found that the digital industries are having a strong impact on employment across the UK and creating highly paid job opportunities, accounting for 1.56 million jobs across the UK. It reports the UK’s digital Gross Value Added as £87 billion and says the UK’s digital technology industries are growing 32 per cent faster by turnover than the national average of the rest of the economy. But the UK Government's Science & Technology Committee report on "Big Data: the Dilemma" (2016) warns that existing data is nowhere near fully exploited – companies are analysing just 12% of their data, and if 'data-phobe' businesses made good use of their data they could increase UK productivity by 3%. The Government can also do more to make its databases 'open' and to share them with businesses, and across Government departments to improve and develop new public services.

7.14 It is clear from this narrative that the role of the public sector is completely different from the role of subsidiser and enterprise support agency in the UK space economy of today. Intangible assets and data ownership management within ethical frameworks is much more important than making grants available for firms in the burgeoning "Big Data" sector in which many new Cambridge and other UK locations now house expertise in such activities as cybersecurity and big data analytics. Thus the kind of Cambridge Phenomenon evolution of public policy for digital-tech firms is shown in the following. It may be more directly partnership with the Defence Department than the Economy Department in the age of the digital tech entrepreneur. Senor & Singer (2009) showed Israel had more venture capital investment per person than anywhere in the world and the largest number of NASDAQ-listed companies (63) after the US and China. So, in 2010, the Israeli Army (Israel Defence Force, IDF) signals intelligence (SIGINT) Unit 8200 alumni decided formally to offer their expertise to other young Israeli entrepreneurs. The result was the 8200 entrepreneurship and innovation support programme (EISP), a five-month high-tech incubator in which Unit 8200 alumni volunteer to mentor early-stage startups. Between 2010 and 2013, 22 received funding totalling $21m (£13.5m) and employ 200 people, joining the 230,000 employees of Israel's 5,000 tech companies that earn $25bn a year – a quarter of Israel's total exports. This can be judged, on a scaled measurement, as a remarkable achievement, which has become a model for cybersecurity entrepreneurial ecosystems, now including corporate technology investors. All the main elements for generative growth are present: collaborative institutional and pioneering enterprise pursuit of social value, cohesion and solidarity that is driven, not foremost by profit, but collective citizen security. As a model of enterprise ecosystem practice, it is already influential.

7.15 Accordingly, in the UK, budding GCHQ spies may become entrepreneurs by exploiting GCHQ "Big Data" intellectual property (IPRs) for Cybersecurity applications or "Apps". The scheme is based on the UK's "Teach First" programme success whereby selected bright graduates work in challenging schools for two years on the promise of a commercial job if they leave teaching. To further this, the UK's Government Communications Headquarters (GCHQ) set up 11 university cyber-research centres & 2 virtual-research institutes. In 2014 its first cryptography "app" was released under National Cyber Security Strategy designed for firms and the public sector to combat cyber attacks (e.g. N. Korea). Today, it is often overlooked how much *innovation* originates at public initiative (as "collective" or "demand-driven" innovation). Historically, the public sector has had traditional conventions and rules against exploiting taxpayer funds for risk-investments. But where funding is strategic (and enormous) as in defence and healthcare, this risk-fear is lower. With the threat of Islamist-inspired jihadi terrorism at home and abroad, the strongest source for public innovation today is from spying. As we note below, this means Big Surveillance Data for Cybersecurity, especially as evolved over time in Unit 8200, NSA & GCHQ. Derived from the "dark web" skills obtained over decades by SIGINT that USA, UK and Israeli exporters of cyber security products find in demand, are the following. They include algorithms designed to protect companies, banks, governments and – since 9/11, 7/7, Madrid, Mumbai, Paris, Brussels and Nice – citizens far away from the Middle East war zones -- from the growing "dark web" of hackers, fraudsters, snoopers and terrorists.

8.0 The Role of Intermediaries: Associational Governance and Individual Entrepreneurship.

8.1 The previous section (7.0) on the changing role of enterprise and innovation support by government in a digital-tech age demonstrates how the world has moved on to the following position. This is a scenario, acted out in reality where individual entrepreneurs now know the high-tech post-venture capital risk-capital games like "crowdsourcing" and "crowdfunding" so they do not require hard public cash to invest, and where quasi-private governance (e.g. Cambridge II led by entrepreneurs and academics like Hermann Hauser, David Cleevely, academic spatial planner

Marcial Echenique and vice-chancellor Broers) takes future-oriented initiative for economic development because government has no resources of significance to make a difference or government's are prisoner to a "neoliberal" dogma that places faith only in the market to solve difficult problems. This is equally found in Silicon Valley where philanthropy, charity, and social infrastructure often substitute for public action where it has failed.

8.2 Where, by contrast, we see a role for intermediary institutions is in the panoply of cluster support activities that are in the "soft infrastructure" of entrepreneurship and innovation marketing support. In Cambridge, the following intermediaries have been active at one or other time assisting the ICT, biotech, software and systems and cleantech sectors.

- The Cambridge Network, which links together members and provides services modeled on those pioneered by San Diego's CONNECT organisation, since emulated in Leuven and elsewhere for academic entrepreneurship.
- St. John's Innovation Centre. St John's Innovation Centre provides early stage knowledge-based companies with tailored business services and flexible accommodation. It exists to provide a dynamic and supportive incubation environment to accelerate the growth of ambitious innovative firms in the Cambridge region.
- Cambridge Science Park. Established in 1970 the cluster began to grow rapidly. 39 new companies were formed between 1960 and 1969. In the 1970s, 137 were formed. By 1990, company formations had reached an average of two per week
- ideaSpace is a community of people in Cambridge starting high impact new ventures. ideaSpace members are creating new business models
- Cambridge Enterprise helps Cambridge University students and academics to commercialise innovative ideas by establishing a business.
- One Nucleus, formally known as ERBI is a not-for profit membership organisation which aims to maximise the global competitiveness of its members.

