Clustering and economic complexity — regional clusters of the ICT sector in the UK

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The electronics and ICT industry is an important element of the UK economy. Although its employment appears relatively small, accounting for one-thirtieth of all employment, more important is the level and the intensity of the R&D expenditure associated with the sector, and distributed across business, government and higher education sectors . However, there are several fault lines within the industry which make its treatment as a single cluster highly problematic. Firstly, there are very strong regional specialisations within the country, with regional clusters almost as important to understanding the industry as the concept of a national cluster. Secondly, there are significant gaps in the cluster, with a preponderance of defence electronics, and a predisposition towards communications and information services; certainly, the UK strategic electronics base is significantly narrower in terms of world-class firms than any of its major economic rivals. Thirdly, it is a very open economy, and has a great deal of inward investment, but this inward investment is has its own spatial division of labour following the indigenous geography of electronics clusters.

This short paper aims to provide an overview of the UK electronics cluster, to explain its key features and how their success has influenced UK cluster policy, which lies at the heart of current national competitiveness (industrial) policy. Central to this has been the peculiar UK national system of innovation (NSI) which has recurrently reduced the incentives for companies to invest across all industrial sectors. However, the main features of this system do not arise from successive sets of science policy, rather there is a distinctive culture towards innovation and finance which have had a significant influence on the industry as a whole, and the particular regional clusters. This paper examines the legal and policy environment, and then explains a little of the history of the electronics industry in UK, in terms of corporate histories as well as the evolution of Government policies which have supported those firms; there are clear relations between particular policy regimes and particular geographical clusters *within* the UK.

The key characteristics of the UK national system of innovation

The electronics and ICT industry in the UK has been profoundly affected by its relation to the state. On occasion, this has come through explicit policy measures; when the Ministry of Technology was formed in 1964, three of the four sectors to which it related (telecommunications, computing and electronics) have become what we would describe as the ICT industry. The industry has been influenced by procurement and regulation decisions emanating from the Government as well as public corporations; the British Broadcasting Corporation and the General Post Office were central to the creation of a technologically-sophisticated market for electronics and IT. The industry has also been affected by the framework conditions which government, and the culture set by government, determine the nature of economic activity.

The key factor influencing the behaviour of the UK ICT sector is undoubtedly the financial system which is based on short-term rationality driven through the Stock Market. UK company law has for a long time stressed the importance of industry as a primarily financial concern; its purpose is to generate wealth for the benefit of its owners, rather than providing a national strategic asset or being of value because of the employment created. This has a number of important consequences, the most regularly cited is the negative comment that British firms systematically under-invest in new products, attempting to maximise current profit, and so tend to fail to maximise the potential of their innovations; the UK electronics industry is characterised by a failure to consolidate strengths, strengths systematically undermined by churning of ownership and a concern with immediate profitability. However, there is a positive side to this particular system, and that is a great flexibility in the economic base; the UK electronics industry has been characterised by rapid redeployment of resources in response to perceived profitable opportunities. The aggregate effect of this is to encourage the ICT industry to be incredibly dynamic but volatile, and subject to extensive closures during enduring period of industrial down-turn.

Government procurement policy has had more tangible impacts on the industry; until recently, defence contracts were underpinned by the principle that a defence contract had two purposes, to obtain a product, but also to identify a British team to make that product, and give them resources to learn how to make that product. This stands in stark contrast to the financial principles stated above, in which industry was not considered to have inherent strategic value. It is no surprise that the defence electronics industry was one of the more durable elements of the sector, and a corollary of this was that it was driven by firms headquartered near to those Ministries in and around London making those procurement decisions. Indeed, the explicit spatial bias of Whitehall against the more remote locations of the UK (those more than fifty miles from London[1]) meant that much of the R&D capacity of defence firms was located in the South East.

A third element of Government policy which historically influenced the growth of electronics and ICT industry was spatial planning policy, which in the post-war period was based around tight planning controls in the south eastern core, and an attempt to disperse industry to the periphery. However, the means employed were the use of industrial development certificates, in which companies in the South East could gain permission to develop in the South East but usually only for office and R&D activities, with manufacturing being pushed out to the development areas in the north or west of the country. This had the effect of enforcing a spatial division of labour in the ICT industry, and although relaxed under Conservative administrations and finally abandoned in the 1980s, this planning regime concentrated surviving elements of the UK-owned electronics industry in the south of England, as the UK-owned companies exited from large scale production and closed manufacturing capacity in the periphery. This in turn created very strong positive externalities for the later growth of IT, software and computer consultancy activities. More recently, DETR has examined in some depth the possible ways that the planning system could be used to improve clustering activity in the future.

Fourthly, Government industrial policy did little to help the electronics industry overcome the problems of lagging UK industrial markets for ICT products raised by other countervailing policy measures and cultural attitudes. A particular confrontational attitude to labour relations actually hindered demand for new electronic technologies in manufacturing; managers were unwilling to invest in numerical control (NC) systems because of their financial implications, whilst organised labour saw those machines as a threat to the employment of their members. Hence there was a effectively a Faustian pact between managers and unions across manufacturing which militated against the introduction of new technologies. This weakened the domestic market for electronics firms involved in the development of industrial automation and control systems, increasing their volatility. Although several of the largest UK electronics firms were involved in NC machines, their interest withered as it became clear in the 1960s and 1970s that the domestic market for those products was growing very lethargically. When the Government did intervene, it was only at the margin of this problem, addressing peripheral issues such as the size of the business, their access to basic scientific research, or modernising working practices rather than dealing with the issue of technological adoption.

