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Academia–Business Links

European Policy Strategies and Lessons Learnt

Edited by

Rüdiger Wink

Anglo-German Foundation for the Study of Industrial Society

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1
Academia-Business Interactions in Europe: An Introduction

Rüdiger Wink

The academic world is in fast change: scientists and students recognize new opportunities as entrepreneurs, multinational companies base their location decisions on proximity to leading academic research laboratories, and policy-makers all over Europe look for new incentive schemes to maximize economic and social output of academic work, to prevent brain-drain in particular to the US, and to support the emergence of regional innovation systems around universities and public research organizations. Two often-cited central developments caused this unprecedented economic interest in the economic world: (i) the emergence of 'knowledge economies' where science-driven technologies are developed without clear borders between basic and applied research and where high (academic) qualifications become prerequisites for employment within industry and service sectors (Gibbons *et al*. 1994; Etzkowitz and Webster 2000), and (ii) the internationalization of markets initiating still-increasing mobility of financial and human (scientific) capital and influencing spatial patterns of academic excellence (Cantwell and Janne 2000; Osegowitsch and Madhok 2001). Even after the bursting of the 'Internet bubble' on capital markets, ending illusions of never-ending growth of information and communication technologies and causing doubts about the sustainability of many biotechnology business models, there is still a 'new economy' for academic–business linkages, as survival of firms in the science-driven sectors can only be expected if excellent science is translated into convincing new products and services (Porter 2001; Henderson *et al*. 1999).

For a long time, debates on the economic impact of universities and public research organizations have been restricted to investigations of demand effects by staff and students (Beck *et al*. 1995; Harris 1997). Nowadays, with knowledge as the central production factor influencing growth potential, academia faces a new function within economic systems (Lucas 1990; Mankiw *et al.* 1992). New business options have been opened for all academic activities, for research as well as for teaching and consulting. All elements along the knowledge value chain – generation, examination, exploitation and diffusion – are affected by universities and research organizations, leading to the expectation that academic institutions have to play a central role within innovation systems (Clark 1998; Godin and Gingras 2000). But there is still confusion about how to achieve the expected impact by academia. Is there more need for new linkages or more scientific excellence? Compared to US counterparts and their success during the last three decades, European academic institutions still seem to be less prepared for these changes of environment and expectations (Pavitt 2001; Mowery *et al.* 2001). In many European countries, researchers have to choose between academia and business, as any activity in one field will lead to rejection by the other. In particular, those researchers who are used to lifelong employment by public authorities only see a limited attractiveness in producing knowledge for private markets, where risks (but also opportunities) are higher. Within business, lack of experiences with scientists and scientific knowledge and its uncertainty caused misunderstandings of actual potential by academia–business interactions. In many cases, it seems as if both sides (academia and business) use different language codes and are permanently suspicious of being exploited by the other side. The achievement of the EU Lisbon objective to become the world leading market in 2010 will critically depend on overcoming these barriers.

Thus, most European governments tried to change long-lasting incentive schemes within academia and business to foster the emergence of new markets and cooperation. Many policy fields are affected by these changes; for instance:

- *science and technology policies* looking for new criteria of evaluation, new funding schemes including competitive structures, and new strategies including the emergence of systemic and evolutionary approaches (Geuna and Martin 2001);
- *intellectual property rights policies* looking for more incentives to use patents as strategic assets in international trade by extending the range of patents and by supporting the exploitation through technology transfer offices (Hicks *et al.* 2000);
- *financial markets* policies looking for the support of academia-business links by venture capital markets and mezzanine instruments (Lerner 2001);

- *regional policies* strengthening decentralization of political competencies and supporting the emergence of new public and private organizations to be integrated into regional networks as incubators for academia–business linkages (Jones-Evans and Klofsten 1997);
- *education policies* stressing the internationalization of degrees and the importance of entrepreneurial skills and enhancing conditions for academic supply of further education (Maskell and Robinson 2001); and
- *sectoral industrial policies* reducing entry barriers to new markets and improving the access to a scientific knowledge base (Reiss 2001).

The following chapters by leading European scientists give an overview of experiences with policy changes in the field of academia–business interactions from a theoretical and empirical perspective. As these policy changes affect many diversified objectives and activities, a restriction to selected issues which are at the heart of the policy debates was necessary. The main questions for this compilation were:

- Which changes in academia–business linkages can already be observed on university, industry or regional level?
- What can theory say on the effectiveness and efficiency of current policy approaches to support academia–business interactions?
- Which recommendations can be given for further theoretical improvements and new policy initiatives?

The single papers have been structured according to their primary concern on universities, industries or regions.

The five chapters in Part I deal with changes within universities to foster academia–business interactions. One prominent phenomenon of the changed world within universities is the increasing number of 'academic entrepreneurs' being 'academia' and 'business' in the same person. Douglas Hague in Chapter 2, 'Spin-offs, Start-ups and Networks in UK Universities', presents an overview of recent empirical data on this development and driving forces in the UK. By referring to three biographies of academic entrepreneurs, he stresses the importance of personal characteristics for improvements in academia–business linkages. Jürgen Egeln *et al.* also refer to spin-offs in 'Are Research Spin-offs a Local Phenomenon? Empirical Findings from Germany' (Chapter 3). The authors explain why proximity to universities and public research organizations is an important factor for regional policy-makers in evaluating the impact of academic institutions. By using empirical data from Germany they show that there are no significant differences in the location decisions of research spin-offs compared to other new firms. The proximity to the incubator depends critically on the access to knowledge and demand. Compared to the experiences in Germany and the UK, Spain only recently started policy initiatives to promote the emergence of research spin-offs. Javier Alfonso Gil and Antonia Sáez-Cala present in Chapter 4, 'Academia and Business: Links and Lags in Spain', some first results of field studies in Spanish regions and discuss, why academia–business links face specific challenges in Spain.