- Cambridge Biotechnology Campus. Houses 7,000 professionals and scientists
- The Wellcome Genome Campus is home to some of the world's foremost institutes and organisations in genomics and computational biology at Hinxton
- Babraham Biosciences Incubator & research Campus
- Cambridge CleanTech Member organisation for cleantech start-ups and evolved firms.

We may anticipate here the fairly obvious conclusion that this is both an agency and structure process in which individual scientists, technologists and entrepreneurs are institutionally embedded in a variable geometry of collective interactions and relationships with an organised ecosystem of innovation and entrepreneurship support institutions. It is not a directly public or managed bureaucracy. It is an innovation system in which there are cluster ecosystems focused upon evolving yet distinctive specialisms. Accordingly it is what the innovation systems literature differentiates into an entrepreneurial regional innovation system (ERIS) not an institutional or public one (IRIS). But no individual can function to develop innovative knowledge new to the market without institutional (formal and informal) collaboration or cooperation with appropriate actors, agencies, or other institutions.

8.3 So, to conclude, Cambridge's cluster is an "associational economy" with strong institutional links with government ministries for defence, health, technical innovation and environment. But it does not receive much direct public funding. But indirectly it is highly influenced by and influential upon such institutions. Increasingly, there is a rich tapestry of associational intermediaries, including risk-funding, venture capital and business angels. Accordingly most entrepreneurship is in some way integrated into diverse entrepreneurial ecosystems for ICT, telecom systems, cleantech and biotechnology. Accordingly, it is mostly a collective process but can appear individualistic though it is in reality, ecosystemic. Thus Cambridge, and its surrounding region, represents a high-tech "paradigm" of distinctive, advanced industries. In Schumpeterian fashion these recombine across boundaries as well as within them to enable innovation to be commercialised. Thus each part of this paradigm interacts with intermediary “associations” and other governance to constitute a “regime”. This in turn comprises the two main sub-systems of a RIS or “regional innovation system”. Within the Cambridge RIS and operating nearer to the market are the four “enterprise ecosystems” discussed in section 3, These are imitative more than innovative but do not simply consist of competitive atoms of entrepreneurship, rather they consist of particular ecosystems focused upon their specific market segment. This might be biotechnology, cleantech, ICT hardware or “digital tech”.

9.0 Initiatives have a History of Incrementalism while Policy Emerges from Below.

9.1 There is no specific cluster strategy for Cambridge. To the extent there is organised action to further collective cluster-platform interests among the ICT, biotechnology, cleantech, systems and software elements of the platform, they are captured in the “associational” agencies (discussed earlier in para. 8.0 to 8.2). Key among these is the Cambridge Network. To this may be added the Local Enterprise Partnership (LEP) which, as noted, is a UK government supported private-sector led enterprise support agency. Officially the LEP is known as the Greater Cambridgeshire & Greater Peterborough LEP. This is a sign of the small scale of the local cluster geography which is normally of a large city scale. So the local LEP is designed to drive forward sustainable economic growth in a mainly semi-rural area with local business, education providers, the third sector and the public sector working together to achieve this. Its goal is to create an economy with 100,000 major businesses and create 160,000 new jobs by 2025, in an internationally-significant, low-carbon, knowledge-based economy balanced wherever possible with advanced manufacturing and services.

9.2 Strategic areas of focus are:

- Skills and employment
- Strategic economic vision, infrastructure, housing and planning
- Economic development and support for high growth business
- Funding, including EU funding, regional growth funding and private sector funding

The GCGP area currently has a population of 1.3 million people, which is estimated to grow to 1.5 million by 2031. It hosts a number of globally-significant business clusters (as discussed in paras. 3.0 – 6.6), world class research capacity linked to universities, a number of thriving market towns, and is the UK's leader in agriculture, food and drink. The area boasts 700,000 jobs, 60,000 enterprises and generates £30 billion per annum. A number of Cambridge-based companies were listed in the Sunday Times Hiscox Tech Track 100 league table. The table ranks Britain's private technology, media and telecoms companies with the fastest-growing sales over three years. Key innovators featured in the list, including Cambridge-based Breathing Buildings* that has developed a patented way to ventilate buildings using the heat generated by bodies and technology and Green Energy Options*, also based in Cambridge, which designs devices to help people monitor energy usage in

Table 3: Tech Track 100 league table 2016

Rank	Company	Location	Sales (3 years %)	Sales 2016 (£'000s)	Staff
7	Semblant	Cambridge	173	5,496	13
29	Retail Telematics	Cambridge	106	8,792	20
39	Green Energy Options	Cambridge	87	14,835	60
73	Breathing Buildings	Cambridge	52	7,800	44
94	Cashflows	Cambridge	46	19,909	75
91	Grapeshot	Cambridge	47	5,020	59

their homes using their smartphone. The table features payment services provider Cashflows, advertising technology developer Grapeshot and liquid repellent non-coatings business Semblant.