The final area where Government influence is less perceptible is in the culture surrounding the science, education and technology system. A frequent criticism of the UK science base is its weakness in commercialising research, which has at its root a gulf between scientific and technical communities. It has been observed that British entrepreneurs at heart aspired to join the aristocracy and disdained the businesses which had generated their wealth; those that persisted tended to be practically-minded with no orientation towards embracing and transforming emerging scientific principles. The academic community were for a time unwilling to accommodate technical training; a second tier, subordinate in prestige and technical depth, of education (the Polytechnic system) was only created to train engineers from the late 1960s onwards.

The UK electronics industry — a historical perspective

In the 19th Century, although the UK had been successful in developing a range of new industries, particularly in mechanical and electrical engineering, by the end of that epoch it was clear that there were fundamental problems with this industrial structure. Central to the problem was the reliance of these industries on the established financial structures for investment capital. Investment was provided through joint stock issues, which were a poor structure for re-investment, because any investments were necessarily a trade-off against current dividends. The result of this was two-fold; the first was that existing engineering firms innovated strategically to access the most immediately profitable new markets, which as a consequence of British Imperial activity were frequently in what we would now term defence markets. Secondly, there was a rapid growth of new firms who, unencumbered by a reliance on financial markets for their capital, were able to move quickly to develop and adopt new technologies.

In the 20th Century, the central government has proven very important in the emergence of the electronics industry in the UK. The First World War quickly revealed how reliant the UK had become on Germany for the import of industrial staples necessary to wage a military campaign, chemicals, optics, precision and electrical engineering. The strategic imperative of Empire overcome commitments to non-intervention, leading to treatment of the defence industry as a valuable asset with inherent value, encouraging its prosperity. A consequence of this was that much of the growth in research expenditure post-1918 has been in military R&D, which remains the greatest category of expenditure in the UK (40% of R&D) a percentage second only to the USA in the G7 (Jones, 1999).

New firms were important in the development of the telegraph and later radio telegraphy, but Central Government regulation was central in providing a framework and funding source for the industry as a whole. The British Broadcasting Corporation and General Post Office were critical to providing profitable markets for these new firms, providing large, sophisticated monopsonistic purchasers of electrical and electronic products who could specify and fund high-technology development activity, which in turn provided funding for innovation for a select group of companies which could meet the procurement requirements of these Government-funded corporations. Naturally, as these new companies grew, the search for new markets frequently took them back to the defence industry, and indeed, the various Ministries involved in defence, the Admiralty, and the Ministries of Air, Aviation, and Supply were a large, sophisticated monopsonistic purchaser *par excellence*. This created an environment in which those firms which able to meet the needs of public corporations and departments thrived, and in turn encouraged those firms to organise themselves to best supply public bodies.

This encouraged the growth of exceptionally large firms; the certainty which Government and public corporations' orders in defence and telecommunications permitted allowed growth by internal expansion as well as through acquisition of rivals. In turn, this increased the pressure on those firms; strategic technological positions were less important than supporting the share price and the dividend. The leading UK electronics firms therefore developed in line with particular fashions of the bourse, particularly in building conglomerates in the 1970s, and later, refocusing on core technologies and expertises. These two periods saw many smaller independent electronics firms bought up by larger firms, and then rationalised, and all but the supra-profitable divested when the trend shifted towards focus on world-class competencies.

The orientation of the UK electronics industry towards fulfilling Government contracts came at the expense of other services. Although a number of firms, *inter alia* Pye, Bush and English Electric were at times involved in the supply of consumer electronics, there was little corporate commitment to these business areas, and so when in the 1960s these sectors came under strong overseas competitive pressure, there was a corporate willingness to curtail these activities. Government policy towards the electronics sector also affected the behaviour of these firms. Partly in response to perceptions of rising overseas competition in the 1960s, Government industrial policy focussed on encouraging those industries and firms under the most pressure to improve their competitiveness through merger and reorganising to yield benefits of scale. Although this policy was most visible in those industries which were later nationalised, such as aerospace, automobiles and shipbuilding, the Industrial Reorganisation Corporation (IRC) was instrumental in the formation of a few dominant electronics companies in the UK, most notably the General Electric Company, but also International Computers Limited (ICL)and Plessey.

In the 1970s, it was clear that there were whole sectors of the electronics industry which the large firms were overlooking. Although the absence of consumer electronics appeared of little consequence, more worrying was a failure to develop a strong semi-conductor industry. In Japan, although post-war R&D expenditure had been relatively limited, it had been focussed onto those sectors which were critical for growth, and had unlocked a wave of modernisation. The fear existed in the UK that a failure by UK companies to invest in new enabling technologies would lead to a continued decline of the UK's competitive position. Because of the huge entry costs, small firms were unable to succeed as had their (now colossal) predecessor small firms in previous waves of technological innovation.

Therefore the UK Government took the decision to invest itself in the creation of a business in one such large-scale capital intensive industry, micro-electronics. The Government provided the capital, and recruited a number of experienced executives from competitor firms, who came together to form INMOS, whose sole shareholder was the Government. However, INMOS failed to generate a lasting competitive advantage for the UK despite early technical superiority because of an absence of commitment to a long term programme of intervention in the economy.

In 1979, the Conservatives came to power with a manifesto commitment to increasing the efficiency of the economy through exposure to free markets. The fad of monetarism led to the engineering of a deliberate monetary squeeze which in turn resulted in a huge recession which reduced manufacturing employment by one-third. After re-election of the Conservatives in 1983, the Government embarked on a programme of privatisation. These influences were extremely disruptive to the established UK electronics industry; at the same time as the recession and its aftermath placed them under acute shareholder pressure, a significant share of their markets were opened to competition, and the Government signalled its willingness for any uncompetitive businesses to either face closure or acquisition.

INMOS was sold off to Thorn-EMI in 1985, and then onwards to the (French-owned) SGS-Thompson in 1992; this signalled the end of any strategic industrial policy outside defence, which was itself soon to be subject to the rigours of the market. Within Europe, the Commission adopted a stance that European competitiveness required European-scale businesses to compete against Japanese and American firms. Deregulation of industrial support in the UK in tandem with changes in European competition policy led to ownership of many flagship British companies to change hands. However, it did give UK telecommunications providers a head-start in developing competitive advantage as the single European telecommunications market gradually emerged.

