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Regional Competitiveness & the Role of the Knowledge Economy

A number of recent studies show wide variation between the competitiveness of regions in the UK. Further work suggests that differences in the distribution and location of high-tech, technology-based industries are a major contribution to this divergent performance. This Paper looks at what competitiveness is, and at the experience of high tech industry in the UK, within a context of a policy framework which stresses the importance of supporting knowledge-based industries. Skills training, innovation and support for research & development are all important elements of competitiveness and, therefore, this Paper looks at these issues too. Developments in the UK are compared with examples of successful industrial achievement abroad.

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Summary of main points

The UK Government's industrial strategy has focussed upon the opportunities offered by the 'knowledge industries' including those in the telecommunications, IT, electronics, electronic engineering and pharmaceutical sectors of the economy. Success in these sectors, it is claimed, will substantially raise the overall competitiveness of the economy. Evidence to support this view has come from work on regional competitiveness. There is a very close association between regions with a poor economic performance overall and those that have a low representation amongst the knowledge sectors.

The high performing regions are those in the south and south east of the country. Their established lead in the crucial sectors may date back to at least World War II and is thought to have been due to a combination of increased access to venture capital and the provision of suitable premises. If backward regions are to catch up the policy implication is that it will take substantial public sector investment to overcome existing deficiencies: deficiencies that the private sector has either exacerbated or failed to reduce.

The organisation of these industries into either 'clusters' or around science parks is examined with respect to experience in the UK and in the US. The successful development of Silicon Valley is found to have been due to a number of supportive influences such as close academic linkages and generous employers, allowing time for formal and informal study leave for employees. The ready availability of venture capital finance in the US and a commercial system that controls business failure, rather than punishes it, is also seen to be important. UK science parks have grown significantly and their contribution to employment and growth has risen. They have, however, yet to produce a national champion company in the way that Apple or Microsoft has gone on to be.

The history of a 'Silicon Glen' in Scotland is examined in some detail. Comparison between it and Silicon Valley was found to be based more upon journalistic licence than upon facts on the ground. 'Silicon Glen' has been a successful attempt to attract large amounts of manufacturing capacity in the electronics sector to a region of central Scotland. Most of this was foreign based and accounts for a substantial proportion of Scottish manufacturing output. However, linkages between foreign producers and Scottish suppliers were limited. Employment fluctuated as world markets for products such as memory chips fluctuated and the higher-value research and development work, with associated links to the Universities in Edinburgh and Glasgow, never really took off on the scale experienced in the United States.

Sustaining the knowledge industry are policies towards skills, training and support and finance for the universities and other higher education and research institutes. Work on skills policy suggests that employers have adapted their manufacturing processes to a less than optimal level of given skills. University funding is currently linked to an assessment procedure that reflects in-house work by departments such as the publication of papers and so on. Currently there is little link between funding and economic performance or the applicability of university ideas to the world of work.

CONTENTS

I Introduction

> Our competitiveness depends on making the most of our distinctive and valuable assets, which competitors find hard to imitate. In a modern economy those distinctive assets are increasingly knowledge, skills and creativity rather than traditional factors such as land and other natural resources.[1]

This government statement, and others like it, are the springboard for a large number of government micro-economic activities and policies. In a manner somewhat reminiscent of the programme driven activity directed towards small firms in the 1980's, the raising of competitiveness and productivity in industry and the application of new 'knowledge activities' and technologies has become a central feature of much of government's economic and industrial strategy.[2]

In one sense this is unfinished business from the previous administration. Under the then Conservative government, a series of White Papers were issued as a way of focusing on problems and providing an intellectual framework for action by both government and industry.[3]

This Paper looks at competitiveness primarily from a regional perspective, drawing upon a number of new sources of regional interest. In particular it looks at the contribution made by the 'knowledge economy' sector to competitiveness, which is often regarded as being a pre-requisite for a competitive economy. It looks at why some regions of the country are so much better represented in these sectors than others and what conditions are needed to either establish a presence or encourage growth. A number of related issues are also examined such as innovation policy, skills and training.

II Regional Competitiveness

A. The UK Regions

Regular regional competitiveness indicators were first published in February 1998. Fourteen indicators were assessed, chosen to 'give a balanced picture of all the statistical information relevant to regional competitiveness'[4] However, several indicators are expressions of overall competitiveness (such as GDP per head) i.e. they are outputs. There is no explanation as to what is driving the results for each region. Furthermore, there is no overall 'score' that aggregates the results in some fashion. The only two significant measures that could be classified as inputs, and which are of particular relevance to this Paper, are the indicators for

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1 *Our Competitive Future: Building the Knowledge Driven Economy*, December 1998, Cm 4176

2 Also see the latest DTI White Paper, *'Excellence and Opportunity, a science and innovation policy for the 21st century'*, July 2000, Cm 4814

3 For example see: *Competitiveness, Helping Business to Win* (Cm 2563), *Competitiveness, Forging Ahead* (Cm 2867) and *Competitiveness, Creating the Enterprise Centre of Europe* (Cm 3300)

4 *Regional Competitiveness Indicators*, February 2000, p 2, GSS

'educational and vocational attainment' and 'Research & Development Density & Employee jobs in High Technology'. Of the latter, the study notes that:

> R&D establishments can be a significant source of new firms as those involved in R&D activities establish their own companies. High R&D activity can therefore be a source of regional dynamism and increased competitiveness.[5]

A more ambitious treatment of sub-national competitiveness was highlighted in a recent publication: *An Index of Competitiveness in the UK: Local, Regional and Global Analysis*, published by Robert Huggins of the Centre for Advanced Studies, Cardiff University.[6] The aim of the Report was to:

> Assess the relative economic competitiveness of regions and localities in the UK by constructing a single index that reflects, as fully as possible, the measurable criteria constituting 'area competitiveness'.[7]

This work is more interesting from a policy point of view than the GSS study, worthy though that is, because it focuses on key input factors rather than outturns . The three inputs analysed were:

> Business density (firms per capita) is a strong measure of the potential for sustainable economic growth through the generation of new entrepreneurs and new firms.
>
> The number of knowledge based businesses (as a proportion of all businesses) is now recognised to be the key driver of growth at all levels and provides the crucial link between firm-based competitiveness, in terms of innovation, and aggregated geographic-based competitiveness.
>
> Overall economic participation rates (economic activity rates) currently provides the most robust measure of the 'raw' human capital available at an area level.[8]

The result of this analysis in terms of overall regional rankings is shown in the table on the following page:

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5 *Regional Competitiveness Indicators*, February 2000, p 21
6 April 2000, ISBN 1 899184 29 5
7 Op cit p 6
8 Op cit p 11

UK Regional Competitiveness Index

Rank	Region	Index UK = 100
1	London	115.5
2	South East	105.6
3	South West	100.8
4	East	100.8
5	East Midlands	96.1
6	West Midlands	95.5
7	Scotland	95.1
8	North West	94.5
9	Northern Ireland	93.7
10	Yorkshire & Humberside	93.4
11	Wales	90.7
12	North East	88.8

Source:Cardiff University

The author's summary of this table is worth quoting in full:

> The most striking feature…is the continuance of a North-South divide in economic fortunes. While the regions of London, the South East, the South West and the East all perform above the UK average, the East and West Midlands, Scotland, the North West, Northern Ireland, Yorkshire, Wales and the North East are all significantly under-performing when compared to the UK. The index makes it abundantly clear it is the southern regions of England that are driving economic growth in the UK. It is these regions that are home to the highest density of firms, the most knowledge-intensive firms, the highest levels of economic activity, which in turn gives firms based in the areas a higher level of productivity, resulting in higher wages and less unemployment.[9]

To emphasise the difference in capability and performance of the regions the study compared them with other countries in terms of their relative competitiveness. For example the Executive Summary (reproduced extensively in the press) noted that:

> At a global level, London and the South East are performing as well as the top-ten most competitive nations, alongside countries such as Singapore, Switzerland and Denmark. At the lower end of the scale, Wales, the North East and Yorkshire and the Humber are ranked alongside such nations as Hungary, Chile and Israel.[10]

The study found that there was a massive disparity between the proportion of knowledge based industries found in the different regions. The South of England has what is described as a 'highly significant competitive advantage over other regions since an expanding core of growth businesses are already sited there'.[11] The inference is that unless developmental

9 Op cit p 13
10 Op cit p 5
11 Op cit p 15

policies make a real impact on attracting outside investment and in nurturing indigenous entrepreneurial talent the competitive gap between London, the South East and the rest of the country will widen still further. The derived rankings, where the UK average score = 100 are shown in the table below. The overall ranking of each region is repeated in the far right column. The close relationship between the two lists is fairly apparent from this table. Due to data availability problems no figures are available for Northern Ireland.

Index of Regional Knowledge-Based Business

Knowledge Industry Rank	Region	Index	Overall Competitiveness Ranking
1	London	146.7	1
2	South East	130.3	2
3	South West	124.2	3
4	East	107.6	4
5	North West	83.6	8
6	East Midlands	78.4	5
7	West Midlands	76.4	6
8	Yorkshire & Humberside	76.0	10
9	Scotland	73.3	7
10	North East	72.6	12
11	Wales	64.5	11

Source:Cardiff University

What is perhaps most surprising about this table is how long the ‘tail’ is. Of the eleven regions, the top three register scores of between a quarter and a half over average. One, the East, is about average; the rest are substantially underrepresented in this sector. Worst of all, Wales has less than two thirds of the national average quotient of knowledge industries.

Knowledge industries do, of course, extend beyond the confines of science parks. An occupational analysis of employees who work in computer and IT technology jobs, by region, is shown on the following page. Again it highlights the difference between the regions in terms of employment density in the key sectors.

Regional distribution of employment in IT occupations [(a)]

Winter 1999/2000

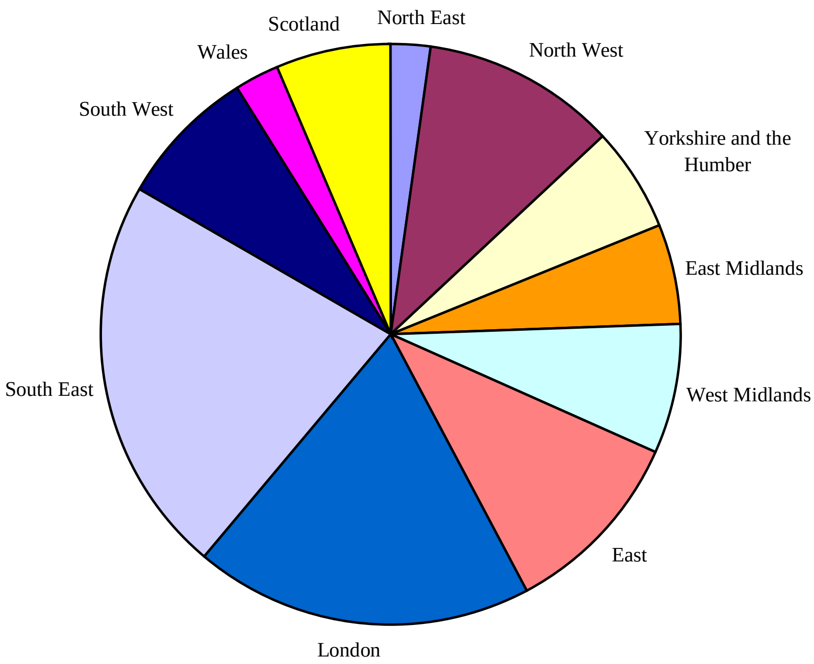
	Employment in IT Occupations	Regional IT employment as a % of British IT employment	Regional IT employment as % of total employment	IT employment quotient (b)
North East	19,000	2%	2%	55
North West	92,000	11%	3%	94
Yorkshire and the Humber	50,000	6%	2%	69
East Midlands	48,000	6%	2%	76
West Midlands	61,000	7%	3%	79
East	90,000	11%	4%	108
London	160,000	19%	5%	150
South East	189,000	22%	5%	148
South West	67,000	8%	3%	91
England	776,000	91%	3%	105
Wales	21,000	2%	2%	53
Scotland	54,000	6%	2%	73
Great Britain	850,000	100%	3%	100

(a) Computer Systems Managers, Software Engineers, Computer Analysts, Programmers, Computer Operators, Computer Engineers

(b) A value of 100 implies that employment in IT counts for the same share of employment in the region as in GB as a whole

Source: National Statistics, *Labour Force Survey*, Winter 1999/2000

Employment in IT Occupations in Great Britain



As one might expect, differences between sub-regional areas reveal even sharper differences in performance:

Index of Local Knowledge-Based Business
Best & Worst Performers

	Rank	Locality	Index
Best	1	Bracknell Forest	202.6
	2	Wokingham	197.5
	3	Inner London - West	182.1
	4	Windsor & Maidenhead	165.9
	5	Surrey	157.3
	6	Reading	152.5
	7	Milton Keynes	148.9
	8	Buckinghamshire County	147.8
	9	Outer London South	147.2
	10	Hertfordshire	145.7
Worst	136	Dumfries & Galloway	43.0
	137	Blaenau Gwent	42.7
	138	East Ayrshire	42.3
	139	Caerphilly	41.9
	140	Isle of Anglesey	41.5
	141	Scottish Borders	41.3
	142	Shetland Isles	40.2
	143	Argyll & Bute	38.7
	144	Orkney Isles	35.6
	145	Western Isles	32.1

Source:Cardiff University

At the risk of simplification, this table breaks down into the English M4 Corridor and the Celtic fringe. So far, hopes that new technology will end the barrier of remoteness appear to be unrealised. This table is a particularly poor outcome for Scotland that, at one time, held high hopes for the long-term development of its own ‘Silicon Glen’. But why has the South East dominated this sector?