9.3 An indication of the platform nature of increasing "crossover" innovation among different Cambridge cluster engineering firms is given in the following Cambridge Network notice. This notes that engineering companies are redefining the way in which they work, moving away from generalist sector specificities, and instead looking to re-define their core expertise. This may be the use of data, communication between different expertise, materials science or another particularity where they differ from competitors and other engineering companies. New opportunities and recognising market interfaces are perceived as important in ensuring a connected and successful engineering sector. To support the sharing of specialist knowledge and further development of the sector, the LEP's Regional High Value Design Group held an October networking seminar event at Cambridge's Granta Science Park about the crossover between aerospace, automotive engineering and healthcare. Forward Composites (materials science) reported on operations in the aerospace, defence, automotive & motor sport sectors. Crossover presentations from advanced combustion engine designer Cosworth Group of Cambridge, now a leader in the transfer of motorsport electronics technologies into adjacent markets were made. Other presentations linked AEC SELEX, part of the Italian company Finmeccanica Leonardo, one of the world's largest defence and homeland security technology companies and the largest Italian investor in the UK, to identify areas where SELEX's expertise can be used to keep people alive in a different setting, in the healthcare sector.

9.4 It is noteworthy that Apple was reported to be contemplating a £1 billion bid to acquire or make a strategic investment in nearby McLaren, the British motor racing company and technology business in its effort to enter the market for electric vehicles (EV). McLaren's technology (notably carbon fibre composites expertise) allows the Californian ICT giant to compete with Google and Uber's self-driving cars. McLaren not only manufactures luxury sports cars but technologies for healthcare, airplane scheduling and "black box" telemetry used in Olympic cycling. McLaren also has a partnership with pharmaceuticals corporation GlaxoXmithKline (GSK) to translate racing telemetry for patient monitoring systems (Eason & Dean, 2016). This follows Ford Motor Company's new strategy to position itself as a software company in a world of ride-sharing, non-car-owning individuals and autonomous vehicles. It aims to establish itself as an "auto and mobility" firm and find out optimal mobility mixes for customers. Ford has invested in Chariot, a private, crowd-sourced shuttle-van service in San Francisco. It has invested in bike-share firm Motivate and in September 2016 it supplied driverless Ford Fusion vehicles in Pittsburgh's mobility experiment initiated by Uber in collaboration with IBM on passenger wearable safety devices.

9.5 The UK-wide Technology Strategy Board was absorbed into the country's first Innovation Agency in 2014. It funds applied technology research for appropriate companies and partnerships. An example of how it supports innovation may be seen in this recent announcement. Innovate UK has up to £15 million to invest in the following call for innovative business projects in agriculture, food and healthcare. Projects must involve a small or medium-sized business and focus on one of the following priority areas:

- increasing yield, quality and sustainability in agriculture and food production
- improving precision medicine, advanced therapies, pre-clinical technologies
- advancing biosciences in healthcare and agriculture and food production

A growing and ageing global population, increased burden of disease and greater wealth are all accelerating demand for food and improved healthcare. The food and drink sector represents 30% of the $20 trillion global economy and healthcare 10%. There is a £250 billion global market opportunity for improvements in agriculture. At the same time, advances in bioscience, medical research, engineering and physical sciences are making new business innovation possible. This competition aims to stimulate innovation in health and life sciences under a number of themes:

- increasing agricultural productivity
- improving food quality and sustainability
- precision medicine
- advanced therapies
- pre-clinical technologies
- biosciences

9.6 The tools and programmes offered by the organisation include Collaborative Research and Development, SBRI (the Small Business Research Initiative), Knowledge Transfer Partnerships, Launchpad (young entrepreneur start-ups) competitions and overseas missions. It has developed Innovation Platforms - an approach to innovation which harnesses the activities government departments use to address societal challenges to stimulate innovative solutions within UK businesses. In 2010 the Government announced that certain innovation activity would transfer from regional development agencies to the Technology Strategy Board, including the Grant for Research & Development (now branded as Smart) and Innovation Vouchers. In 2012 the Technology Strategy Board began to establish the network of “Catapult” centres. This is a long-term investment to create world-leading centres where scientists and businesses will work together to accelerate the pace of innovation in particular sectors and help businesses bring new products and services more quickly to market. These include: Digital Catapult; Cell & Gene Therapy Catapult; Offshore Renewable Energy Catapult; and others in Transport Systems, Medical Diagnostics, and Satellite Applications.

9.7 Feeding into Cambridge's science infrastructure and throughout the UK is London's Knowledge Quarter (KQ) a 2014 partnership of 35 large and small research, science, cultural and media organisations located in the Kings Cross, Euston and Bloomsbury areas, including the Wellcome Trust, University College London, Google, the British Library, University of the Arts, the British Museum, The Francis Crick Institute and Alan Turing Institute in a platform of major research universities. Its goal is to use the power of this concentration of world-class organisations to spur productive, sustainable and inclusive economic development. Its work will focus on knowledge exchange and collaboration, including partnership projects between organisations; partnerships and cross-sector initiatives leading to long-term investment and economic growth; improvements to local infrastructure and transport that will benefit employees and visitors to the area; and strengthened alliances with local communities.

