Research and regions: An overview of the distribution of research in UK regions, regional research capacity and links between strategic research partners

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Executive Summary

1 This paper is concerned with regional aspects of the research structure of the UK. It considers the prospects for improving the transfer of knowledge from higher education to industry and increasing the economic development of less well-favoured regions through regional research funding.

2 Substantive sections of the paper report a quantitative, though preliminary, overview of the regional research profiles of the higher education and business sectors and the strategic cluster priorities of the Regional Development Agencies (RDAs). The policy and literature background is reviewed first, to set the scene for the quantitative analyses.

Policy alignment

3 Economic development of the regions via the exploitation of research brings into play a tension between two objectives. First, current UK Government policy favours selectivity and concentration of research funding (DfES, 2003) in a research base that has conventionally been conceived as a national (and international) entity rather than a regional one. This policy has potential regional impacts and the evidence is that the balance between concentration and diversity needs to be carefully struck if UK research excellence is to be maintained (Adams and Smith, 2003).

4 Second, since 1997 a central element in government policies for economic development, innovation and regeneration has been an enhanced role for regional government. The assumption has been that certain decisions, especially those with implications for regional prosperity and quality of life, are better devolved to the representatives of the regions involved. This philosophy has underpinned the creation of new regional bodies – RDAs, Regional Assemblies, expanded Government Offices (GOs) and a central Regional Co-ordination Unit (RCU) – although there are different arrangements in place for the devolved nations.

5 The assumption is that RDAs (or the responsible devolved national bodies) have a legitimate interest in their regional universities and in stimulating university-industry partnerships. It is a logical step from this perspective to the view, recommended in the Lambert Review of Business-University Links (Lambert, 2003), that the delivery of RDA objectives might be better facilitated by direct regional control of a portion of the research funding hitherto distributed according to national benchmarks and assessments.

6 It is not always clear, however, that the emergent regional framework is consciously linked to pre-existing, and nationally oriented, policies and agents relevant to knowledge growth and exploitation. First, there is the research funding distributed for the DfES by the HE Funding Councils. Second, there is funding for specific research projects, functionally the responsibility of the Office for Science and Technology (OST) and distributed by the UK Research Councils

(RCs). Third, there is DTI policy, where competition and technology are key aspects of the state's interest in stimulating innovation.

7 Consequently, it is in the region – spatially as much as culturally - that the questions addressed in this paper arise. They concern, on the one hand, the connectivity between university research activity and economic performance and, on the other, the importance of proximity to the transfer of research findings from discovery into application.

Dimensions of university research – literature review

8 Universities have diverse and pervasive impacts (Charles and Benneworth, 2001 and associated reports). They are significant economic entities: they are major employers, particularly of skilled people, and have a significant demand for goods and services. Research activity enhances those dimensions, adding to employment opportunities and increasing and diversifying demand for goods.

9 Universities import talented people to their regions. Graduates represent a skilled workforce of enormous economic value, many of whom choose to stay in the area where they graduated. Research adds to the experience of those students, but more importantly research leads to advanced research training and the output of more highly skilled people with research experience and the ability to transfer knowledge and know-how to companies.

10 Universities produce knowledge and innovative ideas. These are made available as tacit knowledge, through consultancy and the movement of people, as intellectual property 'close to market' that can be licensed and exploited, and as codified knowledge emerging from basic research and particularly in the form of journal articles.

11 Universities also offer consultancy, instrumentation and high-tech research services, short courses and industrial research training, and advanced and complex facilities for testing, imaging, and modelling.

12 Cities benefit from the presence of a university and research excellence boosts awareness and reputation (Goddard et al., 1994). Cities with universities may also be better places to live because they lower stress levels by contributing to economic stability (news item in Science 2004, vol **303,** 463) as well as employment and culture. Universities are key players in innovative clusters, which we discuss in more detail below.

13 To summarise, many studies have demonstrated the wide range of economic and cultural contributions that Universities make. Only some of these are directly related to research but most of them benefit from research activity generally and research excellence in particular.

Economic benefits of research – literature review

14 Economic and policy studies have in the past sought to quantify the widespread assumption that basic research fuels a stronger economy. Recent syntheses have emphasised the more diverse benefits of research investment, affecting labour and capital.

15 Governments fund research for many reasons, none of them disinterested, but perhaps most readily summarised under the headings of 'wealth creation' and the 'quality of life'. Basic research represents an economic good and thereby justifies public support. The outcomes of public research are made available without restriction to users, because application is both uncertain and potentially pervasive. The United Nations has recently endorsed the view that developing countries would benefit if they boost their R&D base (news item in Nature 2004, vol **427**, 577).

16 One evident association between research and the quality of life is through improved health, social and living conditions. Even so, benefit measurement for health services remains a real challenge for those seeking to determine how NHS R&D should be used. Furthermore, the volume growth of activity in biology has been measurably greater (doubling every 10 years) than the rate of return in new discoveries (doubling every 50 years for biology generally and every 22.5 years for genetics this century: Glass, 1979). Such statistics are a characteristic of every research field and the consequence is that the productivity of publicly funded research becomes a matter for enquiry.

17 Arguments asserting the benefits of research have tended to rely on studies using data for a particular industry or innovation that is readily susceptible to analysis, while other studies have emphasised the importance of the spillover effects of research (that is, the many-to-many relationship between research fields and industrial sectors) (see e.g. Pavitt, 1985; Martin et al, 1996; Salter and Martin, 2001).

18 The spillover effect makes simple analysis of research-economy linkage a challenge. If research investment results in diverse outcomes, it is difficult to develop a single, consistent model of economic benefit. For example, while case studies on biotechnology and optical communications show a clear and direct impact of investment in basic research, there is uncertainty about the importance and utility of discovery in other disciplines (Sornette and Zajdenweber, 1999) and thus an early DES analysis of the impacts of research on the semi-conductor industry came to few clear conclusions (Byatt and Cohen, 1969).

19 Cross-sectoral studies in the USA measuring State and Government returns for research funding and returns for R&D spend by commercial organisations indicate positive net outcomes. In a study of 883 companies, Griliches (1980) found a consistent positive relationship between company productivity and investment in R&D with high private rates of return. Mansfield (1998) looked at 77 major firms and estimated that over 10% of the new products and processes

introduced in those industries could not have been developed in the absence of recent academic research. Additionally, a reducing time lag between research and product innovation (from around 7 to 6 years) indicated accelerating cycles of knowledge exchange.

20 Generally, studies find that the impact of research investment is often both fuzzy and delayed in time. Estimates may consequently seem to be unstable and, although illuminating, “at best a very crude beginning” (Mansfield, 1992). Summarising past work, Martin et al (1996) pointed to evidence of different forms of economic benefit. They argue that basic research must be seen as not only a source of useful codified information but also of wider benefits such as trained researchers, improved instrumentation and methods, tacit knowledge, and membership of national and international networks. Martin and Trudeau (1998) similarly note that traditional economic impact studies sought only to assess how spending on research affects the rest of the economy: “they do not describe its underlying, dynamic impact on the two primary factors of production, labour and capital”. Furthermore, after graduating, “students become a primary source of innovation in the organisations they join”.

21 To summarise, while there are sound examples of good rates of return for specific research investment in some sectors, such as pharmaceuticals, these are not readily generalised. In many fields, such as chemical engineering, the returns are less readily quantified because of spillover between discoveries and innovations. Although the generic benefit of research becomes diffuse, it nonetheless has measurable and pervasive impact mediated particularly by skilled labour.

Clusters and scales – literature review

22 The analysis of research and policy documents concerning national and regional economic development is made more difficult by conceptual confusion. This applies particularly to the term ‘cluster’ and to the use of ‘region’ as an indicator of geographical scale.

23 The modern concept of ‘clusters’ (local aggregations of interdependent manufacturing and service companies) as economic entities that exhibit particularly effective rates of innovation and growth, and thereby enhance competitiveness, is associated with Michael Porter (e.g. Porter, 1990). The importance claimed for clusters is that proximity (usually in space but sometimes also in sector) enables a level of interaction that adds to the inherent growth potential of each member. Universities can be important players in such clusters because they are a source of knowledge and of skilled people, but such interaction between companies themselves is thought to be equally important.

24 This makes clusters a focus for policy. It is assumed that stimulating cluster development should add to economic growth generally but could boost it further through better knowledge transfer between the research base and users. Not surprisingly, there have been extensive studies on cluster formation, structure and distribution.

25 The problem is that ‘cluster’ is variably interpreted. While original studies of clusters have usually been fairly specific about both scale and scope, this has not always been true when such material is adopted by policy makers. Thus examples relating to Silicon Valley in the USA (principally a localised IT cluster with good research links), carpet-making in Belgium (a widespread ribbon of related companies with less research), aerospace-defence in the UK (a set of distant locations linked by a common sector and a diffuse research base) and the Cambridge phenomenon (a localised IT and biotechnology development and an excellent but loosely connected research companion) are cited as if they refer to essentially the same thing. Rather obviously they do not and their sectoral and structural differences seem likely to be important.

26 The concept of region is bound up in this. The region affected by Cambridge is the area around the city, not the East of England. Other clusters, such as European textiles, link regions that spread across national boundaries. Again, while original research recognises these differences and sometimes supplies reference typologies (Trends Business Research, 2003), secondary documents sometimes fail to preserve those distinctions and risk basing policy on shaky evidential foundations.

27 It remains unclear whether there are regional dimensions to the suite of University research services that could be distinguished from the local (city) scale and the wider (national) scale. Goddard et al (1994) suggest that local research contracts are usually few and small whereas inter-regional links are more substantial. Instrument testing and consultancy may be more local, while IP exploitation tends not be local because of the need for a good match with the user.

28 To summarise, there is little doubt that ‘clusters’ involving HE can be powerful promoters of innovation and can have profound economic effects on their locale. However, the fudging of distinctions of both structure and scale weakens the evidence base for policy development and gives room for scepticism - perhaps inappropriate - about whether some phenomena are as widespread or general as claimed.

<u>What do companies want from higher education?</u>

29 As noted above, research is not the only way in which universities can have an economic impact. In fact, a detailed study carried out for the Council for Industry and Higher Education showed that more than half the financial input to universities from industry is related to teaching (White and Horton, 1991) and there is also significant spend on industrial short courses.

30 Data from the DTI R&D Scoreboard and from university statistical returns shows that over 98% of the £16 Billion annual industrial R&D spend in the UK is either ‘in house’ or contract research placed with other companies. Only about £250 million goes into university research.

31 Although there has been a cash increase, in relative terms there has been a decline in industrial investment in university contract research from about 14% to less than 10% of the HE sector’s

R&D income over the last twenty years. The consequence is that, although there is extensive evidence that the international excellence of the UK research base has improved, the industrial share of support for the research base has not kept pace with either UK public support or the growth of European funding.

32 To summarise, industry invests less in research than in teaching and, although universities do more and better research, industrial research support is now a relatively smaller part of universities' research funding than in the past.

The regional distribution of research

33 The paper sets out a series of analyses leading to maps of UK research. First, the development of the present UK research structure from the early 20th century established a strong concentration of major research facilities along the London-Bristol corridor prior to the development of the university research base or the modern industrial R&D base.

34 Second, the report presents a series of maps of UK university research. These show that staff, funding, PhD awards and research publications are highly concentrated in the three regions in the south east quarter of England. This area accounts for about half of England's research, or about 40% of UK research staff and a rather greater percentage of funding and publications. There is a concentration of research excellence. On the whole, contrasting diversity in subject coverage or specialism between regions is less marked than differences in capacity and performance. Because of relative concentration, however, the south east has an exceptional level of biological and medical research while there is strong engineering and physical sciences in some other regions.

35 Third, the report draws on data relating to the 700 companies on the DTI R&D Scoreboard to map the distribution of industrial R&D. Company names are linked to addresses for research publications and these are used to link both R&D spend and research articles to regions. The evidence again shows a concentration of R&D in south eastern England, and it is even more concentrated than public sector research. The three regions in the south east account for 60% of company R&D spend and 75% of company research publications. While there is an apparent clustering effect, such clusters spread across regional boundaries as defined by RDAs.

36 Most of the companies that produce research publications (a significant proportion are in the biotechnology-pharmaceuticals sector) are in the top 200 of the DTI Scoreboard. These spend £15 Bn of the UK's £16 Bn annual industrial R&D. Publications tend to indicate the support of research that is less near-market. There is a correlation between the volumes of expenditure and publication. In other words, overall commitment to R&D is reflected in engagement in collaborative research that is less near-market.

37 The combined picture is really rather stark. There are regional concentrations of public and private sector research and they are co-located around London and in the south east. The

concentration of bio-pharma activity is most marked, in both sectors. Research output is more concentrated than expenditure in both sectors. And that part of industrial R&D that is most likely to engage with the research base, through collaboration and publication, is at the heart of the concentration. It is difficult to see how such a national concentration of infrastructure and activity could be re-balanced by regional strategies, even if it were desirable to do so.

38 The relatively undifferentiated spread of regional specialisms might suggest a lack of tuning to regional economies, but it is argued elsewhere that it may be beneficial to have regional research that is as diverse as the national research base (Adams and Smith, 2003). Rather than fitting closely to current industrial peaks, diversity offers a range of research support and innovation interaction across sectors and time.

39 To summarise, most regions reflect the national research base in diversity but the playing field for both university and industrial research is heavily tilted towards south eastern England. Research-intensive industry, particularly in pharmaceuticals, would seemingly have little incentive to locate to other regions unless there is some change in balance.

The regional distribution of research collaboration

40 Many studies assert that for industry ‘proximity matters’ when it comes to research collaboration and knowledge transfer. The evidence on co-location of public and private sector research concentration seems to support this. In an era of global competitiveness and on-line knowledge bases, however, it is a legitimate question to ask to what it is that proximity matters.

41 Studies of research collaboration have shown that the average distance between collaborators has increased over time (Smith and Katz, 2000). An analysis of the university and public contacts of UK chemical firms shows that most research links are inter-regional (Charles and Howells, 1992).

42 For this paper, information about research publications authored by UK companies were analysed to determine which were co-authored with a UK university, what was the regional distribution of those co-authors and how many of the papers were co-authored with an overseas institution. Publication is an effective mode of engagement in research networks, is now more common among R&D active companies and signals research that is less near to market. On the other hand, culture plays a role: biotechnology tends to use journals to communicate more than does engineering which prefers conference proceedings.

43 The outcome is quite clear. R&D intensive companies collaborate with a wide network: these are the major publishers and the major R&D spenders. It is equally clear that these companies have much overseas collaboration. Proximity does not seem to be a constraint for such businesses. Does this signal indicate that proximity is more important for some firms, or sectors, or types of company than for others? Or does it indicate that proximity is more important for some types of research interaction than it is for others?

44 To summarise, the signals on collaboration and on concentration (see above) should be read together. The companies that are co-located with the concentrated research base are also collaborating with universities all over the country and with other institutions outside the UK. This must lead to a re-consideration of the report by Goddard et al (1994) and his distinction between those research services that have a strong local base and those that do not. In other words, knowledge transfer activity is not all the same.

Regional economies and regional research policy

45 The significance of clusters to the innovation process has been acknowledged. The final pieces of evidence introduce analyses of the main sectors (clusters) of employment in each region and the cluster priorities of the Regional Development Agencies (RDAs).

46 Work for DTI by Trends Business Research (2003) demonstrates the spread of principal concentrations of employment (clusters) in each region. There is some differentiation between regions and the clusters in the south east seem to match the R&D base better than those in other regions, although there is some symbiosis in the East Midlands which has strength in engineering.

47 A review and analysis of the RDA web-sites leads to the overwhelming impression that RDA cluster priorities have a great deal of similarity. It was found that there is a particular focus on biotechnology-pharmaceuticals, communications and IT, leisure and media, advanced engineering and tourism. These are also common to many national strategies on economic competitiveness in other parts of the world.

48 While there is some overlap between employment clusters and RDA priorities, the employment clusters tend to relate to mature industries while RDA priorities tilt towards the R&D and innovation agenda of new industry.

49 The conclusion is, therefore, that, despite distinctions related to the support of historic employment sectors, RDAs are relatively undifferentiated in their plans for innovative research clusters.

What are the implications for Government and RDA policy?

50 Universities provide many benefits to the economy, some of which are research based and others - like graduates - get added value from research. The balance of evidence confirms that R&D investment provides real returns in commercial innovation and competitiveness, and that clusters create good conditions for bringing producers and users of knowledge together. The regional dimension is unproven, but it seems reasonable to suppose that the development of appropriate clusters would promote regional economic development and would also further business-university links at a city level that might then benefit the wider region.

51 However, the literature review and analyses reported here suggest that funding more collaborative research is not the most likely route to increase the transfer of knowledge from universities to industry. Furthermore, it also seems unlikely that a regionally-based research strategy could significantly affect economic development without some more fundamental rebalancing of national research disparities.

52 The evidence in this report suggests that the problem for many RDAs will be that their industrial R&D base is weak, is not engaged with the research base and has little capacity to develop that engagement. In addition, the HE research base is strongest in the south-east alongside the most substantial R&D. For many of the companies in the other regions, finding money for collaborative research is unlikely to be the most congenial route forward, although it could be for newer businesses that have emerged from a research background.

53 The RDAs will also need to consider the challenge for the universities, which have seen a relative decline in industrial research support, which can see significant costs in working with companies with low research capacity and, by the same token, which will see only low rewards a long way off in any new ventures. They will need significant persuasion and support to engage in this mission.

54 Because public support must not be linked to near-market research, that will also restrict the range of companies that can benefit from regional collaborative research funding. In fact, the greatest beneficiaries could be those who are already most closely engaged with the research base, publish widely and collaboratively and need least encouragement to maintain those links.

55 RDAs will also need to consider the wisdom of chasing the same opportunities. Their cluster priorities are both sensible and problematic. It is universally agreed that these areas are where great opportunities lie and where huge economic benefits might be found, yet it seems unrealistic to suppose that each region in the UK can possibly develop critical mass in all sectors. It seems even more unrealistic when the existing playing field in the key sectors is tilted so steeply towards one corner. RDAs should also apply a wary eye to the structure, scale and reality of the clusters in which they propose to invest and they should test the match between evidence and policy.

56 Research strategy and funding is currently organised at national level, and there are potential risks to be considered if this were to change. There is only so much funding from Research Councils; there are only so many talented researchers; there is only so much venture capital. The risks are both that small pulses of regional investment will be nugatory, failing to ignite cluster development at an adequate level, and also that there will be a competitive drain on existing excellence, spreading talent and resources to a greater number of smaller centres.

57 There are implicit tensions between regional strategies and national agencies. Will RDA plans tend to work against DfES policies for supporting existing excellence? Will RDA priorities work

against Research Council disciplinary strategies for structured investment in facilities and leading research groups? Will RDA investment increase HE's funding plurality, and will regional initiatives add to or detract from those at a national level?