The subject of why industries are where they are and how knowledge industries and high-tech clusters in particular, come to group together and survive is explored in some depth later in this Paper. However, what appears to be a recurring theme in much of the literature is the importance of the role that property, development space and finance plays. One typical account of why so many knowledge industries came to be in the South East is given in a study of science parks.[12]

According to the theory, knowledge industries need very different premises from standard manufacturing premises; there is no need for a large factory floor. Knowledge industries

[12] *Science Parks & the Growth of High-Tech Firms*, KPMG

require flexible accommodation where there is little segregation between design, development and production functions. At the start of the 1980s there were very few premises of this sort and the typical small, knowledge-rich, capital-poor, firm could not afford to commission and buy them. Renting was in many cases the only option. It was only in the South East that the right combination of venture capital and property development existed to make available the new high tech premises. Once established, such units generate their own demand and act as a pull on other units and entrepreneurs.[13]

This study was published in 1988; even at that late stage it could be written that:

> Despite the expected higher rates of return from 'high-tech' premises, there has been a virtual absence of provision by the private sector outside south-east England. This reluctance of the private sector to provide suitable premises for technology based industry meant that public sector organisations, such as local authorities and government development agencies, committed themselves to filling this gap.[14]

Outside of London and the South East (including Cambridge in this area) the boldest attempt to establish a US style, high-tech industrial and academic complex involved Scotland and the self styled Silicon Glen. Although the emphasis in this case was industrial and manufacturing rather than theoretical, cutting edge technological research, the experience of a region attempting to build a new industrial identity via technology is instructive in the context of current regional imbalances.

B. Whatever Happened to Silicon Glen?

1. The growing industry

Chance played a part in the establishment of the electronics industry in Scotland. According to one press report:

> The electronics industry took root during the second world war, when companies shifted north to avoid the bombs dropping on English factories. Some geographical advantages quickly became clear. Central Scotland has a plentiful supply of water - essential for any kind of manufacturing. Transport connections are excellent with two big cities on the doorstep and good air and sea links.[15]

The first major company to arrive was IBM, at Greenock in 1951. It was followed by a wave of companies in the 1960s including National Semiconductor, Hewlett Packard and Motorola. Followed later by Compaq (1970s), NEC (1980s) and, lately Cisco (an internet specialist). One of the characteristic features of these companies was their focus on the manufacturing of goods rather than on the more esoteric aspects of the industry such as basic research. At their

13 Op cit p 75
14 Op cit p 76
15 "Glen where history begins in 1951", *Guardian*, 8 June 2000

height, in the mid 1980s, the companies employed thousands in the very latest manufacturing conditions. IBM claimed to sustain about 10,000 jobs in the United Kingdom[16] and Motorola claimed that its East Kilbride facility was the most advanced 'chip' facility in Europe.[17] Not to be outdone, National Semiconductor, which invested £100 million at Greenock in 1984, claimed that it was creating 'Europe's largest and most advanced production facility'.[18]

There can be little doubt that Scotland has been successful in developing a sizeable electronics industry as the tables below show. Two tables are necessary since changes in classification would otherwise prevent recent data being presented.

Electronics Industry in Scotland

Index of Production **1985=100**

	Data processing equipment	Electronic components	Other electronics
1973	6	32	50
1979	13	80	54
1985	100	100	100
1990	190	211	80
1991	196	211	91
1992	241	261	84
1993	321	354	94
1994	399	512	126

Source: Scottish Office, Statistical Bulletin C1.7 & D2.4

Electronics Industry in Scotland

Index of Production **1995=100**

	Electrical and Instrument Engineering	Electronics	Basic Electrical Equipment	Medical and Other Instrument Engineering	Other Electrical Equipment, Domestic and Industrial
1986	33	26	73	110	106
1990	47	41	88	74	118
1995	100	100	100	100	100
1996	109	110	102	98	106
1997	128	130	126	100	109
1998	140	146	107	99	100
1999	156	165	n/a	n/a	n/a

Source: Scottish Executive Figures for Scotland

Without the significant expansion of the electronics industry in the region, manufacturing output as a whole might well have declined in absolute terms. Hence, one of the aims of the

16 Andrew Hargrave, *Silicon Glen, Reality or Illusion*, p 26
17 Op cit p 31
18 Op cit p 31

Development Agencies, first the Scottish Development Agency and, lately, Scottish Enterprise, namely to diversify manufacturing in Scotland away from a reliance upon the traditional industries of steel working, shipbuilding etc, has been achieved.

The important feature of the Scottish experiment (its finest achievement or its largest single weakness depending upon the point of view taken) has been its dependence upon attracting foreign owned companies to set up in the region. Large amounts of regional selective assistance (RSA) funding has been made available to attract multinational companies to invest in the region. Between 1994/95 and 1998/99 the industries classified under the heading electrical and optical equipment received 22% by number and 56% by value of all RSA offers made to manufacturers. In the four year period companies in this sector accepted aid worth £272 million.

Apart from the immediate benefit to employment, one of the justifications for using public money to attract foreign business is that the new companies will revive and stimulate indigenous business through supplier relations and co-operative ventures. A significant literature exists that suggests that this has not been as extensive as was hoped for over the last twenty years or so.

2. Spin offs from foreign inward direct investment in Silicon Glen

Backward linkages to indigenous suppliers have long been regarded as a major economic benefit of inward investment. As was shown above electronics gross output in Scotland increased at a very rapid rate of 14% per annum in the 1980s. By 1990 electronics was a sizeable part of the Scottish economy accounting for 20% of gross manufacturing and 42% of manufactured exports. However, the direct benefits for the local economy were far less than this suggests. To gain a better impression of the contribution made by the industry it is helpful to remember that gross output includes the value of all the intermediate inputs. For example the output of the furniture industry includes the inputs of the timber and textile industries. For this reason *value added* is a better measure of the amount of work done by plants to develop and manufacture the products sold, and hence of the income generated locally.[19] Between 1983 and 1989, while gross output increased at a rate of 16% per annum the industry's value added only increased by 7.1% and by only 1.8% per annum for employment.[20]

Changes in the degree of local sourcing are shown in the table on the following page:

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[19] Op cit

[20] Ivan Turok, *Loose Connections? Foreign Investment and Local Linkages in Silicon Glen*, University of Strathclyde. p 4-5, January 1993

Source of Material Inputs by Value
Percentage of total inputs

	Scotland	Rest of: UK	Rest of: Europe	Asia	USA	Rest of World
1986	12	23	9	8	38	5
1988	15	25	9	30	9	9
1991	12	30	19	30	8	1

Source: *Loose Connections?* , University of Strathclyde

Subsequent surveys by Scottish Enterprise suggest that, if anything, the percentage of inputs for the electronics industry sourced in Scotland has declined since 1991 (latest figures are for 1994/95).[21] Even within this overall decline those products that are sourced from within the country tend not to be the most 'high tech' components. Details of the breakdown of bought in components by source is shown below:

Distribution of Scottish Sourced Electronic Inputs

Percentage of total Scottish Spend

	High - tech components							
	Storage media	Display units	PCBA	Higher level assembly	Power supply	Input devices	PCB	Average (unweighted)
1991/92	0	7	45	30	2	32	41	22
1992/93	0	1	36	51	2	14	37	20
1993/94	0	1	40	51	6	15	30	20
1994/95	0	1	43	78	12	12	16	23

	Lower grade production inputs						
	Cables	Plastics/ rubber	Metalwork	Printed goods	Packaging	Machined parts	Average (unweighted)
1991/92	61	46	64	81	79	21	59
1992/93	49	42	58	62	88	18	53
1993/94	36	36	47	60	87	29	49
1994/95	45	38	58	69	93	40	57

Source: Scottish Economic Bulletin, March 1996

The types of inputs have been categorised according to whether they are high or low 'tech'. This is a rather approximate categorisation. Printing, to take one example, can be very high tech and can utilise latest technology, however, although it uses such equipment the industry itself is more easily categorised in the traditional camp. With the exception of the assembly services (which have a significant labour content) virtually all of the high tech categories have indigenous content levels of significantly less than 50%. 'Display units' refer to disc drives that are almost all produced abroad. PCB and PCBAs refer to printed circuit boards in various stages of completion and production. Again, the indigenous element is low, and declining. By contrast machined components in plastic, rubber and metal and the packaging that they are sent out in is largely sourced in Scotland.

[21] Quoted *Scottish Economic Bulletin* March 1996

3. A record of success?

Because of how Silicon Glen is structured its history, success and failure, is accurately charted by the changing fortunes of its largest investors and employers. Demonstrable success occasioned by a new inward investment victory is offset by failure when a previous company shuts down a factory and relocates in Asia or elsewhere. Thus the performance of the sector has been highly related to the overall economic business cycle.

In the 1980s a succession of high profile company closures with large associated job losses appeared to be a sign that the hopes of Silicon Glen becoming a permanent fixture were doomed to disappointment.

For example, Wang, a US data processing company, came to Stirling in 1983 with the help of nearly £4 million of regional aid and the promise of jobs and links with the universities. The promised expansion plans never materialised and, under pressure from head office in the States, the plant closed and its manufacturing capability was transferred to Limerick in Southern Ireland. Coming on top of other pull-outs by American companies in both electronics and traditional industries (e.g. the Caterpillar tractor plant near Glasgow closed in 1987) even by the late 1980s the inward investment route had its critics. For example one newspaper commentary in 1989, after recognising the large number of jobs that the industry sustained (45,000) and the prestigious companies that operated within the region (IBM, NCR etc), noted:

> The downside is that employment in the Scottish electronics industry has not grown noticeably in the past few years. Hopes that the foreign owned plants would spawn a strong indigenous electronics industry have not been fulfilled. Scottish based companies only supply 15% of all components consumed in Silicon Glen. Multinationals go first to tried and tested suppliers, and Scottish companies have sometimes been found wanting. Nor have the multinationals been the [hoped for] launchpads for teams of executives 'spinning out' to set up on their own.
>
> The shortage of spin- outs is thought to be due to the fact that most plants in Scotland are solely manufacturing operations, lacking research and development and marketing personnel: few contain people who understand the whole business and would be able to set up on their own.[22]

With a pause in growth between 1989 and 1991 the Scottish electronics industry looked as though it had failed to live up to some of its own publicity. A major facility owned by Seagate in East Kilbride closed during this period. However, other parts of the Scottish manufacturing sector were performing even worse. A contemporary Scottish Office Economic Bulletin commented that 'growth in Scottish manufacturing between 1987 and 1993 may be entirely attributed to increased production in electronics plants'.[23] A spate of

[22] "A Shiver in Silicon Glen"; *Financial Times*, 28 June 1989
[23] "Sun rises Higher over Silicon Glen"; *Financial Times*, 22 September 1994

new companies and expansion by existing companies from 1993 onwards saw a major revival in its fortunes. NEC announced a £530 million investment in its semi-conductor plant in its plant in Livingstone in 1994. Other investments and expansion plans were announced by Motorola, Digital, National Semiconductors, Hewlett Packard, Mitsubishi and Compaq. In 1995/96 the Scottish electronics industry received nearly £750 million in inward investment. By then, the 55,000 people employed in electronics, which accounted for about 30% of Scottish manufacturing output, produced about 35% of all branded personal computers in Europe.[24] In late 1996 the South Korean company Hyundai announced an investment plan worth £2.4 billion to construct semiconductor plants in Fife creating a further 2,000 jobs. However, this surge of good news was cut short by the fall-out from the Asian financial and industrial crisis in 1997.

Once more the arguments about over-dependence upon inward investment were revived. In 1998 retrenchment and closures occurred at Compaq/Digital, the Lite-On monitor makers and at Viasystems in the Borders. Seagate Technology scaled back its production and National Semiconductor shed 600 jobs from its Greenock plant. One trade union official was quoted as saying that:

> I genuinely don't want to be alarmist, but as each day seems to bring another round of redundancies, it becomes awfully reminiscent of the early 1980's- only this time the jobs are in electronics rather than engineering, mining and shipbuilding.[25]

Within five weeks in the autumn of 1998 about 2,500 individuals either lost their job or were told that their job was likely to disappear in the near future.

So has Silicon Glen been a success? The above record is one of plusses and minuses. Over fifty years Scotland has become the geographical base of a substantial proportion of the European and world electronics production capability. A substantial number of Scots' jobs depend upon this sector and it is a significant proportion of total Scottish manufacturing output. Against that, a substantial amount of public money has gone into attracting and sustaining its growth. The output is primarily dependent upon imported inputs and is then largely exported. Most of the jobs are in the lower end of the value added chain and it is a highly cyclical industry dependent upon a range of factors that cannot be influenced to a great degree from Scotland.

Time and again in the literature the same complaints emerge. Linkages with the local economy are paltry. Too much money has been spent chasing footloose manufacturing capacity. The technology spin-offs and the development of local, indigenous clusters have not taken off due either to lack of incentives or lack of venture capital. Lack of access to finance is a constant refrain in much of the regional literature and appears to be one of the primary reasons why the high-risk, knowledge industry clusters are where they are now and

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[24] Quoted *Financial Times* 2 November 1996

[25] "Lights go out in Glen", *The Herald*, 7 October 1998

why new regions find it so hard to 'barge-in' at the table. This problem is not confined to the electronics sector.

A recent survey of life science (bio-technology companies) in Scotland drew the following complaint/response:

> The Scottish financial community based in Edinburgh, is seen, by bio-tech companies at least, as being very conservative. There is not as much venture capital in Scotland as there is in the German bio-regions, or around Oxford or Cambridge.
>
> "What's missing is the easy access to rich folks." Says one chief executive. "If you spin out technology from Oxford, someone with connections in the City (of London) will arrange for you to meet money over dinner and fine wine."[26]

Although by no means the definitive judgement on the success or otherwise of the Scottish endeavour, the Library attempted to follow up about a dozen firms that had been specifically marked out (in 1985) as 'front runners', new companies that were thought to have a promising future by the author Andrew Hargrave.[27] Some of these companies were entrepreneurial based, others were spin-offs from university research and others were management 'escapes' from larger, more established firms. A search of the Companies House Register revealed that four have disappeared altogether. Three were dissolved and two were in the process of liquidation. Of the remaining three, one has migrated south and operates out of an address in Berkshire. The other two have both merged with other companies but are active within their fields (chemicals and R & D on natural sciences and engineering) and just one appears to be based in one of Scotland's science parks.

Having discussed competitiveness and adduced a link between it and 'knowledge industries', somehow defined, it is appropriate at this stage to step back for a moment and consider what is really meant by terms such as competitiveness and look in more detail at its alleged linkages.