What did thrive in these conditions were a relatively small number of internationally competitive defence and telecommunications firms. At that time, ICTs were beginning to alter dramatically the way business operated. UK electronics firms were unencumbered by a commitment to existing forms of production, and so the (private-led) growth of infrastructure in support of these new technologies, new wire and mobile telephony systems acted to encourage established firms to move in those directions. The dominance of computer systems by US firms created a huge market in IT consultants with the skills to adapt these new technologies for UK businesses as well as being supported by Central Government's intention to outsource as much of its routine data processing as was feasible. At the same time, these new technologies were adopted by new firms who used one feature of software, the ability to codify and package expertise, which meant for consultants that their ability to generate revenue was delinked from the number of fee-earners, which promised incredible profitability and stimulated much growth in the software industry.

The current state of the UK electronics industry

The historical narrative makes the point that elements of the UK electronics and ICT industry have experienced extreme instability throughout their history, and this has undermined many of the benefits that stability provides. However, the corollary of this instability is incredible dynamism; UK firms have failed to fully exploit technologies, but are often in the vanguard of their adoption and development. Those firms and sectors which have succeeded in the UK are those which have been able to develop some degree of stability whilst managing to appropriate the benefits of the liberal trade, industrial and financial regimes offered in Britain.

In recent years there has been a marked decline in the manufacturing of capital goods, although this has been greatest in the assembly of computers, given the relatively small size of the UK process control market. The greatest increases have been seen in the growth of computer services which have doubled since 1991 in employment terms, both in the sale of consultancy services, but to a greater degree in the rise of sub-contract computing in which firms manage computer systems on behalf of their clients.

Table 1 Employment in the Great Britain ICT industry in the 1990s by sector

ICT sector[2]	1991	1997	Change
Domestic Electricals (TV, white goods)	61,900	63,800	3.1%
Capital Goods (including computers)	110,100	96,800	-12.1%
Electrical apparatus and components	203,700	230,700	13.3%
Computer consultancy	118,400	234,300	97.9%
Sub-contract and other computer services	51,000	117,400	130.2%
Total	545,000	743,000	36.3%

Source: Census of Employment 1991; Annual Employment Survey, 1997. © Crown Copyright Reserved ONS Statistics (NOMIS), 2000.

Table 2 The growth of the computer services industry 1981-1997[3]

Year	Employment
1981	54,800
1984	78,700
1987	108,400
1991	169,400
1997	351,700

Source: Census of Employment 1981, 1984, 1987, 1991; Annual Employment Survey, 1997. © Crown Copyright Reserved ONS Statistics (NOMIS), 2000.

The ICT industry does not appear to be a particularly important sector of the UK economy, comprising 3.3% of all employment. However, a significant element of that activity is in business areas in which the UK has world-class competitive advantages and globally competitive firms, such as communications infrastructure management. A critical element of this competitiveness is the expenditure on R&D, particularly made by businesses, but also the Government and University support for electronics and ICT firms. Businesses spent £3.6bn on ICT R&D in 1997, which comprises 38% of all business R&D; in comparison, the chemicals and pharmaceutical industry, in which the UK has a definite R&D-based competitive advantage has a research and development expenditure of £2.8bn. Proportionately, this expenditure is split in favour of the service sector, arising from the UK's strengths in computer and telecommunications services. The table below shows the composition of this expenditure.

Table 3 Composition and sectoral distribution of ICT Business R&D, 1997

	All BERD £m	Capital £m	Salaries £m
Office machinery and computers	102	16	31
Electrical Machines	424	25	167
Radio, TVs, comms equipment	655	54	277
Precision Instruments	336	19	162
Aerospace	893	28	308
Post & Telecommunications	496	29	192
Computer services and related activities	703	84	301

Source: Economic Trends, 1999

A further contributory factor to the competitive advantage of the UK cluster is derived from the concentration of particular specialisms in certain regions of the UK; in the South East, the industry contributes greatly to the economic success of its host region, whilst in Wales and Scotland, large branch-plants are important in palliating the persistent unemployment in those regions. Table 5 below shows the distribution of manufacturing and service ICT sub-sectors between the British regions. There is quite a strong split between manufacturing and services in the UK as a whole, with services concentrated in London and the wider South East, and manufacturing in Scotland, the North East and Wales.

Table 4 Employment in the electronics and ICT industry in Great Britain by Government Office region, 1997.

	Manufacturing	Services	All ICTs	*All Industry*	*ICTs/ Ind*	Service Index[4]
South East	60300	94100	154300	*3172100*	*4.9%*	174
Eastern	43600	39200	82800	*2014100*	*4.1%*	100
Wales	33000	5300	38200	*962200*	*4.0%*	18
West Midlands	45500	25700	71300	*2107300*	*3.4%*	63
South West	36200	23900	60200	*1839700*	*3.3%*	73
Scotland	47200	15700	62900	*1964200*	*3.2%*	37
North East	21100	6600	27700	*897000*	*3.1%*	35
London	22100	79700	101800	*3456600*	*2.9%*	401
East Midlands	24100	17800	41900	*1623600*	*2.6%*	82
North West	30800	24000	54700	*2129100*	*2.6%*	87
Merseyside	6100	4000	10200	*442600*	*2.3%*	81
Yorkshire-Humber	21300	15500	36800	*1922500*	*1.9%*	73
Great Britain	391300	351700	743000	*22531000*	*3.3%*	100

Source: Annual Employment Survey, 1997. © Crown Copyright Reserved ONS Statistics (NOMIS), 2000.