1 What does this study investigate?

Would regional management of research funding provide a remedy for the problem of business-university collaboration and thereby increase and diversify business investment in university research and boost regional economies?

The UK research base[1] is outstanding in world terms and has improved in quality and effectiveness over the last 15-20 years (May 1997; Adams 1998; Adams and Smith 2002). By contrast, successive reports over 30 or 40 years have expressed the widespread concern that the UK is poor at turning new knowledge into innovative products and processes (e.g. House of Commons 1976). It is generally agreed that UK business[2] is not research intensive, its R&D record is poor and that R&D is concentrated in a narrow range of sectors. The Lambert Review of Business-Industry Collaboration (2003) proposed a new stream of university research funding that should be vested at regional level and aimed at the improvement of research collaboration so as to increase knowledge transfer.

This report assembles data to evaluate whether these proposals would be helped or hindered by the regional distribution of public and private sector research, the research profiles and behaviour of companies, and the policy priorities of the RDAs.

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1. This paper is concerned with regional aspects of the research structure of the UK. It considers the prospects for improving the transfer of knowledge from higher education to industry and increasing the economic development of less well-favoured regions through regional research funding. The substantive sections of the paper report a quantitative, though preliminary, overview of the regional research profiles of the higher education and business sectors. Later, their potential interface with the strategic cluster priorities iterated by the Regional Development Agencies (RDAs) is considered. To set the scene for the quantitative analyses, the paper first reviews the policy and literature background.

2. Why focus on regionalism? First, regions are a leading policy focus for Government. Universities interact more with regional bodies than they did ten years ago. More pertinently, the Lambert Review of Business-University Collaboration (Lambert 2003) has proposed that a new stream of funding be made available to Regional Development Agencies (RDAs) to match fund business contributions to collaborative research projects, prioritising these by their fit to regional economic strategies.

3. Lambert's proposals seem pragmatic and sound sensible. They address what Lambert describes as the 'biggest single challenge', which lies not in the supply of new products and services from universities, but in boosting business demand for research[3].

4. However, if implemented, this will be the first time in the UK that any part of university research funding would be managed and prioritised at regional rather than national level. Proximity is frequently identified as an issue that companies believe affects their ability to collaborate with universities. The benefits that a more local focus would help to bring might include a more hands-on touch relevant to regional economic needs and priorities and therefore more likely to engage with local industry. But there are potential costs that might emerge because of underlying disparities between regions and issues about national research structures, regional research structures and the tensions that might arise between them.

5. The issues of regionalism and research exploitation are closely linked in policy thinking. Two specific problems need to be addressed: continuing concern about whether the UK is good enough at exploiting its national research excellence; and the regional disparity between research bases and economies. Many studies have suggested that location is a factor in enabling fruitful links between companies and universities, so those regions with a weaker research base may also have built-in problems in boosting knowledge-driven innovation. But which needs tackling first: the disparity or the linkage?

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1 The research base is defined here as the staff, facilities and activity in Higher Education Institutions (HEIs) and Public Sector Research Establishments (PSREs) including the laboratories of the Research Councils and those associated with Government departments.

2 The terms 'business' and 'industry' are used interchangeably in this report and are not meant to indicate any subtle contrasts in the commercial sector

3 This echoes the House of Commons (1975, para 21) comment that 'the Government must seek to release industrial management from a situation in which, because of the low added-value of their activities, they have insufficient funds to invest in technological innovation

6. The policy and academic literature confirms that analysis of specific links between the research base and economic development is fraught with difficulty, not least because many research outcomes can have multiple effects and most product and process developments are the consequence of multiple sources of innovation. The number of studies and initiatives that have been applied to the business-university 'problem' should signal that it is both complex and difficult. Nonetheless, there has been a tendency to identify fresh panaceas and over simplifications.

7. Problems associated with the understanding and use of the terms region and cluster, both central to policy deliberations, exacerbate the difficulty. Insofar as clusters relate to any potential regional impacts of university research, the topic is clearly a crucial one and is considered in further detail below. It is sufficient to observe here that, at the heart of clusters, there are a string of questions about how knowledge produced by universities is accessed, incorporated and used by business.

8. The cluster concepts developed by Michael Porter (e.g. Porter 1990) seemed to offer a solution to some of the UK problems. Universities are identified as players in knowledge intensive 'clusters', helping to provide the glue that binds a group of interdependent companies together. The tight inter-relationship and tacit knowledge interchange boosts innovation and growth. Because there are a number of evident examples of well-defined clusters, such as Silicon Valley and Route 128 in the USA, the phenomenon was perceived much more widely.

9. While there are some undoubtedly successful UK clusters, such as that around Cambridge (growing from just 150 staff in 4 companies at the end of 1975 (House of Commons, 1976)) the interpretation of the cluster concept has often been muddled. Many ideas have become similarly confused through over-simplification in the journey between original studies and policy applications. This means that it is difficult to determine whether one set of findings has relevance to another, and whether all conclusions and policy options are well founded. In particular

- The definition of a cluster has become diffused and many 'clusters' in policy documents differ markedly in structure from the Porter model, so are likely to function differently. Not all are linked either to sources of R&D innovation or to a specific locality. There are, for instance, sectoral clusters and there are employment clusters (Trends Business Research 2003 - TBR also provides a cluster typology).

- The scale factor seen as relevant to business-university links and clusters varies widely, with proximity being interpreted as local in the sense of neighbouring (e.g. on a science park) through to regional at a variety of scales including UK Regional Governments and trans-national regions in Europe.

- Discussion about what business (or the economy more widely) wants from universities tends to focus on knowledge transfer. Not all companies want the same thing. There is no simple, uniform set of expectations or requirements. Only some of the reasons why companies work with universities are about research and knowledge-transfer and only some of the links are location dependent.

10. The proposals for a regional tier of business related research funding have implications for the inner landscape of the research base, in two senses.

- *The nature of the relationship between research and the regions*. Conceptually and empirically the idea of a regional research base is under-explored. Because the UK research base is conceived conventionally as a national (and international) rather than regional entity, analysis of the shape, size and inter-relationship between the different regional elements of the national research base is rare. Logically therefore very little is known about the regional dimensions of research.

- *The alignment between the public and private sector research base at regional level*. How closely does the pattern of university research activity and research strengths align with the pattern of business R&D and business interaction with the universities? Furthermore, how closely do these patterns map onto the political dimensions of the regions as indicated by the strategic priorities of the RDAs?

2 The alignment between research, science, industrial and regional policies

Regional research funding for business-university links would intersect with Government policy on Higher Education research funding, on the excellence of UK science, on industrial competitiveness and on regionalism. These all come together in the focus on how best to enhance regional economies, but may not all point in the same direction.

Regionalism in university and research funding in the USA and Germany may deserve further examination. It suggests that there are regional-national tensions to be considered and that there are innate problems in allocating funding at a local level.

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11. A central element in government policies for economic development, innovation and regeneration since 1997 has been an enhanced role for regional government and decision making. The assumption has been that certain decisions, especially those with implications for regional prosperity and quality of life, are better devolved to the representatives of the regions involved. This philosophy has underpinned the creation (post-1997) of new regional bodies – the Regional Development Agencies (RDAs), Regional Assemblies and expanded Government Offices.

12. This patchwork institutional framework, containing as it does enhanced roles for business leaders in regional strategic and investment decision-making, cuts across existing governmental structures and related policy strands. For example, how might the funding of university research (currently determined via national assessment) be better integrated with the needs of regional economic development?

13. Experience elsewhere suggests that regional funding approaches and regional-national tensions can be problematic for universities and for research. State funding of universities in the USA has been criticised for creating roller-coaster funding linked too closely to fiscal cycles (McPherson and Schapiro 2003). Debate over Federal and Länder funding of research in Germany, with proposals for a switch to HE funding by the Länder, reveals concerns about an overall decline in investment, less reliable research funding and political influence threatening quality and coherence of HE infrastructure (Einhäupl 2003).

14. In the UK, regional research funding is a concept that highlights not just the strategic importance of research to the economy both nationally and, it is assumed, regionally, but its place at the intersection of four separate but overlapping policy strands, each with different departmental responsibilities:

2.1 Research policy

15. The first and most obvious strand concerns research funding. The distribution of public funding for research takes place within a tri-partite relationship between the responsible government departments acting as budget holders, the agencies responsible for assessing research quality and distributing monies according to established formulae and protocols, and the university institutions responsible for carrying out research.

16. The universities receive their research funding via a system known as dual support. Under this system part of funding for research, the Quality Related (QR) element, is sourced from the education budget held by the Department for Education and Skills (DfES) or devolved governments in the case of Scotland and Northern Ireland. The Funding Councils distribute QR funds to the universities to provide for research infrastructure including part of academic salaries and some basic research. The level of QR distributed to each institution is determined by past research performance assessed by a periodic Research Assessment Exercise (RAE).

17. Current policy in relation to research funding is informed by international comparisons of UK research performance. Meeting the challenge of growing international competition lay at the heart of the White Paper 'The Future of Higher Education' (DfES 2003). As suggested above, the thrust of Government's proposals is to focus resources on the very best UK research performers and to concentrate those resources in larger units, the assumption being that further concentration would facilitate critical mass and drive up international competitiveness in several key areas of research excellence.

18. A second concern adumbrated in the 2003 White Paper is driven by renewed interest in how to forge stronger links between universities, business and the economy. Noting that less than one in five

businesses tap into the skills and knowledge of universities, the White Paper signposted a series of initiatives designed to encourage and reward those universities forging closer links with business.

19. These ideas have been followed by the more detailed recommendations contained in the Final Report of the Lambert Review of Business-University Collaboration. Whilst accepting the need for increased selectivity and concentration on world-class research, Lambert also argued that the dual support system may provide insufficient support to departments not rated world-class, but nevertheless engaged in work of value to business. It is this 'tension within the system' that led the Review to recommend a range of new and enhanced funding channels, including a new role for the regional development agencies funding directly those university departments able to demonstrate strong demand from business for research activities (Lambert 2003).

2.2 Science policy

20. A second part of the dual support system, funding for specific research projects, is distributed by the UK Research Councils (RCs). This second funding stream is functionally the responsibility of the Office for Science and Technology (OST). The OST has responsibility for the health and public funding of UK science. In addition to the RCs the science budget also provides support for a range of directly funded government scientific establishments and facilities.

21. Science policy is a key area of interest for the universities. In addition to being the major client group of the RCs, they are significant users of government research facilities. The latter also provide major opportunities for researchers from different organisations, including industry, to collaborate directly on projects that may have important regional, national or international dimensions.

22. The dual support system is predicated not just on national structures but on the long-held assumption that it is the research community itself that is best placed to determine its own priorities and investments. Furthermore it has been assumed since the earliest days of public funding of research that the priorities of research and the research system exhibit a dynamic of their own.

23. Intervention by government or other agencies in order to influence priorities and/or outcomes in terms of economic or social impacts has been a contested feature of the system and, until fairly recently, has proceeded only cautiously. How far the priorities of the research community are congruent with government priorities, especially in terms of national economic performance and competitiveness, has become an increasingly salient question, especially so with increased scrutiny of public investment in research and the higher education system generally.

2.3 Industrial policy

24. The third policy strand concerns industrial policy. Although there is a lack of consensus on what this term comprises, it has traditionally embraced thematic priorities concerning international competitiveness, innovation, competition and skills. More recently however two elements of policy – competition policy and technology policy - have been highlighted as key aspects of the state's interest in stimulating business innovation and competitiveness.

25. Universities are deeply implicated in this policy since they are themselves key players in helping to commercialise basic research. The assumption has been that closer partnership between business and universities will speed up the rate of commercialisation (Beath 2002: 225). In the UK at least such thinking follows precedents in the United States where university-industry partnerships have been seen as an effective antidote to perceived innovation market failures and a declining rate of technological innovation (Poyago-Theotoky et al 2002).

26. Creating the right climate in which industrial R&D can grow in the UK is the responsibility of the Department of Trade and Industry (DTI). Acting in its role as a proxy for business, the DTI provides the principal governmental vehicle for inserting a public interest angle on issues relating to industrial and business investments. The strategic objectives for both public and industrial R&D, as much as the overall level of spend, are key issues for the economic competitiveness of the UK and also exert a direct influence on university research activity through funding secured through business research contracts.

27. The terms of policy debates have shifted appreciably in recent years. While research policy has continued to reflect traditional concerns with performance and excellence, especially in relation to international competition, industrial (and science) policy has focused more intensely on processes and relationships

that might lead to greater commercialisation of basic and strategic scientific research carried out by universities. Indeed, the notion that universities can (should?) act as powerhouses of the knowledge economy is now entrenched in government thinking at the highest level. Such thinking encapsulates the idea that innovation and competitiveness hinge on the creation of entrepreneurial universities and that these in turn need to be closely integrated into the strategic aims of national, regional and local economies.

2.4 Regional policy

28. The fourth policy area overlaps with economic competitiveness but is regionally rather than nationally focused. The regional dimension of government policy is expressed in the work of the various Government Offices (GOs) distributed regionally and, at the centre through the Regional Co-ordination Unit (RCU). Since May 2002 both the GOs and the RCU have been located within the Office of the Deputy Prime Minister (ODPM) and have been responsible for delivering policy including inter alia policy for regional regeneration. The potential overlaps with DTI concerns with business and economic competitiveness are evident if not always clearly understood.

29. Universities are increasingly being drawn into this complicated policy arena because of the perceived direct and indirect impact of their work on regional economic performance not just through their research activity but increasingly through their collaborations with business generally. The most research intensive, like the University of Cambridge cited by Lambert (2003) undoubtedly see their research role primarily in international terms, but even for Cambridge the importance of local/regional links can scarcely be ignored. This point is raised again below. A key component of such links relates to business-university partnerships and the process of transferring the findings of research into business relevant applications. In this respect all research universities work closely with business and industry.

30. There is a further dimension to the notion of universities as engines of innovation and competitiveness. There have always been connections between universities and their regions and this has long been reflected in close ties between the profile of university research strengths and the presence of local and/or regional agglomerations of industrial specialisms. However, the rising political importance of regions has raised the prospect of formalising the links between university expertise in research and the delivery of strategic objectives for innovation and business development at the sub-national level.

31. In policy terms the assumption is that RDAs have a legitimate interest in their regional universities since interventions to stimulate university-industry partnerships will foster business innovation and competitiveness in key strategic areas. It is a logical step from this perspective to the view, referred to above, that the delivery of RDA objectives might be better facilitated by direct regional control of a portion of the research funding hitherto distributed according to national benchmarks and assessments.

32. It is therefore in the region – spatially as much as culturally - that the key questions addressed in this paper arise. They concern, on the one hand, the connectivity between university research activity and economic performance and, on the other, the importance of proximity and learning to the process of transferring the findings of research from discovery into application.

3 What are the economic benefits of research?

Universities are significant economic entities (as employers and as purchasers of goods and services), import talented people to their regions, produce knowledge and innovative ideas and offer consultancy, instrumentation and high-tech research services, short courses and industrial research training, and advanced and complex facilities for testing, imaging, and modelling. Cities benefit through reputation as well as employment and culture. Only some of these effects are research dependent but many benefit from research activity. What is less clear is which effects are located at the local (city) scale, which are essentially national and which have real regional effects.

Economic and policy studies have in the past sought to quantify the widespread assumption that basic research fuels a stronger economy. Recent syntheses have emphasised the more diverse benefits of research investment, particularly those affecting labour and capital. There are sound examples of good rates of return for specific research investment in some sectors, such as pharmaceuticals, but these are not readily generalised. In many fields, such as chemical engineering, the returns are less readily quantified because of spillover between discoveries and innovations. Although the generic benefit of research becomes diffuse, it nonetheless has measurable and pervasive impact mediated particularly by skilled labour.

3.1 The literature on regions and economies

33. In policy discussions the level of interest in regions is often conflated to that of the Regional Development Agencies (RDAs). However, in the economic and research literature the term is used to cover a range of scales and concepts from an immediate locale through city-wide, sub-regional, regional (sensu RDA), national, and trans-national areas.

34. To ‘region’ as a unit of spatial analysis, must be added the word ‘cluster’ as a unit of economic analysis. Both concepts have salience not just as analytical units but as political terms in debates about a broad range of government policies, particularly in relation to devolution and regional economic development. This undoubtedly presents some problems in analytical terms because there is an unhelpful elision in interpretative reviews, and then into policy documents, that crosses between scales and contexts. The problem of terminology is discussed further below and a review of the literature confirms the frequency of this problem. To better understand and conceptualise the relationship between research, regions and clusters three broadly related strands of literature were investigated.

35. The first focuses on the economic benefits of publicly funded basic research. This has been usefully summarised by Salter and Martin (2001) and others: the literature is reviewed in the next section. In essence there are three main methodological approaches – econometric studies, surveys and case studies. The principal findings support the view that there are high social rates of return to investment in basic research – although the estimates vary considerably, typically falling somewhere in the range between 20 and 50 per cent (Salter and Martin 2001: 514).

36. Despite these benefits the authors consider that it is not possible to arrive at simple policy prescriptions. Nor do they highlight any overt regional elements in the existing literature on economic benefits. However, work by the Centre for Urban and Regional Development Studies (CURDS) has suggested that universities have a significant effect on their surrounding region. This may be through direct employment, through demand for goods and services and through the spending power of students. In addition, universities act as net importers of highly skilled people who are then available to the local labour market (Goddard et al, 1994; Charles and Benneworth, 2001).

37. Much of this is potentially unlinked to research, although assumptions might be made about interdependencies. Furthermore, the scale is undetermined: region may be limited to the university’s host city but it could extend over a wider area; scale may vary according to other economic and geographic factors. Possible research specific outputs would include the very highly skilled workforce generated by research training (and there may be added value from graduates trained in a research rich environment), local exploitation of transferable knowledge, and the local establishment and retention of spin-out

companies. Many effects could be relatively small scale and may not be sustained over any period in a way that allows an association between the profile of the research base and the profile of the economy.4

38. The second strand focuses on business clusters. This is an old but currently burgeoning field in which issues relating to clusters and regions may be seen as two distinctive strands. Economic studies of business 'clusters' have deep roots, traceable back to the eighteenth century theories of Adam Smith (1776) and, in the late nineteenth century, Alfred Marshall (1890). The issues have been summarised in a report for the DTI by Trends Business Research (2001 Volume 3) and need not be rehearsed in any detail here.

39. The key source cited in the DTI report (and elsewhere) is Porter's (1990) argument that the more geographically localised an industry the more internationally competitive that particular industry is. The concept has also been developed in various ways by other economists (for example, see the concept of high-skill ecosystems, Finegold 1999), economic geographers and economic historians (see for example: Cannadine 1984; Hudson 1989; Sabel and Zeitlin 1997).