Spin-offs and start-ups are only part of a general debate on the output of universities and public research organizations. After implementing evaluation schemes for research and teaching quality there is still the question of how the other services can be identified and evaluated. Jordi Molas-Gallart describes in Chapter 5, 'Measuring and Funding the "Third Mission": The UK Policy Debate', the recent policy debate in the UK – a country with a strong record on quantified evaluation schemes – on developing such a third pillar of university evaluation. One common indicator for the performance of universities and research organizations in the context of knowledge exploitation is the number of patents. In the US, an increase in patent performance after legal reforms has been seen as evidence for the importance of incentive-compatible intellectual property rights schemes. This positive US example led the German government to change its law in 2002. Ulrich Blum and Simone Müller assess this reform in Chapter 6, 'The Role of Intellectual Property Rights Regimes for R&D Cooperation between Industry and Academia'. They interpret academia–business linkages as an institutional challenge, and look at incentives to overcome uncertainties on the market potential of new research results. According to their model, the introduction of intermediaries without any additional incentive to the university researcher will reduce incentives to provide quality-signalling strategies by the researchers, preventing any positive effect of the reform on the exploitation of the knowledge base.

The chapters in Part II deal with industries that are particularly dependent on a scientific knowledge base. Biotechnology is a prominent example for the emergence of an industry fuelled by cooperation between incumbent multinational companies and academic entrepreneurs. In Chapter 7, 'Why Invest in Biotechnology? German and British Biotechnology Policy Compared', Rebecca Harding discusses the different political approaches to support biotechnology in the two leading European countries. Despite all the similarities in the need to foster academic–business links and regional innovation systems, institutional specificities in both countries still influence the potential for industrial changes. Delphine Gallaud and André Torre in Chapter 8, 'Geographical Proximity and Circulation of Knowledge through Inter-Firm Cooperation', focus on the common hypothesis that the emergence of new science-driven industrial sectors leads to spatial concentration, as geographical proximity is necessary to transfer tacit knowledge between academic and business players and to overcome uncertainties between the two sides of the new markets. Using empirical material from French biotechnological firms, the authors show that this hypothesis can only partly be confirmed, with temporary geographical proximity having central importance at the beginning of academia–business links. But generally, organized proximity seems to play a more important role,becoming more and more independent from spatial factors with increasing experiences within cooperation.

Many firms and institutes in science-driven sectors have still not achieved a stage where actual market entry is realistic. Policy would be interested in supporting future key technologies, but simultaneously fear risks of failure as the market potential of many leading-edge projects have not been proved. Michael Kraus and Guido Benzler in Chapter 9, 'Evaluating the Future Impact of New Technologies: The Case of Biophotonics in Germany', discuss the expected potentials of this new technological paradigm and the challenges that policy faces when attempting to foster market success. They look for a methodological framework for regional policy-makers to assess the potential of this technological paradigm and the prerequisites necessary to gain from future developments. Riccardo Cappellin (Chapter 10) even takes a step further. In 'The Matrix INT (Instruments and Needs of Technology) and the Evaluation of Innovation Policies' he presents a tool for policy-makers to evaluate different instruments of academia–business linkages by looking at the actual demand by regional firms, in particular small and medium-sized enterprises (SME). Thus, a necessary differentiation can be reached within evaluations according to different types of regions, firms and technologies creating inevitable transparency to avoid assertion of particularistic interests within policy-making processes.

Part III focuses primarily on the regional dimension of academia–business linkages. The prominent examples of successful centres of excellence for science-driven new technologies with universities and public research organizations at the core of innovation systems, motivate a new paradigm of regional science policy. For many lagging regions, however, in a transition to knowledge economies there is a risk of losing access to global knowledge pipelines. The chapters in Part III deal with these fears and with approaches to cope with them. In Chapter 11, Paul Benneworth and Stuart Dawley interpret regional academia–-business interactions as evolutionary processes, where any experience within a single cooperation leads to new expertise that can be used as an input to cooperate with other – less experienced – partners, thereby creating some kind of learning processes. Based on their model and empirical data, they show in their paper, 'The Territorial Development of Innovation Support Assets Through University-Business Interactions: Towards a Dynamic Model', which type of company might be most suitable for which type of cooperation with academia at which stage of market development. Increasing awareness of the regional dimension of innovation systems encouraged policy to strengthen decentralization of competencies with new intermediary organizations to span boundaries between academia and business. Phil Cooke in Chapter 12, 'Regional Innovation System Barriers and the Rise of Boundary-Crossing Institutions', assesses the experiences with different kinds of these boundary-spanning organizations in different countries and considers their specific institutional background. He focuses particularly on those industrialized regions at the margin of knowledge economies which are in need of industrial change and new institutional solutions to create and process the necessary knowledge to attain catch-up.