C. What is Competitiveness?

1. National & Corporate Competitiveness

Although seemingly a simple concept, competitiveness as applied to countries is less easy to define than one might imagine. Competitiveness has two basic elements, the technical costs of production (productivity) and the costs at which the goods are sold abroad (the exchange rate). In a world of reasonably freely floating exchange rates one might see competitiveness as a problem of exchange rate management. Some manufacturers in the UK have argued that although they are technically highly efficient sterling's strength limits their competitiveness. If one took this view then the major preoccupations for policymakers would not be how to

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26 "Life Sciences Survey" *Financial Times*, 28 October 1999

27 A Hargrave, *Silicon Glen: Reality or Illusion*, p 52

encourage technical efficiency, but how to manage the adjustments that necessarily accompany periodic exchange rate revaluation and the accompanying dislocation to internal economic policy. This is not, however, the majority view. The definition of competitiveness adopted in one of the previous government's White Papers is as follows:

> For a firm, competitiveness is the ability to produce the right goods and services of the right quality, at the right price, at the right time. It means meeting customers' needs more efficiently and more effectively than other firms do.
>
> For a nation, the OECD defines competitiveness as: the degree to which it can, under free and fair market conditions, produce goods and services which meet the test of international markets, while simultaneously maintaining and expanding the real income of its people over the long term.[28]

The emphasis on two sorts of competitiveness, one for firms and one for countries is important from the policy perspective and acts as an aid to clarity of thought.

The conventional wisdom is implicit in, for example, the title of some of the UK government's White Papers on the subject referred to already. For example, *Competitiveness: Helping Business To Win*, published in January 1995, included frequent references in the text to 'prizes' to be won in competition with other countries. Somehow the global economy is reduced to a game show with one lucky winner and a handful of contestants who go home with only consolation prizes for their pains. Although not the only 'dissident', one of the most outspoken critics of this view is an American Professor at Massachusetts Institute of Technology, Paul Krugman. His views were summarised in a famous article in *Foreign Affairs* (March/April 1994) and the comments in this section rely heavily on that article.

At the root of the problem is a confusion between what is meaningful for a company and what is meaningful when talking about a national economy. Clearly, to a company competitiveness matters and it can be easily measured in terms of the price, quality and other attributes of its products against those of similar producers at home or abroad. The issue is less clear when applied to countries. Ultimately an uncompetitive company goes out of business; it is taken over or ceases to trade when losses become too great. This is not, however, as repeated debt crises have shown, an option for a country. The national equivalent of company profitability might be thought to be the balance of trade. In a harkening back to nineteenth Century debates, surpluses are good, deficits bad. In modern parlance, newspaper headlines 'Britain in the red' equate national performance to personal financial indebtedness. However, overseas balances can reflect the level of internal demand in the economy rather than industrial failings that could be simply corrected by exchange rate management.

The other main reason why it is wrong to think that countries are equivalent to corporations is that whereas companies by and large earn their money from groups outside of themselves

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28 *"Competitiveness Helping Business to Win,"* Cm 2563, p 9

countries do not. For example, the makers of Rolls Royce cars sell virtually none of their output to their own employees. Countries by contrast do. Exports of goods and services in the UK account for less than 30% of national income. In the US the figure is about 10%. Thus whereas the principal determinant of company income is externally determined, national income is more dependent upon internal factors, the role of government being an important one. Furthermore, whereas lost markets for a company are just that, imports in country A generate income in country B and therefore export demand for other goods produced by country A.

To summarise, Krugman asserts that:

> The moral is clear, while competitive problems could arise in principle, as a practical, empirical matter the major nations of the world are not to a significant degree in economic competition with each other. Of course, there is always a rivalry for status and power - countries that grow faster will see their political rank rise. So it is always interesting to compare countries. But asserting that Japanese growth diminishes US status is very different from saying that it reduces the US standard of living- and it is the latter that the rhetoric of competitiveness asserts.[29]

Krugman puts forward simple, psychological reasons for the deep-seated attachment to 'competitiveness' as a notion:

> Tell businessmen that a country is like a corporation writ large, and you give them the comfort of feeling that they already understand the basics. The subtitle of [a] huge best seller, Head to Head, is 'The coming economic battle among Japan, Europe and America', the jacket proclaims that 'the decisive war of the century has begun ...and America may already have decided to lose.' Suppose the subtitle had described the real situation: "The coming struggle in which each big economy will succeed or fail based on its own efforts, pretty much independently of how well the others do.' Would [the author] have sold a tenth as many books?[30]

Is there truth in this competitive 'heresy'? Clearly trade is important, but in varying degrees to different countries. The success or failure of national companies will affect certain national aggregates; the composition of the industrial base; the distribution of wages between sectors and perhaps their level too. But, there is also something rather strange about a story in which the UK is afraid of European competition, Europe fears the US and Japan, the US fears Japan and Japan fears the new East. Obviously the benefits of world trade are not packaged up into one 'winner takes all' prize and much the biggest impact of trade is a redistributive impact, shifting production from one area to another as factors determine.

The European Commission talked about competitive advantage as compared to comparative advantage in this context. In this light, the gains from trade and the search for competitiveness are symbolised by the attraction of inward investment projects, of which the UK has an enviable

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[29] Op cit p 35
[30] Op cit p 39

record. In the wider context, Krugman may be right to say that competitiveness is a chimera. However, if, as he suggests, what people should really concentrate on is the search for productivity increases, and it is the constant improvements in productivity that are crucial to material prosperity, then much of the force of his argument is lost. Many of the factors that affect productivity are those that are already bound up in the national competitiveness policy debate; the concentration on investment, training, skills, management, the use of labour and so on.

Within this general debate about national competitiveness attention has focused recently upon the role that the 'knowledge industries' contribute.

2. Knowledge Industries & Competitiveness

The current Government's contribution to a long series of White Papers gave a clear indication of what is officially seen as one of the key drivers of a modern competitive economy. Entitled, *Our Competitive Future; Building the Knowledge Driven Economy*[31], the summary notes:

> In the global economy, capital is mobile, technology spreads quickly and goods can be made in low cost countries and shipped to developed markets. British business therefore has to compete by exploiting capabilities which competitors find hard to imitate. The UK's distinctive capabilities are not raw materials, land or cheap labour. They must be our knowledge, skills and creativity.[32]

The White Paper demonstrates influences from the writings of a number of economists (such as Krugman and Thurow) and clearly borrows from the experience of what has been found to work in the past and what was important to those successes. Thus there are comments on the importance of encouraging innovation, raising entrepreneurial culture, 'tackling fear of failure' and the accumulation and sharing of knowledge. All of these issues have emerged as being important in the establishment of dynamic, high-tech, knowledge industries and groups.[33] However, similar comments to these appeared in policy statements of ten to fifteen years ago with respect to small firms policy: seen then as the antidote to the economic problems of industry in the 1980s.

For example, a White Paper published in January 1988 noted:

> Successful businesses innovate, often using technology to improve their products and processes. Innovation is essential to sustain a competitive edge in world markets. The objectives of DTI's innovation policy will be to encourage:
> 1. Industry to increase its funding of R&D and to apply new technology more effectively;

31 Ibid Cm 4176, December 1998
32 Op cit p 6
33 These issues are discussed with respect to successful high tech clusters later in the Paper.

2. The translation of both inventive capability and best practice technique into commercial application
3. Industry to make most effective use of its own academic resources through collaborative research and development both nationally and internationally, with particular emphasis on Europe;
4. Innovation by small firms, especially in advanced technologies, and in the regions [34]

The entrepreneurial/knowledge focus for successive government initiatives has been buttressed by the writings of influential economists such as Paul Krugman (above) and Lester Thurow (below):

> A telecommunications-computer-transportation-logistics revolution has permitted global sourcing and the development of a world market. Both have made it easier for poor countries to export to rich countries and for rich countries to source abroad in poor countries. Effectively, everyone now has access to the same world capital market. More equal access to capital has reduced the edge that being born in a rich country used to give.
>
> In the future sustainable competitive advantage will depend more on new process technologies and less on new product technologies. New industries of the future such as biotechnology depend on brainpower. Man-made comparative advantage replaces the comparative advantage of Mother Nature (natural resource endowments) or history (capital endowments).[35]

Coming from someone based at MIT, at the centre of one of the most famous high-tech conurbations in America, these views have been highly influential abroad. At the heart of the thesis that knowledge matters is the contention that in some senses competition in the making of *things* has ceased.

Manufacturing techniques will be the same world-wide. Capital constraints are far lower world-wide than they have been for decades. Lower transport costs permit production concentration since goods no longer need to be near their final market. Furthermore, although the increasing industrialisation of third-world countries will boost the global demand for raw materials this will be substantially offset by a continuing fall in the intensity of use of commodities in world production. There are still powerful forces reducing the demand for most commodities: substitution by man-made materials, such as synthetic rubber and plastics; the shift in rich-country output towards goods and services that require fewer raw materials; and a decline in the input of materials into most goods (American cars, for example, are 15% lighter now than in 1974). Increasingly the location of production will be determined by non-manufacturing considerations such as national tax policies, political stability etc.

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[34] *DTI the department for Enterprise*, Cm 278 January 1988 p 33-4
[35] Lester Thurow, *Head to Head: The coming battle among Japan, Europe and America*, p 16, 1992

Thurow then turns to what he calls the seven key industries of the next decades:

> Consider what are commonly believed to be the seven key industries of the next decades - micro-electronics, biotechnology, the new materials industries, civilian aviation, telecommunications, robots plus machine tools, and computers plus software. All are brainpower industries. Each could be located anywhere on the face of the globe. Where they will be located depends upon who can organize the brainpower to capture them. In the century ahead comparative advantage will be man-made.[36]

Thurow contrasts excellence and innovation in products with the same qualities in processes. If country X invests heavily in a new mousetrap it will probably end up with a better mousetrap. But the mousetrap will be made at a few mega-sites to supply the global market (possible due to low transport costs between production bases and markets). That will depend upon some amalgam of low labour/land costs not necessarily in country X. By contrast investment in new processes and/or materials will be used world-wide and generate sustained income for country X. The 'trick' therefore, for a country to enjoy the benefits of progressive competitive gains is to ensure that there is a satisfactory base for the enhancement and application of knowledge at the interface between work and academia. He illustrates this argument with reference to three nowadays common, household products - the VCR, the fax and the CD:

> Americans invented the video camera and recorder and the fax, Europeans invented the CD player. But measured in terms of sales, employment and profits, all three have become Japanese products.[37]

This has happened because the Japanese invested most of their effort in the process of making these goods rather than inventing them in the first place. It is argued that virtually all goods and services will increasingly rely upon very high-tech machines or processes.

Retailing, although a basic service, now relies upon sophisticated systems of stock control and delivery with customer profiling thrown in as a marketing extra. An article in the *Economist* in April 2000 illustrated this point with respect to the textile industry in the United States. It starts with a familiar roll-call of problems:

> THE epitaph for America's textile and garment industry was written decades ago. Clothes-making is labour-intensive, and ten Chinese will work for the price of one American. Everyone knows that sunset industries are best left to developing countries hoping to pull themselves out of poverty; and that only tariffs, quotas and other barriers have sustained America's enormous textile and garments industries, which together employ 1.4m workers, nearly 10% of all American manufacturing, and produce more than $100 billion of goods each year.

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36 Op cit p 45
37 Op cit p 47

> Each week comes news of another factory closure, the jobs sent to Latin America or Asia where they belong. As go garments, so go textiles - fabric-making tends to "follow the needle", and over the past few years dozens of American textile makers have moved mills to Mexico to be near border clothes-making factories, a trend accelerated by the North American Free-Trade Agreement, which lowered tariffs.
>
> Those who view the global garment and textile industries through the prism of labour costs see it as an industry dominated by commodities. If The Gap is going to sell a million blue polo shirts year in and year out, Mexico or China is the place to make them. Lead times may be long and the supply chain inflexible, but you can't beat the price.

However, American textile makers have found ways to exploit parts of the market in novel ways:

> But today's Internet-driven retail trends go in the opposite direction: mass customisation, "lots of one", rapid product changes and just-in-time manufacturing. Retailers such as Levi's and Brooks Brothers are already experimenting with the Dell Computer model, where customers order products that are made especially for them.
>
> In a black-curtained cube at (TC) 2 , the textile industry's research consortium, technicians show how this future might work. A customer walks in, closes the curtain, strips and dons special disposable undergarments that do not distort her body shape. Then she grabs two ski-pole-like handles, presses a button and waits as beams of light trace over her body.
>
> Within seconds, a computer generates a 3-D body scan with every possible measurement precisely quantified. The scan booth could be in a clothing store or a stand-alone service. (TC) 2 , even imagines chains of "tan and scan" parlours in shopping malls.
>
> American garment makers increasingly offer electronic ordering, automated distribution centres and inventory-management systems tied into those of their customers. The best manufacturers have learned how to deliver orders at a few days' notice, something their offshore competitors cannot match. It is, the authors claim, 'a triumph of information technology, speed and flexibility over low labour rates'.[38]

Other Sections of this Paper will look in more detail at the 'knowledge industries' generally and, firstly, at their specialised, refined form - high tech clusters. However, it is worth spending some time examining how 'knowledge' translates into better performance: a process normally referred to as innovation.

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[38] *Economist* , 29 April 2000,

3. Innovation

The link between innovation and science funding is assumed rather than statistically proven. There have been instances of academics calling for an end to public financing of science research because there are no established links between such funding and innovation success.[39]

There are many theories about what engenders innovation and how creativity can be encouraged from within the rigid systems of academic science research. The spur that university research can give to industrial innovation would seem likely to be greater with increased contact between the academic community and industrialists. This has some conflict with the view that the closer academics work with industry the less trusted they become.[40] There may have to be some balance between academics providing an objective viewpoint with their role as a mainspring of industrial innovation.

Universities currently represent a collection of individuals trained to a high level. Most of these academics have specialist knowledge in order that they might become as expert in that part of their subject as it is possible to be. They have no requirement to broaden their knowledge to deal with the vagaries of business, nor incentives to change topic due to the disinterest of the public at large. This means that universities contain a repository of knowledge and expertise different from those bodies (such as businesses and charities) that are limited as above. Any change to the requirements of academics with respect to the work they carry out may change the nature of this repository of knowledge. It is uncertain whether universities provide better support by being more like business or by providing a wide ranging, more esoteric collection of knowledge and expertise.