40. Silicon Valley and Route 128 are the most frequently cited examples of clusters (e.g. House of Commons 1976), but similar phenomena are indicated elsewhere. The two classic USA examples are clearly regional. The carpets cluster in Belgium is in an area about 20x100 km. Some other exemplars are more local in nature. One example is the Cambridge area in the UK (see below). Historically too, UK clusters of textile production were sub-regional rather than local. The wool-based cluster in West Yorkshire was linked to the foundation of the Yorkshire College in the latter part of the C19 and its departments of Mechanical Engineering, Colour Chemistry and Textiles. The College provided technical training, a knowledge base, and research facilities required by the local industrial base and aimed at maintaining a competitive edge over French and German rivals.

41. A more explicit focus on the region and regional dimensions to economic policy may be discerned in the third strand of literature, discussions of knowledge transfer. This is not a particularly coherent strand but one that embraces several related, sometimes disparate, themes concerning organisational learning, organisational 'competences' and economic performance, and technology transfer.

42. For example, a series of articles in the Cambridge Journal of Economics (1999) reflected the (re)discovery of core competences as a central determinant of economic performance in organisations. The argument, in brief, is that in an age of rapidly evolving technologies, turbulent markets and complexity of knowledge and information, competences – what organisations 'can do well' – and core competences – what they 'do better than others', are essential to business performance (Amin and Wilkinson 1999 – the definition of competences is from Prahalad and Hamel 1990).

43. The notion of competence has been extended to include analyses of the behavioural influences on different types of learning, the relationships between proximity and learning, problems in the mobilisation of tacit and codified forms of knowledge – the study of each aspect of competence being a reflection of the importance of learning and adaptation to competitive survival. Extension of the competence theory of the firm to analysis of region – the concept of 'learning regions' is one manifestation - is evident in several of these papers (see especially Lawson 2002) and provides further evidence on the importance of proximity between organisations to interactive learning processes (see Maskell and Malmberg 1999).

44. A related strand of academic literature in which universities, research and regions figure more explicitly is provided in various studies of the processes involved in technology transfer. A central question running through this literature is how different economies effect efficient transfer of technologies. For example, addressing this question from the American perspective it has been argued that different cultural, legal and regulatory traditions play a key role in the formulation of various regional approaches to technology transfer (Schmiemann and Durvy 2003).

45. It has also been contended that regions themselves may act as 'regional innovation systems' thereby raising important empirical questions about the interplay between regional policies, technology and innovation policies systems' (Leydesdorff et al 2002).

46. An important paper on this theme in an American context by Zucker and Derby (1996) provides a relevant empirical analysis of the diffusion and commercialisation of bioscience breakthroughs. It focuses on the research 'stars' that form the scientific elite, the forces shaping their behaviour, particularly in relation to ties across university-firm boundaries. They suggest that 'star scientists embodying breakthrough technology are the "gold deposits" around which new firms are created or existing firms transformed.'

[4] CURDS produced a benchmarking tool to evaluate the regional impact of a university. The document has rather few measures that relate specifically to the university's research function. Charles, D and Benneworth, P (2000) A benchmarking approach to the evaluation of the regional impact of a HEI. Available at http://www.ncl.ac.uk/unireg/hefce/draft-tool.doc.

Such scientists have a key role to play in both national and regional growth, particularly, as the authors confirm, ‘where knowledge is tacit and requires hands-on experience.’

47. Zucker and Darby’s findings challenge some of the established parameters of thinking about the relationship between basic and applied research, and the importance of star researchers to the location and development of new biotechnology enterprises (NBEs). The authors identify levels of activity among 207 stars who have ever published in the USA. They found that among these stars those with greater commercial involvement had higher average annual citation rates to genetic-sequence-reporting articles. For the USA as a whole, stars with firm affiliations and with patented discoveries are cited over 9 times as frequently as ‘pure’ academic peers with no such patents or commercial ties. They also found that many new firms in this field were ‘literally “born” with strong ties to academic star scientists’

3.2 The literature on the economic returns on research

48. The bulk of the material gathered for this part of the review was published after 1990. (Only two of the top 10 papers ranked by numbers of citations were published earlier). Most of the key literature identified the need for research to focus, show value for money and demonstrate potential to perform. In order to demonstrate value for money, assessment of research in terms of the outputs generated (or their potential to be generated) was a particular focus. The most influential (highly cited) paper expressing the need for an explicit and systematic science policy indicated that this could only be constructed on the basis of an evaluation of the output from research (Martin and Irvine, 1983 p61).

49. The location of the studies covered by the literature spans a wide geographical area but is focused primarily on North America (17 studies in the USA and 1 in Canada) and Europe (14 in the UK and 4 others across the EU). In some instances, the geographic location was not definable - for example in the case of general commentary or overview pieces. Other studies covered: OECD nations (1); China (1); Netherlands (1); Australia (1); Zimbabwe (1); Morocco (1); and the Republic of Ireland (1).

50. The case for spending on research rests on the assumption that basic research fuels the engine of a stronger economy (Sornette and Zajdenweber, 1999 p653). In 1969 the Department of Education and Science (DES) commissioned work to quantify the economic benefits of scientific research. The study attempted to specify the national benefits arising from university teaching and research in science and in doing so illuminate the broader impact of research activity (Byatt and Cohen, 1969). In the USA, other major studies sought to measure the impact of funded research in a number of subject/industry areas (Mansfield, 1998). A focus on State or Government return for funding has been matched by similar studies focusing on the returns made for R&D spend by commercial organisations. Grilisches (in the USA) studied a large number of companies, spanning a number of industry sectors, which invested in research activity and developed mechanisms for measuring the rate of return on their investment (Grilisches, 1980). The importance of the spillover effects of research and the relationship between university research and its capacity to lead to innovative commercial applications have also been central to recent studies (Grilisches 1979; Mansfield and Jeong-Yeon, 1996; Martin and Trudeau, 1998; Pavitt, 1985; Sornette and Zajdenweber, 1999).

51. Commercialisation of research, or the transformation of research results into innovative products, was a recurrent theme or issue within a great deal of the literature. Spillover effects and spin-outs were also considered as methods used to commercialise research in many of the papers reviewed (Bania et al, 1993; Rappert, 1997; Rappert et al, 1999; Rappert and Webster, 1998; Reed, 1991)

52. Key literature discussed the problems associated with defining and assessing the economic impact of ‘basic’ research as the term basic encompassed a variety of activities. Some use the term basic to imply experimental or theoretical research and others use broader terms such as scientific and academic research. Therefore the term has been taken to include these various permutations of definition (Martin et al 1996).

53. One recognised way of assessing the economic impact of research activities is via a rate of return analysis. Two routes to determining rate of return are well documented in economics textbooks: the private and the social rate of return. A private rate of return measures the benefit acquired from a successful research project to its principal investors. The social rate measures the wider benefits that accrue to society. Whilst some of the literature acknowledges these two rates of return much is focused on specific, quantifiable and direct benefits associated with research investment (Hall, 1993).

54. As noted earlier, Martin et al (1996) indicate three main approaches to measuring the economic benefits from basic research: (i) econometric studies (e.g. of rates of return); (ii) surveys (e.g. of the views of industrial R&D managers); and (iii) case studies (e.g. tracing the research inputs to innovations).

55. Investment in research can result in a number of the six benefits listed above although the financial worth of the benefits gained are linked to such factors as developments in the field, technology and industry. As a result of this fluidity, it is difficult to develop a consistent model of the economic benefits of research investment. Some studies focusing on areas such as biotechnology and optical communications show a clear and direct impact of investment in basic research, but in other discipline areas research is plagued with uncertainty and variability in terms of the importance and utility of discoveries made. For some, "the path from discovery to application is full of surprises" (Sornette and Zajdenweber, 1999 p653).

56. This uncertainty and variability is also present in other activities. Comparisons have been made between investment in research and investment in the development and production of feature films. An analysis of feature films and their potential and actual earnings shows the distribution of returns to be wide and inconsistent. The conclusion is drawn that the impact of research and investment in it is often fuzzy and delayed in time: " important discoveries need a suitable fertile background which derives from long-term investments in education and research and the aggregate cost entailed is very difficult to apportion to a set of discoveries" (Sornette and Zajdenweber 1999 p 662). Mansfield indicated that estimates were unstable and although illuminating were "at best a very crude beginning" (Mansfield, 1992 p296).

57. Generally, studies exploring returns to research have focused upon commercial application/industrial innovation and the returns achieved for the private sector. A major study was conducted in the 1960s and 1970s exploring the relationship between the various measures of company productivity and investment in research and development. The study consisted of an analysis of research and development expenditure of 883 organisations with over 1000 employees. A consistent positive relationship was found between various measures of company productivity and investment in R&D when these organisations were split into industry type: (1) Chemicals and petroleum, with a 43% private rate of return; (2) Metals and machinery, 43%; (3) Electrical equipment and communication, 8%; (4) Motor vehicles and transportation, 31%; (5) Aircraft and missiles, 4%; and (6) other, 44% (Grilisches, 1980).

58. In a major study carried out in the 1980s, Mansfield sought information from 77 major firms exploring the percentage of new products and processes based upon academic research. Firms included: drug and medical products (16); information processing, (14); chemical, (13); electrical, (10); instruments, (10); machinery, (10): and metals (4). The evidence confirmed earlier results where it was claimed that over 10% of the new products and processes introduced in those industries could not have been developed (without substantial delay) in the absence of recent academic research (recent in this case being within the last 15 years). Later, Mansfield noted that the time lag between research and associated product innovation had reduced on average from around 7 years to 6 years – indicating a faster exchange from knowledge to products and processes (Mansfield, 1998: p774).

59. As persuasive and respected as Mansfield's work is, it is not without its critics: "The outputs of basic research rarely possess intrinsic economic value. Instead, they are critically important inputs to other investment processes that yield further research findings, and sometimes yield innovations, … Policies that focus exclusively on the support of basic research with an eye to its economic payoffs will be ineffective unless that are also concerned with these complementary factors" (Pavitt, 1991a).

60. Exploring these complex linkages between investment in research and its eventual commercialisation, Mansfield carried out further work to explore the characteristics of the universities and academic researchers that seem to have contributed most to industrial innovation. His paper, based on data obtained from 66 firms in seven major manufacturing industries and from over 200 academic researchers, helped to illuminate the sources, characteristics, and financing of academic research underlying industrial innovation. He concluded that whilst a significant proportion of industrial innovations are based on academic research there is considerable variation in the amount of credit given to academia for conducting the work (Mansfield, 1995).

61. Recent initiatives have attempted to temper the unpredictability of the research process by quantifying the performance of investment with pre-specified goals. However this "control" approach hinders the development of the rare "pearls" of research and also encourages excessively cautious planning (Sornette, 1998 p663).

62. Drawing upon their survey and case study work, Martin et al (1996) found evidence of a number of the six different forms of economic benefit highlighted above:

- It is not logical or feasible to use estimates to show the rate of return to publicly funded research because of the complex ways in which the benefits are captured. A major problem is the complex linkage between investments in basic research and inter-dependent activities.

- Estimates of the rate of return to basic research are based on questionable assumptions, but most estimates of the impact of research on productivity show substantial positive returns.

- There are several forms of economic benefit from basic research – new and useful knowledge is not necessarily the principal type of benefit;

- Instrumentation is important – the transfer from basic research to industry can open up new technological opportunities or dramatically alter the pace of technological development;

- Skills developed by graduate students conducting research can lead to substantial economic benefit as they move on and carry with them codified and tacit knowledge;

- Well-developed basic research capabilities are required in order to sustain technological development in advanced industrial countries.

- Tacit knowledge and skills generated by basic research are particularly important in new and fast-moving areas of science and technology.

- Involvement in basic research activity is essential in order to develop and belong to international networks of expert opinion;

- Basic research may allow the development of problem-solving skills that are of great benefit to firms and organisations confronted with complex technological concerns;

- 'Spin-off' companies can be the result of basic research allowing the direct transfer of skills and knowledge;

- Economic benefit arising from investment in research varies by scientific field, technology and industry sector – no simple model of the nature of economic benefits from basic research is possible;

- Basic research should not merely be viewed as a source of useful codified information, there are wider benefits such as trained researchers, improved instrumentation and methods, tacit knowledge, and membership of national and international networks; and

- Economic benefits arise in a number of ways and they key issue should be how to best organise the national research system to make the most effective use of them.

63. Martin and Trudeau (1998) similarly note that traditional economic impact studies seek only to assess how spending on research affects the rest of the economy: "they do not describe its underlying, dynamic impact on the two primary factors of production, labour and capital" (Martin and Trudeau, 1998 p2). As such they only throw light on the tip of the iceberg in terms of true economic impact. Analysing Canadian data, Martin and Trudeau conclude that investment in research yields large economic impacts – in both the static and dynamic dimensions. Headline figures based on conservative calculations show a net increase, based on university expenditure, of more than $1.5 billion of GDP and 13,500 jobs. However, an exploration of the dynamic impact of investment in research reveals an increase in over $15 billion of annual GPD and 150,000 to 200,000 jobs. A key reason for this assertion being made is that: "university research is the common denominator for knowledge creation and knowledge transfer in the economy … University training supplies students with knowledge, information and research skills. After they graduate from university and find employment, students become a primary source of innovation in the organisations they join" (Martin and Trudeau, 1998 p6).

4 *Defining clusters and setting scales*

In reviewing the background for this report it was necessary to consider the various definitions and interpretations that have been applied to the concepts of regions and of clusters. The flexibility of both of these has value and neither needs to be redefined but attention should be drawn to the problem of meaning. Poorly defined concepts become weasel words in the development of evidence-based policy.

4.1 Regions

64. What is a region? For this report, the level of interest is that of the Regional Development Agencies (RDAs) established by the UK Government. Each region includes several large cities, which are often the location of major research Universities. In the economic and research literature the term is used to cover a range of scales from an immediate locale through city-wide, sub-regional, regional (sensu RDA), national, and trans-national areas.

65. It is pointless, if not impossible, to provide a single definition of region to apply to the source research literature. There is an unhelpful elision in interpretative reviews and then into policy documents, however, that crosses between scales.

66. The University of Cambridge has unquestionably had a strong impact on the economic development of the area around Cambridge. Lambert (2003) points out that high-tech employment has doubled between 1986 and 1998 and much of this is related in some way to the University. The outcome is dramatic but, as TBR (2001) point out, this is a district effect. Although some commentators include this as a regional cluster it does not extend much beyond the local environment except insofar as it affects housing and transport. Nor is it evident that Cambridge has ever had much effect on the wider Region of the East of England. The cluster of internationally excellent plant biotechnology at the University of East Anglia has a more pervasive relevance to the Region, but less recorded economic impact. On the other hand, Cambridge also leaps the scale and is unquestionably one of the UK's outstanding international research institutions.

67. Attention is drawn to this because the issue of geographical scale has been fudged in some areas of policy development. If the evidence base is to be used properly then it must make proper reference to this issue of scale. The University of Cambridge is a model of success. It has a local effect on a city and its environs. It indirectly benefits the economy of the Region but is not pervasively linked to it. It has a network of national and international collaborative links in the public and private sector.

4.2 Clusters

68. What is a cluster? Clusters were initially identified as an important area of economic development in the Competitiveness White Paper (DTI 1998). The concept is important here because part of Government policy development focuses on the relevance of knowledge production in the research base to business success via local and regional links. The range of research is wide but what is cited as a cluster in one piece of research is not the same thing as that in another. Researchers usually recognise this but the difference is not always made clear in derivative documents.

69. Many authors have drawn attention to the early origins of the concept that like minded individuals and companies benefit from working together. It seems probable that the earliest considered reference is by Adam Smith, who noted how inter-relatedness of trade brings businessmen together; "artificers, too, stand occasionally in need of the assistance of one another... they naturally settled in the neighbourhood of one another" Smith (1776). Frequent reference is also made to Marshall (1890) and Krugman (1998).

70. The more modern model of the cluster concept is that of Michael Porter (e.g. Porter 1990, 1998) whose extensive work has shaped much of current academic and policy thinking. Trends Business Research (2001) in a study for DTI have provided a detailed theoretical background to this in Volume 3 of their report and the reader is referred to this for both detail and bibliography.

71. In essence, knowledge based and innovative industries benefit from agglomeration and proximity. Reasons for this are linked to direct access to knowledge producers (usually, Universities but also other companies), the ready movement of highly skilled and knowledgeable people and supply chains. The

people aspect is critical, because people are now recognised as key resources in themselves but also because they transfer tacit knowledge (know how) rather than just codified (published) knowledge.

72. The Competitiveness White Paper quotes in an analytical report that “Other authors have emphasised the importance of other external benefits within a cluster. Knowledge "spillovers" are an example. Empirical research has shown that there is a positive link between such spillovers and the proximity of innovative activity. It may seem paradoxical that, with the advances in ICT, co-location should still be seen as important. Advances in ICT speed the flow of information but the assimilation of tacit knowledge and innovation requires the kind of repeated contact and collaboration that is easier when firms are co-located. As has been said, "Intellectual breakthroughs.... cross hallways and streets more easily than oceans and continents".

73. The Porter cluster thus includes specific companies and their suppliers, both in terms of products and services and in terms of people and knowledge. It thus includes Universities. The inter-relationship between the University and local business then becomes a legitimate issue for policy attention, and the Lambert Review (Lambert 2003) focuses on this.

74. The DTI itself uses other definitions of cluster in different publications, as do many other agencies. Sometimes cluster is used not in a geographical sense but in the sense of an industry sector. Thus, reference is made to an UK aerospace cluster spread between Avon, the West Midlands and SW Scotland. Trends Business Research, (2001) identify a typology of clusters:

- Vertical production chain (possibly transnational)
- Aggregation of connected sectors (Porter type cluster)
- Regional cluster (regional aggregation of connected sectors, but sometimes crossing political boundaries)
- Industrial district (local concentrations, sometimes specialist)
- The network (not necessarily co-located, possibly transnational)
- The innovative milieu (not necessarily co-sectoral)

75. There are other issues linked to clusters, such as maturity, depth and dynamics, and the types above are not exclusive. The DTI report produced by TBR (2001) looked particularly at regional clusters, not necessarily linked to the research base, of exceptional employment significance to the region.

5 *What do companies want from higher education?*

Research is not the only way in which universities have an economic impact. Their purchase of goods and services and their role as employers and importers of skilled people makes them important regional players.

More than half the services bought and investments made by industry are related to teaching.

Industrial investment in university contract research has declined from about 14% to less than 10% of the HE sector's R&D income over the last twenty years, although the international excellence of the UK research base has improved. That is less than 2% of R&D spend by business.

5.1 What universities do

76. Universities are major players in the economy of their cities and regions.

- Kelly et al (2002), in a report for Universities UK, quantified the impact of higher education on the economy. In 1999/2000, the combination of direct and indirect employment, earnings from overseas and spending by overseas visitors and students amounted to some £35 Billion of output and over 550,000 jobs or some 2.7% of the UK workforce. These figures exclude the local economic effects of staff and student spending and the demand for goods and services.