9.8 It is really quite easy to understand the Cambridge cluster-platform as an evolved, organically grown high-tech phenomenon. The key to it is the term cluster-platform. This means that it is not one but a complex of four or more clusters. These are knowledge-based and interactive combining university and corporate research laboratories ("exploration" function) with academic entrepreneurship ("exploitation" function. The process began with early computer science and production ("The Cambridge Phenomenon" which started with personal computers and developed into advanced software and systems design of microchip technology. Independently, but later, biotechnology grew from the exploration function at – especially the Medical Research Council Molecular Biology Research Laboratory with its thirteen Nobel Prize Laureates (where Fred Sanger earned two Nobels). Monoclonal antibodies was the leading edge of knowledge in the 1970s and gave rise to CAT since acquired by MedImmune a part of AstraZeneca. More recently, related research overlapping somewhat with ICT and biotechnology has evolved as Cleantech and the cluster plan is presented in para 6.5. Now ICT has moved into a new cluster called “Big Data” which involves various “cyber” applications such as “cybersecurity”, data encryption, anonymisation and decoding as well as counter-“hacking” activity. This is how the main elements of the cluster-platform interact and have co-evolved.

10.0 Newer Forms of Open Internationalisation – Growth of Talent, Research, Innovation and Entrepreneurship

10.1 Firm growth in the Cambridge cluster-platform has recently scored some 7% annually on average while firms are small in turnover and overwhelmingly micro-sized firms by employment. This is also consistent with a profile that is suggestive of prodigious numbers of small firm outsourcing contracts in line with “open innovation” (Chesbrough, 2003). The nature of cluster-platform expertise means it is research-based and final firms are in global markets (e.g. ARM-SoftBank; CSR-Qualcomm; Autonomy-formerly Hewlett Packard now MicroFocus, Microsoft, Oracle and AstraZeneca)

10.2 Cambridge life science and healthcare companies are 339 in number. They increased from £1.8 billion in 2011 to £2.6 billion in turnover in 2015. Finally, they employed 2,367 people in 2015. Among international life science firms present in the Cambridge cluster are Napp, Illumina, Amgen, PPD Global Ltd (a Belgian Clinical Research Organisation – CRO). PPD is the largest biopharma firm in Cambridge (employing 1,292 people). Others are Genzyme, Medimmune (AstraZeneca), Envigo CRS (this is next largest at 1,020 as a recently merged Cambridge-Indianapolis CRO company), Fisher, Takeda, Astex, GW Pharma and Gilead.

10.3 For information technology and telecoms (ICT) Cambridge has 2,825 firms with total turnover of £3.7 billion and 20,654 employees in 2015. ARM employs 3,072 persons while CSR employs 2,011 people. These are global leaders in ICT markets, were recently bought by international acquirers but both originated in the Cambridge ICT cluster. Others in the cluster include Nokia Networks & Solutions Ltd, Samsung Cambridge Solutions Centre, Microsoft Research Ltd, Toshiba Research Europe Ltd, and Leica Microsystems Cambridge Ltd. Companies listed in the Cambridge Cleantech sub-cluster are found in para 6.4. These are overwhelmingly small-to-micro in size and are also commonly in sub-contracting relationships with larger local, UK or international client-firms.

10.4 Accordingly, the interplay of localization and internationalization is complex. Cambridge micro-firms can be quite globalised, with distant customers and suppliers. But they may equally be quite embedded in their locality for research, funding and certain categories of talent, like firm leadership and professional services. Cambridge also attracts global firms into its variety of clusters or technology platform. This may occur by acquisition of local knowledge-intensive businesses or by straight foreign direct investment as well as partnership arrangements. Some of the last-named may have begun as research and innovation partnerships, which typically have been high. In the year ended 31 July 2015, Cambridge University had a total income of £1.64 billion, of which £398 million was from research grants and contracts. The central university and colleges have a combined endowment of around £5.89 billion, the largest of any university outside the United States

10.5 During the aftermath of the global financial crash, the Cambridge cluster saw a reduction in new companies starting up between 2008 and 2010 and also a fall in employment in larger firms. Nevertheless, high tech companies in the Cambridge cluster secured more than 25% of the UK's venture capital investments and more than 8% of the European total by value. In 2008, the number of innovative companies backed by venture capital funds was 112 in the platform. This is one of the highest concentrations in Europe — third after London and Paris.
As noted earlier, the University of Cambridge IPR policy was liberal in comparison to most other universities in the UK. IPRs are not automatically assigned but academics can claim ownership of their own inventions. This policy has granted significant independence to scientists in negotiating IPR with industrial clients and overseas sponsors engaging in research commercialisation. This open view on IPR was considered one of the assets of the Cambridge Cluster. This, as noted, is now a less liberal IPR policy than traditionally.