The Government's perspective is provided in its White Paper[41] and in its Innovation website.[42] It emphasises the importance of the education sector as a force in generating innovation in the UK.

> The UK Knowledge Base comprises Universities, Further Education Colleges and public/private research institutions.
>
> The Knowledge Base is
>
> - A repository of knowledge and information
> - A gateway capable of accessing global knowledge
> - A large set of skills in the Arts and Sciences
> - A research organisation capable of generating new knowledge

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39 Peter Williams, "Universities waste science funds", *Nature*, 9 March 1995
40 Lords Select Committee on Science and Technology, *Science and Society* HL 38, 14 March 2000
41 Cm 4814
42 http://www.innovation.gov.uk/knowledge_base/index.html

> The Knowledge Base is a key enabler of Innovation - the successful exploitation of new ideas.[43]

The Competitiveness White Paper[44] said that innovation and creativity were where Britain had to compete:

> The UK's distinctive capabilities are not raw materials, land or cheap labour. They must be our knowledge, skills and creativity.[45]

Part of the Government's competitiveness strategy is aimed directly at universities:

> To strengthen the UK's capability to compete in the modern economy the Government will:
>
> - invest an additional £1.4 billion over the next three years in partnership with the Wellcome Trust to modernise the British science and engineering base
> - vigorously promote the commercialisation of university research - including new incentives for researchers to work with business
> - drive a new programme to help one million small businesses harness information and communication technologies (ICTs) to compete more effectively in the digital marketplace
> - launch a new round of the Foresight programme, linking Government, science and business to identify new market opportunities and addressing important themes like education, skills and training, and sustainable development.

The DTI Innovation Unit[46] is producing a report, *Higher Education Winning with Business*, to communicate the ingredients that make successful partnerships between business and educational institutions. This report indicates that far from Higher Educational Institutions having to become like businesses they need to maintain their unique nature:

> The most potent message coming out of our work for HEIs and their people at this stage is, that to succeed in the creation of beneficial partnerships with business -
>
> - you do not have to change your values
> - you probably do have to change your behaviour[47]

It is difficult to analyse things such as creativity because it is difficult to identify measurable 'outputs'. The production of research papers and successful research grant applications are used as measures of productivity. However, the number of papers submitted to research journals is believed to far exceed those that would be submitted under less motivated circumstances; suggesting that this focus may preclude other, more productive, activity. The

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43 Op cit
44 *Our Competitive Future: Building the Knowledge Driven Economy* Cm 4176
45 http://www.dti.gov.uk/comp/competitive/wh_es1.htm
46 http://www.innovation.gov.uk/home.htm
47 http://www.innovation.gov.uk/knowledge_base/winning_with_business.html#summary

Research Assessment Exercise has decided upon a formula to make comparisons between universities but the criteria are hotly contested and the criteria receive more focus than would otherwise be the case.[48]

A range of Government and Parliamentary reports has identified universities as having a central role in innovation. The 1993 White Paper[49] was the major shaping force of science strategy for the last Government and presented the following themes:

> We are, as a nation, potentially very strong in science and technology. The Government shares the country's pride in the excellent natural and social science and engineering which have been and continue to be done in this country. This strength has been, and remains, an immense national asset. It should be protected. But it will not be properly utilised unless further efforts are made to break down barriers which still exist in the United Kingdom to the acceptance and recognition of the importance of science and technology to our future;
>
> Steps should be taken which, on the basis of other countries' experience, will help to harness that strength in science and engineering to the creation of wealth in the United Kingdom by bringing it into closer and more systematic contact with those responsible for industrial and commercial decisions. Such a systematic interchange between industry, scientists, engineers and science policy makers (both in the public sector and the significant charitable sector from which the United Kingdom derives such benefit) would improve mutual understanding and allow each group to make its decisions against a better informed background;
>
> The direction and management of the Government's own research and development effort in recent years have been broadly correct. However, certain modifications now need to be made to be made to the missions, structures, and management of the research Councils and Government research establishments to meet better the global challenges now faced by the United Kingdom. These modifications will respect the importance of distinctive policies pursued by different Government Departments, and the need for pluralism and diversity in sustaining research vitality. They will enable the Government to present a clearer sense of strategy to the scientists and engineers it supports, and to those working in partnership with them in educational establishments, industry and the research charities.[50]

The major result of *Realising Our Potential*, with respect to innovation, was the Technology Foresight Programme. This programme was produced to inform the annual *Forward Look* prepared by the DTI's Office of Science and Technology as an assessment of publicly-funded

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48 See Section on University funding and Research & Development.
49 *Realising Our Potential: A Strategy for Science, Engineering and Technology* Cm 2250
50 *Realising Our Potential* Cm 2250; para 1.16

research and development. The first Foresight programme has finished and a new one began in 1999.[51]

After the 1997 General Election the new President of the Board of Trade, Margaret Beckett, commissioned an audit of the Foresight programme across Government. The findings were published on 22 October 1997[52] and set out a number of actions arising from the audit:

- The setting up of a Ministerial Foresight Group to provide top-level co-ordination of the program across Whitehall.
- The Foresight Programme will now place more emphasis on small and medium sized companies while recognising that larger companies will remain centre stage in many areas.
- The MOD is broadening its involvement to include senior representation from its Procurement Executive on the Defence and Aerospace Foresight panel. This is intended to further strengthen the links between the MOD's equipment procurement and the UK science base
- Two groups have been established under the Whitehall foresight group, to focus on Foresight's contribution to quality of life and wealth creation respectively.

The Office of Science and Technology has been charged with working with departments to see that all the recommendations arising from the audit are carried through. The Ministerial Foresight Group will oversee this process[53] under the Chairmanship of John Battle, Minister for Science, Energy and Industry.

The Ministerial Group met for the first time in December 1997[54] and receive 6 monthly progress reports from the Whitehall Foresight Group of officials, which is working to foster closer links between panels and the activities of individual departments.[55] Mr Battle said that he expects to publish these reports.[56]

The Government announced, in late 1998, up to £10 million for the future of the Foresight LINK programme and £5 million for the Foresight vehicle LINK programme.[57] Mr Battle commented that:

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[51] The Parliamentary Office of Science and Technology produced a report on the first Technology Foresight programme in June 1997: *Science Shaping the Future? – Technology Foresight*, POST, June 1997 http://intra1.parliament.uk/post/pn097.pdf

[52] Report on the Whitehall Audit of the Foresight Programme, Office of Science and Technology, October 1997.

[53] Ibid (Foreword)

[54] DTI Press Release P/96/686, *Ministerial Group to lead Foresight across Government*, 22 October 1997

[55] HC Deb 5 March 1998 c741W

[56] HC Deb 3 February 1998 c610W

[57] HC Deb 18 December 1998 c479W

> As a practical demonstration of its commitment to Foresight, the Government has launched the Foresight LINK awards, which will bring together business and the science base to work together on projects addressing Foresight priorities. We have also launched several new LINK programmes in response to Foresight, notably the Foresight Vehicle programme, which will develop the technologies for cleaner, leaner and safer vehicles of the future.[58]

Currently Foresight has been working on their view of the future. Each of the Foresight panels has published a draft document which outlines where they see the future of their particular field. These documents are available on the Foresight website[59] and are available for comment until September 2000.

There are any number of small grant giving schemes which seek to achieve greater communion between the university based science community and the business sector (the SPUR and Smart schemes for example). The Research Councils also have a remit to make those applying for grants to consider the wealth creation potential of their research proposals. It is the Technology Foresight Programme, however, which attempts to direct the focus of all these small schemes and to drive creativity into the areas where innovation is required.

The difficulty in measuring the success of national innovation has already been mentioned, however, undaunted, OECD[60] go one better and produce, under the auspices of their Industry and Scientific and Technological Policy committees, a biennial publication benchmarking progress in science and technology across Member States.[61]

The OECD analysis looks at the data such as investment in tangibles and knowledge, computers and internet usage and venture capital to assess knowledge based economies. Twenty such categories are presented with a range of OECD countries presented according to their score. A similar exercise is carried out looking at ‘The Globalisation Challenge’ and ‘Economic Performance and Competitiveness’. Some things can be quickly taken from the statistics presented.

One measure of innovation used is the number of patents lodged by various countries. Figures for 1996 show the UK as lodging 5.5% of all European Patent Office patent applications. This puts them fifth after the US (28%), Germany (21%), Japan (18%) and France (7%). This ranking would suggest that the US, Germany and Japan are far more productive in terms of scientific activity than the UK. In 1995, however, the UK published 10% of all scientific papers produced by OECD member nations which was more than Germany (8%), Japan (9%) or France (7%) and was exceeded only by the US (36%).

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[58] HC Deb 8 December 1997 c462-3W

[59] http://www.foresight.gov.uk

[60] The Organisation for Economic Co-operation and Development

[61] OECD, OECD Science, technology and Industry Scoreboard, 1999

The UK, with a large proportion of science publications but a smaller share of patents might indicate that there is a deficit somewhere in applying scientific advances to exploitable patent applications: a common criticism of UK science performance.

Scientific publications rarely represent an exploitable idea in themselves but require financial development investment to turn them into products or services. UK business was reported to have spent $12,551 million (1990 dollar equivalents) on research and development in 1998. This was roughly equivalent to that spent by France but less than the $22,016 million spent by Germany, $52,196 million by Japan and the staggering $133,487 million spent by the US. These figures are perhaps better highlighted by presenting them as a percentage of the domestic product of industry. UK businesses spend only 1.65% of their industrial domestic product compared with 2.24% by US business and 2.35% by Japanese business. The largest (4.4% of industrial domestic product) proportionate spend on R&D is carried out by Sweden.

The next section of this Paper looks in more detail at the stage beyond basic scientific research; at when R & D and manufacturing capability fuse into one. In particular it looks at the most refined form of the knowledge industry: high tech clusters.

III The Knowledge Industries and High-Tech Clusters [HTC]

A. HTCs Abroad

The UK is not alone amongst developed economies to show interest in the successful performance of concentrations of high-tech industries. Such areas, it is suggested, contribute more to an economy than their component members by virtue of the support given to existing companies and the encouragement given to individuals to establish and grow new companies.

The most successful examples of HTCs are in Silicon Valley in California and in Boston.

Silicon Valley began with huge defence related funding for research into electronics for the military in the 1940s and 1950s. This produced a cluster of aerospace companies attracted by cheap land, access to military installations and a supply of engineers from nearby universities. When the aerospace industry went into recession these companies had to look to other outlets and jobs. At the same time William Hewlett and David Packard were encouraged by a Stanford Professor to turn a PhD into a commercial project. This started technically advanced business machine development in the area from which the computer industry later evolved.

The story in Boston was similar, with a large electronics company and University (MIT) acting as the catalyst. Civic planners world-wide looked as Boston turned itself, in a ten year period, from a depressed, textile and engineering dependent area to one renowned for its development and exploitation of electronic technology.

According to David Finegold, himself a Professor at the University of Southern California, an HTC requires various elements for it to succeed and develop. These are described below.[62]

a. Catalysts

An event or external trigger that sparks off the development. In the Silicon Valley example it was Cold War related defence research expenditure.

An article from Paul Krugman illustrates the 'cluster' idea outside of high-tech industry. He writes:

> There is a small "Japantown" near my house - a cluster of noodle shops, sushi bars, groceries, and Japanese bookstores. Most though not all of the shops are in Porter Exchange, a grand old building that used to be the Cambridge Sears outlet. The building, with its high ceilings and open floor plan, was unable to find a good use for an extended period after Sears moved out, but turns out to be quite well suited to use as a sort of mall. The location also turns out to be excellent: because many of the patrons are public-transit-using students at MIT and other area schools, it benefits from its proximity to the Porter Square stop on the Red Line. The cluster seems to be growing; perhaps one day Porter Exchange will be only the nucleus of a large and distinctive shopping district.
>
> I think Henry Ford once said that history is just one damn thing after another. Maybe not, but explanations of economic location are almost always historical, and the history does tend to have a "one damn thing after another" character. If you try to explain why a particular region is home to a particular industry, you usually end up explaining it largely by describing the sequence of events that caused the industry to be there. A Georgia teenager makes a tufted bedspread as a wedding gift; 60 years later, that event makes Dalton, Georgia America's carpet capital.[63]

b. Nourishment

A crucial factor in sustaining growth on a long term basis is the existence of universities and business schools in close proximity such as UCLA & Stanford. But, despite the existence of a lot of domestic students, 40% of all engineering and science PhDs go to foreign born students and it appears vital to attract this pool of mobile talent. California attracts a massive inflow of labour at all levels and virtually all the production activities are carried out by immigrant labour.

Finance is also vital and venture capital, by allowing risk sharing, encourages risk taking. Silicon Valley firms alone received 23% of all new venture capital investment, by far the largest share of any US region.

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62 "Creating Self Sustaining, High Skill Ecosystem", *Oxford Review of Economic Policy*, Spring 1999

63 Paul Krugman, *'Some chaotic thoughts on regional dynamics'*, 3 October 1999, http://web.mit.edu/krugman/www/whatsnew.html,

c. Supportive Environment

Three elements of an external environment that are conducive to an HTC are: a basic infrastructure, a social and business climate conducive for knowledge workers and a permissive commercial legal system.

Beyond the normal requirements of many industries (adequate infrastructure, good airports, travel between locations and good telecommunications) HTCs also benefit from a greater intensity of infrastructure provision. Science & technology parks provide the infrastructure links to act as 'incubators' for new firms. These areas provide things such as shared secretarial support, legal advice, financial accounting, consulting and export marketing. In the United States the model for established computer parks was copied to provide similar support for the biomedical HTCs.