The greatest strengths in the UK electronics industry are where for some reason there has been some manner of transient stability which has managed nevertheless to capture the benefits of that dynamism. This has tended to be when particular elements have achieved a coherence that has given them durability. Sectorally, telecommunications and defence electronics and ICT have been afforded a degree of durability by Government funding regimes. Spatially, stability has also been provided through the labour market, because of the relative inertia of highly skilled employees, which mean that clusters experience very strong positive externalities from the availability of skills. Conversely those areas without those high-skill labour markets have experienced difficulty in developing them, so have had difficulty in competing with those strong regions.

Table 6 below splits the sector into two constituent elements, manufacturing and software, reflecting recent trends in the industry, and presents location quotients for the sector by Region. The industry has two very distinct geographies, with a concentration of manufacturing on the peripheral fringe, whilst the software and consultancy elements of the sector are strongly concentrated around the South East. Defining clusters as sectors of industry with a competitive advantage which transcends pure cost competitiveness, there appear to be three distinct geographical electronics and ICT clusters in the UK. Although Wales has a strong electronics manufacturing sector, it is necessary to discount this as a geographically-bounded regional cluster. The Welsh electronics industry was based on the attraction of inward investment to replace the rapidly-declining heavy engineering and extractive sectors. Inward investors were attracted into what was an entirely greenfield location (fresh land and employees), with no real history of electronics, which drove the firms there to compete effectively on the basis of their cost competitiveness.

Table 5 The regional location quotients for the electronics and ICT cluster, 1997

Region	Manufacturing LQ	Region	Software LW
Wales	1.97	South East	1.90
Scotland	1.38	London	1.48
North East	1.35	Eastern	1.25
Eastern	1.25	South West	0.83
West Midlands	1.24	West Midlands	0.78
South West	1.13	North West	0.72
South East	1.09	East Midlands	0.70
East Midlands	0.85	Merseyside	0.59
North West	0.83	Yorkshire	0.52
Merseyside	0.80	Scotland	0.51
Yorkshire	0.64	North East	0.47
London	0.37	Wales	0.35

Source: Annual Employment Survey, 1997. © Crown Copyright Reserved ONS Statistics (NOMIS), 2000.

The sub-national clusters of national competitiveness

There are three areas of the UK where it is possible to identify that there are durable clusters of the ICT industry which contribute to the competitiveness of the UK economy. In each of the three regions, there are very different reasons for their rise, with Scotland's cluster, supported by Government to alleviate the problems of the decline of heavy industry, much more defensive in its nature than either the Thames Valley or Cambridge clusters. All the clusters have benefited from Government policy support, and their present state today remains heavily influenced by Government policy. As successful clusters, each of the three has in turn influenced

Government thinking in a range of policy areas. In this section, we present an overview of the three exemplar ICT clusters in the UK, explaining

- how their current state relates to the policy framework within which they developed,
- how they have developed competitive advantage, their characteristic forms of innovation, and their contribution to UK plc, and
- how their success has influenced *ex post* Government thinking and policy-making.

Scotland and the rise of Silicon Glen

Since the first regional aid map was drawn in the UK to identify regions with poor economic performance in 1934, Scotland has been the beneficiary of significant public investment to effect industrial modernisation. The fillip to this process came with the Second World War, where Scotland's distance from the main bombing targets made it a suitable location for mass production. This introduced a set of new technologies into Scotland, and the pressures of warfare encouraged the development of a skilled workforce able to deal with the demands of electronics. In the post-war period, Scotland was the recipient of a great deal of inward investment from British and overseas-owned companies creating manufacturing facilities in Scotland to offset their IDC requirements in the South or benefit from incentives, and drawing on the emerging pool of trained labour.

Ferranti was an important player in this process because they realised that for their factory there to succeed and be profitable, they had to develop indigenous talent in particular sectors. Ferranti also realised that diversification away from war-time products was critical, and hence they transferred the responsibility for the post-design engineering services for their radar systems to their Edinburgh plant. They also managed a Government-funded laboratory, whose purpose was to develop staff with the right mixture of engineering, entrepreneurial and academic skills to drive the business forward, which created a pool of highly capable senior managers as well as resulting in a number of spin-off businesses. The presence of highly skilled operators and engineers, as well as an extremely favourable grant regime attracted many overseas investors, and this mixture of high-value adding manufacturing and design functions has been dubbed "Silicon Glen".

More recently, Scottish Enterprise, the Regional Development Agency for Scotland, identified electronics as one such industrial sector worthy of support, and designed a cluster strategy for electronics firms to capitalise on the advantages offered by Scotland. The competitive advantage of the Scottish electronics cluster is undoubtedly in high skill, high value-added and low cost manufacturing. There is a significant presence of micro-electronics firms whose competitive advantage in manufacturing are based around maximising the quality of the production process. There was significant emphasis in the Scottish Enterprise strategy on maintaining this skill base, and the ability of workers to deal with the most modern manufacturing technology available.

The Scottish cluster has a strong dynamism, although the demise of Ferranti[5] highlighted the fact that the sector has latterly come to be dominated by foreign-owned firms, whose manufacturing facilities were inherently unstable and prone to closure during downturns. The nub of the problem is that Scotland tends to specialise in manufacturing the most technological mature products, and thus when technology advances, plants are left obsolete and it is often not cost-effective to upgrade them. Hence, when electro-mechanical technologies for office machinery were replaced with electronics, around 15,000 jobs were lost in Scotland. Relying on cost competition of mass product markets (which is what many micro-electronic products are) means that adverse market movements can make plants rapidly uncompetitive, and in no position to adapt to price pressures. The collapse of computer memory prices in 1997/98 and the contemporaneous Asian monetary crisis led to the mothballing of a new semiconductor facility before completion. However, the continued availability of grant aid, and the undoubted quality of the workforce has meant that after each collapse, Scotland has recovered and inflows of investment have resumed.