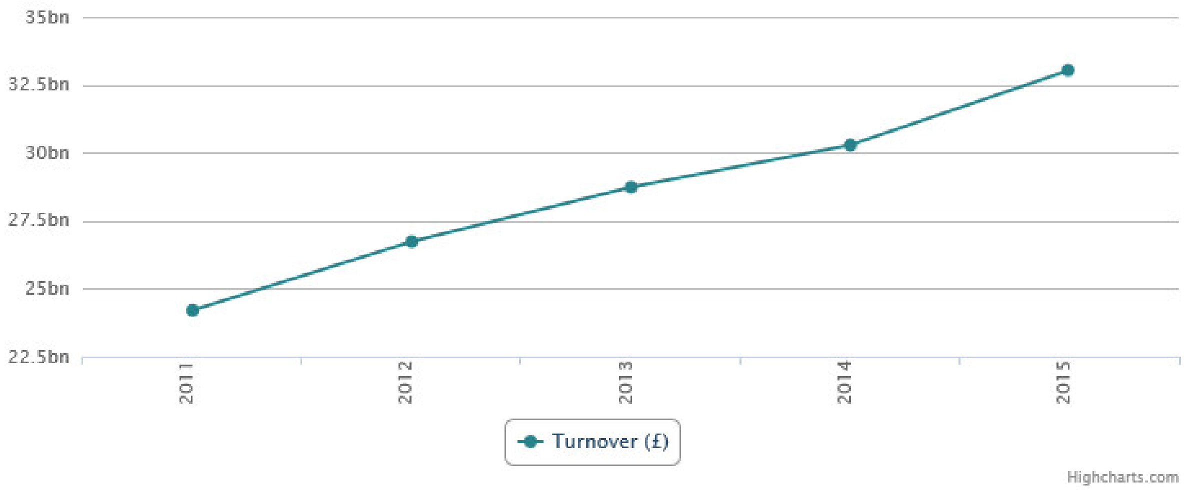
10.6 Another international factor leading to cluster growth has been the adaptability of companies towards finding new business models and eliminating the ones that no longer worked. Originating as a cluster with many manufacturing companies, the last decade saw an increase in assembly operations being outsourced while ICT and system software companies in have focused on design and research resulting in related industries such as digital tech growing. The business model has changed for many companies and is now based on technology licensing. This has resulted in a change from high-tech manufacturing to high-tech R&D services in technology related sectors, as we have seen. The company Advanced RISC Manufactures (ARM) exemplifies this change in company behavior where manufacturing is avoided and instead licensing is used. Since no production and mostly little assembly work is conducted, the implications of technology licensing are less than would be entailed in a blue collar to white collar skills transition. Much Cambridge employment is "quarternary" knowledge economy software and systems-related. Talent is highly qualified in advanced computational skills and such flexibility and job autonomy is part of the work relation. A more important difficulty is that due to previously abundant venture capital was invested too soon in start-ups, especially those licensing knowledge to MNCs as in biopharmaceuticals. This led to their absorption too early into the corporate bureaucracy of "Big Pharma" and somewhat undermined their evolved strengths in creativity and flexibility. Ironically, the effects of financial crisis have mitigated the "jumping too soon" implications of the previous investment environment. Regarding the implications of "knowledge flow" exploration and exploitation, acquisition of cluster founders by foreign multinationals has a clearer pedigree than the reverse. However, as noted in 3.8 above the "Ownership" category towards foreign multinationals by Cambridge founders occurs in "reverse FDI" (IMF, 2004). This takes at least two forms: the first (so-called "sticky" FDI *acquisition* category; OECD, 2015) firms include: CCL (acquirer of Synapse [US]) but earlier acquired by French engineering innovator Altran.; "sticky FDI" *attractions* include Cambridge firm acquisition Evi attracting Amazon R&D to Cambridge; Cambridge acquisition Deep Mind attracted Google artificial intelligence (AI) R&D facility to Cambridge. So, for business "knowledge flow" exploration it is mostly true that academic researchers and entrepreneurs are in first and second place. However for "knowledge flow" exploitation – in the sense of commercially marketed innovation – entrepreneurs are most important. University leaders and Professors are most useful as "ambassadors" able to negotiate with government on issues like infrastructure (e.g. funding for new Oxford-Cambridge Expressway link), planning for industrial and housing sites, university-wide partnerships with global knowledge centres like MIT;

and large FDI deals with the likes of Microsoft, Apple, Google etc. who seek to tap into the leading knowledge centres contained in the university as R&D bases in Cambridge cluster-platform.

10.7 Finally, the Cambridge cluster-platform has been successful in creating an enterprise ecosystem for entrepreneurs. This enables representation of the Cambridge cluster-platform in overseas clusters of relevance that concentrate leading global buyers of technology. Hence Boston has strong links with Cambridge biopharma cluster firms. Similarly, Silicon Valley has close links through its international "flagship" clients with Cambridge ICT suppliers like ARM and CSR. These networks, linking to many relevant overseas clients and suppliers, is the core of the new knowledge-intensive technology hubs in the world. The intermediary agencies, the University and business actors all participate in creating an "enterprise ecosystem" for scientists and entrepreneurs, where spillover effects are high.

This is shown again for ICT by ARM that was in 1983 spun off as an independent subsidiary of parent-firm Acorn. However, the UK market was small, making it necessary to rely on exports to survive. Moderate manufacturing capabilities in advanced micro-processing in the UK made it hard for firms to undertake manufacture of science-based products. As we learned earlier, ARM evolved a new business model where its focus was on designing chips, but not manufacturing them. Instead of traditionally subcontracting *manufacturing*, or even subcontracting *assembly,* they selected the *licensing* route to selling their technology. Accordingly today some 95% of mobile phones have ARM chips in them and they have long overtaken Intel's position in the market. Accordingly, ARM design the chips in the UK. They are then processed in prodigiously expensive silicon "foundries" in Asia (mainly Taiwan and China). Thereupon ARM sells their design to other system integrator companies that supply a chip in their required product (e.g. an iPhone). Such chips are very complicated to design and therefore hard to copy. Several other companies in the Cambridge cluster have taken the same route.

Fig. 2 Cambridge Company Turnover



10.8 A related vignette involving one of these, notably Cambridge Silicon Radio (CSR) and its links to, recently becoming an acquisition by, telecom chip customer, Qualcomm of San Diego is instructive. Qualcomm is at the centre of creating a rich "enterprise ecosystem" of companies building products that take advantage of wireless technology. They are also the largest "fabless" semiconductor company in the world which makes them a feeder for local (or, like CSR, distant) suppliers wishing to design integrated circuits and coordinate the long supply chain. This expertise in distant sourcing (e.g. Asia) and supply chain coordination extends to the consumer video cluster as well. Additionally, the cluster became quite adept at coordinating consumer need (thanks to innovative retailers in the area like Costco) with rapid specification and sourcing at companies like Vizio which became the number one provider of LCD HDTVs in the United States.