Although good weather is no handicap, the important climate feature is the overall attitudinal climate in and around the HTC. There is a clear attraction for knowledge workers in being close to others who share the same or similar expertise. Linkages within companies and between them encourage the dissemination of ideas and the development of 'best practice' in commercial affairs. Such an atmosphere encourages individuals to set up their own company and they then need to be supported by a cultural regime that supports the risk taking needed to create new enterprises. This highlights the need for the third element of the supportive environment: the commercial legal system. This should make it easy to start a business, to take the business public if the initial idea proves successful, and to go bankrupt without severe penalties if it does not.

d. Interdependence

Finegold argues that there is something distinctive about the interdependence of companies within a HTC:

> The conditions identified above - strong universities, good infrastructure, abundance of human and financial capital are common to many urban areas that do not qualify as HTCs. What the firms and individuals in these regions lack is the shared focus on a common sector and or technology and a high degree of co-operation among the actors that facilitates the learning process.[64]

Finegold identified three forms of interdependence important for a successful HTC.

First, horizontal linkages among specialised firms. High-tech firms tend to be fairly flat organisationally, devoted to the development of a small set of distinctive core technical competencies. This specialisation works best if it can relate to other companies engaged in similar competencies. For example, the company Sun Microsystems established separate

[64] Op cit p 70

divisions for chips, hardware, software and so on. Each division was encouraged to participate with each other and with other companies.

Secondly, vertical connections with different companies at different points in the cycle of the product. This type of connection is common, for example, in the bio-medical industry, where company A develops DNA modelling software. It then links up with company B which develops a DNA data resource which it links with company C which produces the drug that company D eventually markets and sells.

Lastly, networks among individuals. These are essential for collective knowledge creation and diffusion. It has been observed that informal training and links are actually more important and common than formal intra-company training. In California, for example, there are lots of employees' groups, continuing education courses, regional alumni associations and professional associations that allow workers involved in similar work to discuss problems and solutions outside of the formal work environment. Finegold notes that:

> The knowledge creation and diffusion process is at the heart of why firms cluster. It is the difficulty of transmitting tacit knowledge, particularly when it is new and changing rapidly, that encourages enterprises to be in direct and frequent contact with each other and the researchers creating the new knowledge. Just as firm structure and inter-firm relationships differ in the HTCs and more traditional settings, so too the process of developing individual capabilities and organisational knowledge within HTCs is very different from conventional approaches to training and skill development.[65]

This very different way of working (which as one commentator puts it innovation becomes, first and foremost, a collaborative social endeavour) imposes, or encourages a very different form of relationship between employer and the employed.[66] Finegold again:

> Within these turbulent, high-skill environments, the responsibility for career development has also shifted from the firm to the individual and the HTC itself. Gone is the notion of a corporation that would provide opportunities for career progression and a high degree of job security in return for employee loyalty and commitment. In its place is a project-based culture, in which individuals have ownership of their career development. Indeed, Silicon Valley is often cited as the archetype of the new employment relationship in which 'employability' (the continuous development of marketable skills) has replaced 'employment security' as the bargain which firms can offer workers in return for their effort towards achieving business objectives.[67]

This less formal relationship between employer and employee dates back to the early days of science parks. The one centred on Boston University (Route 128), which grew around the electronics giant MIT, became established through the formation of numerous high-tech

[65] Op cit p 71
[66] Op cit p 73
[67] Op cit p 72

businesses. The inspiration for these was, frequently, the encouragement that faculty staff were given by virtue of a day off a week to undertake consultancy duties. In many cases consultancy led to design and development work, with this being the basis of an embryo business. After a time this 'soft' business became 'harder' when a manufacturing capability was added.[68]

One feature that rapidly emerges from even the most cursory reading of the literature about HTCs is that change is a constant. One rough estimate put the typical life of a high tech cluster until it reaches maturity and starts to stagnate at 50 years. Silicon Valley has evolved from research into aerospace to the production of calculation and memory devices. Then from a memory chip industry and PC industry into specialised chips, workstations and software. Lately it has concentrated upon developing applications for the internet. A similar story can be told for healthcare clusters that started around the research coming out of the University of California. This attracted government funding which expanded the work and took it out of the laboratories and into mainstream production.

B. High Tech clusters in the UK

1. The coming of Science Parks

Government encouragement for technology and the application of science first came to prominence in the 1960s. The then Prime Minister, Harold Wilson, saw the 'white heat of technology' transforming industry. However, the first real science parks in the UK were set up by universities without external assistance and then not until the 1970s. They were founded by Trinity College Cambridge and the Heriot-Watt University. Of the two, Cambridge is now the better known. Its establishment is recorded below:

> Trinity College, having a 130-acre undeveloped site on the edge of the city…. decided to create a prestige environment offering high quality buildings on a well landscaped site, with the objective of achieving a long term financial rate of return comparable with the College's other commercial investments. A critical step was the granting of an innovative planning agreement in 1971: the original designation of the site was part of the greenbelt. Use of the Science Park was limited to those engaged in the following activities:
>
> Scientific research associated with industrial production;
>
> Light industrial production of a kind which is dependent on regular consultation with either or both of the following (a) the tenants' own research, development and design staff established in the Cambridge area, or (b) scientific staff of the University or of local scientific institutions;
>
> Ancillary buildings and works appropriate to the use of the land as a Science Park.

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[68] KPMG, *Science Parks & the Growth of High-Tech Firms*, p 65

> Construction of the Park began in 1973, with the first tenant moving in within the year.[69]

The second park set up around the same time was one established by the Heriot-Watt University in Edinburgh. Even before it was set up the University had a strong tradition of applied research and links with industry. This was reflected in the type of facility that was finally constructed. The main motivator behind it was the Principal, who had previously worked at MIT in Boston (see above) and it was established as a research park with a far tighter criteria for the selection of tenants than at Cambridge, namely:

> There should be a significant proportion of research and development in the activities to be carried out at the park; that there should be some equilibrium between the discipline employed by the tenant and at least one department of the University; and that there should be a willingness in principle to collaborate with the University when collaboration was possible.[70]

Partly because of the more restrictive criteria the growth of tenants was far slower than had been the case in Cambridge.

The second wave of business parks began in the early 1980s. The idea caught on for a variety of reasons. First, the economy performed very badly at the start of the decade. GDP at constant market prices fell between 1979 and 1981, and did not regain 1979 levels until 1983. The failure of so many large companies prompted an academic and political interest in small firms as a path to improved economic performance. Business parks clearly benefited from this rising tide of interest. Furthermore by the early 1980s, a number of 'enabling' technologies had also reached a stage of offering substantial business breakthroughs. These included new applications for microprocessors, microcomputing and software advances. Also worth mentioning in this regard is the reaction of large established companies to the recession of the early 1980s. Many adopted a strategy of reducing their range of activities to a 'core'. Other activities were either shelved or contracted out. R & D fared no better than other non-core activities in this respect and several previously in-house R&D departments were either abandoned or hived off.

Aside from industrial and economic factors that promoted science parks, there was an impetus from the academic world. This is described below:

> Many commentators place particular significance on the reduction in university funding announced by the University Grants Committee [UGC] in September 1983. For some universities the UGC cuts required the most seriously affected to reappraise their options, including, their surplus land holdings, alternative funding arrangements, and their relationships with industry and the local community. In the aftermath of the

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69 *Science Parks & the Growth of High-Tech Firms*, KPMG, p 71
70 Op cit p 72

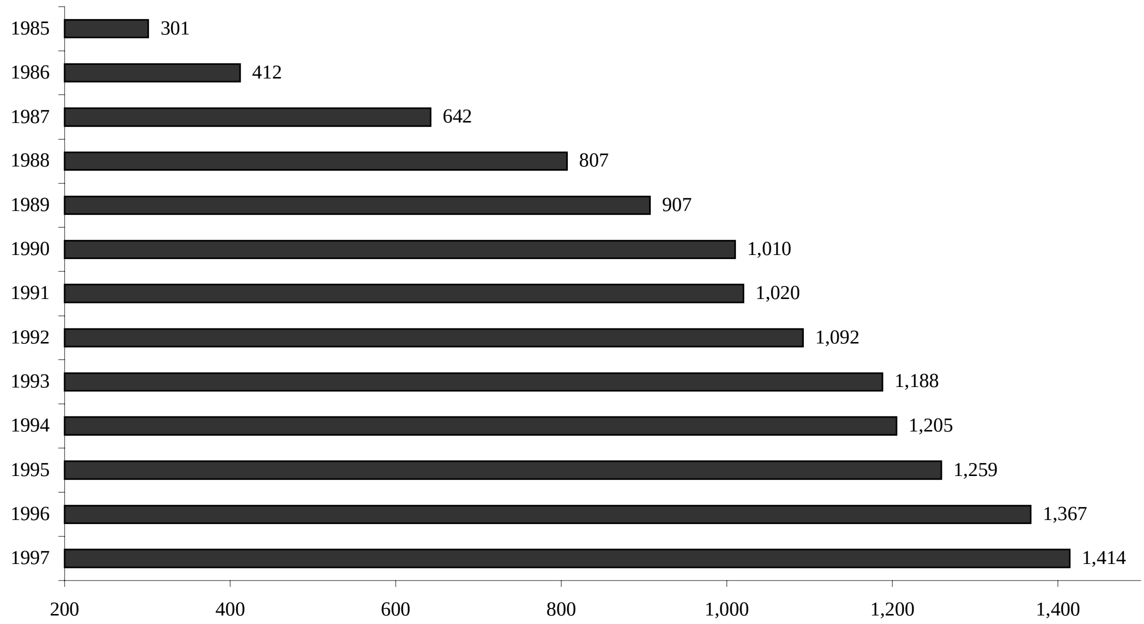
> cuts, however, there was a greater recognition of the potential benefits of a science park to a university as a focus for development and as an indication of commitment to the local community.[71]

The cuts announced in 1983 were followed up by a new system of research appraisal in 1986. The UGC's ‘star rating’ system meant that henceforth universities were in competition for funding for applied research and their abilities were significantly influenced by the extent of collaboration between the research teams in the university and contacts with industry. Against this background science parks were seen as a key component for the success of the university more generally.

In 1983 science parks opened in Aston, Bradford, Leeds and Glasgow, and eight more (Norwich, Southampton, St Andrews, Warwick, Nottingham, Loughborough, Manchester and Hull) were opened in 1984. By the end of the 1980s there were nearly 40 science parks in the UK. There are currently 55 science parks listed as members of the UK Science Park Association.

The graph below shows how the number of tenant companies housed in science parks has increased since the 1980s; from just over 300 at the end of 1988 to 1,367 at the beginning of 1997 and 1,414 by the end.[72] A similar picture emerges if one looks at the increase in employment provided by these firms.

Number of tenant companies in Science Parks



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[71] Op cit p 76
[72] UKSPA personnel communication

Table 4
Number of jobs in tenant companies in UK Science Parks

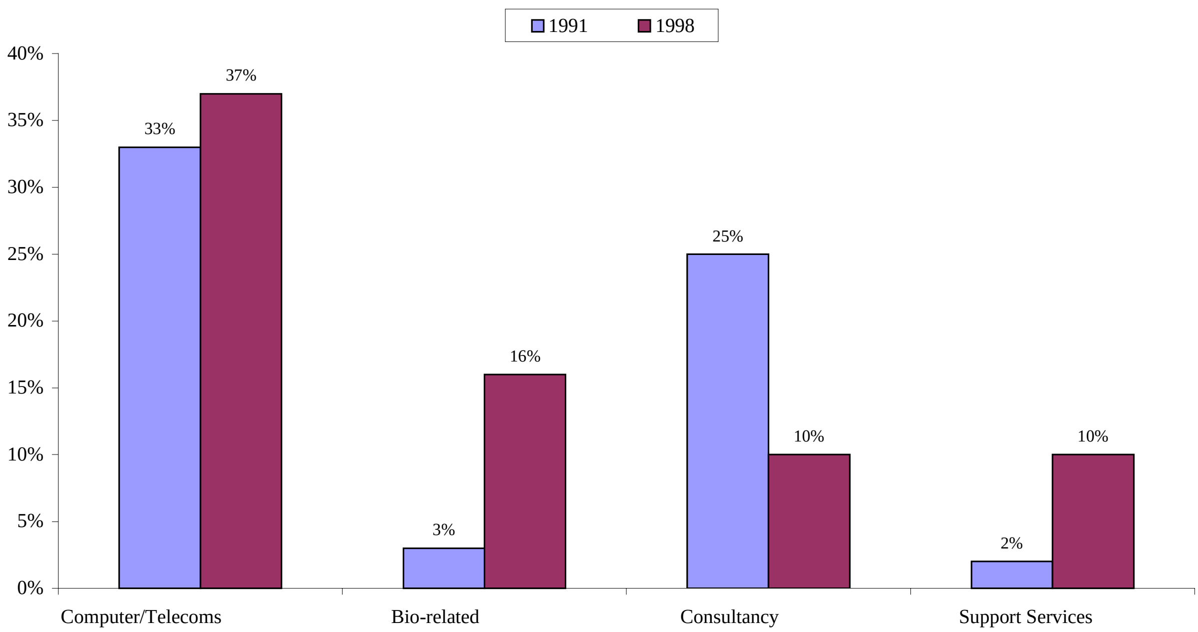
1985	3,800
1986	5,300
1987	7,600
1988	10,540
1989	12,971
1990	14,708
1991	15,131
1992	16,587
1993	19,922
1994	22,086
1995	23,526
1996	25,278
1997	27,371

Source: UKSPA Annual Reports various years

The number of jobs in tenant companies of UK Science Parks has increased almost seven-fold from almost 4,000 at the end of 1985 to just over 27,000 at the beginning of 1998. This is well above the growth in employees of other sectors of the economy and geographical regions within the UK.

The tenant mix, by product sector, in UKSPA Science Parks is shown in the table below:

Largest Product Sectors in UKSPA Science Parks



By far the largest number of tenants in UKSPA Parks, in both 1991 and 1998, were from the Computer/Telecoms product sector. Tenants from the Bio-related product sector accounted for approximately 16% of the total number of tenants in UKSPA Science Parks in 1998 an increase from just 3% of the total in 1991.

A note of caution is required when dealing with UKSPA statistics. Some of the companies originally formed in UKSPA Science Parks have outgrown the environment and have found it necessary to relocate to new premises. Companies that have relocated elsewhere are not included in the statistics above once they have moved so that the value and influence of Science Parks to the economy as a whole could well be underestimated.