Innovation in the Scottish electronics cluster is profoundly affected by the dominance of foreign-owned businesses, and the research strengths of Scottish universities, and the mismatch between the two. There are relatively few strong and extensive science-technology-market networks in the Scottish cluster because of the disjunctures associated with the techno-economic structure. On the one hand, the Scottish universities pursue the commercialisation of their knowledge base with partnerships on a global scale, limiting their local involvement to technology transfer and technical assistance. On the other hand, there are large multi-national firms present in Scotland, and whose Scottish locations are involved in cross-border R&D projects, particularly the *in situ* downstream elements of development and implementation.

The case of the Scottish ICT cluster has been a great influence on British industrial policy for peripheral regions. Although a policy of modernisation through inward investment was attempted in Scotland, Wales and the northern areas of England, Scotland has been used as a best-practice case study for those other regions. The key essence of the policy was the intelligent use of support to generate capacity of generic use to the industry, investing in schemes which employed people in high-value occupations, and providing tailored support for individuals to fill those positions. Furthermore, support has been provided to encourage firms to embed themselves in the region, and supporting the upgrade of the elements of the manufacturing process present in the region. The attraction of Cadence to Scotland in 1998 to establish a design centre was seen as proof that this policy was producing tangible results. Scottish Universities were awarded £4m under the Science Enterprise Challenge Fund to co-operate in micro-electronics to provide opportunities to work closely with inward investors.

Although inward investment in mature manufacturing has a degree of inherent volatility, it is clear that Scotland has a competitive position in a niche for high-value manufacturing, and policy support is directed at ensuring that this is sustained in the longer term, and attempting to use this activity to generate endogenous potential. Thus, the attraction and embedding of high value-added and high-technology inward investment has formed a key element of the modernisation of Wales and the North East. In Wales this policy has been slightly more successful than in the North East. In Wales, a great deal of effort was expended to bring LG to Newport as a flagship investor; the same factors which led to the mothballing of Hyundai's plant in Livingston led to plans for a semi-conductor fab at the Newport site being shelved. In the North East, two lead semi-conductor firms had been attracted, Siemens and Fujitsu, only for both of those firms to close their factories (and snuff out the industry) during the market downturn in 1998.

Defence electronics and IT services in the Thames Valley

The growth of the IT service cluster in the corridor to the west of London was much more endogenous in its mode of propulsion than the Scottish electronics industry, which was heavily subsidised through Special Area Assistance and its successor programmes. However, it is clear that a number of Government policies were instrumental in leading to the development of a cluster of similar firms in the Thames Valley, and this in turn established a dynamic which sustained the industry through the rise of electronics, and subsequently provided the basis for ICT services. The framework within which this cluster grew was post-war planning policy, in which a strategic decision was taken to develop the area west of Heathrow airport beyond the London green belt. The rationale for this was proximity to London and the airport would make the location attractive to industry, whilst taking some of the pressure off the capital's land market.

There were a number of other policies which supported the rise of this cluster. Military procurement policy was very important in funding the growth of the industry; the military contracts specific a cost-plus basis for development work, ensuring it would always prove profitable. Military contracts were placed with extant companies and when seeking expansion in the south of England, the area west of Heathrow was a natural location for development establishments, a position reinforced by the locations chosen for the Military's own defence research establishments. Industrial policy in the 1960s was based around the promotion of competitiveness through merger and creation of giant companies, which had the effect of concentrating encouraging rationalisation of research capacity around strong locations. The aggregate effect of this was to create the conditions in the Thames Valley as a site of a highly competitive although defence-oriented electronics sector.

Science policy has also benefited the Thames Valley, which is home to a number of flagship Government research centres, from the Rutherford Appleton Laboratory, Aldermaston and Harwell in Oxfordshire (Harwell is home to what was the Atomic Energy Authority, now AEA Technologies plc which in the 1970s for a number of years the largest single funder of R&D in the UK) to the Royal Aeronautical Establishment in Farnborough to the south. The strength of Government-funded civil R&D was critical in supporting the development of a workforce with particular expertise in the development of new technologies.

Deregulation of the telecommunications market in the UK has made a significant contribution to the competitiveness of the industry. It removed the British Telecom monopoly on land line services, and allocated frequencies for the development of mobile telephony. Contracts to develop the infrastructure were allocated on the basis of a proven capacity to manage the network rather than to develop the infrastructure. A number of UK electronics companies had collaborated on a lengthy telecommunications project which had systems management of mobile telephony at its core, the Ptarmigan defence communications system; one of the lead contractors on this project, Plessey, had also been involved in the development of System X, at the core of the BT fixed-line telecommunications management. This provided the natural spur for defence electronics firms to diversify into commercial technologies, and indeed one defence-interested company, Racal, set up Vodafone as a subsidiary business. As the Thames Valley was already a home to many of those highly-skilled professional staff with experience in the development of telecommunications systems, the deregulation provided a spur to the growth of new firms.

In the last decade, Government policy has once more encouraged a shift into services, and the telecommunications management skills portfolio has provided a solid foundation on which to make the shift. Government policy has been decisive in encouraging this shift; the adoption of commercial procurement conditions in the defence sector has reduced the attractiveness of development contracts. Government has also involved the private sector in the development and management of IT services for Departments as well as Executive Agencies. In parallel with this, the explosion in the internet has benefited telecommunications firms. Although part of this benefit comes from their role in selling access to the internet, their expertise in network management has obvious commercial spin-offs. In particular, BT has diversified into the sales of network consultancy through Syntegra, who sells integrated IT and business consultancy solutions drawing on BT's own experiences in managing complex ICT network systems.