10.9 The data in Fig. 2 summarizes all company turnover, which grew from £24 billion in 2011 to £33 billion in 2015, a 40% increase. The following Figs. 3 and 4 show the main size-band for company turnover is between £100,000 and £250,000. Supporting the small firm-sice picture of the cluster-platform economy, the some 18,000 firms are between 1 and 4 employees in size. It is important to realise that this cluster-platform represents an advanced knowledge-based "enterprise ecosystem" or more accurately a "crossover" cluster-platform complex consisting of the earliest and largest group of firms that began in computing with the manufacturing by Sinclair and Acorn of early personal computers. This then "mutated" into what has become a substantial ecosystem of software and systems design firms in digital tech that despite their local origins are wholly international as they face the market, and dominate the expert systems inputs they sell to the "flagship" smartphone and tablet producers worldwide.

Fig. 3 Turnover Size Band of Firms

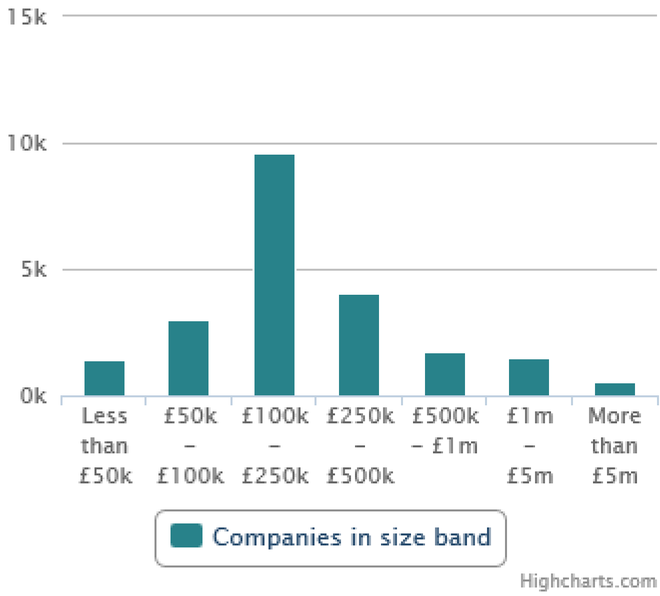
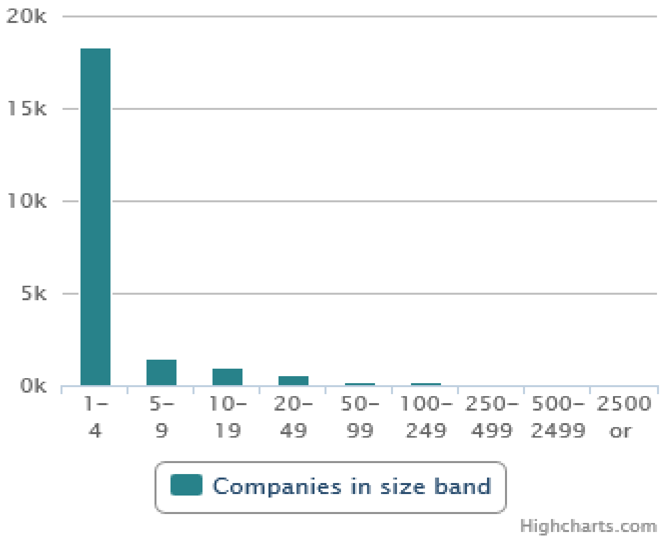


Fig. 4 Employment Size Band of Firms



There are also connections between advanced electronic engineering that have "mutated" into healthcare, life science and biopharmaceuticals in another element of the platform. Finally, a cleantech cluster has also emerged with many crossover interactions with the other elements of the cluster-platform ecosystem, as discussed in section 6 above.

11.0 Concluding Remarks

11.1 We can conclude with a list of ten key points arising from this analysis of the growth, emergence and take-off of the Cambridge cluster platform in ICT, Biotechnology, Digital tech (systems and software design, including computer games; Evans et al, 2006) and Cleantech. First, the brief timeline of key events is important to register. The Cambridge high-tech cluster arose around the University of Cambridge, beginning with its decision to establish the first European Science Park in 1970, influenced by that successfully established by Stanford University in 1949. The science park was intended to attract existing science-based industry and, importantly an ecosystem of science and technology-based start-ups grown from funded university research in the nearby campus. This aim was fulfilled and academic entrepreneurship in the form of new science and technology-based business has been growing ever since, with a strong acceleration in the 1990s. The Cambridge Network company providing services of networking and interaction was created in 1998. The role of private initiative has been pronounced in this, whether by the University or the new businesses that created the private innovation network that interacts fruitfully with the cluster-platform.