Due to regional disparities of access to world-class knowledge, a persistently increasing gap between regions that have knowledge and those having an insufficient knowledge base serves as a continuous threat to lagging regions. Transregional access to global knowledge pipelines is seen as a prerequisite for regional cohesion, and there have been many national and European initiatives to promote such diffusion of knowledge. Rüdiger Wink, in 'Universities as Hubs to Global Knowledge Pipelines? A Strategy-Focused Perspective on Regional University Policies' (Chapter 13) looks at the necessary prerequisites for successful transregional strategies using universities as transmitters. He stresses the importance of strategies to develop suitable objectives, instruments and evaluation criteria for transregional knowledge management and considers regional-specific options and competitive advantages. Finally, Riccardo Cappellin and Michael Steiner in Chapter 14, 'Enlarging the Scale of Knowledge and Innovation Networks: Theoretical Perspectives, Methodological Approaches and Policy Issues', analyze the possibilities and limits of the European Union acting as a promoter to assist the inclusion of lagging regions and countries, in particular in Central and Eastern

Europe, into academia–business interactions. They discuss remaining needs for improving scientific analysis as well as political strategies within EU R&D policies.

The diversity of methodological approaches and policy concepts reviewed underlines the fact that there is no blueprint for successfully implementing academia–business interactions. Universities will still vary according to scientific priorities and organizational experience. Nevertheless, the chapters in this book show that no university and no company can succeed in persistently neglecting the need for change.

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Part I

The Changed Environment of Universities

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2
Spin-offs, Start-ups and Networks in UK Universities

Douglas Hague

Introduction

The aim of this chapter is to give information about important aspects of university–business interaction in the UK, in order to provide a general background to the more theoretical studies in the rest of the volume. Its aim is therefore not analytical, but to provide an overview of the nature of UK universities' engagement with spin-off and start-up companies, and of its scale. The chapter then goes behind this to look more closely at the types of individuals responsible for these developments, their attributes, skills and roles. The chapter emphasizes that most of those who help to establish spin-offs and start-ups are linked with and through networks of individuals who provide a crucial element in both narrower and broader business–university links.

First, we need basic terminology. In the UK spin-offs are defined as companies set up to commercialize discoveries arising directly from university research. University start-ups are also created by staff members or students. They do not result directly from university research projects, however, but arise from the inherent knowledge and expertise of those individuals. Because spin-offs, in particular, are concerned with the transfer of technology, the offices set up by universities to oversee their creation are known as technology transfer offices (TTOs). The University Companies Association (UNICO), an association of TTOs, recently published detailed information about spin-offs. The UNICO-NUBS 2001 Survey on 'University Commercialization Activities' was carried out for UNICO by Nottingham University Business School, and gives figures for 79 UK university institutions (NUBS 2002). The 'Higher Education–Business Interaction Survey, 2000–01' provides similar information for about 160 UK institutions (HEFCE 2003) and pays more attention to start-ups than does the UNICO-NUBS study.

While this chapter concentrates on spin-offs, start-ups and their associated networks, it must not be forgotten that UK universities also earn substantial income from patents and licences. No one should underestimate their importance, but to include this kind of intellectual property (IP) would lengthen the chapter unduly. In addition, the financial statistics for UK universities, as currently published, separate out the amounts of income earned from patents and licences only for a proportion of universities. Other institutions include any earnings they have from IP in a catch-all category of 'other operating income'. Therefore, valid comparisons between the earnings from IP in individual universities cannot be made, though the UK funding councils are anxious to make such comparisons possible in future, by insisting that statistics become more transparent.

Spin-offs

The UNICO-NUBS study shows that, between 1997 and 2001, 79 UK institutions spun off 554 businesses, 175 of them (35 per cent) being set up in 2001 alone. The HEFCE paper reports that there were 248 spin-offs in 2000–1 from its larger, but overlapping, sample. The rate of spin-off was increasing until 2001 but, with the end of the high-tech and dot-com booms, it is likely that performance in 2002 was less good. The 175 UNICO businesses that were set up in 2001 came from 53 institutions, but 14 of them established more than five spin-offs and one more than ten. On average, therefore, the remaining 38 institutions established fewer than 2.5 businesses each.

Organizing for spin-offs

To avoid financial risk for them, many universities have set up wholly owned subsidiary companies to work at arm's-length in establishing spin-offs, though the dividing line between a university and its subsidiary differs considerably. For example, the university has a much bigger role in Nottingham than in Oxford. On one point there is greater, though not complete, agreement between universities. Most believe that the researchers who are responsible for the scientific and technological discoveries, which make spin-off companies possible, frequently – though not always – lack the skills and personalities which would make them good chief executives of those companies. These researchers may, however, become non-executive members of the boards of these spin-offs, or technical directors.

The reason for all this is that many UK universities see it as very important that a commercially successful researcher continues with his or her research career, because the university's interest is in exploiting that researcher's comparative advantage rather than allowing him or her to attempt to found a company – unless both keen and competent to do so. Incidentally, the fact that successful researchers are encouraged to continue with their research may provide a partial explanation for one interesting phenomenon. This is that increasing numbers of the patents established by UK universities are now being licensed to their own spin-off companies.

But these arrangements add a degree of complexity to the way in which a spin-off is set up. Above all, they mean that the task is much more a team effort than it is with the traditional (low-tech) entrepreneur or the leader of a start-up where that individual plays a leading role. For spin-offs the 'team' must include the researcher(s) whose discoveries underlie the spin-off as well as representatives of the university, the TTO, and certainly any subsidiary company set up to establish spin-offs. Together they will perform the key task of writing a commercially viable plan for the company, often bringing in consultants, accountants or other experts to assist them. This will make it possible to obtain the necessary finance, management and premises for the company, at which point the role of the university participants will diminish and that of its newly appointed board of directors, chairman and chief executive will become dominant.