The dominance of large and formal research activities in the region has had an impact on the pursuit of innovation in the Thames Valley. There are many large business, higher education and government research centres located in and around the Thames Valley area with the consequence that collaboration based on world-class expertise can be contained within the cluster. An additional feature of innovative activity is that the region is a hub for innovation, and the site of a great deal of research management, and many of the decisions which are responsible for creating national and international research networks are taken within the cluster. Furthermore, it is important to stress the effect of Racal on the cluster, whose own attitude to innovation remains important on its operation; Racal expanded successfully into new and innovative fields by establishing new operations as independent businesses, creating internal capacity for innovation. These firms pursued their own innovative activities independently from other business units in the group, thus enabling each site to remain at the forefront of technological development, and removing the possibility of the emergence of an inter-site division of labour. Given the need to populate the new subsidiary businesses with staff from existing businesses the new operations were always established close to the old. The success of this approach is demonstrated by the success of the Racal offshoot company, Vodafone.

In the case of Thames Valley, there are questions which must be raised as to the degree of geographical coherence of the Thames Valley cluster. Certainly, it is very hard to decide exact definitions, given that the "M4 corridor" runs 100 km further west to Bristol, and there is a crescent from the Thames Valley which runs North East to Hertfordshire, itself an important site for electronics and IT services. One explanation for the choice of the Thames Valley as a cluster is because it is the closest of the three sites to a national-scale cluster; there are many R&D locations for UK multinationals, and a significant element of civil and defence public R&D is performed within the cluster. There is a great deal of co-ordination work for R&D and innovation networking which is located in and around this cluster, and so far more than 'Silicon Glen' or 'Silicon Fen', the Thames Valley is an exemplar of a national cluster of ICT competitiveness.

This fact is reflected in the two main policy areas where the success of the cluster has significantly influenced Central Government thinking, although there is a third change which has particular spatial policy implications. The first is in what remains of industrial policy, which is heavily influenced by conceptions of national competitiveness. It is clear that this cluster is globally competitive; the takeover of Mannesmann (a diversified German electrical and electronics engineering concern and owner of Orange, a second UK mobile telephony provider) by Vodafone, itself a spin-off from Racal, indicates the strength of the cluster. The 1998 Competitiveness White Paper (DTI, 1998), *Our competitive future — building the knowledge-driven economy*, stresses the importance of ICTs to the development of a new knowledge economy, and although the concept is generalised to cover industries across the UK, it is clear that at least part of the model is derived from the strength in the Thames Valley communications and IT services cluster (especially chapter 4, *Competitive Modern Markets*).

The second area where the cluster has influenced policy is in the area of science. It is clear that one of the competitive advantages of the cluster is derived from the proximity of scientific research establishments to high value-adding manufacturing and service firms, creating a common labour market and supporting the innovative culture. The Government appears to have accepted the need to concentrate scarce scientific resources to the benefit of the UK as a whole, something borne out by the recent decision to relocate a synchrotron from Cheshire to the Rutherford Appleton Laboratory in Oxfordshire, which implicitly involves the relocation of some 500 high-technology, high-skill jobs. Although the predisposition for the location of Government R&D in the South East has endured since WWII, the success of the Thames Valley cluster in contributing to national competitiveness has vindicated and helped to sustain the orientation of national SET expenditure.

The third policy area to which the Thames Valley cluster has made a significant contribution is in the area of land use planning, something with ramifications beyond central Government because of the organisation of planning in England. The Central Government and regional groupings of local authorities, the Regional Planning Conferences agree on a decennial target for house building in each of the regions, balancing the need for nature conservation, sustainable communities and the housing demands of economic development. The success of the Thames Valley cluster has led to rapidly rising demand for housing stocks, and the argument has been advanced, very successfully, that more land must be released for house building to accommodate rising demand from the industries. The economic argument is reinforced with lobbying that argues that if more housing is not forthcoming, then the South East in general will lose out to other regions with more flexible spatial planning regimes. The latest version of Planning Policy Guidance Note 3 *Housing*, emphasises that it is important to provide houses to sustain economic dynamism, and "[e] conomic growth should not be frustrated by a lack of homes for those wishing to take up new employment opportunities", clearly signalling the continuation of the previous Government's predict-and-provide policies.

Cambridge — embodying professional expertise in new media

The 1985 report by consultants Segal, Quince and Wicksteed signalled the emergence into the popular and public consciousness of what they termed *The Cambridge phenomenon*, the existence in and around Cambridge of a highly dynamic and innovative cluster of high-technology industries. The city of Cambridge was host to one of the UK's most prestigious and research-active universities, but it was clear from the report that the relationship between this cluster and the university was more complex than merely as a source of highly-skilled employees and new high-technology spin-off firms. There was a certain historicity to the cluster; Cambridge Instruments was formed by the grandson of the Cambridge zoologist and philosopher Charles Darwin, but had retained a fair degree of independence from the university. There were two main policy measures which had historically contributed to the growth of the cluster.

The first element was a very stringent planning regime both within the city area of Cambridge as well as in the wider county of Cambridgeshire in which new industrial premises are only made available if there are compelling reasons for location in Cambridge. The selection and concentration of high-technology firms has the potential to create clustering benefits from proximity to competitors as well as the Cambridge location boosting the prestige of small companies. The contribution the university made to this situation was the early creation of a science park on the land of one of its colleges, offering serviced areas where small firms can grow and thrive; although science parks are now common across the UK, the thirty-year age of the park, which opened in 1970, means that a number of firms born on the Science Park have since matured into dynamic and innovative companies.

The second policy element was Government science policy; Government policy favoured the development of high-technology bioscience companies in the Cambridgeshire area, drawing on university research expertises as well as the natural evolution of Agriculture research into biotechnology. Research in this area was revolutionised by the potential for analysis offered by computer-based technologies. Electronics and instruments firms located in Cambridge therefore benefited from a highly demanding and inquisitive market with whom cutting-edge products could be developed and sold globally. Metals Research, based in Cambridge and later to merge with Cambridge Instruments developed the Quantimet, the first digital image analysis system, with widespread medical and biotechnology research applications. The Babraham Institute has also had a number of spin-off firms who have drawn extensively on the bioscience base of the Cambridge area to develop new ICT-derived products made commercially feasible by advances in ICT processing power and software programming languages.