- Charles (2003) reports that 60% of universities identified the economic development of their local region as a high priority in their missions, although that proportion was lower in the south east of England than elsewhere. An effective way for universities to improve economic development is to improve the competitiveness of neighbouring companies[5].

- Universities bring talented people and provide them with high level skills and training, and many graduates choose to stay and work in the area where they studied (http://www.yorkshiregraduates.info)

77. What do universities produce that benefits companies? Innovative knowledge that leads to new products and processes is only one item in a much more diverse menu. Crespi and Patel (2003) report on recent work at SPRU (see also Martin et al. (1996) and Salter et al. (2000)) and summarise the main ways in which research contributes to industrial R&D. Their list and others identifies the following direct and indirect elements of economic benefit:

- Economic entity – universities are major employers, their staff and students have a huge total spending power, and the institution itself has a massive demand for local goods and services.

- Highly skilled people with skills and training that can be applied well beyond the scope of the specific degree subject.

- Very highly skilled people, who have been engaged in and therefore carry know-how from cutting-edge **research**.

- Services to industry including:

  - Contract **research**

  - Access to **research** instrumentation –laboratory instruments and techniques

  - Access to **research** design tools and techniques - including modelling, simulation and theoretical prediction not available within companies

- Spin off IP from **research** usable as products (end-user and instruments) and processes.

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[5] See also Charles and Benneworth (2001) and related research from CURDS (University of Newcastle upon Tyne) for much greater depth on the wide ranging role that universities play in their regional missions and their social as well as economic contributions

- Spin-off companies based on knowledge accumulated and discoveries made in **research**, which can contribute to the local economy and attract more activity.

- Background knowledge – tacit knowledge emerging from **research** of direct use to industrial practitioners and knowledge leading directly to prospects of application

- Scientific publications – codified knowledge emerging from basic **research**

78. This list makes the point that a university has direct value to its 'region' whether or not it is doing research. The value of all these things may be increased by research but some aspects are not necessarily dependent on research. Even within the research-dependent list, some elements are not obviously tied to location, although proximity is a factor flagged by many companies as a requirement for collaboration.

5.2 What companies buy

79. Research may make up less than half of what companies spend in universities. The Policy Studies Institute carried out a 1989 survey of UK 'Top 200' companies for the Council for Industry and Higher Education (White and Horton, 1991). This survey found that the two largest areas of corporate spending in universities were R&D, as expected, and support for students, which was a novel and unexpected outcome. Furthermore, spending in these areas was at a roughly similar level. In addition there was spending on teaching through sponsored chairs, continuing education and training, and other industrial short courses. Thus the total industrial support for teaching was somewhat greater than that for research. Research itself included not only contract research but also LINK schemes and academic consultancy.

80. Data on sources of funds for teaching and student sponsorship are not collected on a standard basis so the figures in the CIHE report cannot be readily updated. The only figures available are those from HESA on 'other services rendered' which have remained at around half the value of research contract income over recent years. OECD data on business expenditure also suggest that total business investment in HE is about twice the level of industrial research grants and contracts reported by universities.

81. Compared with overall growth in the research base, the relative level of industrial support for contract research in universities has fallen over the last 15 years. *Evidence*'s long-term dataset of expenditure within the UK research base reveals the decline of R&D spend by industry in the higher education research base (Figure 1). It is worth also pointing out that the research impact of the UK has actually increased in international comparisons over the same period.

82. In 1984-5 industrial research contract income to UK universities represented nearly 14 per cent of total research grant and contract income. By 2001-2 the proportion had fallen to less than 10 per cent (Figure 1). This analysis shows that industrial investment in public sector R&D has failed to keep pace with other (mainly public) sources of funding. Not only that, but there is the somewhat anomalous picture of a decrease on the demand side of knowledge transfer during a period when the product quality on the supply side appears to have increased. The product got better but the demand fell.

83. The level of research spend in universities should also be set alongside the total R&D spend by companies. The DTI's R&D Scoreboard estimates that research expenditure by UK companies in 2000/01 was about £15 Billion. This compares to a figure from the Higher Education Statistics Agency (HESA) of about £250 million on university contract research supported by UK based industry, or about 1.6% of the UK corporate total. This proportion is a little higher than some other estimates but broadly agrees with *Evidence* analyses of long term trends in OECD data on BERD and HERD[6].

84. The conclusions from this are troubling. Research is only part, perhaps a minor part, of what UK industry chooses to source from universities. Industrial investment has fallen as a share of university research income although universities have more and better research to offer. This supports Lambert's conclusions that the 'problem' in transferring knowledge to users is squarely on the demand side. There may be more engagement actually in place, but the evidence does not show it.

[6] BERD is expenditure on R&D in the business sector. HERD is expenditure on R&D in the HE sector, including research contracts from industry. BE-HERD (spend by business in HE) has varied between 1.5-2% for the last 15 years.

6 *What is the structure of the regional research base?*

The UK research base is strongly influenced by a long history of research growth around London

There is now a great disparity in the capacity and, to a lesser extent, the quality of the research base in different regions. The three regions on the south east quarter of the UK have the greatest concentration of research (over 40% of UK research staff), have a higher level of activity per staff and have a concentration of research excellence. Bio-medical and physical sciences are more concentrated than engineering and technology.

On the whole, differentiation in the range of research between regions is less marked than the disparity in capacity and, to some extent, quality. The south east has an exceptional level of biological and medical research and there is strong engineering and physical sciences in some other regions.

It is difficult to see how this concentration of infrastructure and activity can readily be re-balanced by regional strategies, even if it were desirable to do so. Regionally differentiated research bases would not necessarily provide a long term benefit to the regional industries to which knowledge might be transferred, since industry draws on many sources of innovation.

6.1 Introduction

85. The UK research base performs strongly in international comparisons (Figure 1; Adams 2002; Adams and Smith, 2002). It is dynamic and has improved in performance at all levels over the last fifteen or so years, but earlier studies have shown that research is not uniformly distributed across the UK regions, in terms of either volume or performance.

86. This section of the report presents a broad quantification of the research profile for each region and asks:

- How great is the disparity between the strengths of the regional research bases?
- Is there a differentiation between the specialisms of the regional research bases?

87. A high level assessment is easier to digest, and to complete, within a review of this kind. At the same time it may miss important underlying detail, particularly in differentiating between research themes within major fields. However, there is only rarely a one-to-one link between a research specialism and innovation in a significant industrial sector. It is more usually the case that one research field (for example, chemistry) contributes pervasively to innovation across multiple sectors (see Crespi and Patel 2003 and sources reviewed therein) while any industry (for example, IT) draws on research from many sub-fields to enable its innovative products and processes.

88. The steps that have been followed have been to:

- Analyse and compare the regional distribution of departments graded 1-3, 4 and 5 in the UK Research Assessment Exercise (RAE) and research active staff.
- Group these departments within the 8 disciplinary categories that are used for the *Evidence* Higher Education Research Yearbook: (1) clinical, (2) biological and (3) physical sciences; (4) engineering & technology; (5) social sciences, (6) humanities, and (7) creative arts; and (8) subjects allied to health and medicine.
- Map total and industrial research grant and contract funding, research student output (PhD awards), research publication and impact (performance measured as average citations per paper) and to analyse this by staff FTE (full time equivalent, rather than head count) where feasible.

6.2 The origins of regional research patterns

89. An historical pattern of investment dominates the present research landscape. The distribution of Public Sector Research Establishments, concentrated around London and along the Thames-Avon corridor, influences the research base and has an effect on the national distribution of research. One North East

(the Regional Development Agency) specifically refers to the absence of Government sponsored research facilities in the context of regional R&D weakness. Some regions have more HE institutions and this affects research diversity as well as capacity. The regional distribution of members of the Russell Group of leading research institutions is fairly even (Table 1) but universities which have had decades if not centuries of investment in facilities are inevitably placed in a position that predisposes further capital and recurrent investment to build on that infrastructure.

90. An historical pattern of investment dominates the present research landscape. Those Universities that have had decades, if not centuries, of investment in facilities are inevitably placed in a position that predisposes further capital and recurrent investment to build on that infrastructure.

91. The research base contains more than just Universities. Since the early part of the 20th century there has been a strong axis of public sector research investment along the London-Bristol corridor. This now encompasses such major non-University establishments as Aldermaston (Atomic Weapons Establishment, 1940s), Porton Down (Defence Science and Technology Laboratory 1916) and the Rutherford Appleton Laboratory at Didcot (CCLRC, 1921). The MAFF Central Science Laboratory was at Slough until moving to Yorkshire in 1996. The Meteorological Office has been at Bracknell since 1912, though now moving to Devon. The Laboratory of the Government Chemist (1843) and the National Physical Laboratory (1899) are also located in the south-west edge of London.

92. This regional concentration of public sector research establishments has been noted before. It inevitably influences the evolution of other parts of the public sector research base, and it also has an effect on the general national distribution of research activity. The recent debate over the future of the research at Daresbury in Cheshire (linked to RAL, Didcot) reflects the importance attached by regions to securing such facilities. One North East (the Regional Development Agency) specifically refers to the absence of Government sponsored research facilities in the context of regional R&D weakness.

93. Some regions have more HE institutions and this affects research diversity as well as capacity. The following table shows, however, that the regional distribution of members of the Russell Group of leading research institutions is fairly even (Table 1).

94. The largest four research institutions (Cambridge and Oxford Universities, Imperial and University Colleges) are clustered in the south-east quarter of the country. The research portfolios of these four have not developed in ways that are obviously dependent on their location. Three of these have had an exceptionally long period of development as institutions with national research significance. Imperial has evolved more recently (1872), but its exceptional post-Robbins development as a science and technology focussed specialist, subject at times to overt policy influence, was not emulated by similar institutions further away from Whitehall in Manchester (UMIST) and Glasgow (Strathclyde).

95. The ‘big civic’ universities in the Russell Group have often had strong links with the technology interests of the industrial heartland supporting their city. These ancient links, perhaps allowed to fall into abeyance as missions evolved, reflect the stimulus for their foundation.

- Glasgow (now jointly with Strathclyde, itself once a Royal College of Science and Technology) supports a School of Naval Architecture and Marine Engineering with extensive large scale facilities that are as relevant to innovative renewable energy technologies as to their Clydeside ship-building origins.

- Leeds inherited Departments of Textiles and of Colour Chemistry & Dyeing that were parts of the original foundation of the Yorkshire College, aimed as much at the training of skilled technologists for West Yorkshire industry as for the development of original research.

- Newcastle’s School of Marine Science and Technology maintains large facilities that support research with national and international links although the original marine construction industry on the Tyne is now much changed.

- Sheffield has extensive research activities associated with steel and has been associated with the shift to high quality specialist products in the South Yorkshire industry.

96. The major expansion of the higher education system in the 1960s was driven by and associated with national rather than regional policies. The institutions then created, or that then became independent, often have a broad and undifferentiated subject base although in some case this has acquired particular flavours. There are many research strengths, of which much is of national and international significance, but some exhibit a more local linkage.

- East Anglia has particular research strengths in agriculture and plant biotechnology that are the product of its association with a suite of specialist public and private research laboratories linked to the Norwich Research Park. This cluster springs from the economy of the surrounding area.

- Warwick has a strong association with the motor industry sector in the West Midlands. It had Rootes money (from the local car industry) at an early stage, reflecting the area's demand and support for a university. The Warwick Manufacturing Group continues to have active links to related industry around the Midlands (Lambert 2003, para 5.21).

97. The former polytechnics, which became Universities in 1992, have more obviously local associations because of their original mission and focus. Many have also acquired national and international status in specific areas. The local associations are originally derived from their urban location, but others have branched out into strong regional networks supporting training, access and lifelong learning. The research base of these institutions has not, on the whole, been marked by top grades in assessment; greater selectivity in research funding would tend to move resources away from this part of the research base (Lambert 2003).

6.3 Regional research capacity

98. Research capacity is related to the numbers of research active staff and the diversity of units in which they work. Regions vary in the distribution of staff numbers across departments. This leads to different balances between the sciences and the arts. Figure 2 and Figure 3 summarise the distribution by region of research active staff submitted to RAE2001. Nationally, a high proportion of those staff who are in grade 5 (the most highly rated) departments are in the three regions in the south east quarter of England (East, London, South East). This is not just a consequence of concentration of university research. The same regions also have a higher relative proportion of their total staff who are in grade 5 departments.

99. The differential distribution of staff at different grades is made clear if one considers, for example, at staff in science and engineering UoAs (Figure 3). Less than 20% of science and technology staff in the South East and the West Midlands and less than 25% in the East and Yorkshire & Humberside are in grade 4 units. By contrast more than 40% of the science and technology staff in the East Midlands are in grade 4 units and so are more than 60% of the science and technology staff in Wales and Northern Ireland. For the social sciences and the arts and humanities there are similar patterns of regional difference. The East, South East and London all have 25% or fewer staff in grade 4 units while Scotland has more than half its staff in such units.

100. Table 2 summarises the regional distribution of units by grade and subject area. The concentration of highly graded research units in the south eastern regions is again apparent. The numbers of units affects more than just staff numbers, it also affects research diversity. Larger units will, on the whole, be able to support a greater diversity of specialisms than smaller ones. Given a like for like spread of units of different size, a region with more units will tend to have greater breadth in its research and hence be able to offer a richer spectrum of research.

6.4 Regional research activity

101. This overview looks at selected components of the research process: inputs, outputs and impact. What research activity is generated by the research staff?

102. **Inputs**. This covers both the total project-based research income (distinguishing this from the core research income from the Funding Councils) and that part of it that comes from industry. Income is a good reflection of success in competing for limited funds and of capacity for doing research. Income per staff provides a further reference point. A balance between public and private sources reflects the mix of fundamental and applied research.

- Total research grant and contract funding and relative funding per FTE (Figure 4)

- Research contract funding sourced from the private sector as a total and as a fraction of total grant and contract income (Figure 5)

103. **Outputs**. This is simplified this to two measures: people and knowledge. Highly skilled people are a key resource for employers and provide the most effective means of transferring know-how and tacit knowledge. Codified knowledge comes in the form of journal articles.

- PhD awards (Figure 6)

- Papers recorded on the databases of Thomson ISI® (Figure 7)

104. **Impact**. For University research, the influence that each published paper has on the wider community can be indexed by counting the number of times it is subsequently cited. More influential papers have more citations, or greater 'impact'. Excellence is frequently associated with units that have more citations per paper on average, particularly in the natural sciences. Citation rates vary between fields but this can be accounted for by benchmarking against world average within each field.

- Citations per paper (Figure 7)

6.5 Regional research disparity

105. The data in Figures 4-7 provide a set of complementary maps, each reinforcing the impression of the others. It appears from these maps that university research is highly concentrated in the south eastern quarter of England (the three RDA regions of London, East of England and South East England).

106. The impression can be roughly checked by aggregating the activity data by region (Table 3). The Table shows that the broad impression is indeed correct. More than 40% of UK activity, and about half of English research, is in the three regions around London. Activity is even more skewed than staff capacity in these regions. The share of research activity for the south east exceeds the share of staff across all measures. To put it another way, there is a concentration of people and there is more money per person.

107. The average research quality of the regions also differs. Figure 7 provides information on research performance, measured as citations per paper indexed against world average for each subject area. World average is indexed at 1.0, which is the second line up on each of the small figures. Research impact in the three south east regions is always above world average, with the exception of arts subjects, and often at 1.5 or above. In most of the other regions, impact tends to vary around world average or slightly above, with some specific exceptions noted below.

6.6 Regional research differentiation

108. Two factors might affect the diversity of research in a region. First, there is the mix of different types of University and the various influences of their histories. In fact, inspection suggests that no substantial differences in regional research specialism would arise from this since each has both older and newer institutions. There is thus little to build on *at this level* in developing a regionally specific research strategy, and industry would no more benefit from sourcing its knowledge on any regionally differentiated basis than by seeking the best research wherever it occurs.

109. The second factor affecting diversity leading to possible differentiation stems form the disparity in volume. If there are differences between subjects in the degree of concentration, then this will produce an apparent differentiation between regions. That is, some region may seem to be more specialist simply some subjects are more or less concentrated. This does seem to be the case.

- Clinical research is strongly concentrated in London and in the South East and East regions where research income generally and Research Council income per FTE particularly is also highest. There is no evidence that output per FTE is any higher in those regions, but research impact is much higher there than in any other region except Scotland.

- Biological sciences are concentrated in the same quarter, although less so than clinical. Research income, in total or by source, is more even across the regions with East Midlands and Yorkshire & the Humber matching the East and South East and exceeding London. Productivity is similarly even, but only West Midlands matches the south eastern quarter on impact.

- The spread of the physical and mathematical sciences is less concentrated, but East and South East lead on per FTE total research and Research Council income and on productivity. Output and impact is strong in North East, where physical sciences are an important strength in the research base, and good in many areas but East, South East and London are in the top four.

- Engineering and technology is probably the least concentrated science and technology area. Research income per FTE is highest in South East, East Midlands and Wales with peaks of industrial income per FTE in East Midlands and Wales. Productivity is highest in South East and East but impact is second highest, after East, in South West.

110. Regional peaks, as a share of research within a region compared to the national share, can tentatively be identified. However, these relative peaks may not always be an exceptional national peak if they are a consequence of differences in the underlying disparity. That is to say, the may stand out because of greater weakness in other subjects rather than because of strength.

- London - the research base is dominated by its peak of medical research which makes up almost half of the total research activity in the region;
- Eastern England - physical and mathematical sciences are a peak for income and output;
- South East – biological sciences and physical sciences;
- South West – subjects allied to medicine and physical sciences both have an above average share and both are above average on impact;
- West Midlands - engineering & technology and social & related sciences both have a strong share of regional activity; biological sciences is stronger on impact;
- East Midlands – engineering & technology stands out, particularly on industrial income although not on impact, but social & related sciences is also strong;
- Yorkshire & Humberside – engineering & technology and physical sciences are the peak shares;
- North West – physical & mathematical sciences are a peak strength and physical sciences does marginally better on impact;
- North East - physical & mathematical sciences are strongest on impact and, for income, engineering & technology;
- Scotland – biological sciences is a regional peak and impact is better in biomedicine than most regions outside the south east;
- Wales – there is an inconsistent pattern between indicators but engineering & technology is strong except on publications.

6.7 Conclusions

111. There are significant disparities in the research capacity and performance of the regions. Much of the difference in research diversity between regions is linked to that initial difference in concentration and capacity. The greatest concentration of research activity is in the bio-medical and related sciences and in the three regions around London. This area has been a focus for public sector research development, not only in the HE sector but also in other establishments, for over a century. Some of the key HE institutions have a far longer research history.