This points to a further key task for the 'team'. That is to recruit managers to take the spin-off through its early years. With the researchers usually not taking on key management roles, the team has to use either university employees or consultants to recruit, from outside, good early-stage managers for spin-offs. Interviews with a number of TTOs suggest that, thus far, universities have found this reasonably easy, but if spin-offs continue to be established at even the current rate it may become more of a problem.

On finance, some explanation is needed. A university will often become a shareholder in a spin-off, but will rarely pay for its shares. The UNICO study shows that its member universities own on average 6 per cent of the shares of their spin-offs. The university is, however, unlikely to be given preferential treatment over other shareholders and will therefore have to wait some time – perhaps years – before it receives a dividend. All shareholders in a university will certainly hope to profit substantially, though, if they do, this will not normally be through dividends but through a capital gain made when the spin-off is floated off to a larger group of shareholders, or acquired by another company. Because of the difficulty of financial (and all other) forecasting, shareholders have to recognize that valuations put on companies before they are floated or sold must be treated sceptically. For what it is worth, UNICO-NUBS reported that in 2001 the aggregate valuation of all the spin-offs in 58 UK institutions was about £3 billion. This figure was, however, the aggregate of estimates made at about the time when the dot.com boom peaked and should be treated with even greater caution than valuations made in more normal times. These valuations were also dominated by the spin-offs of a small number of universities. So were the amounts realized from share sales in 2001, when nine of the 58 institutions sold shares for about £20 million. These were genuine capital gains, but just three universities accounted for about £18 million (80 per cent) of them.

Moreover, however effective a university is in promoting spin-offs, outstanding successes will be rare. In the UK, the conventional wisdom is that far fewer than 10 per cent of spin-offs will be substantial financial winners. In addition, as many as half of all spin-off companies that are established will either fail or become 'living dead'. Others may become 'lifestyle companies', which provide the researcher(s) responsible for the discoveries underlying those companies – or their early stage management – with reasonable income for themselves and their families, but give little return to shareholders.

In 2000, Kate Oakley and I wrote a report (Hague and Oakley 2000), which showed that a number of UK universities were spinning off up to four companies each year, and aiming at more. This may seem a small number of spin-offs, but comparison with US experience is interesting. The UNICO survey shows that, in 2000, 140 US universities created an average of 1.45 spinouts each against 2.2 each for 79 UNICO respondents. What is more, the average research expenditure for each of these US universities was ten times the £8.9 million for the UK respondents. Given the relative size of the two countries and of their universities' research expenditures, British universities have no need to apologize for their performance.

It is also encouraging that, since technology transfer in the UK acquired momentum during the 1990s, those employed by universities to work with researchers in setting up spin-offs have achieved so much. I have been impressed by their calibre, professionalism and enthusiasm. Universities are creating a new breed of project manager by bringing together, motivating and developing teams with the attitudes, attributes and skills needed to tackle this difficult new field. And they are doing it well.

Financing spin-offs

The UNICO-NUBS survey provides information about the ways in which the 554 spin-offs created between 1996 and 2001 were financed. Venture Capital (VC) companies provided varying proportions of the equity capital raised by each of 136 spin-offs (24 per cent), but a large proportion of these funds went to more than 120 spin-off companies in only 6 universities, one of which established 25 spin-offs with VC support. And 64 per cent of respondents used no VC funding at all.

Business Angels provided differing amounts of finance for a further 92 spin-offs in only 22 universities (17 per cent of the total). As with VC companies, therefore, many UNICO-NUBS respondents did not use business angels. The UNICO report finds this ‘surprising given the significant role that business angels are assumed to play in providing the seed finance necessary to develop promising ideas into business start-ups’.

The English University Challenge Competition, SMART awards and other government schemes were introduced – especially in Scotland – to give universities money, which they could use to move ahead scientific discoveries that were still at too early a stage to be safely financed by business angels or venture capitalists. The term ‘Proof of Principle’ is often applied to this phase of developing a discovery and will, for example, cover research and development work intended to show that a process that works well in a laboratory can be operated on a commercial scale. The Scottish Proof-of-Principle and Welsh Spinout programmes have a similar objective.

Over the five years 1996–2001, as many as 59 universities (78 per cent of the respondents) received no University Challenge money at all. Such money went to 68 spin-offs (12 per cent of the total) in about a quarter of universities. This means that 17 institutions, or 22 per cent of the 76 of the respondents to this question, received University Challenge Fund money, which they used to establish about one spin-off each. We should note, however, that a growing number of spin-offs are now being helped through the stage in their development immediately before they turn to business-angel money by the Smart awards described above. But there appears to be more of a financing problem in the earliest stages of the firm’s development.

Joint Ventures provided finance for 35 companies (6 per cent). These were set up in conjunction with industrial partners, and usually resulted from joint research that led to new IP or to know-how that could be exploited commercially. Again, funding was heavily concentrated. Only 19 universities received any joint-venture support, establishing between one and five companies each, but this kind of finance can be used only if a research link exists, or can be established, with a company that has the resources to develop commercial products stemming from a discovery and to market them.

'Other' funds – including the capital or savings of founders, investments by their colleagues, families or friends, and bank loans – financed 223 spin-offs in 41 per cent of institutions. This may seem a large proportion, though closer inspection might mean that some of these financiers could also be classified as business angels. But it reinforces the point made above that there is apparently a financing gap at this very early stage where the amounts of money required can be rather small, but the number of potential borrowers can be quite substantial.