IV Skills & Training

A. Introduction

In a report by a House of Lords Select Committee, *Growth Competitiveness and Employment in the European Community* several witnesses referred to the lack of skills and the skills gap[73]. The frequently prescribed remedy for this is widely accessible and more training for the long term unemployed. However, as the economist Roger Bootle pointed out:

> it is far easier to mouth the magic words 'education and training' than it is to devise a practical strategy which will actually pay dividends What sort of education and training? Is it more people in higher education or higher average school leaving standards?[74]

Skills and investment in human capital received further attention when its role in the process of economic growth (as opposed to the more 'micro' consideration of employability) was highlighted by both academics and politicians. When the then Shadow Chancellor, Gordon Brown, made comments about 'endogenous growth theory', comments that were subsequently ridiculed in the press and elsewhere, in 1994, he was building on an academic literature that had grown up since the popularisation of the 'low skills/low equilibrium' notion in 1988.

The quote from Mr Brown that drew such criticism centred on the following extract from a speech given at an economics seminar in September 1994. Mr Brown said:

> Our new economic approach does not simply require us to adapt to changes in the practical world but is also rooted in changes in the world of economic ideas. Ideas which stress the growing importance of international co-operation and new theories of economic sovereignty across a wide range of areas - macroeconomics, trade, the environment, the growth of post neo classical endogenous growth theory and the symbiotic relationships between growth and investment in people and infrastructure; a new understanding of how labour markets really work; and the rich and

[73] HL Paper 43 1993/94
[74] Op cit p 169

> controversial debate over the meaning and importance of competitiveness at the level of individuals, the firm or the nation and the role of government in fashioning modern industrial policies which focus maintaining competitiveness.[75]

Less is now heard of endogenous growth theory, but, by other names, it forms a central part of the policy ideas now focusing on the 'knowledge economy'.

B. The Skills We Deserve?

The academic input began with the publication of work by two authors, David Finegold and David Soskice who popularised the notion of the 'low skills/low quality equilibrium'.[76] This marked a new stage in the debate about the role that skills and knowledge might play in competitiveness and organisational performance within advanced economies. Essentially, Finegold and Soskice argued that an economy would adapt its productive profile to the existing skill base of its workforce. Thus 'skill shortages would still exist, but only as short term recruitment problems for individual firms. Were the average standard of skills and training to be raised economy wide then that economy would adapt to new working practices and expand into the more high-tech operations as seen in such places as Silicon Valley in California.

A follow-up study ten years later noted that:

> UK skill failings were recognised in the 1970s and a major part of the 'supply side' revolution of the 1980s was directed towards improving the supply of skills. Little stress was placed on addressing the possible lack of demand for skills, which is what Finegold and David Soskice hypothesis emphasised. This general thrust of policy continued into the 1990s.[77]

A fuller history of the last twenty years training policy initiatives appears later in this Paper however, some features are worth recalling now.

It had been recognised that the system of industrial training based upon apprenticeships was deficient in both quantity and quality. Reforms demonstrated a greater awareness of a link between education and economic success and many more children left school with qualifications than before. The training system became more qualification driven than before. At school level the National Curriculum and GNVQs system were established. Post school, the Tecs were employer led training services based on a vocational training (NVQ)

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75 'The Chancellor of Gobbledegook: Why Gordon the obscure spoke at such length on Labour policy', *Daily Mail*, 28 Sep 1994

76 See, Finegold & Soskice, 'The Failure of Training in Britain: Analysis and Prescription', *Oxford Review Of Economic Policy*, 1988

77 Keep & Mayhew, *"The Assessment: Knowledge, Skills & Competitiveness"*, Oxford Review Of Economic Policy, Spring 1999

system with levels from one to five. At the corporate level one could mention the establishment of the Investors in People (IIP) kitemark.

The upshot of the reforms was a large increase in the number of workers undergoing training, although there is evidence that the duration of this training fell; thus the volume of training remained fairly static.[78] Furthermore, most of the NVQs were in the lowest grades. Although it is very difficult to be certain, there is no clear evidence that the UK has caught up with other economies in the fostering and encouragement of skills in the workforce.

The reason could be either because the schemes themselves, despite all the money spent on them, failed or because the Finegold and Soskice hypothesis was right- for whatever reason, large numbers of UK employers did not want or need skilled workers. If UK employers decide to work at the low-spec end of the market it is wasteful to pump money into training and therefore sensible to abandon excessive work-based training. Competition in low spec goods is essentially competition on price and thus on unit labour costs. Employers were reacting rationally to the 'battery of incentives provided by the institutions and attitudes they had inherited.'[79]

One further point made in the article is that:

> in the last decade or so, UK conceptions of what comprises skills have shifted away from hard, technical expertise towards softer interpersonal capabilities,[80] many of which could be conceived of as personal characteristics or attributes rather than as skills in a traditional sense. This kind of focus in part reflects shifts in the UK employment structure and the decline of manufacturing employment and it may well fit the needs of those parts of the economy delivering mass produced services, but it produces a poor match with the needs of the type of high tech sectors discussed by Finegold, where mastery of leading-edge developments is a key to developing and sustaining competitive advantage. If the government is serious about promoting growth in the UK as a knowledge economy, then a training system primarily geared to meet the needs of the lower segments of the service economy may be a problem.[81]

Since this whole issue is inextricably linked with competitiveness and hence with comparisons of international performance inevitably commentators on vocational skills/training issues have looked at the United States where 'high-spec' performance is perceived to be more common.

Certain segments of the US economy have found a route to extremely high spec, but it is uncertain how quantitatively significant this is in the context of the whole US economy.

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[78] See Felsteed et al, *Getting the Measure of Training*, Leeds Centre for Industrial Policy & Performance, 1997.

[79] Keep & Mayhew, p 4

[80] Literacy, numeracy, problem solving, use of IT etc

[81] Keep & Mayhew, p 5

Robert Reich, one of the founders of the knowledge economy approach to economic competitiveness within developed countries, put forward a three-fold occupational typology (1991):

> High level symbolic manipulators or analysts, precisely the types of knowledge worker discussed in Finegold's article;
> A dwindling group of those engaged in routine production e.g., workers in car factories, low level supervisors, and data entry staff;
> A third group providing interpersonal services- waiters, hotel receptionists, security guards, shop assistants and hairdressers.[82]

If this categorisation holds then it has implications for vocational training policies. Long periods of formalised post compulsory education and training and high levels of academic qualification would not necessarily appear to be tremendously relevant for fitting people for employment in interpersonal services. The study continues:

> Even Reich admits that only a limited proportion of the work force can be employed as 'symbolic manipulators' and the US Bureau of Labor Statistics figures suggest that the proportion of the US work-force that can genuinely be described as 'symbolic analysts' may be as low as 7%. This raises issues about the need for ever greater expansion of post compulsory education - the White Paper [*Our Competitive Future: building the Knowledge Driven Economy*, Cm 4176] trails a further 700,000 students in further education. Scottish higher education already has a 45% age participation. Are 45% of the future Scottish work-force going to be symbolic analysts?[83]

Clearly universal training implies an element of over provision of skills for society however, the alternative problem, of deciding at birth who gets what academic training, is both potentially socially divisive and equally hard to solve. A partial, market orientated answer in the US appears to be immigration. In the very high-tech environment of Silicon Valley in California virtually all the low grade production activities are carried out by women from Vietnam and Central America.[84]

Clearly it is difficult to establish a base upon which the skills and training necessary for future employment can be efficiently and economically provided. Essentially free and democratic societies may have to suffer the problems of market failure, where companies do not train workers they believe will leave to work for other companies when trained, or the consequences of social inclusivity, providing training for more people than will conceivably use it. Over the last twenty years training has increasingly been qualification and employer/job driven but with no obvious and apparent 'catching-up' on those countries deemed to be superior to the UK in this respect.

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82 Keep & Mayhew, p 7
83 Keep and Mayhew, p 11
84 D Finegold, 'Creating Self-Sustaining and High Skill Ecosystems', *Oxford Review of Economic Policy*, Spring 1999, p 68

C. UK's Training Approach

1. Introduction

This section briefly describes government training policy over the last two decades and how this has attempted to accommodate the new industries associated with the knowledge economy. It concentrates particularly on the government-approved strategic sector organisations that have been developed to promote training and oversee occupational standards. A report produced by the Information Technology, Communications and Electronics Skills Strategy Group in November 1999 recommended some changes to the current structure in this sector.[85]

2. Background

Since the early 1980s, the UK government has pursued a predominantly voluntary and employer-led approach to training policy. The current government has developed the system of government recognised non-statutory training organisations which was established by the Conservative government largely to replace the network of statutory Industrial Training Boards. The Labour Party's decision to drop its commitment to a statutory training levy in March 1995, and the policies that it has pursued since 1997, mean that both the major political parties now appear to support a system of employer-led voluntary sector bodies to help meet the objective of raising skill levels in the workplace. The Liberal Democrat Manifesto for the 1997 General Election proposed a 2% training levy on some employers.[86]

The two party consensus on the voluntary, employer-led approach to training has developed alongside a more general consensus on the importance of the knowledge economy and the need for a highly skilled and flexible labour force. It is argued that the relative decline of manufacturing has led to a change in the types of jobs available and the skills needed to do them. These assumptions which underlie UK training policy are usefully summarised by the academics Ewart Keep and Ken Mayhew:

> The next two assumptions are interlinked: firstly that the future of work in the UK will increasingly require highly educated and skilled, flexible, autonomous workers; and following on from this, a belief that UK employers will require a highly educated and trained workforce at all levels. These assumptions are reflected in the work of popularisers of a vision of 'post-industrial' society, such as Toffler, Handy, and Drucker, and in macroeconomic models of labour market developments, such as those undertaken by the Institute of Manpower Studies (IMS) and the Institute of Employment Research (IER).
>
> It has been a commonplace assertion during the last decade that Britain is faced with a fundamental choice about the basis on which the economy faces international

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[85] Information Technology, Communications and Electronics Skills Strategy Group, *Skills for the Information Age*, 1999

[86] The Liberal Democrat Manifesto 1997, *Make the difference*, p 13

> competition. One major strand of the official prescription for economic development in the UK has tended to embrace a particular conception of a competitive strategy based upon high-quality, technologically advanced, flexible production. Coupled with this have been frequent references to the changing structure of employment. The decline of manual occupations, craft apprenticeships and craft-based occupations, the reduction of manufacturing jobs, the rise in demand for technicians, and the growth in white collar and professional employment are constant themes in official policy statements. Increasing competition and demand for quality, coupled with these shifts in occupational structure, are seen as pointing to a future where an independent, self-reliant, flexible and highly skilled workforce will be a necessity.[87]

These themes of international competition, new technology, a changing labour market and the need for a training policy which will deliver a high skilled workforce are evident in government policy papers in the 1980s and 1990s under Conservative and Labour administrations.[88]

The emphasis on voluntarism and the changing nature of the labour market have dictated government intervention in the provision of training. The degree to which governments have intervened has depended partly on differing ideological positions on the role of the market and, more often, on practical responses to the prevailing economic and political situation. Direct intervention in this period has concentrated on the unemployed and young people as the two groups who do not have the financial capacity to compete in the training market. It is argued that the unemployed no longer simply require income support to support them until they find a job appropriate to their skills but rather training support that helps them make their skills appropriate to changing jobs. Similarly, school leavers need training to help them find work and acquire skills that are flexible and transferable. This approach has led to the large number of government programmes for young people and the unemployed which are based, in recent years, on an National Vocational Qualification (NVQ) framework designed by sector bodies.

For those already in work, governments have tended to be less interventionist and have relied on measures to support a free training market. In theory the market should provide sufficient benefits for employees and firms to reward them for the training costs that they have to bear. According to this analysis of investment in human capital, the benefits from training fall exclusively on workers and those providing the training. The costs must be shared according to the benefits that each receives and rules of supply and demand will dictate that the right amount of training is provided. Training will "be provided as long as the associated benefits exceed the associated costs, and both the trainer and the trainee will be compensated fully for the costs they each incur".[89] Government intervention has therefore concentrated in more

[87] Keep and Mayhew in *Acquiring skills: market failures, their symptoms and policy responses*, ed. Booth and Snower, 1996, pp 307-8

[88] See for example, Department of Employment, *Employment for the 1990s*, Cm 540, December 1988, pp 12-13 and DfEE, *The Learning Age: a renaissance for a new Britain*, Cm 3790, February 1998, p 7

[89] Booth and Snower, *Acquiring skills: market failures, their symptoms and policy responses*, 1996, p 4

recent years on measures to support the market or correct a perceived underlying market failure. For example, one such failure is the problem of "poaching". In a flexible labour market, workers are mobile and the benefits from training accrue not only to the firm providing that training but other firms in the market who may not have contributed towards its costs. Employers therefore have less incentive to provide training as their employees may be poached by their competitors. A system of statutory training levies such as that introduced under the Industrial Training Boards (ITBs) attempted to deal with the problem of poaching by requiring employers to invest in the training of their employees.