112. It is difficult to see how the fact of regional disparity could be readily overcome in any broad strategy for research support, even if it were desirable to do so. It seems likely, if it is true that knowledge-based industry would be more likely to benefit from and therefore move to clusters of research, that the disparity will inevitably have a continuing impact on regional economic growth.

113. As might be anticipated, the indicative evidence of regional differentiation in research really requires more detailed examination. Although there are very likely to be local specialisms at a sub-disciplinary level, and many of these may be linked to local or regional industry, this is not carried through to convincing distinctions in research profile or capacity. This is almost certainly a product of a national policy for the development of higher education which has resulted in a dispersed distribution of educational and training (and hence research) capacity across subjects. This is least apparent in the clinical sciences, which have clustered around the major teaching hospitals in or near London, and most apparent in engineering and technology, which has supported the UK's former broad manufacturing base. This pattern may suggest that there is a different link between research strength and industrial activity to be tested, where research concentration would be seen to change as the regional industrial base declined.

114. It was noted earlier that there is a many-to-many relationship between research innovation and new products and processes. It could be regionally differentiated research bases would not necessarily provide a long term benefit to the regional industries to which knowledge might be transferred. New industry may need to draw on a wide range of innovative sources, while key disciplines may be a source of innovation for many sectors. Universities might seek to grow their research strengths to match industrial concentrations, as the big civic universities did in the past, but the cost of significant research growth of real value to industry will be a major hurdle for most to address.

7 *What is the regional distribution of industrial R&D?*

Industrial R&D is concentrated in south eastern England and it is even more concentrated than public sector research. The three regions in the south east account for 60% of company R&D spend and 75% of company research publications.

Most of the companies that produce research publications (indicating research that is less near-market) are in the top 200 of the DTI's R&D Scoreboard of 700 companies. These spend £15 Bn of the UK's £16 Bn annual industrial R&D. There is a correlation between the volumes of expenditure and publication.

7.1 Introduction

115. There is a significant regional disparity in the concentration of the research base (Table 3) but less differentiation in research profile, at least at the broad level explored in this study. This section asks related questions about the industrial users of research.

116. Industry wants access to research to be able to explore problems related to innovation and development and to access tacit as well as codified knowledge at the earliest possible stage. It also wants to acquire highly skilled people, so this interaction is complex. It is widely suggested that many of these needs are better met by proximity between producer and user (e.g. Lambert 2003), leading to the beneficial effects of clusters (Porter 1998). Because there are some excellent examples of clusters, albeit on a diversity of scales, the phenomenon has been generalised (see Appendix).

117. Is there any general relationship between the structure of the research base and the pattern of the industrial R&D base? And how much of the UK R&D structure corresponds to the favoured 'Porter' model? This is a huge and challenging problem. The Higher Education Business Survey has provided a qualitative overview (Charles 2003). This paper starts to explore quantitative aspects.

118. Only some commercial research activity can be indexed; much is difficult to map, some is hidden and the motivation for industrial funding of university research is complex. The mapping here is necessarily partial, but it is mapping nonetheless. It is mapping of that part of commercial research that spends most on R&D and interacts most with the public sector research base via knowledge creation and dissemination. Some of the data are about R&D inputs (expenditure) and some are about outputs (research papers). It will be pointed out that it is not the business of business to publish its results. Research publications do, however, provide a medium for business to share codified knowledge and thus engage with the research base in pre-competitive research.

119. The source of data for this part of the analysis is the DTI's R&D Scoreboard.

- The R&D Scoreboard is produced by Company Reporting Ltd and the 2003 R&D Scoreboard includes the top 700 international companies (companies with R&D over £34m) and the top 700 UK companies. The Scoreboard says how much money is spent on R&D by each company but not where it is spent[7].

- UK companies are matched to research locations via *Evidence*'s database of Thomson ISI® research publications for the UK. This provides additional information on published outputs (not necessarily a commercial priority) and on research location from author addresses. The address data identifies regional locations for R&D input and output activity.

120. The questions to address here include:

- What is the distribution of industrial R&D, in terms of input and output?

- Is there a relationship between R&D spend and publication output? [Collaboration in publications is analysed in the next section].

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7 Business R&D expenditure is variously reported by source and by site of spend. BERD is a standard OECD measure of R&D performed in the business sector. This may be 'in house' spend or as a contract from another company. HERD is R&D performed in the HE sector, but this may be financed by the business sector or by Government or by the institution itself. Here, we measure the sum of business R&D expenditure as the company reports its spend and this may have been directed to R&D in-house or elsewhere.

121. A later section draws on a recent 'clusters' report for the DTI by a consortium led by Trends Business Research (2001). This focuses not on R&D but on the main employment sectors for each region and thus provides a further cross-bearing on business clusters. It asks whether there is any regional differentiation in employment clusters and whether this relates to R&D.

7.2 Companies on the R&D Scoreboard

122. The data on R&D expenditure by companies are not entirely transparent. First, a company may make adjustments in the allocation of funds between different accounting heads in order to present a particular kind of picture of its investment strategy. Generally, R&D spend is seen as positive because of its contribution to innovation and competitiveness whereas returns were in the past seen as too long term by some stakeholders. However, it remains true that estimates may either over- or under-estimate true spend. Second, the sector in which R&D investment is made is not usually identified in aggregated data. This makes it difficult in any brief overview not to appear tentative about conclusions. Third, company reports are published by head offices, not the sites where the R&D takes place. An ability to reconcile company R&D outputs to addresses (see below) does, however, enable us to posit a proxy location for R&D capacity. And, of course, there is research investment by non-UK companies and there is spend by business in other research sectors.

123. The Lambert Review (2003) notes a broad trend in company research , that companies "are moving away from a system in which most of their R&D was done in their own laboratories, preferably in secret, to one in which they are actively seeking to collaborate with others in a new form of open innovation." Elsewhere it has been concluded that industry engages in research leading to publications for a number of reasons (Godin 1996, Hicks and Katz 1997, Calvert and Patel 2003) but the most important is using codified knowledge as an entry to networks accessing tacit knowledge. Crespi and Patel (2003) note that if companies signal their capability in a scientific area, then this allows them to join knowledge networks in fast moving areas of science and technology. They conclude that one way of assessing the importance of different disciplines is to examine the distribution of publications involving scientists based in firms.

124. *Evidence* has carried out an address reconciliation for all UK research journal publications recorded by Thomson ISI®. Crespi and Patel (2003) note that "In an ideal world an examination of which scientific fields are important in which industrial sectors should be based on all publications by firms". The *Evidence* database now allows us for the first time both to identify which firms are publishing and to allocate these publications to specific geographical locations.

125. Potentially the data could also be disaggregated by field and impact then benchmarked against universities but this was not central to this report. There is also an issue about mapping classifications. The companies are classified according to industrial sector but the publications are classified according to research discipline. If one maps between the two then a rather diffuse and complex picture emerges and it is not clear if either classification provides a 'better' picture. This is because of a second reason for side-stepping categorisation. There is a many-to-many relationship between fields of research innovation and fields of development application. A research outcome can have application in many areas, while process innovation draws on many discoveries. This seems to be most true in engineering whereas biotechnology research has less pervasive application outside pharmaceuticals (Crespi and Patel, 2003).

126. There are three questions to be asked about industrial R&D input and output.

- Is R&D expenditure and publication output correlated?
- What are the regional locations of firms with significant R&D budgets?
- Which regions are the main sources of publications for R&D active companies?

7.3 Linking R&D spend and publications

127. The top 700 UK companies, ranked by R&D spend, were linked with unique organisations in the *Evidence* publications' address database. R&D active UK companies are dominated by pharmaceuticals & biotechnology (40%) and aerospace & defence (9%) whereas internationally the largest sectors are IT hardware (22%), automotive (18%) and pharmaceuticals & biotechnology (17.5%). Total R&D spend is about £16 billion per year.

128. There was a clear pattern for the highest R&D investors also to be more commonly active research publishers. Most of the top names in the table were in the publications' database; most of the bottom of the table were not. This strengthens the overall analysis. It also has implications for proposals by Lambert (2003) who points out that public money should not subsidise near-market research. Which company-university relationships might it be directed to? Codified (published) knowledge is a marker of research that is not near-market.

129. There was an apparent sectoral split, so that companies in manufacturing and engineering appeared lower in the table and were less likely to publish in journals. Engineering research in Universities also makes extensive use of non-journal publication modes; conference proceedings are much more likely to be appropriate as a communication forum. It is therefore desirable to spread this analysis to other modes of publication.

130. This analysis focussed only on the top 200 companies, for which there was good publication as well as financial data. This still covers £15 billion of the £16 billion total spend in 2002. There was a total spend of just over £60 billion in the period 1998-2002. This is very clumped, with just 20 companies spending over £100 million per year. The variation in reported R&D spend per company is significant, ranging from GlaxoSmithKline at about £2,500 million per year through to the 200th company at around £5 million per year. There is also a great deal of year to year variation within companies.

131. The companies among the top 200 in the R&D Scoreboard were matched with the unique organisation names in the *Evidence* address database and all their associated address variants were extracted. All linked publications for the period 1993-2002 were then abstracted from the UK ISI publications database (the ISI National Citations Report).

132. There were 17,572 unique publications for these companies. For each publication, the postcode component of the address for the named company was extracted and linked to a specific region. This meant that for any one company the R&D output could be partitioned by specific laboratory or establishment. The commonest address variants and postcodes were linked back to the R&D expenditure data from the R&D Scoreboard.

133. Expenditure and publication data are summarised by region without reference to company or sector (Figure 8). It would, of course, be feasible to disaggregate this analysis further and consider the detailed pattern for each sector but for present purpose the overall pattern is sufficient.

134. The concentration of R&D activity in the regions around London was noted by TBR (2001) and later by Lambert (2003). TBR (Main Report, para 3.12.5) report "a concentration of software and R&D in the south and east of the country – it is clearly an attractive location for these activities, many of them internationally mobile". It is a long established pattern, as noted above. Over 60% of company R&D spend is by firms with research arms located in the south east quarter (Table 4). The University research regional distribution shows a similar, though less marked, disparity: about 40% of HE research activity is in this quarter (Table 3).

135. Some company internal R&D distribution may potentially be misrepresented, because of the necessarily arbitrary way in which spend has had to be allocated. Thus, most Ford spend goes to the East of England because most Ford publications come from Dagenham.

136. Almost 75% of research publications co-authored by the top 200 companies come from laboratories or establishments in the same regions. Thus, not only is R&D very concentrated regionally, and more concentrated than University research, but that part of commercial R&D which is publishing and most likely to interact with the research base is most concentrated. The leading publishers by far in the East are GlaxoSmithKline (as it is for London) and Merck Sharp & Dohme. The South East is less concentrated but Pfizer stands out. Thus, the concentration by industrial sector is also clear; it is in pharmaceutical and related areas. In the university research base this is also more concentrated in the south east than other disciplines.

137. Trends Business Research (2001, section 3.8) also refer to the clustering of R&D in the south east and comment that outside those regions there are "less well defined relationships between research excellence and clusters". The East Midlands has 6.5% of company R&D spend but only 3.8% of outputs. Reference back to Figure 2.4 shows that this region also has a relatively high University industrial research contract income for engineering. Journal publications are less common in this research area, compared to conference proceedings. This suggests some coherency between the different analyses. In fact, the bulk of publications are sourced from Rolls Royce, Astra Zeneca and BG Group (natural gas). East Midlands RDA is one of the few to identify power generation as a cluster priority (see later section on RDAs).

138. The North West and Yorkshire & Humberside also have publication deficits compared to Company spend. Corus is the lead publisher for Yorkshire & Humberside, but in the North West there is a complex of significant volume publishers including Astra Zeneca, Unilever, Shell, ICI and BNFL.

139. The West Midlands was identified in the research base analysis as an area of relatively high research performance but it is very low in the analysis in Table 4. Scotland similarly has much lower commercial R&D intensity than the size of its research base would have suggested. BP, Shell and Exxon are notable players on Scotland and reflect the significance of the energy sector.

140. The summary conclusions are that:

- There is a correlation between the indicative R&D spend of companies and their propensity for publishing in research journals.

- Industrial R&D, measured by the address locations of companies with recorded expenditure and publications, is concentrated in the south east quarter of the UK, particularly for pharmaceuticals

- Industrial R&D is more concentrated than the research base, though in the same direction.

8 *What is the regional distribution of industrial collaboration?*

R&D-intensive companies collaborate with a wide network. In addition to collaborative partnerships with universities from many regions, most companies also have extensive overseas collaborations.

This raises issues about the significance of proximity as a factor in business-university research relationships. It may suggest that proximity is more important for the less R&D aware, but proximity may also be important for reasons other than research itself.

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141. Lambert (2003) comments at para 5.19 that ‘businesses are clear that proximity does matter’. He goes on to note that data from the DTI Community Innovation Survey shows that this particularly applies to SMEs and to firms with local markets. Firms with local markets choose to work with local universities for about 90% of their collaborations, but firms with regional markets go national for over 50% and firms with wider markets seek overseas collaborations (Lambert 2003: Table 5.2; data from DTI/ONS).

142. How significant is proximity in partnership for the most research active companies? On the whole, the data on R&D expenditure and publication suggest that the most research active companies are also those with active collaborative engagement with the research base, engaging in the sense of participating in publishable research less close to market. Inevitably, by their size and resources, these will be companies with national and international markets and so should fit Lambert’s category of broad collaboration. This can be quantified by analysing the pattern of industrial links, via co-authorship with the research base?

143. The source of data for this part of the analysis comes via the publication profiles of all UK companies that have published in journals indexed by Thomson ISI®. Again, it is acknowledged that many companies have in the past had little interest in the dissemination of codified knowledge, but those that increasingly do so also increase their interaction with the research base.

    - The numbers of publications co-authored with the UK HE sector were tallied, as were the numbers of publications that were co-authored outside the UK.

    - The regional distribution of co-authors was assessed. The distribution of co-authors is a measure of the extent to which companies draw preferentially on proximity partners compared with the extent to which they draw on the best partners wherever they are located.

144. Because *Evidence* can reconcile all UK addresses for research publications on the Thomson ISI® database to named organisations, the broader patterns of university-industry research collaboration can be explored and its geographical pattern then determined.

145. Sylvan Katz (e.g. Katz and Martin 1997; Smith and Katz, 2000) has looked at the geographical pattern of research collaboration, calibrating distance between collaborative partners and assessing trends. He has shown that the median distance for collaboration (the distance within which 50% of collaborators may be found) tended to increase between 1981 and 1994. The percentage of pairs of collaborations that occurred within 20 km decreased from 39% to 19% (excluding London data, Smith and Katz 2000, para 152). This mirrors a trend for increasing international partnerships.

146. In this analysis, only co-authorship is used as a criterion for collaboration. Funding is an equally good, or better, measure of the value a company places on University research. However, such data are not readily available but joint publications are likely to be associated with contracts. The data type does mean that this analysis is biased towards those sectors that favour journal publication as an output mode, so life sciences will tend to predominate over engineering.

147. Firms with local markets, and SMEs generally, may differ in their R&D investment and research intensity from firms with wider markets. They may therefore differ in their capacity to interact with the research base and in their interest in research that is not near-market. It cannot be stated definitively that this is so: some SMEs are highly innovative and research active having spun out of the research base. Nonetheless, attention is drawn to the categorical distinction that Lambert has shown.

148. University collaborators for industrial publications can be considered from a number of perspectives:

    - Did R&D active firms, in the sense of being active authors or co-authors, tend to have few or many University partners?

- Did R&D active firms tend to have a wide network of partnerships or to focus their collaboration locally and regionally?

- Did R&D active firms show any pattern of internationally collaborative publication?

149. To do this, ISI's UK publication database for 1981-2002 was processed to reconcile 2.5 million address lines to a database of unique organisations and their address variants. These were categorised by sector (Univ, Public, Company etc) and data was then abstracted for all the publications for a recent ten year period (1993-2002) that included a Company among the organisations in their address field irrespective of whether this address was associated with the first or other authors..

150. For the Company data sample, all the co-author addresses for each Company were then determined. The unique organisations for each address were identified and a matrix of collaboration for each Company was developed. The collaborating organisations were then assigned to regional groups.

151. Table 5 shows the collaborative distribution pattern for all companies with 15 or more papers co-authored with a UK University during the 10 year period. Regions are listed clockwise from Scotland to North West. The numbers of papers that had at least one international co-author are also given.

152. The companies at the head of Table 5, which is ranked by number of University collaborative publications not by total volume, are often those that were picked out in the R&D Scoreboard regional analyses (above). Thus, they are lead industrial publishers for their regional location and also both lead collaborators and very diverse collaborators.

153. The data show that many companies have a regional spread of collaborations. Others have clear regional bases. For example, BT with a research base at Martlesham is firmly plugged into the south eastern research base. Filtronic publishes mainly within Yorkshire and Humberside, its home region. DanBioSyst and Pharmaceutical Profiles similarly have strong local links in Nottingham. Imutran is linked into Cambridge.

154. It is equally clear that many leading companies draw on as much and sometimes more expertise from outside the UK. In fact, international co-authorship extended well down the list and beyond the cut-off point used here. This fits with the model that suggests that those with knowledge awareness seek the best researchers to work with, not the most readily available. The impression is that, in this sense of publication and collaboration, the most research active companies have knowledge links with many institutions in a diversity of regions. Paul Miller (Trends Business Research, pers. comm.) suggests that another interpretation here is that a cost is borne by industries in needing to collaborate outside a proximity cluster. This then raises a policy issue about the concentration of research.

155. If research intensive companies are likely not to focus on proximity as a criterion for research collaboration then proximity as a justification for collaboration is more likely to be associated with less research intensive companies and sectors. This conclusion appears to be in accord with Lambert (2003) and others, but it does focus attention on the question of the research-collaboration potential of those companies that are not high in the R&D Scoreboard and are not collaborating on knowledge outputs with the research base.

156. The summary conclusions are that:

- The earlier work by Katz (Smith and Katz 2000) suggests that proximity remains an important factor in collaboration but that collaborative distance is increasing over time.

- R&D active firms (in the sense of being active authors or co-authors) tend to have many University partners and to have a wide regional network of partnerships. R&D active firms also publish extensively with international collaborators.

- It seems likely that the tendency of companies to co-locate with cognate sectors of the research base is driven by factors other than access to research *per se*.

- It may be concluded that proximity matters more to those less closely engaged in R&D, working close to market and less likely to invest in the research base.

157. These conclusions raise questions about whether the co-funding of research collaboration that is not close to market is likely to achieve the intended support of research awareness and engagement in those sectors which are not presently making effective use of the knowledge potential of the research base.

9 What is the regional distribution of employment clusters?

Employment clusters seem to match R&D rather better in the south east than in other regions with more mature industries which have a weaker R&D base.