Start-ups

The UNICO-NUBS report ignores start-ups, but the HEFCE report gives figures showing that 69 were established by university staff in 2000–1 and 238 by graduates – a total of 307. I later explain why I believe there must be more.

I have already pointed out that because start-ups do not come from specific research but from the inherent knowledge and expertise of the founder, he or she will frequently become the chief executive. This is *his* or *her* company and the university may well not hold shares in it. Of course, if the company later outgrows the founder's managerial competence, new management will be needed. Indeed, 'serial entrepreneurs' often consciously set out to sell each of their companies quite quickly in order to move on to the next.

Few universities positively seek out potential start-ups which they could help, though they do not refuse assistance to staff or students who seek it. Because start-ups rarely stem from specific research, few patents are associated with them, which means that start-ups are more heterogeneous than spin-offs. Consequently, most existing project managers in TTOs who are employed to work on technological spin-offs inevitably lack the range of commercial knowledge and technical expertise needed to keep up with changes in the start-up scene, especially since the advent of the Internet and e-commerce. This very heterogeneity, though, means that other staff members of UK universities do have the knowledge and enthusiasm required to help to establish start-ups. They are doing so and replicating US experience. My contacts in the Business School at Stanford University report that of its annual MBA class of over 200 students, around 10 per cent are now establishing their own businesses after graduation, and the faculty of the Business School are often their mentors and supporters.

As this suggests, many start-ups in the UK receive no financial contribution from any university. Indeed, no university may know that the company exists, which is why I believe that the HEFCE figure of 307 start-ups in 2001 is an underestimate. While there are therefore no precise figures for the financing needs of start-ups, the Professor of Computing at University College London, Philip Treleaven, has pointed out that, with IT start-ups, no initial funding may be needed from a university. As little as £5,000 or £10,000 can finance a useful beginning and, as he puts it, 'most students can put their hands on this kind of amount'. Where greater funding is needed, venture capitalists are often avoided as too 'greedy' for start-ups, but business angels can provide capital running into hundreds of thousands of pounds, and most 'angels' maintain close, continuing relationships with companies they help.

Networks

Beyond faculty members, a variety of individuals and organizations around universities help to establish and develop companies, though there are more of them in the USA than in the UK. For example, many people are surprised to learn that Stanford University, as an institution, virtually never helps its staff or students to establish new businesses, even spin-offs. (There are, however, four funds created by Stanford alumni to support new companies, from which the university benefits. Nevertheless, the university has no 'say' in how or where the money is invested, and therefore does not consider it to be 'Stanford' money.) Stanford believes that students should go ahead unaided by the university to demonstrate that they have 'fire in their bellies'. The university can more confidently take this line because of the support networks in the surrounding business milieu of Silicon Valley, where successful entrepreneurs, lawyers, venture capitalists, business angels and other supporters of small companies abound – and, of course, generous alumni.

While in many parts of the USA a variety of people and organizations are keen to help to establish and develop companies, in the UK such local entrepreneurial cultures have too often been weak, though the position is improving significantly. Cambridge has for some time been an outstanding example of an area with a strong culture of this kind, and the local consultancy, Segal, Quince and Wicksteed, coined and publicized the phrase as the title of a report, 'The Cambridge Phenomenon' (Segal *et al.* 2000; Lawson Smith *et al.* 2003). It is, however, significant that the influence of Cambridge University on the local economy has come less from the two dozen or so companies spun-off by the university than from dozens of Cambridge academics. They have been much involved with start-ups, through freelance activities outside the university. Few of them have left Cambridge University to take part in running the businesses they have helped to found, but it is difficult to underrate the value of such a local network either to the region or its universities.

Oxford has been slower to move into its entrepreneurial phase. Cambridge Instruments was established by Horace Darwin, son of Charles Darwin, as early as 1881. Oxford industry, however, was dominated until as late as the 1970s by the successful motor car manufacturing business built up by Lord Nuffield, and Oxford Instruments was set up by Martin Wood and his wife Audrey – now Sir Martin and Lady Wood – only in 1959. Oxford University itself has, however, played a substantial and direct role, through its subsidiary company – ISIS Innovation – having established over 30 spin-offs since 1997. Science parks and a network like the one that has assisted entrepreneurial growth in Cambridge, are now also thriving around Oxford.

What has happened in Cambridge and Oxford emphasizes a key fact. Setting up significant numbers of high-tech spin-offs is only possible with substantial access to world-class scientific research, and the two universities engage in this on a large scale. In 2001–2, Cambridge University spent £130.7 million on research and Oxford £131.8 million. The other three of the five largest research universities in the UK in 2001–2 were in London: University College, with £133.5 million, Imperial College with £128.0 million and King's College with £81.1 million. These five institutions – with a total of £605.1 million – therefore accounted between them for about 35 per cent of the English universities' research spending of £1.715 billion in 2001–2. Of this, the three big London colleges accounted for £342.6 million. Indeed one could add to this the research expenditure of the other London-based bodies: £31.1 million for Queen Mary College, £26.8 million for the School of Hygiene and Tropical Medicine, £24.6

million for the Institute of Cancer Research, £10.3 million for the London School of Economics, £5.7 million for City University and £7.2 million for Brunel University.