In more recent years the emphasis has shifted to measures which encourage training and share the responsibility for it between individuals, employers and government. Recent examples of this include tax relief on training and the current government's proposals for Individual Learning Accounts. However, it is not always clear in what way the market has failed or how intervention may best correct this failure. The extent to which government interventions in the market have been successful has thus been the subject of some debate. Some argue that government intervention often creates new market failures and therefore, "it is only when the market failures outweigh the 'government failures' that a case for public provision or finance of training can be made".[90]

There are therefore broadly two strands to government training policy for which the skills perceived as central to the knowledge economy can be seen as important. Firstly, there are the all-sector skills and entry level qualifications that form the basis of government-funded training for the unemployed and young people. Information and communications technology is one of the key skills which are designed to be taken alongside the main programme of study in all post-16 qualifications routes from September 2000.[91] Secondly, there are the higher level skills needed in the specific sectors which form part of what is termed the knowledge economy. Skill shortages in some of these sectors have been well documented.[92] For these higher level work-based skills the government's strategy is to encourage individuals to undertake training, and employers to help provide it, with incentives such as Individual Learning Accounts and the University for Industry. It believes that "transforming learning in the workplace will primarily be for employers, employees and the self-employed to achieve".[93] This echoes the Conservative government's 1988 White Paper which stated that "employers and individuals need to accept a greater share of responsibility for training".[94]

In both these types of training governments have seen their role, among other things, as overseeing a framework and in recent years this responsibility has passed to government-recognised sector bodies. These are non-statutory employer-led bodies and are currently

90 Ibid, p 11

91 DfEE, *Departmental report: the government's expenditure plans 2000-01 to 20001-02*, Cm 4602, April 2000, p 90

92 see, for example, First Report of the National Skills Task Force, *Towards a National Skills Agenda*, 1998, paras. 4.17-4.20

93 DfEE, *The learning age: a renaissance for a new Britain*, Cm 3790, February 1998, p 33

94 Department of Employment, *Employment for the 1990s*, Cm 540, December 1988, p 30

known as National Training Organisations (NTOs). Their remit and responsibilities have grown in recent years. In many cases NTOs have their origins in the old statutory ITBs and therefore for many industries there was an infrastructure already in place. In the "new" industries NTOs have tended to emerge on a relatively ad hoc basis from trade associations and similar groupings of employers as new sectors have developed. In 1999 a strategy group of the Skills Task Force published a report advising the government on "a national strategy to address the specialist skills in the Information Age".[95] In the report the Information Technology, Communications and Electronics (ITCE) Skills Strategy Group recommended that the five current ITCE NTOs should form a "Council for ITCE skills" to ensure a strategic overview of specialist skills needs and ensure coherence between different parts of the ITCE sector. The following section briefly summarises the history of sector bodies from which the ITCE NTOs have developed.

3. The development of sector bodies

Industrial Training Boards (ITBs) were originally established under the *Industrial Training Act 1964*. This Act implemented proposals contained in a White Paper, *Industrial Training*, published in 1962.[96] The White Paper identified weaknesses in Britain's industrial training which left provision very much to individual firms and lacked incentives for employers to train because of problems of poaching. To overcome this, the 1964 Act gave the Secretary of State the power to establish Training Boards in any industry with the function of improving training facilities for people over school leaving age. The objectives of the Act were to ensure an adequate supply of properly trained men and women at all levels in industry; to ensure an improvement in the quality and efficiency of industrial training; and to share the cost of training more evenly among firms. The Boards were given the power to impose a levy on employers in the industry to finance their operations. Amongst other activities, the Boards could provide training courses run by other institutions and set training standards for their industry. By the end of 1969, 28 ITBs had been established by Statutory Instrument covering sectors as diverse as engineering and carpets, civil air transport and hairdressing.[97]

The ITBs began to be dismantled during the 1980s. Following a review in 1981, the Conservative Government decided that satisfactory training arrangements in many sectors could be better developed without the bureaucracy and compulsion which characterised the statutory scheme.[98] During the Second Reading debate on the *Employment and Training Bill 1980/81*, James Prior, then Secretary of State for Employment, repeated the arguments about bureaucracy and inefficiency but he also pointed to the emerging technologies and the impact these would have on individuals' training needs:

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95 Information Technology, Communications and Electronics Skills Strategy Group, *Skills for the Information Age*, 1999 available from http://www.dfee.gov.uk/skillsforce/1165skillsp.pdf

96 Cmnd 1982

97 B. O. Pettman, *The Industrial Training Act and the Industrial Training Boards: History, Machinery, Progress and Criticisms,* Institute of Scientific Business Ltd, 1971

98 Manpower Services Commission, *A Framework for the Future*, July 1981

> We have entered a new industrial revolution – the microtechnology revolution, or the telematics revolution whatever one prefers to call it. That economic revolution is unique … Whereas very few people realised the import of the industrial revolution when it was taking place, there is now a much greater awareness of the significance of the changes taking place around us.
>
> With that awareness, it would be a terrible folly if we continued to be unresponsive to change and remained inflexible and hide-bound by traditional thinking. Training and retraining are areas where it is absolutely vital to introduce a much greater sense of flexibility and responsiveness. There will be new demands, new pressures and new opportunities. Our duty therefore must be to devise a system that can adapt and respond to them, and which can thus enable us not only to keep up with the pace of change, but also to make the most of the opportunities which lie ahead.[99]

The technological revolution to which Mr Prior referred in his speech has been invoked during discussion of most training reforms in the intervening 19 years. The *Employment and Training Act 1981* gave the Secretary of State power to abolish ITBs without a recommendation from the Manpower Services Commission and this the government proceeded to do by a series of Orders in 1982.[100]

As a result of the 1982 changes, the number of ITBs was reduced from 23 to 7, and the percentage of the relevant workforce covered was reduced from 50% (11 million) to 30% (6½ million).[101] The industries which lost statutory training boards were expected to establish their own non-statutory training organisations (NSTOs). In December 1988, the Government published a White Paper, *Employment for the 1990s*, in which it announced its plans to phase out the remaining ITBs completely and replace them with voluntary bodies.[102] Two ITBs survived and these boards were reconstituted so that they are now employer-dominated.[103] The 1988 White Paper also signalled a further shift of responsibility and power to employers with proposals for the development of employer-led Training and Enterprise Councils (TECs).

Some commentators have been dismissive of the development of the voluntary bodies set up to replace the ITBs. More than just failing to respond to a changing labour market, they argue that the voluntary, employer-led approach has actually been instrumental in bringing about that change:

> Poorly funded, poorly staffed and regulated by employers, the NSTOs evolved first into Industrial Training Organisations (ITOs) and more recently into National Training Organisations (NTOs). Despite a continual change of name, ITOs are

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99 HC Deb 9 February 1981 c 617

100 See HC Deb 14 June 1982 cc 620-699 and HC Deb 20 July 1982 cc 270-310

101 Michael Alison, Minister of State, Department of Employment, HC Deb 14 June 1982 c 633

102 Cm 540

103 The Construction Industry Training Board (CITB) and the Engineering Construction Industry Training Board (ECITB) still have levy raising powers.

> generally powerless against the corrosive force of the unregulated labour market. Employer self-regulation reinforces the practice of poaching skilled labour, assisting the collapse of Fordist regional economies and heightening the undergoing transition from manufacturing towards 'servicing' the economy through the exploitation of labour.[104]

Such criticisms may be seen as based on a general distrust of an employer-led, voluntary approach to training but early studies of the emerging network also pointed to particular failings. A study conducted by the Institute of Manpower Studies in 1987 found that, of the 102 designated NSTOs, only 56 were considered effective.[105] In the same year, Manpower Research similarly found "a poorly funded and heavily grant dependant" system which "constrains many NSTOs to a low-key administrative role".[106] However, the latter report also concluded that the best NSTOs had a conviction about the importance of training in the sector, competent staff and strong working contact with member firms: 'armed with not much more than these some NSTOs have been hugely effective'.[107] Subsequent government policy has tended to concentrate on ensuring standards across the network. The 1988 White Paper welcomed the establishment of a new National Council of Industry Training Organisations (NCITO), one of whose aims was 'to bring all sector training organisations up to the standards already set and achieved by the best'.[108] A later report in 1991 found that the voluntary framework for the sectoral training infrastructure "is starting to mature".[109] It also concluded that, although there was much still to be done particularly in terms of establishing credibility with employers, some of the earlier problems had begun to be addressed by the ITOs as they had since become known. The government of the time saw the report as an "endorsement of our approach to sector based training of removing the compulsion and bureaucracy of the statutory system and replacing it with voluntary arrangements".[110]

By the mid 1990s, the ITO network had developed alongside other organisations associated with the vocational qualification framework. In many cases one and the same organisation acted in three different capacities: Industry Training Organisations; Lead Bodies which set standards and assessment procedures for NVQs; and Awarding Bodies which as their name suggests actually awarded the qualifications. In his review of NVQs Gordon Beaumont advocated a more strategic approach to education and training and argued that there were 'too many layers and organisations in the structure'.[111] The review also criticised some Industry Training Organisations stating that some were 'not making an impact on sectors'.[112] In April 1996, the

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104 Martin Jones, *New institutional spaces: Training and Enterprise Councils and the remaking of economic governance*, 1999, pp 78-79

105 Carol Varlaam, *"The Full Fact Finding Study of the NSTO System"*, Institute of Manpower Studies,1987

106 Manpower Research, *Non-statutory training organisations: their activities and effectiveness*, July 1987

107 Ibid

108 Cm 540, para 4.23

109 The Host Consultancy, *Review of the Industry Training Organisation Network*, July 1991, p 68

110 HC Deb 8 July 1991 cc 297-8

111 *Review of 100 NVQs and SVQs: a report submitted to the Department for Education and Employment by Gordon Beaumont*, 1996, p 22

112 Ibid, p 25

government therefore announced proposals to introduce a single framework of National Training Organisations.[113] These would offer a simpler contractual relationship with government covering training and qualification recognition. The new NTOs would be kitemarked and the criteria for this would be: broad representation from sector employers and occupations; a commitment to forging national, sectoral and local partnerships (for example with TECs/LECs); and the ability to access resources within their sector. The development of the NTO network has largely taken place under the Labour government which is committed to the new network. There are currently 75 government-recognised NTOs.[114] The key roles of NTOs are:

- identifying skill shortages and the training needs of the whole of their sector;
- influencing education and careers guidance provision;
- developing occupational standards and NVQs/SVQs and advising on the national qualifications structure;
- influencing and advising on training arrangements and training solutions;
- effective communications and networking with their employer base and key partners to implement strategies.[115]

Sector bodies in Information Technology, Communications and Electronics (ITCE)

There are currently five different NTOs in this sector: the Engineering and Marine Training Authority (EMTA); e-business.nto representing the electronic and software services sector; Information Technology NTO (ITNTO), a sector and all-sector NTO; nto.telecom covering occupations in the voice, fax data, and image communications industries; and Skillset, the NTO for the broadcast, film, video and multimedia industry. The ITNTO and the e-business NTO plan to merge in July 2000. In most cases these NTOs developed from small, voluntary trade associations. For example, the ITNTO developed from a trade association, Cosit, set up in the early 1980s. It became a recognised ITO in 1992 and was accredited as an NTO in September 1997. The ITNTO is a membership organisation and derives most of its income from membership fees.

Shortly after the publication of its Green Paper on lifelong learning in February 1998, the government set up a National Skills Task Force to advise the government on the development of a National Skills Agenda. The Skills Task Force expressed concern about the availability of ITCE skills and as a result the government's Competitiveness White Paper contained a commitment to produce a strategy to meet the skills needs of the ITCE sector.[116] The ITCE strategy group published its report in November 1999 and, among other recommendations, the group proposed a "Council for ITCE skills", funded initially by the government, to ensure

113 DfEE press release, *New kitemarked national training organisations will help us to meet industry's needs says James Paice*, 18 April 1996

114 NTO national council, http://www.nto-nc.org/newsite99/index-java.htm

115 www.dfee.gov.uk/ntopromo.htm

116 DTI, *Our competitiveness future: building the knowledge driven economy*, Cm 4176, December 1998

effective collaboration between the various NTOs and the other sector bodies that had developed. The report concluded that there was potential for confusion in the current arrangements:

> The current NTO structures have evolved over time but the fast changing industry infrastructure and convergence of markets continue to impact on their objectives and activities. As technologies develop and converge the discrete nature of the NTOs' organisation may no longer fit the current situation. We believe that there is confusion among smaller employers about the individual roles and purposes of the different NTOs.[117]

It went on:

> The increasing interconnection between the skill needs of different ITCE occupations would suggest that greater strategic collaboration between the relevant NTOs will be increasingly important. In order to avoid duplication of effort, and to ensure a strategic approach across ITCE as a whole, it would make sense for some activities to be carried out by one body instead of 5 separate ones. This kind of approach has worked well in other industries such as construction, oil and engineering.[118]

The ITCE strategy group also expressed concerns about the ability of some of the current NTOs to address skill needs effectively.

In response to the report, the ITCE NTOs have established a strategic group to provide greater coherence. The merger of the ITNTO and the e-business NTO is another attempt to provide a single voice in the IT industry. The new chair of the merged NTO said:

> The global competitiveness of the IT sector in the UK and the growth of IT skills at all levels are critical to the UK's future in the knowledge-driven economy of the 21st century. This merger represents a major step forward in addressing inhibitors to growth. For the first time, there will be a co-ordinated approach across the whole remit of IT skills, which will better serve the needs of the NTO member companies and the UK's workforce as a whole.[119]

4. Other government training policy

Some of the current government's training initiatives are designed to offer incentives to individuals to train and some of the proposals specifically target skills associated with the knowledge economy. Individual Learning Accounts (ILAs) will be available on a national basis from September 2000. Individuals and employers may contribute to the accounts, and

[117] Information Technology, Communications and Electronics Skills Strategy Group, *Skills for the Information Age*, 1999, p 35
[118] Ibid
[119] IT NTO press release, *e-business NTO and ITNTO to merge*, 8 June 2000

obtain tax relief, and in certain cases the government will also contribute. The aim of the accounts is to help people plan and manage their retraining. Various incentives will be available to encourage people to open accounts and these include 20% deductions on some approved courses. The discount will be 80% for certain core courses including computer literacy.

The University for Industry (UfI) is a public/private partnership designed to meet the government's aim of a new learning network providing high quality learning to individuals and businesses through use of the internet and information technology. In its Green Paper on lifelong learning the government described the UfI in the context of the knowledge economy and said that it would use new technology to improve learning and skills.[120] One of the early targets for the UfI is that within five years, an additional 200,000 people per year will undertake programmes for information and communications technologies at levels 1, 2 and 3.[121] Other government initiatives in this area include the National Grid for Learning[122] which is intended to provide the "national focal point for learning on the Internet" and the ICT learning centres initiative which aims to increase access to information technology.[123]

The government has explicitly stated that it has placed skills deemed necessary for the knowledge economy at the centre of its training strategy. The general principles of its approach to training remain similar to those of the Conservative governments of the 1980s and 1990s. That is, there is direct training provision for the unemployed and young people, with incentives to train for those in work. Work based training operates within a voluntary, employer-led structure. There has been some change of emphasis. For example, provisions in the *Learning and Skills Bill [HL] 1999/2000* would set up new Learning and Skills Councils to take over most of the current functions of TECs. It seems likely that the new bodies will continue to be employer dominated.[124] Arguably there is a stronger emphasis on new technology in the specific measures introduced since 1997, such as the UfI, the Skills Task Force and ILAs. It remains to be seen whether this approach proves successful in increasing the general skills level in the workforce to the extent that successive governments have deemed necessary to compete in the knowledge economy.