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158. For the purposes of the current study, the summary of clusters mapped for the DTI by Trends Business Research (2001, Figure 2) were abstracted and are shown in Figure 9. Business Clusters in the UK – a First Assessment' uses a definition of clusters and a methodology that focuses primarily on exceptional concentrations of employment. It identifies the industries that are 'over represented' in a region in terms of employment and which are significant employers. It then groups them together to form a 'cluster'. While this type of cluster has no necessary R&D linkage, it does reflect an important aspect of the regional economy because it focuses on employment. The industries are not necessarily the most research active but they are the ones where the jobs are located.

159. The report led by Trends Business Research contains a huge amount of detailed information on industrial clusters, grouped by region. It contains a full and detailed methodology. The DTI web-site comments

> "Business Clusters in the UK - A First Assessment, published in February 2001, is the first UK-wide systematic assessment of UK clusters. It has been prepared by Trends Business Research for the DTI. Its purpose is to provide a snapshot of existing clusters across the UK to inform the thinking of Lord Sainsbury's Clusters Policy Steering Group and the development of clusters policy. It will be used by the Regional Development Agencies (RDAs) as a base source of information for their clusters development work.

> "The report is based on employment data and, although supported by qualitative information, it will not identify all embryonic or aspirational clusters. The joint DTI and DfEE White Paper Opportunity For All In A World Of Change, also published in February 2001, encourages RDAs to continue developing existing and embryonic clusters in their regions building on their existing capabilities."

160. TBR note at section 3.12.5 of their main report that "the UK's deepest and apparently strongest clusters are found in the south east of the country … south eastern clusters tend to be more service based while the northern clusters tend to be built around ... manufacturing" and at 3.12.6 "some region's clusters are spread thinly and lack depth". This is consistent with findings relating to the concentration of bio-medical research and pharmaceutical R&D.

161. In other regions, strong clusters are less evidently associated with knowledge intensive activity. Paul Miller (Trends Business Research, pers. comm.) confirms that it is often difficult to establish the nature and strength of research-company links within regions. Universities can themselves be vague about such links, perhaps because of the kudos placed on research collaborations that have national rather than local status. This reflects the competing agendas in the perception of value associated with university-business links.

162. The next section reviews the cluster priorities of the RDAs. On the whole, it is found that these map most easily onto employment clusters in the south east and Scotland. They map less well in the English midlands. This is perhaps because many employment clusters represent mature industries. The emphasis of the innovation agenda is on new and emerging sectors, such as C&IT, materials and biotechnology, but sustaining the competitiveness of the established employment clusters might reasonably be deemed to have some significance.

10 What are the strategic priorities of the RDAs?

The headline cluster priorities of the English RDAs and Scottish Enterprise show a great deal of similarity. They focus particularly on pharma-biotechnology, communications and IT, leisure industries, advanced/aerospace engineering and tourism. If new research funding was used to support these priorities then there would be competition between the regions for key researchers. Such competition could work against the research objectives of other funding agencies and might weaken the national research base.

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163. Lambert (2003, Recommendation 6.3) suggests that the network of Regional Development Agencies (RDAs) are well placed to manage a new funding stream of business-relevant research funding. The priorities they place on different areas, or clusters, might reasonably be expected to be a key policy signal of regional strength and the potential for investment.

164. The English RDA web-sites were searched to determine their cluster priorities.

- Is there an alignment between the RDA cluster priorities and the research strengths of the regions, and between the RDA cluster priorities and industrial clusters?

- What is the degree of differentiation between the regions?

165. The cluster priorities that could readily be identified are summarised in Table 6. Data for Wales and Northern Ireland was not available. Only the headlines are listed here and some RDAs make it clear that there are also sub-regional priorities. The headline information is itself a little difficult to access in some places (specific data sources are listed). If it takes several layers of mining to pull out this essential strategic information then it might be pointed out that a challenge is imposed upon both knowledge producers and users before they can engage with the regional strategy.

166. It is evident that there is a great deal of commonality between the regions. (To help with the analysis a reference column is inserted to the left of the Table but the words used on the regional web sites are retained in the Table.) It may be argued, almost certainly correctly, that there is actually a significant level of differentiation between the regions at a more detailed level. At the broad level, however, all regions (indeed all economies globally) are focussing upon rather similar innovation objectives. It is the more innovative and emergent sectors (C&IT, biotechnology, tourism) where overlap is most marked.

167. The lack of regional differentiation will have implications for research. There is a many-to-many relationship between innovations and applications. Innovations from research in a University chemistry department can have broad application not only across the chemicals industry but in many other areas from biotechnology to materials. It is for this reason that Crespi and Patel (2003) were able to demonstrate the pervasive linkage of research in engineering and physical sciences.

168. The sectors highlighted in bold in Table 6 and Figure 9 indicate that there is a degree of alignment between RDA priorities and employment clusters in the south east and in Scotland. This alignment is less apparent in the rest of England, but a certain degree of interpretation is required. The disparity in industrial R&D volume between regions indicates that most RDAs will have a limited industrial research base on which to draw. The low level of regional research base differentiation means that an alignment between research peaks and RDA priorities could only be partial.

169. In other words, in most regions, the generalised nature of the research base would appear to have little specific linkage to regional priorities but the nature of the knowledge transfer chain may make research base diversity the most desirable outcome. The disparity in capacity and performance appears a more serious issue. To put it another way, basic research of value to one RDA's priorities, and to the industries the RDA wants to stimulate, is as likely to come from its neighbours – or from concentrations of excellence further afield - as from within.

11 What are the implications and what are the options?

The evidence seems to suggest that the Lambert (2003) proposals will not benefit regional research and economies if they remain focussed on research co-funding. It is also possible that none of the new industry clusters that the RDAs seek to promote can be established unless the more serious hurdle of regional R&D disparity is overcome.

Intensive industrial research is co-located with concentrations of high-quality basic research but not because it needs proximity to source expertise. It shops globally. If clustering is not driven by research alone then it must be led by other factors more dependent on location, perhaps the ability to recruit highly skilled people.

Non-R&D intensive industry spends less and has less capacity to handle knowledge. Proximity to universities may be an issue but, if it is, then low investment and low interaction make these companies challenging partners. Their R&D activity will be close to market and so cannot be subsidised by match funding. University rewards will be limited and uncertain, since investment is falling and these companies seem less likely to commit long-term. In consequence, universities will need persuading that this is a fruitful and appropriate mission and they will need substantial resources to underpin their efforts.

RDA priorities are problematic because they are competitive. Short term funding pulses cannot counterbalance decades of investment in infrastructure. There is potential tension between national and regional objectives for the research base, which could create unsustainable dispersal of former concentrations of activity. Regional research budgets and strategies may be insufficiently stable for purpose, whereas research investment is repaid over a long period and not always in direct or predictable results.

Regional disparity will not be remedied by policy tweaks and it would be a heavy price top pay if it were tackled at the cost of existing R&D excellence. It is possible that the only effective way of changing the regional balance will be by a sustained and focused increase in investment in a research base that supports a wide range of industrial opportunities.

170. The UK is perceived to have a problem in turning its knowledge capital into commercial innovation. Industrial R&D funding for universities has declined over the last twenty years, despite the rising excellence of the UK research base (Figure 1). Lambert (2003) suggests a shift from a national to a regional strategy to address this problem, through the engagement of the RDAs in co-funding business-university research collaboration.

171. This paper has considered whether regional management of research funding provide a remedy and thereby increase and diversify business investment in university research and boost regional economies. The evidence leads to two considerations. First, whether the hurdle of regional disparity may need to be overcome prior to the realisation of any benefit from a regional R&D policy. Second, whether co-funding of research is a tool likely best to aid businesses already engaged with the research base.

172. The most research intensive businesses have clustered around a concentration in the national research base, reinforcing a disparity that will be difficult for any regional policy to overcome. The companies in the south east represent not just the gross bulk of industrial R&D but the overwhelming specific part of the R&D base that demonstrates an ability to interact effectively with the HE research base. Research publication is an indication of research that is less close to market (and therefore more acceptable for public support) as well as being an indication of a company's preparedness to engage with the research base and to contribute to knowledge networks.

173. For these companies, proximity is balanced by sourcing excellence wherever it occurs yet there is a common concentration of basic and applied research that must surely be driven by some linking factor. If this is not research itself (if the co-authorship data are right) then it must be things that the research base supplies that are more dependent on location. It may be that the particular requirement is the 'people thing' flagged in many studies on the economic benefits of research: the ability to recruit the best and most highly skilled people from nearby universities (Figure 6) as businesses in clusters do from other companies.

174. If true, this would be a signal about which policies might be most relevant to regional research and what might be more effectively retained at national level. The indication is that the broad sweep of research investment should remain a national strategy and regions should concentrate on funding related to the 'people thing' including tacit knowledge transfer. This will not be easy because of the nature of the companies that are not engaged.

175. The rest of industry, outside the R&D intensive group, not only spends less but has less capacity to handle innovative knowledge. It is, presumably, this group for whom proximity to knowledge sources is the issue. It is this group that the Lambert proposals would seek to assist through match funding of collaborative research. However, their low level of investment, output and hence interaction will make them challenging partners to work with: they are not 'intelligent customers' in the sense of Lord Sainsbury (26 January 2004, quoted in Hansard). Furthermore, it seems likely that more of their R&D activity will be close to market and Lambert (2003) argues, in line with established policy, that it is specifically in this area that public money should not be used.

176. The university research base will see significant costs in developing this partnership and finding the resources to bring these businesses up the learning curve. The rewards will appear limited and uncertain, at least for the foreseeable future, and these companies seem the least likely to commit significant long-term spend. In consequence, universities will need persuading that this is a fruitful and appropriate mission and they are likely to wish to see substantial resources to underpin their efforts. This simply does not look like a major source of future income for collaborative research especially if that is not near market and therefore eligible for subsidy incentives.

177. The RDA priorities are both sensible and problematic. They sensibly focus on those sectors that are universally agreed to be the most likely breeding grounds of innovative, knowledge intensive companies. They are problematic because they are inevitably competitive. Current strengths in the research base and in industrial R&D are in similar sectors and in the south east, and the playing field is steeply tilted. This must raise a question about the likelihood of success if that depends on relatively small volumes of additional local expenditure.

178. For instance, consider the high priority almost universally attached to biotechnology-pharmaceuticals. There is only so much basic research funding, from Research Councils and charities; there are only so many talented researchers; there is only so much venture capital. The risks are both that small pulses of RDA investment will be nugatory, failing to ignite cluster development at an adequate level, and also that there will be a draining reduction of existing excellence, spreading talent and resources to a greater number of smaller centres. Simply put, without a more profound adjustment in regional R&D levels, why would established industries move their research north of the Trent and why would a new biotechnology company not move to join the cluster of research, R&D and potential employees in the south east of England?

179. If the RDAs were to have significant funds to invest in the research base to support their priorities then what might ensue?

- Short term funding pulses cannot counterbalance decades of investment in infrastructure. Too many units with sub-critical mass will not be able to continue to deliver the same standard of national research excellence. The former polytechnics gained access to additional research funds after the 1992 Research Assessment Exercise. Some of them sought to develop their research profile by investment in big science, attracting research leaders from established groups elsewhere. The consequence was the unsustainable dispersal of some former concentrations of activity.

- It is not clear that RDAs are always an appropriate structural unit for research. The Research Councils will continue to operate a national strategy, and some of them actively facilitate structural as well as thematic coherence in research programmes and in the optimal location of key facilities. The RDA strategies may not fit easily with this. Furthermore, it is unlikely that poorly differentiated regional research strategies would add anything creatively to current national research policies.

- Regional research budgets and strategies have elsewhere been found insufficiently stable for purpose (USA: McPherson and Schapiro 2003) or the possibility of research regionalism has conjured such fears (Germany: Einhäupl 2003). National research strategies, supported in their different ways by the science and higher education budgets, have tended to be long term and sustained. This has fitted well with the nature of the research environment, where investment is repaid over a long period and not always in direct or predictable results.

180. How might the RDAs use any additional resources for research? Lambert (2003, recommendation 6.3) leaves this to the RDAs to decide but suggests that they should match contributions by business to basic and strategic collaborative research projects with universities. But, if this were to be the case, then the money would inevitably tend to facilitate good pre-existing collaborations. The gap, and the proximity factor, lies with companies with poor interactions and less focus on basic research.

181. RDAs could invest the money in basic research directly to support their clusters, by developing and populating new and enhanced research facilities. Indeed, there is some evidence that such investments have already started. If this were to be pursued, and RDA priorities were to become no more diverse, then

the total investment in key research areas will grow but in an uncoordinated way that risks over-dispersal of national research effort, particularly of the most talented people.

182. UK policy has recently focussed on the benefits or otherwise of greater selectivity in research funding (Adams and Smith 2003). To tip the balance of research capacity any further would frustrate any attempt to follow Lambert's proposals. On the other hand it would frustrate the thrust of national policy if regional strategies drove a dilution of research concentration. That is the dilemma that policy markers now face. It seems that the only way to redress regional disparity without national risk would be to make the investment additional to that directed to current peaks of excellence. Such funding might still be selectively focussed, but if so then the findings here indicate that it should be on institutional excellence rather than on specific disciplines notionally essential to specific industries.

183. Whatever emerges from current policy deliberations, the issue of business-university links and the exploitation of knowledge for economic benefit leaves longer term questions, not least those regarding the implicit tensions between regional strategies and national agencies.

- Will RDA plans tend to work against DfES policies for supporting existing excellence?

- Will RDA priorities work against Research Council disciplinary strategies for structured investment in facilities and leading research groups?

- Will RDA investment increase HE's funding plurality, and will regional initiatives add to or detract from those at a national level?

12 Figures and Tables

This section includes all the figures followed by all the tables referred to in the text.

Figure 1 Research contract income from industry and commerce as a proportion of total project based research grant and contract income to UK universities and the bibliometric impact (citations per paper) of UK research compared to world averages

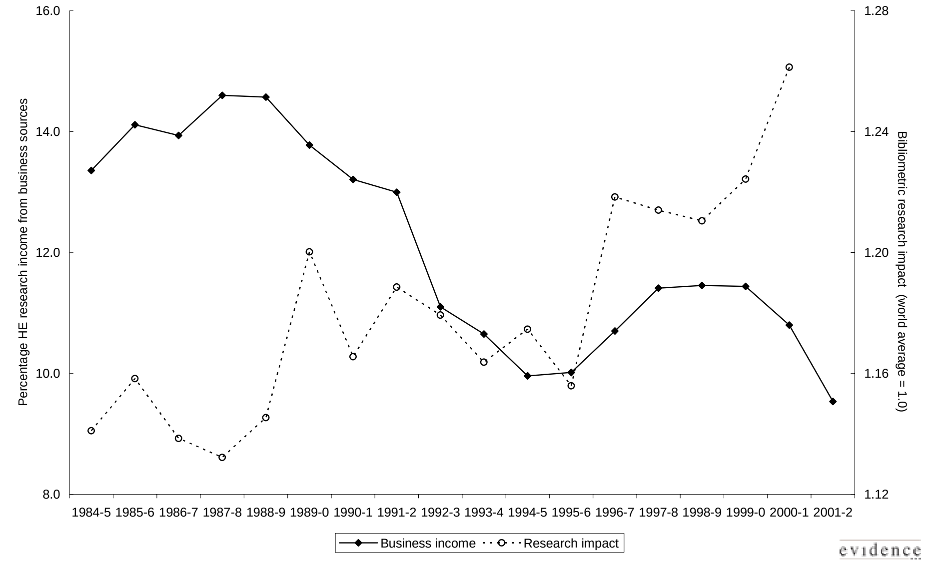


Figure 2 Staff FTEs in grade 4 and grade 5 departments across all subject areas

Figure 3 Distribution of research active staff by region and by grade

Each table shows the numbers and FTE of staff by grade. Data are disaggregated for science & technology and for social science, arts & humanities. Numbers are given for units graded at 1-3, which no longer receive research funding, 4, and 5/5*. Data for the grade 4s is also analysed as a %ge funded units, because 4s are funded at a much lower rate.

Subs = the number of units submitted to RAE2001. This is equivalent to the number of research units and reflects the diversity and spread of research in the region.

FTEs = full time equivalent research active staff included in these submissions. This reflects the total research capacity in the region.

NW	Science & tech		Social & arts	
	Subs	FTEs	Subs	FTEs
1-3s	24	202.6	68	670.1
4s	33	602.6	34	514.2
5&5*	40	1180.2	47	1047.9
All grades	97	1985.4	149	2232.2
4 % 4+5/5*	45.2	33.8	42.0	32.9

SC	Science & tech		Social & arts	
	Subs	FTEs	Subs	FTEs
1-3s	36	330.3	61	526.0
4s	47	898.8	72	1173.0
5&5*	53	1864.2	58	1010.7
All grades	136	3093.3	191	2709.7
4 % 4+5/5*	47.0	32.5	55.4	53.7

NE	Science & tech		Social & arts	
	Subs	FTEs	Subs	FTEs
1-3s	19	171.9	32	344.3
4s	12	231.3	20	277.0
5&5*	22	617.9	24	335.9
All grades	53	1021.1	76	957.2
4 % 4+5/5*	35.3	27.2	45.5	45.2

NI	Science & tech		Social & arts	
	Subs	FTEs	Subs	FTEs
1-3s	8	136.7	12	144.1
4s	12	276.5	16	227.3
5&5*	6	147.7	15	288.9
All grades	26	560.9	43	660.3
4 % 4+5/5*	66.7	65.2	51.6	44.0

YH	Science & tech		Social & arts	
	Subs	FTEs	Subs	FTEs
1-3s	23	226.5	56	515.6
4s	19	330.7	37	533.4
5&5*	45	1208.9	54	1111.6
All grades	87	1766.1	147	2160.7
4 % 4+5/5*	29.7	21.5	40.7	32.4

WA	Science & tech		Social & arts	
	Subs	FTEs	Subs	FTEs
1-3s	12	160.7	43	404.6
4s	19	548.3	19	260.7
5&5*	16	349.5	30	565.6
All grades	47	1058.5	92	1230.9
4 % 4+5/5*	54.3	61.1	38.8	31.6

EM	Science & tech		Social & arts	
	Subs	FTEs	Subs	FTEs
1-3s	22	371.9	41	528.4
4s	22	492.6	25	453.6
5&5*	24	582.3	30	625.4
All grades	68	1446.9	96	1607.4
4 % 4+5/5*	47.8	45.8	45.5	42.0

WM	Science & tech		Social & arts	
	Subs	FTEs	Subs	FTEs
1-3s	35	323.8	53	450.9
4s	9	157.0	19	364.7
5&5*	25	756.9	44	912.4
All grades	69	1237.8	116	1728.0
4 % 4+5/5*	26.5	17.2	30.2	28.6

E	Science & tech		Social & arts	
	Subs	FTEs	Subs	FTEs
1-3s	11	100.0	33	324.9
4s	12	389.6	14	198.3
5&5*	27	1220.7	46	1084.4
All grades	50	1710.3	93	1607.5
4 % 4+5/5*	30.8	24.2	23.3	15.5

SW	Science & tech		Social & arts	
	Subs	FTEs	Subs	FTEs
1-3s	21	263.8	44	472.7
4s	21	322.2	29	355.0
5&5*	30	699.3	41	661.1
All grades	72	1285.3	114	1488.8
4 % 4+5/5*	41.2	31.5	41.4	34.9

SE	Science & tech		Social & arts	
	Subs	FTEs	Subs	FTEs
1-3s	29	326.8	67	849.4
4s	21	422.3	46	673.0
5&5*	63	2234.2	79	1943.0
All grades	113	2983.2	192	3465.4
4 % 4+5/5*	25.0	15.9	36.8	25.7

L	Science & tech		Social & arts	
	Subs	FTEs	Subs	FTEs
1-3s	56	675.6	119	1112.1
4s	39	1089.7	54	870.2
5&5*	66	3014.1	111	2707.4
All grades	161	4779.4	284	4689.7
4 % 4+5/5*	37.1	26.6	32.7	24.3

Figure 4 Total research grant and contract funding

Each graph summarises the data for a region by eight subject categories. These are Clinical Medicine (Med), Biological sciences (Bio), Physical and Mathematical Sciences (PMS), Engineering and Technology (Eng), Visual and Performing Arts (Art), Humanities and Languages (H&L), Social Sciences (Soc) and Subjects allied to Medicine and Health (SAM).