The essence of the competitive advantage of these firms and of the cluster is their dynamism and innovation in emerging activities, and the fact that there are still a large number of smaller firms who have been able to draw upon the strengths of the cluster to penetrate into emerging markets. Although there is a distinctive Cambridge ICT cluster, the benefits from which Cambridge has drawn have seen success grow across a number of sectors. Aside from electronics, biotechnology has benefited from investment in universities and government research institutions, as well as providing a market to whom can be sold high-technology instruments and software. This effect has been wider than purely the biotechnology sector; Cambridge is host to a large number of technical and technological service firms, and each has had their market dramatically changed by new information and communications technologies. Generally speaking, much of the growth in the sector has come from firms whose primary expertise is not necessarily in computers or IT, but in some other area such as geophysics, medical diagnostics or machine vision. These firms have developed electronic and software products which embody their expertise.

The other element of the competitive advantage of the cluster is that it has been able to take advantage of the financial flexibility made possible by venture capitalists. Although venture capital remains extremely volatile as a form of funding, there has been an expectation from financiers that because ICTs are a transforming technology, with long-term potential, which mean that developmental firms have been allowed to run medium-term deficits. Venture capitalists have plugged these gaps in anticipation of future rewards, and in recognition of the strengths which the Cambridge environment offers[6]. The Cambridge economy is supportive of high-technology SMEs in a range of ways; explicitly, a number of science parks provide incubating and mentoring facilities. A Cambridge location has a degree of cachet which can ease accessing global markets. Close proximity to competitors allows new waves of products to be launched against each other, which raises market impressions that they represent a new generation, increasing the imperative for their purchase, and increasing the sales of the firms.

The style of innovation in the Cambridge cluster bears much resemblance to the behaviour of two of the groups from whom entrepreneurs and innovators are drawn. The small high-technology firm approach to innovation is culturally very similar to the team-based approach to research in universities, and the semi-autonomy of fee-earners in professional partnerships. Both those occupations frequently blur the distinction between work and home because of the intensity of the employment, and it is this approach to innovation which encourages small-firm based success. Innovation is also highly reflective in the cluster, with similar firms tending to be aware of how rivals are performing, because of the advantages of roughly synchronous product launch. Indeed, this culture characterised by autonomy and dedication is important to the success of larger R&D-based organisations, such as the Microsoft Research Laboratories.

In policy terms, Cambridge is unequivocally perceived as a success and hence an exemplar. This is because it has overcome all the weaknesses inherent in the UK system of innovation, maximised the potential of opportunities and capitalised on its strengths, with a very limited amount of Government industrial intervention. The Cambridge system of innovation is underpinned by a culture in which traditional divides between academic work and entrepreneurship have been broken down[7]. Traditional financial short-termism has been overcome because of the huge potential of many of the firms has attracted novel forms of finance, particularly venture capital and listing on the Alternative Investment Market (whose listing requirements are designed with regard to small high-technology firms). Cambridge has managed to mix British and foreign ownership with none of the traditional drawbacks of inward investment, particularly in terms of dealing with rationalisation — the business competitiveness strengths of the Cambridge-located firms are embodied in individuals, making their development contingent upon maintaining location in Cambridge.

The identification of the Cambridge phenomenon has been followed by its widespread incorporation into English industrial policy, because it demonstrates that industrial development and modernisation is possible within the UK innovation system at a relatively low cost to the Exchequer. Indeed, because it is argued that most of the investment necessary to secure the benefits of an ICT cluster are already present across the UK in the form of Universities, innovative businesses and government R&D, the level of Government expenditure required to increase regional competitiveness is relatively low. Much of the tone of the 1998 Competitiveness White Paper has been influenced by analyses of the situation in Cambridge, particularly in terms of Government attempts to reproduce the entrepreneurial culture of Cambridge. Whilst Thames Valley is an example of a national cluster of sectoral competitiveness (albeit concentrated within a small geographical region), DTI policy on sub-national territorial competitiveness is derived from an analysis of the highly place-specific success of the Cambridge region.

The other important element of policy which has been informed by the case of Cambridge is science and technology policy and particularly the absence of any kind of spatial consideration in the allocation of funding. The table below shows the R&D index for the British regions, which shows that the Eastern and South East Government Office regions have a higher share of R&D than would be expected by their contribution to regional wealth. The success of both Cambridge and the Thames Valley have justified the argument that national competitiveness is well-served by the existing allocation of funding. The argument is that the pattern of funding follows the efficiency of the users; therefore raising the technological capacity of the poorer regions will improve their performance without undermining the competitive strengths of the UK as a whole.

Table 6 The R&D concentration index for the Government Office regions, 1997[8]

	GERD (£m)	R&D Index
United Kingdom	*14462*	*100*
England	*13185*	*107*
Eastern	2767	208
South East (GOR)	3415	149
South West	1146	98
North West (GOR) & Merseyside	1503	98
East Midlands	899	93
London	1593	73
West Midlands	988	81
Scotland	876	73
North East	334	64
Yorkshire & the Humber	540	49
Northern Ireland	145	44
Wales	257	43

Source: Economic Trends, 1999

The ICT Cluster, cluster policy and the Department of Trade and Industry

The lead responsibility for clustering has lain with the DTI, although since 1998 the Department for Environment, Transport and the Regions has had a role to play in modernising the planning framework in line with the needs of clusters. DTI policy since the 1980s has evolved with the evolution of the Civil Service; in 1983, the DTI was created when the Departments of Trade and Industry were merged, and since then, many of the active functions of the department have been placed in the hands of arm's-length agencies. The key concern of the department is with competitiveness, and its periodic White Papers have set the framework for the bulk of routine intervention in the economy. Prior to 1997, there was predominantly a sectoral concern, and electronics was dealt with in the Foresight exercise as a national-scale cluster. The 1998 Competitiveness White Paper however moved from a purely sectoral shift to thinking about clusters, particularly in terms of the non-material linkages between the various firms in those clusters.