D. University and Research and Development Funding

1. Research In the UK

Most academic research is carried out through the university structure. There are now significantly more universities in the UK than there have ever been. The 'promotion' of polytechnics to university status has been the subject of some debate in UK further and higher education establishments. The public funding of science is largely carried out through

[120] Cm 3790, February 1998, p 18
[121] DfEE, *University for Industry: Engaging people in learning for life*, March 1998
[122] http://www.ngfl.gov.uk/ngfl/index.html
[123] http://www.dfee.gov.uk/ict-learning-centres
[124] DfEE press release, *Business gets biggest say in learning and skills network*, 28 October 1999

the Dual Funding Mechanism that was recently covered in some detail by the Parliamentary Office of Science and Technology.[125] Basically universities are funded through two streams of public money: one is a block grant modulated by the results of the Research Assessment Exercise (RAE) and the other is money specifically tied to research projects from the research councils.

Research is also carried out by specialist research institutes. These may be set up in a number of ways. Research councils sponsor a number of institutes that work in areas directly within their area of competence. These research establishments have usually begun through need and usefulness rather than through any plan of regional expenditure. They may, therefore, skew public funds towards that region if they receive large amounts of funding due to their speciality subject becoming topical.

A final route for the public funding of science research can come through the work of Government departments. Areas of interest that require basic research to be carried out are put to tender and universities, as well as other research capable institutions, can bid to carry out the research.

2. University Assessments

Research councils indirectly assess the research capabilities of universities by awarding research grants on a competitive basis. Those institutions which have ‘better’ research staff will attract greater amounts of funding and so will skew research council funding towards their region of the country.

The Higher Education Funding Council (HFEC) for England (and their equivalents in Scotland and Wales) assess universities, department by department, every four years under the Research Assessment Exercise (RAE). This activity rates the departments on a scale of 1 to 5 (with 5* being available for exceptional departments). HEFCE then award their block grant to universities on the basis of their ‘score’ and the number of academics used to generate that score.

Another assessment of university departments is carried out through the Teaching Quality Assessment (TQA). HEFCE defines the purposes of quality assessment as being:

- to ensure that all education for which HEFCE provides funding is of satisfactory quality, and to rectify any unsatisfactory quality
- to encourage improvements in the quality of education through the publication of assessment reports and the sharing of best practice
- to provide effective and accessible public information on the quality of education

[125] *Striking a Balance – The Future of Research Dual Support in Higher Education*, Parliamentary Office of Science and Technology Report, June 1997. http://intra1.parliament.uk/post/pn099.pdf

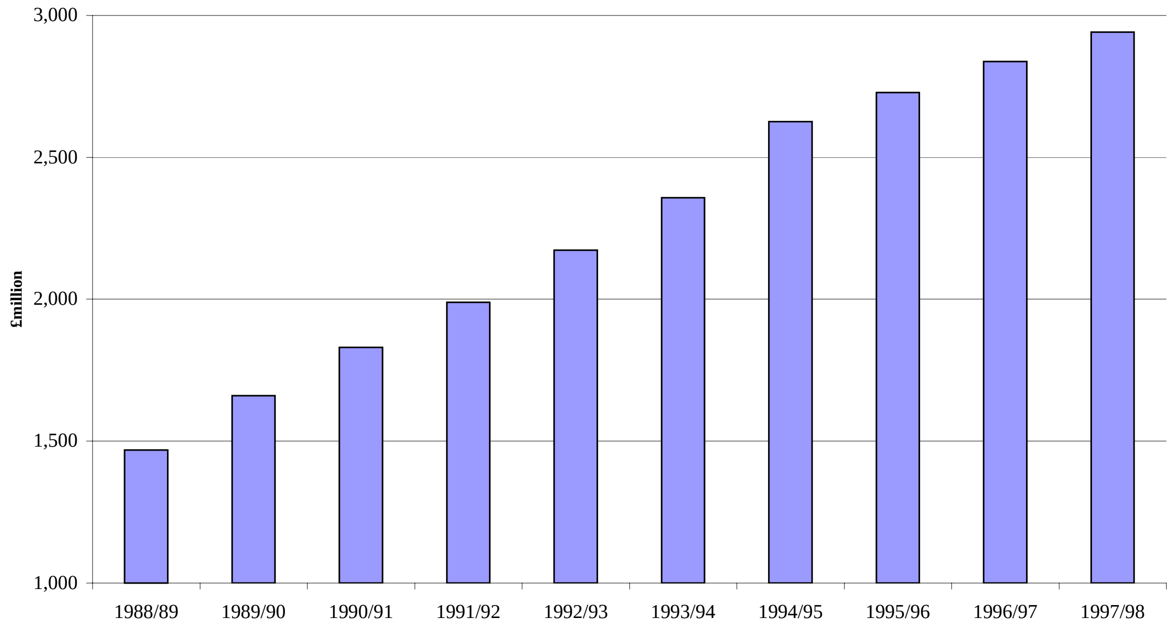
- to inform funding and reward excellence by linking high quality provision with the allocation of funding to institutions.

There are no funding implications, however, of the TQA and so this is unlikely to influence the flow of public funding of research and development in any but the most indirect fashion.

3. R&D funding of higher education institutions

The table on the following page sets out the sources of R&D funding of higher education institutions (HEIs) for science and engineering based R&D in the UK for the financial years 1988/89 to 1997/98. The figures are also summarised in the graph below:

Funding of higher education institutions science and engineering based R&D in the UK



Total R&D funding from all sources for HEIs has increased year on year since 1988/89. From just under £1.5 billion in 1988/89 it has doubled to almost £3 billion by 1997/98. In 1997-98, almost 70% of the total £3 billion R&D funding for HEIs was provided by the UK Government; 20% came from private sources in the UK (7% from UK industry and 13.6 % from UK based charities) and 10% from other sources (including 5% from EU bodies).

Funding of higher education institutions science and engineering based R&D in the UK

£ million

	General support		Research grants and contracts		Total					Total percentages		
	Research councils	HEFC	Research councils	Government departments	Publicly funded	UK Industry	UK based charities	Other sources	All sources	% publicly funded	% funded by UK Industry & UK based Charities	% funded from Other sources
1988/89	80.5	830.4	203.4	102.0	1,216.3	92	131	30	1,469.3	82.8	15.2	2.0
1989/90	90.7	829.8	250.0	103.0	1,273.5	104	154	128	1,659.5	76.7	15.5	7.7
1990/91	104.0	863.2	283.7	121.0	1,371.9	114	194	150	1,829.9	75.0	16.8	8.2
1991/92	111.1	949.8	291.8	128.0	1,480.7	120	219	169	1,988.7	74.5	17.0	8.5
1992/93	133.1	963.3	371.9	142.0	1,610.3	121	246	196	2,173.3	74.1	16.9	9.0
1993/94	144.5	968.4	459.6	149.0	1,721.5	130	290	216	2,357.5	73.0	17.8	9.2
1994/95	150.2	1,017.0	502.3	244.0	1,913.5	158	313	241	2,625.5	72.9	17.9	9.2
1995/96	156.1	1,017.7	533.1	269.5	1,976.4	170	338	244	2,728.6	72.4	18.6	8.9
1996/97	168.0	1,027.5	525.1	296.7	2,017.3	188	364	269	2,837.8	71.1	19.5	9.5
1997/98	175.0	1,033.0	534.0	306.0	2,048.0	207	399	287	2,941.0	69.6	20.6	9.8

Note: Other sources include overseas EU bodies, other overseas and other finance

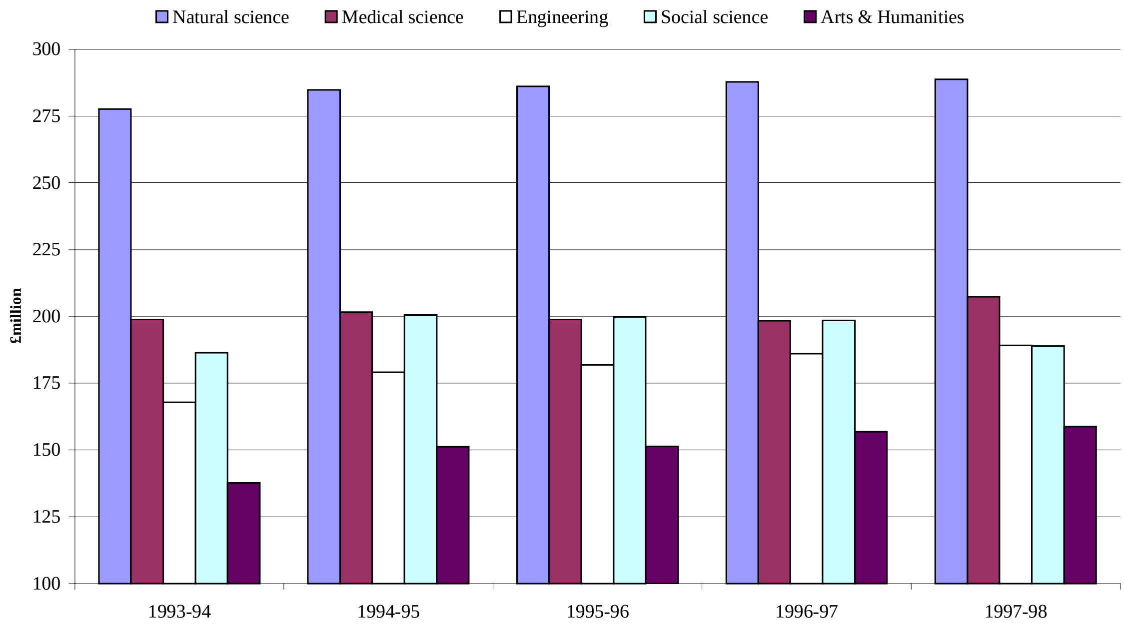
Source: *Science engineering and technology statistics 1999. DTI Office of Science and Technology (table5.1)*

Higher Education Funding Councils (HEFC), R&D and SET expenditure

From 1993-94 the general funding of R&D in HEIs has been organised through separate Funding Councils for England (HEFCE), Scotland (SHEFC), Wales (HEFCW) and the Department for Education in Northern Ireland (DENI).

The table on the next page sets out estimates of Government funded R&D and Science, Engineering and Technology (SET) expenditure through HEFCs, by subject area, for the financial years 1993/94 to 1997/98. Over the period the total funded expenditure through HEFCs in the UK increased by almost £65 million or 7%. However, not all of the individual countries HEFCs increased expenditure by the same amount and expenditure funding through DENI fell in each year and by 14% over the whole period. The amount of Government funded R&D and SET expenditure through HEFCs for the period is summarised by subject area the graph below.

Higher Education Funding Councils R&D and SET expenditure by subject area



The largest subject area during the period, by HEFC funded expenditure, was Natural Science, accounting for over £275 million or a quarter of the total Government funded expenditure. Funded expenditure increased for all the subject areas during the period; Arts & Humanities by 15%, Engineering by 13%, Natural and Medical Sciences by 4% and Social Sciences by just over 1%.

Table 2
Higher Education Funding Councils R&D and SET expenditure by subject area
United Kingdom
£ million

	1993-94	1994-95	1995-96	1996-97	1997-98
Subject area					
HEFCE (England)					
Natural science	216.3	221.1	222.5	224.5	227.4
Medical science	161.7	164.6	161.9	161.4	169.5
Engineering	131.6	141.2	144.1	148.3	150.5
Social science	150.9	160.6	160.2	159	152.2
Arts & Humanities	109.3	119.5	120.6	126.2	127.4
TOTAL HEFCE	**769.8**	**807**	**809.3**	**819.4**	**827**
SHEFC (Scotland) (1)					
Natural science	42.1	42.9	43.3	43.1	43.6
Medical science	21.6	23.4	23.6	23.9	24.2
Engineering	20.9	22.4	22.5	22.7	23
Social science	19.5	21.1	20.9	21.1	21.4
Arts & Humanities	16.8	18.3	17.7	17.7	17.9
TOTAL SHEFC	**120.9**	**128.2**	**128**	**128.5**	**130.2**
DENI (Northern Ireland)					
Natural science	6.3	6.2	6.1	5.9	5.7
Medical science	6	5.8	5.8	5.5	5.4
Engineering	7.4	7.2	7.1	6.9	6.7
Social science	7	6.7	6.7	6.4	4.5
Arts & Humanities	5.1	5.2	5.2	5	5.2
TOTAL DENI	**31.8**	**31.1**	**30.9**	**29.7**	**27.5**
HEFCW (Wales)					
Natural science	12.9	14.5	14.2	14.3	12
Medical science	9.6	7.7	7.6	7.6	8.2
Engineering	7.8	8.3	8.1	8.1	8.9
Social science	9	12.1	11.8	11.9	10.7
Arts & Humanities	6.5	8.1	7.9	7.9	8.3
TOTAL HEFCW	**45.9**	**50.7**	**49.5**	**49.9**	**48**
Subject area Totals (UK)					
Natural science	277.6	284.7	286.1	287.7	288.7
Medical science	198.9	201.6	198.8	198.4	207.3
Engineering	167.8	179.1	181.8	186	189.1
Social science	186.4	200.5	199.7	198.5	188.8
Arts & Humanities	137.7	151.1	151.3	156.8	158.8
TOTAL SUBJECT AREAS	**968.4**	**1017**	**1017.7**	**1027.5**	**1032.7**
TOTAL R&D	**968.4**	**1017**	**1017.7**	**1027.5**	**1032.7**
TOTAL SET	**968.4**	**1017**	**1017.7**	**1027.5**	**1032.7**

Source: ONS Government R&D survey
DTI SET Statistics: Table 5.3

Note:
1 The figures for SHEFC for 1995-96 and 1996-97 include grants which are specifically described as "for Research" plus an appropriate share of other grants. The estimates for 1997-98 are calculated using the percentage changes in the total grants to SHEFC (please see December 1996 SOIED expenditure plans).