11.2 Second, the knowledge arising from the research conducted in Cambridge is of world-class and pathbreaking, meaning that the alumni and staff have an initial advantage in publishing, being awarded Nobel Prizes (13 alone at the Laboratory for Microbiology [LMB])and, for academic entrepreneurs, being early or first in the market with commercial innovations, innovative processes or new business models. This "first-comer advantage" makes it much more difficult for ecosystems elsewhere to emulate or supersede such expertise and advantage. This is why there are in the world so few actual copies of the Cambridge model of technology-based growth and development. Silicon Valley and some lesser – more evolved in the case of the Stanford relationship with its Californian "cluster-platform" – being the obvious exception. But it is clear that, though bigger, Silicon Valley contains the same core technology elements in the form of ICT, Systems software, Biotechnology and Cleantech as Cambridge.

11.3 Importantly, third, Cambridge is a collaborative enterprise complex. It has a high rate of networking among technology entrepreneurs, university researchers and government or military representatives and clients. It is not a top-down hierarchical system in any meaningful way. There is, in effect, no “global controller” as complexity theorists denote “complex adaptive systems” of innovation (Cooke, 2012). This means that certain conventions are important in enabling “open science” to be translated into “open innovation” through academic entrepreneurship as with the tradition of liberal university interpretations of IPR and discovery disclosure. Also, the technology business and university partnership attitudes to planning for growth and investing in needed infrastructure enabled Cambridge to remain a development hub even against significant popular opposition. But entrepreneurship has been collective not individualistic in building a successful networking culture.

11.4 Fourth, Government intervention has been more indirect than direct although the UK has been slow until recently in promoting the idea of “innovation systems” of any kind. Accordingly there was always “arm’s length” government funding for scientific research through the various UK Research Councils that managed competitive bidding for academic research grants that fuelled much of Cambridge’s research excellence over the years (some £400 million in 2015). Until recently this was significantly supplemented by the European Union’s Framework Science & Technology Funding Programmes (€110 million in Horizon 2020). Cambridge research benefited enormously from these types of indirect research subsidy. But so does every advanced, European Union member state. Furthermore, Cambridge also attracted substantial industry and charitable research funding (e.g. through the Wellcome Trust, the largest medical charity in the world). Recently the Technology Strategy Group (now Innovation UK) has co-ordinated applied research for funding partnerships somewhat including industry, SMEs and research centres to strengthen a traditional reliance on “the market” or “lobbying” for research allocations of an only partly transparent (e.g. the MIT-Cambridge link promoted by Chancellor Gordon Brown). But the UK remains an “open economy” and much responsibility for funding relies on banks, investors like pension funds, and private equity or venture capital.

11.5 Fifth, the actors for internationalisation in the Cambridge cluster-platform are; first, the University leaders and professors who are the guardians of the research ethics of a world-class knowledge-intensive research institution, second, the academic and other entrepreneurs that meet the challenge of translating research discoveries into world-beating commercial innovations, third the support infrastructure of research, partnership and entrepreneurial financing and services (e.g. Cambridge Network) that knits the cluster community together and finally, the contacts from the localised cluster-platform to the outside world of global markets for computing and communication "flagship" products, system integrators and consumers, biopharmaceutical therapies and treatments, systems and software for the digital economy (including computer games) and finally cleantech products and services that sell in foreign markets.

11.6 There is no formal strategy, nor has there been. The main driver has been incremental, evolutionary, sometimes rapid, change. The UK is an open not a managed economy and there is no present, recognisable industrial strategy in line with the neoliberal dogma that has influenced British governments since about 1980. There is a UK Innovation agency that manages some aspects of applied industrial research funding and has oversight of the research councils' expenditures. But these are mainly internally determined within each research council. At local level, dialogue occurs between key associational actors and municipality organisations on matters of planning, roads, housing and infrastructure. But most of this – except roads – is privately funded. So it can be concluded that there is no top-down "global controller" determining the future of the Cambridge cluster-platform economy. Nevertheless, it follows successful and divergent but related growth paths in an evolutionary manner, which is probably its unique capability and collective knowledge asset.

11.7 Internationalisation has been based on scientific and technological expertise, knowledge and excellence. Thus globally important discoveries have been made for more than a century of the modern technological era. This ranges from the splitting of the atom, to the discovery of DNA and the science of low energy microprocessor design software and cybersecurity. Such discoveries were shown to be subject to exploitation by foreign entrepreneurs when the UK had no patenting culture and very little patenting law. Many discoveries from Cambridge (like Monoclonal Antibodies, for example) were in 1975 commercialised in San Francisco leading to the birth of the global biotechnology sector. Eventually the UK became wiser about the commercialisation of "open science" and the Cambridge cluster-platform benefited from this. Global customers thereafter realised they should pay for licenses to exploit such discoveries. The world-class nature of many of them ensured that knowledge soon became generalised that international clients should daily monitor innovations and preceding commercialisable knowledge from this cluster-platform.

11.8 There is plenty of outsourcing to global leader firms like Apple, Samsung, Google, Microsoft and so on as testified by the existence of research institutes of many of these being found in Cambridge. It could be argued that Cambridge success-stories have frequently sold to foreign buyers – as with CAT, Autonomy, ARM and CSR. But there remains a tendency for UK financiers to prefer real estate investment for long-term security over technology stocks. Thus where the world sees an excellent firm and has the resources to service its future needs it is not hard to see that entrepreneurs are interested in a less difficult growth trajectory. Hence, this will likely continue to be a kind of exit strategy for Cambridge entrepreneurs at the highest level.

11.9 The local-global interaction works well. Cambridge products and services are in demand globally in diverse product and service niches. Cambridge is understood to be an innovative culture with many exploited and exploitable ideas for foreign buyers. Moreover, now that Britain is leaving the European Union, which tends to be non-innovative, somewhat non-transparent (e.g. fraudulence regarding emissions performance standards) and sluggish in terms of growth performance, it may be that re-focusing on big growth markets like India and China will strengthen globalisation of Cambridge's key platform interfaces.