Much of the cluster policy put forward and developed after the 1998 White Paper relates to the biotechnology cluster, establishing a Minister-led team, developing a "Genome Valley" in UK regions and the "Biotechnology Means Business" initiative. However, there are specific policy elements in current Government thinking which have their origins in the three UK ICT clusters. Clustering is an important element of DTI policy, particularly in terms of the delivery of their regional competitiveness agenda. Thus, when the newly-formed Regional Development Agencies (RDAs) submitted their Regional Economic Strategies to Central Government, all were urged in the strongest possible terms to "to facilitate cluster development by seeking to promote informal networks rather than create new clusters" (DETR, 2000).

Firstly, the Scottish cluster is exemplified as an example of best practice in the collaborative exploitation of research, in assisting a peripheral region to overcome the problems caused by the absence of network linkages between universities and sophisticated multi-national users located in Scotland. "Project Alba is a unique collaboration between public and private sector, industry and academic partners which will propel Scotland to the forefront of world-class research and design of next generation semi-conductors" (DTI, 1998, p. 44). Subsequent programmes and funding stressed the importance of building linkages between centres of excellence in universities and local businesses rather than creating research excellence. In particular, this appeared to indicate an appreciation within Government of the spatial element of clustering, and the importance of proximity in allowing access to technical knowledge.

Secondly, the success of the Thames Valley cluster, and in particular the degree to which the regulation framework has contributed to its competitiveness has influenced Government policy towards world-class firms. In the Thames Valley, large defence contractors were critical to the development of businesses which could compete globally. Government policy towards defence therefore hinges around encouragement of large defence speciality firms, such as BAE Systems (formed from the merger of BAe and Marconi Electronic Systems) and the Rolls-Royce take-over of Vickers. More critical to the industry however may be the £530m provided in launch assistance provided to BAE Systems to develop the A3XX very large aircraft, which reprises the policy of providing stability to the industrial base by removing a degree of the market pressure from the developers.

Thirdly, the success of Cambridge has provided DTI, which has since 1997 had responsibility for Science, Engineering and Technology (SET) to reaffirm its commitment to the funding for basic science. Although applied research and technology transfer are important elements of the national science base and contribute to competitiveness, the attraction of the Microsoft Research Centre to Cambridge demonstrated that multi-nationals have a need for basic research. The rationale for the centre is to undertake basic software research, which may later be applied to particular MS products; this idea of public-private research is an important element of the cluster policy; in the Life Sciences, the Wellcome Trust has been an important co-funder of basic research and infrastructure.

More generally, DETR has a commitment to the reform of the English planning system to take account of the needs of clusters. Although included in the DTI's White Paper Action Plan, DETR have been instrumental in commissioning and accepting the research underpinning those reforms. The research work consisted of an evaluation of six English clusters, including Motor Sports in the West Midlands, and Financial Services in Leeds. However, two of the clusters considered were part of the UK ICT cluster system, Thames Valley and Cambridge. Thus, an understanding of the ICT cluster is informing broader thinking about cross-departmental policy changes necessary to create supportive environments for clusters.

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[1] Apocryphally this limit relates to the distance for which Civil Servants could claim a (very generous) mileage allowance; beyond this distance they were required to take the train, although the contracts they awarded did have allowances for their entertainment and accommodation whilst away from home.

[2] These tables reproduce statistics provided from the Annual Employment Survey, which uses the 1992 Standard Industrial Classification. This classification was designed before the phenomenal rise of the internet. The statistics do not capture those the new media and electronic commerce business sectors, which although employing significant numbers in computer occupations, are currently classified with their legacy industries, and are not included in the totals presented.

[3] There is a break in the series between 1987 and 1991 arising from the redefinition of SIC codes. The value of 169,400 is taken from the new series definitions (1992 SIC); under the 1980 SIC definitions the employment was calculated at 147,500.

[4] This is the proportional importance of the service industry relative to its importance to the national ICT industry, expressed as an index. Thus, Eastern region, with an index of 100, has the same proportional split between manufacturing and services in the ICT industry as does the UK as a whole, whilst in London, there is disproportionately high employment in services.

[5] Ferranti was an successful UK-owned firm with strengths in defence systems, components and industrial electronics. It sought to achieve greater market share in the defence sector in the late 1980s by buying a US-based defence contractor, but this turned out to have been trading fraudently and the resultant losses forced Ferranti into receivership and break-up. At the time of the collapse Ferranti was the biggest UK-owned firm in Scotland and accounted for 20% of all electronics jobs in Scotland

[6] In particular, by supporting small firms with a very high growth potential, this has allowed venture capitalists to invest in a diverse portfolio of small firms which has enabled a longer term perspective.

[7] Although the degree to which this is true is debatable. Certainly, much of the new firm formation has not come from direct academic spin-off, and only the largest of the multi-nationals located in and around Cambridge have the capacity to undertake much collaborative world-class research with the University. Much of the "academic" spin-offs come from either entrepreneurial graduates of the university or from government-funded research institutes, who have been subject to market imperatives since the 1970s, much longer than is the case for University-sector institutions.

[8] This index indicates the relative level of Gross Expenditure on R&D (GERD) as a proportion of all UK expenditure relative to the proportion of GDP produced by that region. A value of 100 indicates that the proportion of R&D that takes place in that region with respect to the UK is equal to its share of R&D; a higher value indicates a concentration of R&D whilst less than 100 indicates a relative absence.