That would then give total London research spending of £442.6 million – about one-quarter of the total English university research expenditure – against about 7.6 per cent each for Cambridge and Oxford. Research spending in London as a whole greatly outweighs that in either Oxford or Cambridge. Interesting stories have been and will be told about Oxford and Cambridge (Segal *et al*. 2000; Lawson Smith *et al*. 2003), but large though their university research spending is, it does not equal London's. The sheer vastness of London as a city has so far deterred economic and social researchers from searching for a 'London Phenomenon' and telling the London story. Indeed, with some evidence that a shortage of sites and high salaries have driven at least some spin-offs and start-ups to establish themselves outside London, some observers speculate that its university research expenditure has been less effectively commercialized than in other areas. Nevertheless, one can understand why universities in the English regions, especially the North East, talk plaintively of the 'golden triangle' of Cambridge, Oxford and London.

In all the support networks for spin-offs and start-ups, business angels are important, and I recently learned that Roger Ashby, himself a business angel, has extended the definition. He argues that there are two kinds of 'angel'. Business angels have money to lend and advice to offer, but there are individuals with little free capital who are willing to help to establish start-ups for modest rewards – or even out of philanthropy. Roger Ashby calls them 'knowledge angels'.

What, then, do entrepreneurs want from knowledge angels, and indeed from business angels, apart from money? First, entrepreneurs ask angels of either type to apply their specialist expertise, and their long-term experience in and around start-ups, to pressing current business issues. But everyone's expertise and experience is limited so that, second, entrepreneurs want angels to introduce them to members of the angels' own network of contacts. Some of these contacts will be able to offer specialist expertise that is different from the angel's own, and all can persuade yet others in their own networks to do the same – giving access to a network of networks. Beyond that, angels can, say, give introductions to civil servants, to potential customers or to investors. The angel has to pick out the people in his or her network who will give most help in each particular case, and to make the necessary introductions.

I go further. The more I talk to knowledge angels the more I realize how much of their time even 'angels' spend networking with each other to obtain new contacts and information for themselves. Networking is very important to the process of innovation, more than most conventional businessmen – and, I suspect, academics and administrators in universities – realize. Universities aiming to help start-ups, and of course those supporting spin-offs too, need to make the best use they can of any networks in their area. It is a matter of spotting members of local networks and developing links with them. Of course, even inside universities there are colleagues who could join and help to extend these networks, and universities should encourage them to do so.

Academics

Because of this, in my researches, I have become very interested in academics having been unusually active in commercializing IP.

Innovators: a professorial trio

In order to illustrate some characteristics of such innovators, I choose three people I have studied. All are Oxford professors – Mike Brady, Information Engineering; John Bell, Clinical Medicine; and Raymond Dwek, Biochemistry. All three are widely recognized in Oxford as leading examples of the type and, early on, each was affected by experience of the USA.

Brady

Brady, a Manchester University graduate, first worked in the University of Essex and then spent the period 1980–5 teaching at MIT in Boston. This experience emphasized just how important well-equipped labs were. Having been hampered in leading-edge work on computer vision by a lack of resources at Essex, he was 'a king in a candy store' at MIT. He also developed an aversion to start-up companies which took lavish initial funding from venture capitalists and splashed it out on expensive offices and high salaries in the hope that they would develop and sell enough products to achieve a positive cash flow before the initial capital ran out. Even if the company succeeded, the founders held virtually no equity. More positively, MIT's industrial liaison office arranged that Brady regularly met local business executives to discuss common research issues. Unlike most UK academics in that period, he therefore became used to meeting business people and to forging links with companies.

Dwek

Dwek was also a Manchester graduate and his first US links were quite fortuitous. In 1968, while working for his PhD in Oxford, he attended a lecture by a US general and made perceptively critical comment on the American army's approach to science. To his surprise this had positive results and he was invited to work for several months with the US army's huge electronics command. It was a very important experience for Dwek because the sheer size of the team there enabled him 'to see how big science could be done'. He had access to all the contracts that the US army had with universities; was free to visit any of the academics working on them; and so could ask how they were tackling their contracts and what they were achieving. Similarly, he could seek assistance from US industry, not least in evaluating research outcomes. He had access to huge resources, 'with no checks and balances' – a unique opportunity for a young UK academic.

Bell

As a Canadian, Bell had grown up with North American enterprise and, following medical training in Oxford and London, he learned more of entrepreneurs at first hand. He arrived at Stanford University as Clinical Fellow in Immunology just as molecular biology was taking off in the Bay area, and saw Stanford academics establishing start-up businesses and the university struggling to handle them. He thought Stanford's refusal to become involved with start-ups at all 'a terrible mistake', because it deprived the university of capital gain. Bell did, however, see Stanford benefit from licensing. He arrived in California just as a the Cohen-Boyer legal case gave to both Stanford and the University of California, San Francisco, patents in the technology which effectively made recombinant DNA research possible. Licensing these patents brought the universities a total of $20 million a year between them.

Returning to Oxford

Brady

Back in Oxford, their American experience led all three into innovation. Brady established an ambitious project to build mobile robots, which 'just took off'. He also continued the practice, learned at MIT, of making regular visits to companies. 'I took one day each week', he says, 'and drove to a company within 100 miles of Oxford just to introduce myself, to find what their problems were, to look for synergies – if any

– and to exchange views.' Brady was warmly welcomed by companies, which had very few visitors from any university. From the visits came some half-dozen research projects and continuing research links, some very long-lived, which provided funding for staff and generated research projects. One of these links, with a subsidiary of GEC, led to two successful research projects on improving robots, but a third project was forestalled because GEC had sold the subsidiary.