These graphs show the total HE regional project specific research grant and contract income, i.e. that not coming in a block grant from Funding Councils. Data are shown as absolute amounts (blue bar) and per FTE staff (red line). Income is for 1998-2002; staff data are 2001-2002.

Blue bar - absolute value, scale unit is £20M to a maximum of £80M. London MED is off-scale at £248M
Red line – relative income, scale is £20K per FTE with a maximum of £80K.

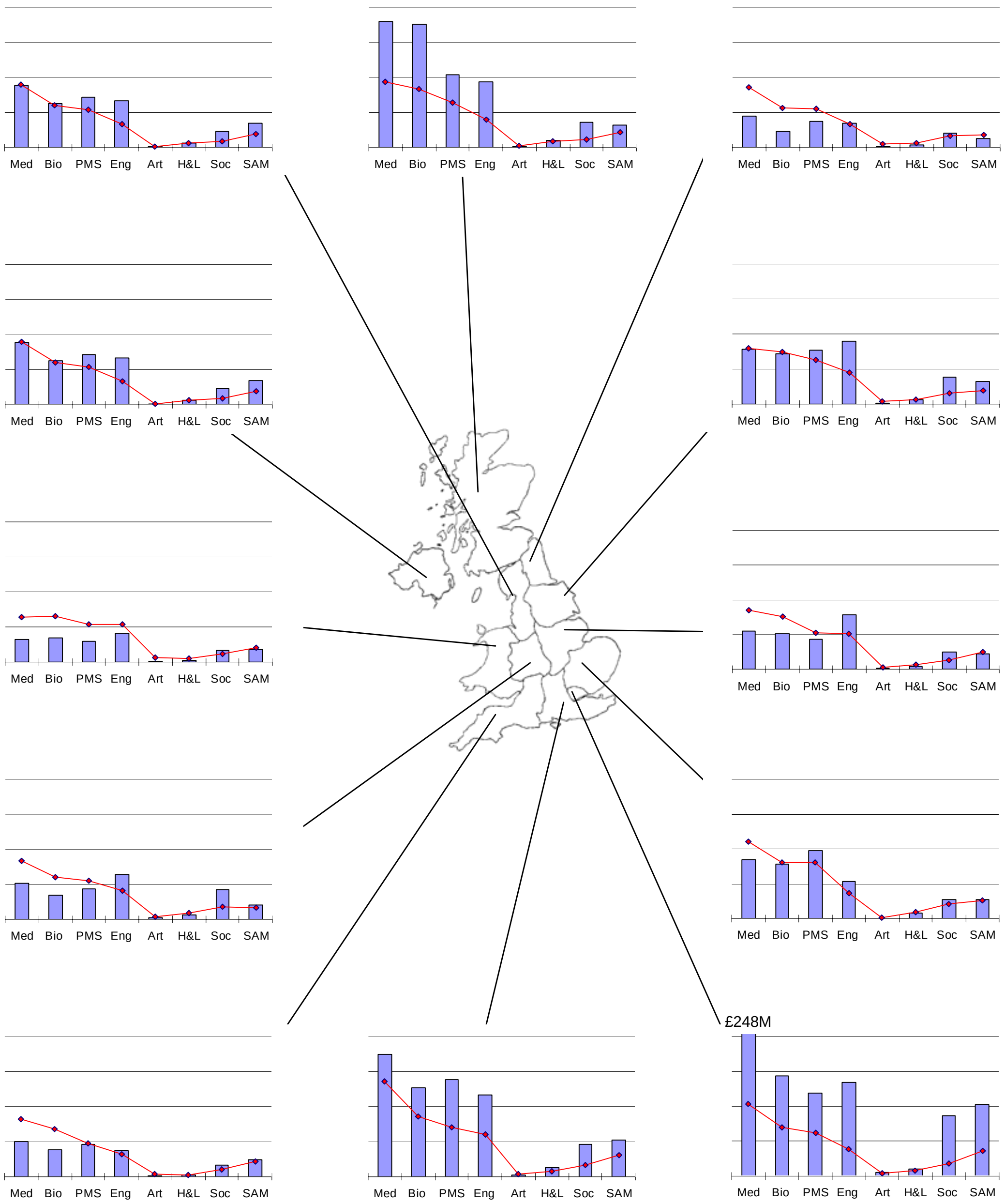


Figure 5 Industrial research contracts

Each graph summarises the data for a region by eight subject categories. These are Clinical Medicine (Med), Biological sciences (Bio), Physical and Mathematical Sciences (PMS), Engineering and Technology (Eng), Visual and Performing Arts (Art), Humanities and Languages (H&L), Social Sciences (Soc) and Subjects allied to Medicine and Health (SAM).

These graphs show the HE research contract income sourced from industry. Data are shown as absolute amounts (blue bar) and as a percentage of total research grant and contract income (red line). Income is for 1998-2002.

Blue bar - absolute value, scale unit is £2M to a maximum of £10M. London MED is off-scale at £24.1M
Red line – relative income, scale is 10% total with a maximum of 50%.

Figure 6 PhD awards

Each graph summarises the data for a region by eight subject categories. These are Clinical Medicine (Med), Biological sciences (Bio), Physical and Mathematical Sciences (PMS), Engineering and Technology (Eng), Visual and Performing Arts (Art), Humanities and Languages (H&L), Social Sciences (Soc) and Subjects allied to Medicine and Health (SAM).

These graphs show the average numbers of PhD awards per year. Data are for 1998-2002.

Blue bar - scale unit is 100 FTE to a maximum of 500 FTE.

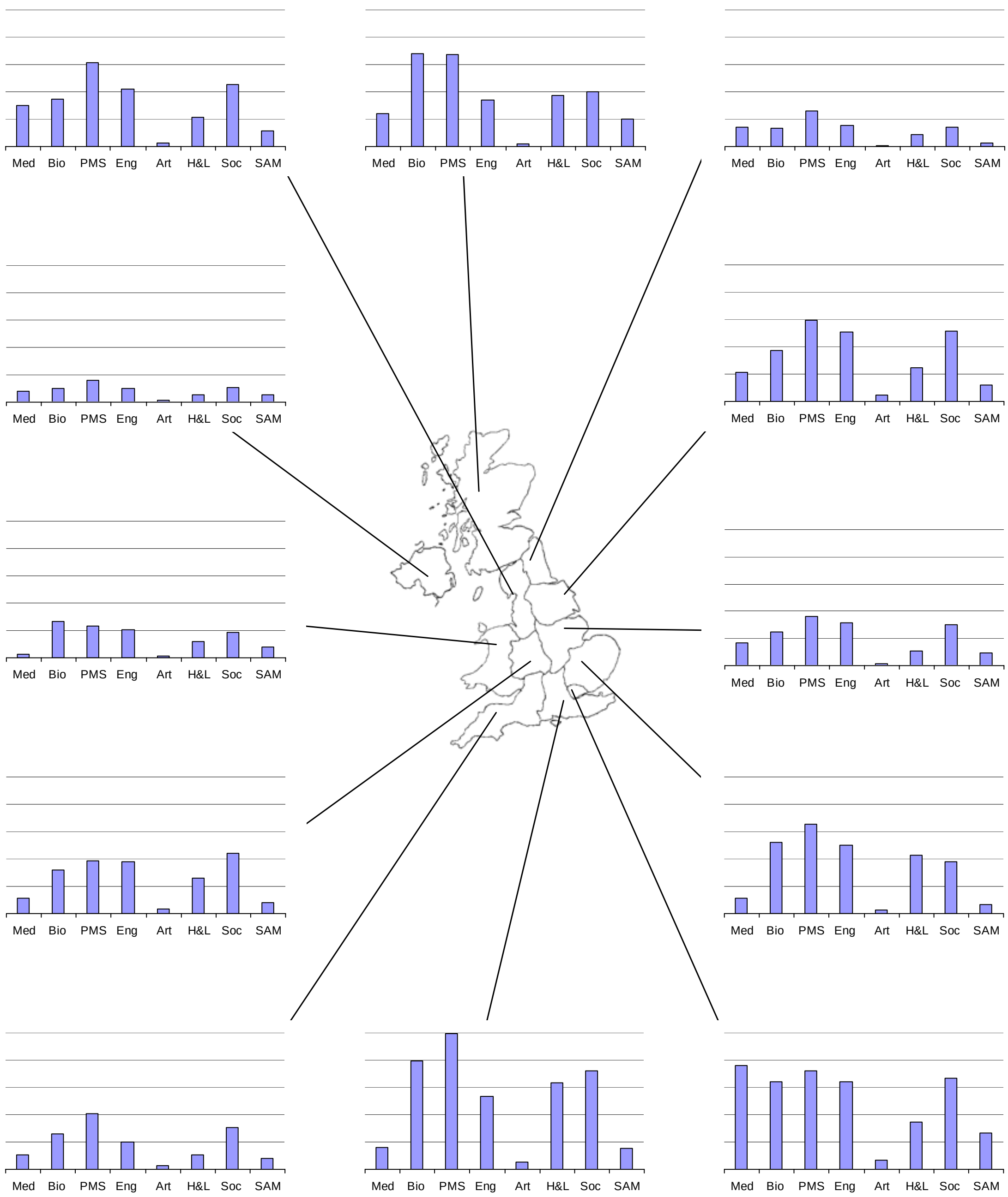


Figure 7 Publication output and impact

Each graph summarises the data for a region by eight subject categories. These are Clinical Medicine (Med), Biological sciences (Bio), Physical and Mathematical Sciences (PMS), Engineering and Technology (Eng), Visual and Performing Arts (Art), Humanities and Languages (H&L), Social Sciences (Soc) and Subjects allied to Medicine and Health (SAM).

These graphs show the numbers of research papers published by Universities in each region and their citation impact. Data are all taken from the National Citation Report for the UK produced by Thomson ISI ®. Citation rates vary substantially between fields so for ease of comparison these impact values have all been rebased against a world average for the stated field. Data cover the 5 calendar years 1998-2002.

Blue bar – count of papers, scale unit is 1000 to a maximum of 5000. London MED is off-scale at 10,500
Red line – relative impact, scale unit is 0.5 with a maximum of 2.5 compared to world = 1.0.

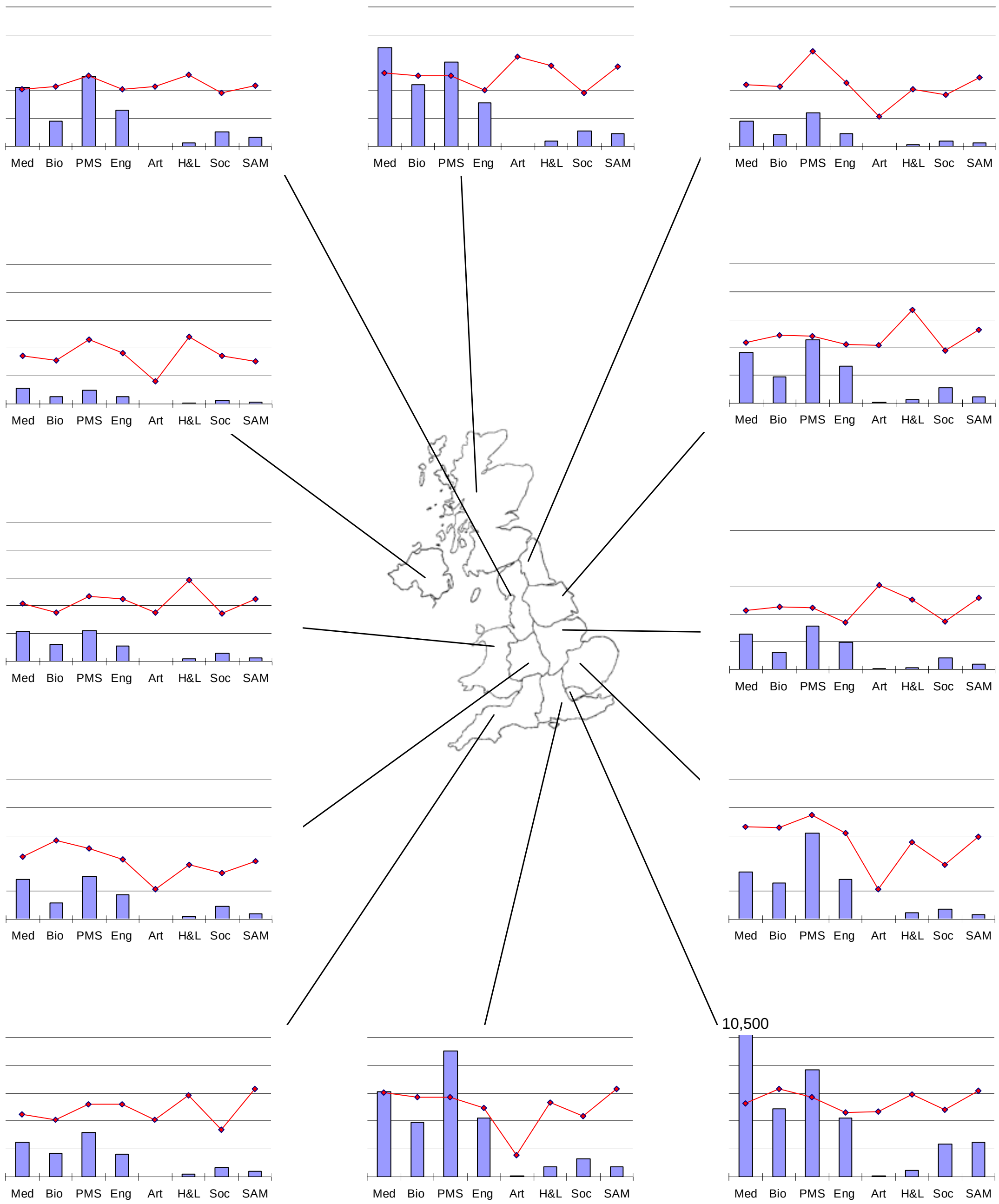


Figure 8 R&D spend and research publication output by top 200 companies in DTI R&D Scoreboard, analysed by region

The data on R&D spend are the totals for 1998-2002 taken from the DTI's R&D Scoreboard, for the top 200 companies ranked by spend in that list. Spending capacity is allocated to region according to the post-codes on the publications of the research units for each company. This may differ from company head office addresses.

The data on publications (ISI papers) are taken from the National Citation Report for the UK produced by Thomson ISI. Company names in the R&D Scoreboard were linked to unique organisations identified in an address analysis by *Evidence* Ltd. Papers for all the organisation address variants are then analysed for postcode and allocated to regions.

R&D £M	8489.4	**%UK**	14.2
ISI papers	2039	**%UK**	11.6

R&D £M	1676.3	**%UK**	2.8
ISI papers	285	**%UK**	1.6

R&D £M	714.2	**%UK**	1.2
ISI papers	386	**%UK**	2.2

R&D £M	47.5	**%UK**	0.1
ISI papers	12	**%UK**	0.1

R&D £M	2211.6	**%UK**	3.7
ISI papers	231	**%UK**	1.3

R&D £M	556.3	**%UK**	0.9
ISI papers	148	**%UK**	0.8

R&D £M	3918.6	**%UK**	6.5
ISI papers	674	**%UK**	3.8

R&D £M	777.6	**%UK**	1.3
ISI papers	91	**%UK**	0.5

R&D £M	17056.6	**%UK**	28.5
ISI papers	6333	**%UK**	36.0

R&D £M	4417.4	**%UK**	7.4
ISI papers	614	**%UK**	3.5

R&D £M	12855.4	**%UK**	21.5
ISI papers	4665	**%UK**	26.5

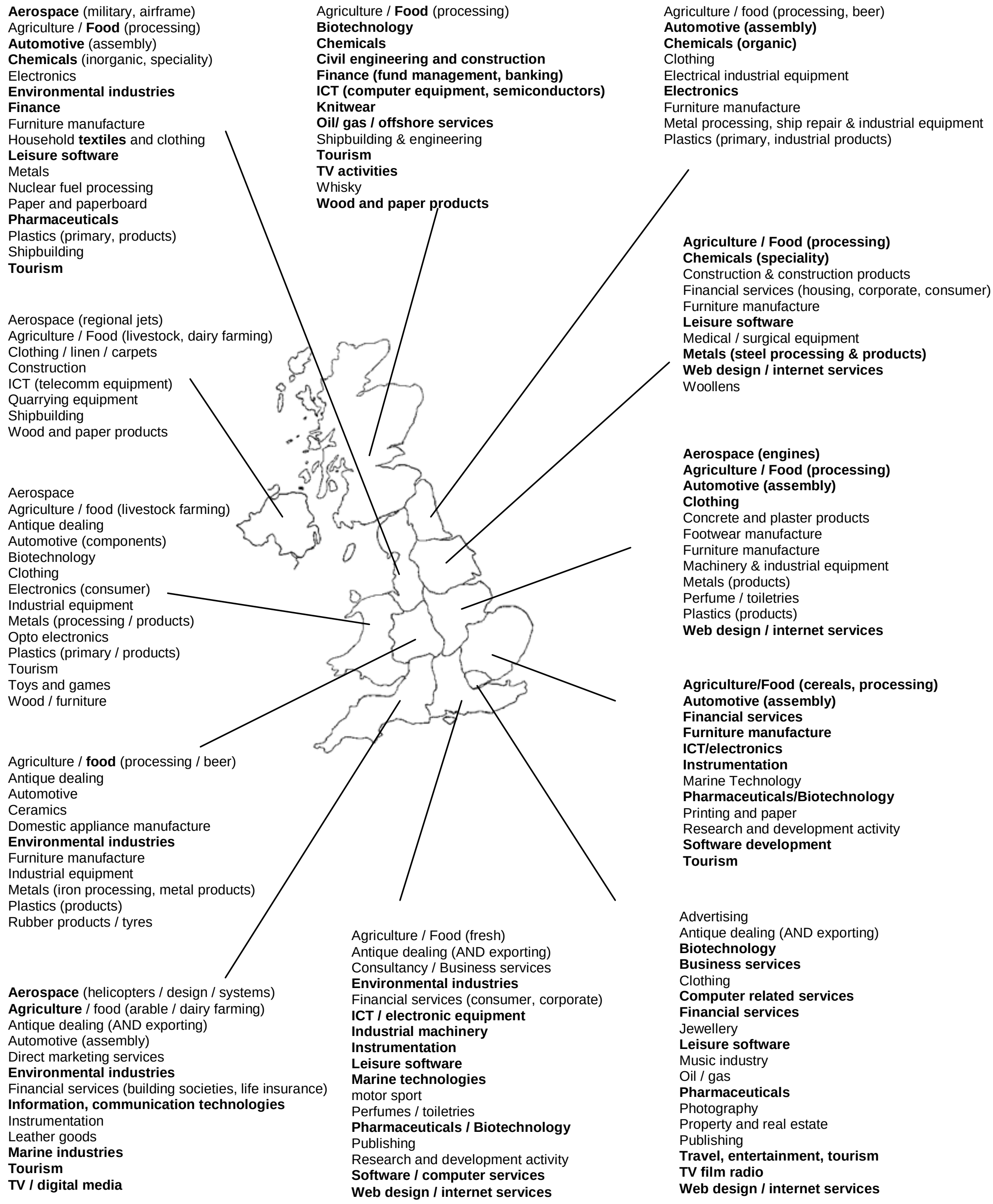
R&D £M	7115.7	**%UK**	11.9
ISI papers	2094	**%UK**	11.9

Source: Company data from DTI R&D Scoreboard. Publication data from Thomson ISI ®.