11.10 Currently the world is in turbulence with climate change threatening, war in the Middle East, mass migration from war zones into Europe and the US caused partly by starvation and economic inequality as well as desertification and poor water resources caused by climate change. There are many more problems connected to aging populations and disease that put pressure on health and social care. Each of these "wicked problems" is met by technological inspirations from large cluster-platforms like Silicon Valley and lesser ones like Cambridge. New innovation models have emerged like that discussed regarding "crossover" innovations from microelectronics to advanced combustion engines and healthcare. This transversal model of innovation is practised in these leading cluster-platforms and they probably mean the ending of big, corporate R&D being conducted in a linear model fashion. It is being replaced by innovation at interfaces by crossover knowledge interaction and translation. This more interactive, non-linear and transdisciplinary model of innovation finds a suitable home in cluster-platforms such as that operating in Cambridge.

Bibliography

Beinhocker, E. (2006) *The Origin of Wealth: Evolution, Complexity and the Radical Remaking of Economics*, Boston, Harvard Business Press

Chesbrough, H. (2003) *Open Innovation*, Boston, Harvard Business School Press

Cooke, P. (2012) *Complex Adaptive Innovation Systems*, London, Routledge

Cooke, P. & Morgan, K. (1998) *The Associational Economy*, Oxford, Oxford University Press

Cookson, C. and Pilling, D. (1999) Biotech trade looks to US to cure confidence crisis, *Financial Times*, Sept. 9, P.11

Cybersecurity Ventures (2015) *Cybersecurity Top 500*, Toronto, Herjavec Group

Department of Trade & Industry (2001) *Clusters in the UK*, London, DTI

Eason, K. & Dean, J. (2016) Apple weighs up £1billion McLaren bid to kick-start driverless cars, *The Times*, September 22, p. 12

Evans, D, Hagiu, A. & Schmalensee, R. (2006) *Invisible engines: How software platforms drive innovation and transform industries*. (Boston, MA: MIT Press)

Frean, A. (2016) Ford has a new model in mind when it talks about the future of cars, *The Times*, September 20, p. 45

Frean, A. (2016) Why the smart money is being invested in university research, *The Times*, December 15, p. 43

Garreau, J. (1991) *Edge City: Life on the New Frontier*, New York, Anchor Books

Hospers, G, van Tuijl, E, & Benneworth, P. (2012) Innovation by imitation? Benchmarking success stories of regional innovation, in: T. Bas & J. Zhao (Eds.), *Comparing High Technology Firms in Developed and Developing Countries: cluster growth initiatives*, IGI Global, Hershey, PA, 14 – 25

Kozlow, R. (2004) Directional principle and reverse investment, IMF-OECD workshop, December, Washington DC, US Bureau of Economic Analysis

Isaacson, W. (2014) *The Innovators*, New York, Simon & Schuster

Kirk, K, Cotton, C. & Rees, M. (2016) *The Cambridge Phenomenon: Global impact*, London, Third Millennium

Lewis, M. (2015) *The Flash Boys: Cracking the Money Code*, London, Penguin

Mott, N. (1867) *The Mott Report*, Cambridge, Senate

OECD (2015) Linking TIVA and FDI statistics: First results and future plans, STD/CSSP/WPTGS(2015)25, Paris, OECD

Patterson, S. (2012) *Dark Pools: High-Speed Traders, A.I. Bandits, and the Threat to the Global Financial System*, New York, Random House

Polenske, K. (2014) *The Economic Geography of Innovation*, Cambridge, CUP

Porter, M. (1998) *On Competition*, Boston, Harvard Business School Books

Reed, J. (2015) Unit 8200: Israel's cyber spy agency, *Financial Times*, July 10, 2015, http://www.ft.com/cms/s/2/69f150da-25b8-11e5-bd83-71cb60e8f08c.html Accessed 7.3.2016

Schumpeter, J. (1934) *The Theory of Economic Development*, New Brunswick, Transaction Books

Segal, Quince, Wicksteed (1985) *The Cambridge Phenomenon: the Growth of High Technology in a University Town*, Cambridge, SQW

Segal, Quince & Wicksteed (1998) *Cambridge Phenomenon Update*, Cambridge, SQW

Segal, Quince & Wicksteed (2011) Cambridge Cluster at 50 – the Cambridge economy: retrospect & prospect, Cambridge, SQW

Senor, D. & Singer, S. (2009) *Start-Up Nation: The Story of Israel's High Tech Miracle*, New York, Twelve Publishers

Swann, P, Prevezer, M. & Stout, D. (1998) *The Dynamics of Industrial clustering*, Oxford, Oxford University Press

Tech City & NESTA (2016) *Tech Nation Report*, London, Tech City and Nesta

Tech City & NESTA (2015) *Tech Nation Report*, London, Tech City & NESTA

Tett, G. (2016) *The Silo Effect: Why Every Organisation Needs to Disrupt Itself to Survive*, London, Abacus

UK Government Science & Technology (1999) Select Committee on Science and Technology Minutes of Evidence: *Memorandum submitted by Cambridge University*, London, House of Commons

UK Government Science & Technology Committee (2016) *Big Data: the Dilemma* London, House of Commons

Wilson, H. (2016) Bank takes an interest in historic seats of earning, *The Times*, 12.12.2016, 40-41