Frustrated, Brady and three researchers from the subsidiary negotiated with GEC to acquire the rights needed to establish their own company – Guidance Control Systems – while Brady referred back to his MIT experience and insisted that GCS must remain small. GCS began by working on a single contract to maintain lorries fitted with GEC equipment, and drew on Oxford University research to develop a second product, hiring new people and new space. Still small today, GCS has about 20 employees and annual turnover around £3 million.

Though he still remains involved with GCS, the death of Brady's mother-in-law in 1994 shifted his focus to computer-generated pattern recognition for the treatment of cancer. In a conversation with Brady one cancer researcher said he would give anything for computer-based systems that would help pattern recognition in this field. Studying the literature, Brady realized that existing approaches were 'scarcely serious science' and persuaded one of his PhD students, Ralph Highnam, to model X-ray flows through the breast. Three years' effort, funded by a research council, produced 'a beautiful piece of work'. But the project was not complete, and the research council's peer review report said that the approach was too new, and must obviously be wrong, because it was 'not professional'. So Brady and Highnam resorted to a classic academic subterfuge, successfully proposing a totally different research project, but designing it to leave more than half of their time for mammography. So after six years, says Brady, 'we had carved out a niche for ourselves and were considered to have pioneered a new approach, which was now "kosher"'. But their discoveries still needed exploiting. With Ralph reluctant to run a company to develop them, they offered their findings free of charge to the market leader, which was contemptuous. Brady reports their response. 'The findings were from a university, and must be rubbish.' Another company did approach Mike and Ralph, but they were not impressed by it. So Ralph then agreed that they should form a company, Oxiva, with capital from 'friends, fools and family' and fees from contract work in California. Oxiva was in business, but needed to broaden its scope.

GCS and Oxiva were not, however, Brady's only ventures. Following sabbatical leave in France he had set up another company – Omia – with a French scientist, Jacques Feldmar. Working in fields like cardiac ultrasound, Omia also needed to grow. The upshot was that British venture capitalists enabled Oxiva and Omia to merge, forming Mirada Ltd, and leaving Oxford University with 10 per cent of its shares and the company's staff with 60 per cent. In 2003, Mirada was sold to the US Corporation CTI Molecular Imaging Inc. for $22 million in cash and notes plus possible payments linked to Mirada's future profits.

Dwek

Initially, when he returned to Oxford, Dwek followed a normal academic career. Then, in 1979, successful consultancy work he had performed for Monsanto led the company to offer him payment. Typically, Dwek refused, but then so interested was Monsanto in his own 'blue skies' research work that the company gave Oxford University £100,000 to fund it. Dwek had tapped a continuing source of example, expertise and funding that would both profoundly influence him and support the university's research. Three years later, in 1982, while strengthening his early links with Monsanto, Dwek's research revealed that besides DNA and proteins 'there was a third biochemical alphabet – sugars'. He was keen to develop a technology for handling it, but his professor, Rodney Porter, insisted that no UK Research Council would have sufficient funds to enable him to do this. 'Why not go back to Monsanto?' he asked, and Dwek did precisely that. Exploratory work revealed big, though expensive, opportunities and Monsanto agreed to provide Oxford's first major industrial contract – which in the event yielded £50 million over 14 years. Dwek was inevitably accused of unbalancing the university, but saw Monsanto as idealistic, providing high-quality people and important spin-offs for Oxford. Not least, Monsanto's finance established Oxford University's Glycobiology Institute, and Oxford's biochemistry department is now by far the biggest in the world.

Dwek saw the commercial potential of sugars as reagents and actually established a company – with two shares! – to exploit them. But Monsanto had just acquired the US drug company Searle, and offered Dwek compensation to leave the field open for Searle. Again typically, Dwek spotted a different opportunity and persuaded Monsanto to send scientists to Oxford. They worked under his direction and reported to Searle, while helping to establish the technology of a new company.

Dwek wanted to create a cycle. 'The university spins off discoveries into a company; the company feeds back technology; and it also provides grants to produce more discoveries.' The company – Oxford Glycosystems (OGS) – was set up in 1988. OGS was the first company in which the university held shares, though it did not pay for them. To demonstrate his anxiety to safeguard the university, Dwek resigned as an individual director of OGS on its first day, becoming a university director instead. The university could then discipline him, if necessary, and prevent conflict of interest. In 1989–90 OGS issued its shares to the public. Up to this point, Monsanto had held a 'golden vote' and had used this to prevent OGS from producing drugs. Monsanto now withdrew that objection, so that as well as producing technology, OGS was able to use some drugs from the Glycobiology Institute and provide funds for the Institute's research.

Dwek's 'cycle' was complete, and OGS, renamed Oxford Glycosciences, brought in top big-company managers. Kurt Raab from Genentech, was appointed Chairman of OGS, while Michael Kranda, from Immunex, became Chief Executive. Interestingly, Raab later became a member of the Chancellor's Court of Benefactors in recognition of the substantial gifts from the company to Oxford University. Thus far OGS is the only spin-off company whose representative has joined the Court, but this appointment reinforced Dwek's idea of support for the university.