Figure 9 Industrial clusters defined by Trends Business Research

These data are set out in Figure 2 (The Cluster Map) of Volume 1 of the main DTI report (Trends Business Research 2001). Additional information is provided in an accompanying Table and a fully detailed regional analysis is provided in Volume 2 of the report. TBR identified 154 clusters with some 8-18 per region. The fundamental quantitative measure used by TBR is that of employment, so these clusters identify the sectors and sector groups with an exceptional relative employment for that region compared to the UK generally.

Clusters highlighted in bold align with those identified as RDA cluster priorities (Table 6) [except Wales and NI].



Source: Trends Business Research/DTI (2001). Data used with permission of Trends Business Research

Table 1Russell Group institutions (primarily pre-1940) and their region

Institution	Region
University of Oxford	South East
University of Southampton	South East
University of Bristol	South West
Imperial College London	London
King's College London	London
London School of Economics and Political Science	London
University College London	London
University of Cambridge	East
University of Nottingham	East Midlands
University of Birmingham	West Midlands
University of Warwick	West Midlands
University of Leeds	Yorkshire & Humberside
University of Sheffield	Yorkshire & Humberside
University of Newcastle upon Tyne	North East
University of Liverpool	North West
University of Manchester	North West
University of Edinburgh	Scotland
University of Glasgow	Scotland
Cardiff University	Wales

Table 2 Regional distribution byRAE2001 grade of units in different broad subject areas

Left side (columns SC to Total): COUNT OF UNITS IN GRADE BAND FOR SUBJECT CATEGORY

Right side (columns SC to NW after grade): REGIONAL UNITS AS % OF UK UNITS IN THAT BAND

REGION															REGION											
SC	NE	Y&H	EM	E	L	SE	SW	WM	WA	NI	NW	Total	Category	grade	SC	NE	Y&H	EM	E	L	SE	SW	WM	WA	NI	NW
11	6	7	1	5	15	11	7	4	3	1	5	76		5 & 5*	14.5	7.9	9.2	1.3	6.6	19.7	14.5	9.2	5.3	3.9	1.3	6.6
9	1	4	5	1	9	1	0	4	4	2	6	46	Clinical sciences	4	19.6	2.2	8.7	10.9	2.2	19.6	2.2	0.0	8.7	8.7	4.3	13.0
2	2	4	5	1	12	4	3	5	0	3	4	45		1 to 3a	4.4	4.4	8.9	11.1	2.2	26.7	8.9	6.7	11.1	0.0	6.7	8.9
8	2	4	3	3	4	6	3	2	1	0	4	40		5 & 5*	20.0	5.0	10.0	7.5	7.5	10.0	15.0	7.5	5.0	2.5	0.0	10.0
3	1	1	1	2	7	2	1	1	2	3	1	25	Biological sciences	4	12.0	4.0	4.0	4.0	8.0	28.0	8.0	4.0	4.0	8.0	12.0	4.0
2	3	1	1	2	4	1	4	4	4	0	3	29		1 to 3a	6.9	10.3	3.4	3.4	6.9	13.8	3.4	13.8	13.8	13.8	0.0	10.3
20	9	19	10	11	23	29	12	11	5	1	18	168		5 & 5*	11.9	5.4	11.3	6.0	6.5	13.7	17.3	7.1	6.5	3.0	0.6	10.7
17	6	9	8	3	12	8	10	3	7	4	16	103	Maths & physical	4	16.5	5.8	8.7	7.8	2.9	11.7	7.8	9.7	2.9	6.8	3.9	15.5
12	5	7	8	6	22	15	10	14	4	3	7	113		1 to 3a	10.6	4.4	6.2	7.1	5.3	19.5	13.3	8.8	12.4	3.5	2.7	6.2
12	5	12	7	4	17	12	7	8	6	4	13	107		5 & 5*	11.2	4.7	11.2	6.5	3.7	15.9	11.2	6.5	7.5	5.6	3.7	12.1
17	3	5	9	6	11	9	9	1	6	3	6	85	Engin-eering	4	20.0	3.5	5.9	10.6	7.1	12.9	10.6	10.6	1.2	7.1	3.5	7.1
19	9	11	7	2	16	8	4	12	4	2	10	104		1 to 3a	18.3	8.7	10.6	6.7	1.9	15.4	7.7	3.8	11.5	3.8	1.9	9.6
19	7	18	8	14	27	18	18	14	9	4	14	170		5 & 5*	11.2	4.1	10.6	4.7	8.2	15.9	10.6	10.6	8.2	5.3	2.4	8.2
29	7	11	9	5	16	19	9	6	2	5	12	130	Social sciences	4	22.3	5.4	8.5	6.9	3.8	12.3	14.6	6.9	4.6	1.5	3.8	9.2
23	13	22	19	12	42	26	16	24	17	6	24	244		1 to 3a	9.4	5.3	9.0	7.8	4.9	17.2	10.7	6.6	9.8	7.0	2.5	9.8
35	14	25	16	27	56	46	18	21	14	7	24	303		5 & 5*	11.6	4.6	8.3	5.3	8.9	18.5	15.2	5.9	6.9	4.6	2.3	7.9
31	9	16	10	4	23	22	13	8	15	7	14	172	Humanities & Langs	4	18.0	5.2	9.3	5.8	2.3	13.4	12.8	7.6	4.7	8.7	4.1	8.1
16	12	16	11	7	35	16	14	15	18	3	21	184		1 to 3a	8.7	6.5	8.7	6.0	3.8	19.0	8.7	7.6	8.2	9.8	1.6	11.4
1	1	5	3	2	12	8	3	3	5	2	2	47		5 & 5*	2.1	2.1	10.6	6.4	4.3	25.5	17.0	6.4	6.4	10.6	4.3	4.3
6	4	4	3	2	8	5	5	5	1	1	6	50	Vis & Perf Arts	4	12.0	8.0	8.0	6.0	4.0	16.0	10.0	10.0	10.0	2.0	2.0	12.0
8	4	11	8	7	18	16	9	7	4	3	13	108		1 to 3a	7.4	3.7	10.2	7.4	6.5	16.7	14.8	8.3	6.5	3.7	2.8	12.0
3	2	6	3	2	10	4	2	3	2	1	7	45		5 & 5*	6.7	4.4	13.3	6.7	4.4	22.2	8.9	4.4	6.7	4.4	2.2	15.6
3	0	4	2	2	6	2	2	0	1	2	2	26	Pre-clinical & health	4	11.5	0.0	15.4	7.7	7.7	23.1	7.7	7.7	0.0	3.8	7.7	7.7
10	3	5	2	5	17	5	5	6	4	0	10	72		1 to 3a	13.9	4.2	6.9	2.8	6.9	23.6	6.9	6.9	8.3	5.6	0.0	13.9

Table 3 University summary research data aggregated by regional groups

% of research activity by regional group	Research Active staff	Research grant and contract income	Industrial research contract income	PhD awards	ISI research journal papers
London, East and South East	40.1	46.8	43.9	40.5	45.5
Rest of England	40.2	34.8	38.2	41.8	36.1
N Ireland, Scotland, Wales	19.7	18.4	17.9	17.7	18.3

Table 4 Regional distribution of R&D spend and research publications by top 200 companies in DTI R&D Scoreboard (see Figure 8)

Region	R&D spend 1998-2002		Publications on ISI database 1993-2002	
	£m	% UK	Count	% UK
East of England	17056.6	28.5	6333	36.0
South East	12855.4	21.5	4665	26.5
London	7115.7	11.9	2094	11.9
North West	8489.4	14.2	2039	11.6
East Midlands	3918.6	6.5	674	3.8
South West	4417.4	7.4	614	3.5
North East	714.2	1.2	386	2.2
Scotland	1676.3	2.8	286	1.6
Yorkshire and the Humber	2211.6	3.7	231	1.3
Wales	556.3	0.9	148	0.8
West Midlands	777.6	1.3	91	0.5
Northern Ireland	47.5	0.1	12	0.1
TOTAL	59836.7		17573	

Table 5 Regional distribution of co-authorship for UK companies publishing research in journals on ISI databases, 1993-2002

Company, ranked by UK collaboration		Regional location of collaborating UK University												Non UK
Name	**Total ISI papers**	**Scotland**	**North East**	**Yorks & Humber**	**East Midlands**	**Eastern England**	**London**	**South East**	**South West**	**West Midlands**	**Wales**	**Northern Ireland**	**North West**	**Other co-author**
GLAXOSMITHKLINE	4767	129	32	114	70	150	344	238	63	63	24	3	85	2436
ASTRAZENECA	1832	53	26	82	48	29	133	100	70	35	20	1	61	725
PFIZER	1297	36	14	78	35	20	92	67	28	17	10		55	689
UNILEVER	1085	37	12	40	40	38	32	77	17	38	25	3	84	618
ICI	563	65	26	52	27	28	26	22	12	24	19	1	56	173
MERCK SHARP & D	1022	29	5	10	18	24	43	31	14	5	3	2	14	446
ROLLS ROYCE	347	3	3	8	14	42	13	44	11	30	6		8	78
AEA TECHNOL	616	7	11	12	9	13	32	32	7	8	4	2	28	347
SHELL	378	16	9	16	11	6	23	26	21	6	7		13	186
BP	292	29	10	16	3	10	22	21	9	1	2	10	6	103
ELI LILLY	536	13	6	6	16	9	20	14	18	10	14	2	7	505
SCHLUMBERGER	400	2		10	6	30	30	26	9	2	2		16	215
TOSHIBA	141	2		14		91	2	11	1					28
HEWLETT PACKARD	222	7		3	3	13	7	12	57	1	4		6	101
ROCHE	317	9	4	6	10	9	15	19	7	3	5	1	24	233
BNFL	171	2	1	13	13	11	6	8	9	5	2	5	34	37
BRITISH AEROSP	215	11	3	3	4	13	11	15	9	8	8		7	38
CELLTECH GRP	242	4	2	14	5	24	13	11	8	1			3	130
CORUS	129	6	2	5	5	1	2	6	1		47	1	7	7
BRITISH TELECOM	537	14	2	5	1	17	15	6	4	6	3	5	1	57
MARCONI	268	6	3	3	4	18	4	17	2	6	1		3	108
BRITISH BIOTECH	197	4	1	4	4		7	32	1	4			6	108
BG GRP	104	5	2	2	4	5	7	11		6		4	5	14
KODAK	91	10			2	1	19	1	7	1	8		2	21
SANOFI WINTHROP	99	6	5	10	1		14	6	1		2		4	39
NATL GRID	68	6	1			6	3	16	2		1		12	6
RHONE POULENC R	232	3	3	5	5	2	7	7	4	4	5		1	35
ALCAN INT	76	2		7	3	5	1	15		4	1		5	34
SYNGENTA	121	5	2	6	4	3	7	6	1	2	2	1	4	71
OXAGEN	47	2	3	1		4	6	21	1				1	49

Company, ranked by UK collaboration		Regional location of collaborating UK University												Non UK
Name	Total ISI papers	Scotland	North East	Yorks & Humber	East Midlands	Eastern England	London	South East	South West	West Midlands	Wales	Northern Ireland	North West	Other co-author
AMERSHAM	145	1	1	2	4	4	3	9	1	4	9			56
OXFORD INSTR	78		1	3	2	2	1	9	2	3	1		4	40
KNOLL	104	2	1	2	4		1			11	1		11	9
TNO BIBRA INT	218	7		1	1		3	12			4	4	1	155
NUCL ELECT	111	3	2	1	4	1	3	1	6	2	1		3	17
OXFORD BIOMEDICA	43			1			5	19					2	3
SEVERN TRENT WAT	81		3	2	1	7	3			8			2	9
DANBIOSYST	38				23					1				15
SYNETIX	31	7	1	1	2	4				1	5		2	3
BAE SYST	56	1		1	1	1	1	3	2	3	5		3	6
PHARMACEUT PROFIL	110				20		1							52
THAMES WATER	65		1			4	4	11					1	5
WRC NSF	134	2	1	4		1	8	4						22
BRITISH COAL	53	2		1		1	4	1	1	4	2		3	4
JOHNSON MATTHEY	55			2		3		5	1	1	2	1	3	14
PILKINGTON	45	1		3				4			8	1	2	45
SHARP LABS EUROPE	55	6		3	2		2	3	2				1	9
COURTAULDS	74		3	2		2	1	7	1				2	7
EASTMAN CHEM	10	3		1			1		2		9		2	1
INORGTECH	20				1		9						8	
MOL SIMULAT	47		1	3		6	3		1	2			2	49
NORTEL NETWORKS	60	1		1	1	5	1	3	3		1		2	13
ALSTOM	58		2	6	1	1			1	3		2	1	3
AMERADA HESS	49	3				3	7	1			2	1		5
EXXONMOBIL	39	3		1		5	2	2	1		3			17
FUJITSU	41				1	14		1		1				19
NOVARTIS	154	4	1	2	1	1	3	2	1		1		1	92
RENEURON	30		1			1	15							8
FORD	31			4	3		2	3	1				3	1
DUPONT	25	5	1	1	2	1			1	2		2		9
NATL POWER	22					1	3	4	3	1	3			7

Table 6 Priority cluster areas identified on web-sites of English RDAs and Scottish Enterprise (bold = aligns with employment clusters -Figure 9)

Cluster subject	Scottish Enterprise	One North East	Yorkshire Forward	East Midlands (EMDA)	East of England	London	South East (SEEDA)	SW of England RDA	Advantage West Midlands	NorthWest DA
Food and agriculture	**Food and Drink**		**Food and drink industry opportunities**	**Food and Drink**	**Agriculture and food processing**			**Food and drink**	**Food and Drink**	**Food & Drink**
Marine							**Marine**	**Marine**		**Maritime**
Environment	**Forest Industries**			Environmental Technologies		The green economy	**Environmental Technology**	**Environmental technologies**	**Environmental Technologies**	**Environmental Technology**
Biotechnology	**Biotechnology**	Life Sciences	Bioscience industry opportunities		**Life sciences**	**Biotechnology**	**Pharma Bio and Healthcare**	**Biotechnology**		**Biotechnology**
Health and medicine		Pharmaceuticals		Healthcare					Medical Technologies.	
Chemicals	**Chemicals**	**Chemicals**	**Chemicals industry opportunities**							**Chemicals**
Tourism and leisure	**Tourism**				**Tourism, leisure and heritage**	**Tourism and hospitality**	Tourism	**Leisure and tourism**	Tourism and Leisure	**Tourism & Sport**
Creative	**Creative Industries & Software/e-business**	Software Development		**Creative Industries**	**Creative industries**	**Creative and cultural**		**Creative industries**	Media	**Creative Industries**
Information and communication technologies	**Comms Technologies & Microelectronics & Optoelectronics**	**Consumer Electronics and Microelectronics**	Digital industries opportunities		**ICT**	**Information technology**	**Technology, Media and Telecoms**	**ICT**	Information and Communication Technology (ICT)	**Digital Industries**
Finance and business	**Financial Services**				**Finance and business services**	**Labour markets**			Specialist Business and Professional Services.	**Financial & Professional Services**
Engineering	**Aerospace**	**Automotive**	**Advanced engineering and metals**	**High Performance Engineering, including motorsports, aerospace**	**Advanced engineering**	Production industries	Aerospace and Defence	**Advanced Engineering (includes Aerospace)**		**Aerospace & Automotive**
Manufacturing					**High-tech manufacturing**		**Manufacturing**		High - Value Consumer Products	
Energy	**Energy**			Power Generation						Energy & Renewable Energy
Building							Property & Construction		Building Technologies	Construction
Textiles	**Textiles**			**Clothing and Textiles**						**Textiles**
Transport					Transport gateways		Transport and Logistics		Transport Technologies	
Employment (other)	Academics/ Business	Call Centres and Shared Services				Public sector employment				
Economy (other)						The social economy	Rural Businesses			
Data source	www.scottish-enterprise.com/sedotcom_home/sig.htm	http://www.onenortheast.co.uk/page/supp_4ii/ind_prof/sectorstrength.cfm	http://www.yorkshire-forward.com/view.asp?id=1013&pw=	http://www.emda.org.uk/documents/CP1Apri1.pdf	http://www.eeda.org.uk/compdetails.asp?id=3252	http://www.lda.gov.uk/workofthelda/industry/	http://www.seeda.co.uk/seeda_documents/Corporate_&_Strategy/docs/SEEDA_Annual_Report_2003.pdf	www.southwestrda.org.uk/sectors/index.shtm	http://www.advantagewm.co.uk/the-ten-clusters.html	http://www.nwda.co.uk/RelatedContent.aspx?&area=86&subarea=133

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