OGS has now diversified into a real drug discovery programme. In late 2002, OGS announced that its drug for Gaucher's disease had been granted a licence for sale in the EEC, and this was a drug that resulted from research in the Glycobiology Institute. Having raised £200 million in cash through a share issue in 2000, OGS had substantial funds, and in 2003, OGS was acquired by Celltech for £106 million, entirely in cash. Celltech told its annual general meeting in May 2003 that it was particularly keen to develop OGS work on oncology, and that its managers were 'installed in key positions to direct the rapid integration of key elements' of OGS but that some activities would be divested. And the research grant to the Glycobiology Institute continues. Dwek himself has been appointed to the Board of the Oxford University subsidiary, ISIS Innovation Ltd (see also the chapter by Cooke in this volume). This recognizes the understanding of the high-technology spin-off arena, which he has acquired during his career.

Bell

Bell's influence has been less hands-on, but widely spread. Returning to Oxford, in 1987, he says he found 'a thriving and flourishing environment, but with scepticism about academics coming close to commercial activity. After California, I had a different perspective.'

A year later, Bell was approached by a New Zealand student, Garth Cooper. Knowing of Bell's Stanford connections, Cooper asked Bell for help in exploiting his research findings, and Bell discussed these with Ted Green, a San Diego venture capitalist. Next day, Cooper left for San Diego! Within two weeks, Cooper and Green had filed patents based on Cooper's data. They gave the name 'Amylin' to one protein Cooper had identified and wrote a business plan for a company also called Amylin. With Bell they tried to establish the company near Oxford, but, in 1990, Bell says they found it was 'just a desert for creating entrepreneurial activities'. Green and Cooper therefore set up Amylin in San Diego, though much of its VC came from London. The company grew rapidly, reached 100 employees and floated on the Nasdaq exchange. But Amylin's lead product was refused approval and the share price dropped below one dollar. After disagreements, Cooper was replaced as chief scientist, sold his shareholding profitably, returned to New Zealand and established another company. In the spring of 2003, Amylin had a market capitalization of $1.4 billion.

This experience showed Bell that there was unexploited IP in Oxford and he sent Elspeth Bellhouse, a London physics graduate, to report how the top six US universities handled entrepreneurship. She found Oxford 'not far behind'. Even so, there remained a widespread feeling in Oxford that the university's technology transfer instrument, ISIS Innovation, was not performing optimally and Bell developed a scheme for doing so. Inevitably, the university launched an enquiry, which proposed a medical division of ISIS. Bell refused to use it, but perhaps his refusal was the catalyst. Bell and others joined the ISIS Board, Tim Cook later became managing director, and Bell now sees ISIS as 'a splendid model'.

Meanwhile, Elspeth Bellhouse and her father had approached Bell. Brian Bellhouse, another fellow at Bell's college – Magdalen – had invented 'an interesting device' for 'sending small particles through the skin' – a new form of vaccination and drug delivery, though even today one not approved. Elspeth was establishing a company – Powderject – to exploit the discovery, and Bell agreed to help, while Elspeth said her father had found a 'great entrepreneur', Paul Drayson, to develop the business. (Incidentally, Paul and Elspeth soon married.) After negotiation with the university to obtain necessary IP, the three became founder directors of Powderject. The company had 'outstanding technology' and Drayson's great strength was in engineering corporate deals. These allowed the company to use the optimism associated with its vaccination device to profit from selling other products while proving its own. Floated in 1996, Powderject now has a turnover of £160 million. Bell calls this 'the most exciting and interesting thing I have done', while he considers Drayson 'one of the great men of UK biotechnology'. (At the time of writing Powderject has recently been acquired by the Chiron Corporation of America for £542 million.)

Bell then saw another possibility. His department had probably the world's best programme in common-disease genetics, and he wanted to spin out a company – Oxagen – from it. Bell discussed this with Ian Lang and Nick Croft, financiers and property developers, who had built a science park near Didcot and had already provided the initial finance for Oxagen. Mark Peyton is now CEO. Oxagen, says Bell, has raised money more easily than any other genetic company he knows, but it has not floated. It has, says Bell, been 'over-managed but under-led'. Bell's latest involvement is with Avidex, a company spun out to exploit work of another senior Oxford colleague, Bent Jakobsen, and especially his development of soluble T-cell receptors, which enable the immune system to recognize abnormal cells. Bell feels the establishment of Avidex shows networking at its best. Its CEO is James Noble, who had been on company boards with Bell. They also knew other founding directors, including Martin Wood – creator of Oxford Instruments and Oxford University's first major entrepreneur – and, as with Oxagen, Nick Cook. Unlike Amylin, 'everything was there – a building, business angel money and employees keen to join'.

For Bell, 'spin-offs have been fun, helped to keep me interested and are among Oxford's greatest successes. People think Oxford is old-fashioned and hopeless, but we are not now.' For that, innovators like Brady, Bell and Dwek deserve substantial credit.

Innovators: lessons

The three professors provide examples of the way four innovators have gone about developing university–business links and offer useful lessons to others. My own observations are these. First, there was the enormous influence of the USA on their activities during their early years, though of course one of the three was brought up in North America. Clearly, academics have a greater range of opportunities available to them today, but the key lesson must be the same. Experiencing a quite different environment is often the best way to see possibilities that one has not imagined and ways of operating that are quite new. Secondly, they have developed their interests in diverse ways. Brady has remained faithful to his early belief in the virtues of working through the organic growth of small companies and avoiding grandiose expenditures. Bell has had a broader influence, over a wider range of activities, all in scientific fields he really understands. Dwek has operated on a grand scale and I am intrigued by the way that he has been able to turn offers made to him to the advantage of Oxford University, for example, through very substantial business donations to the university from Monsanto to support his fields of interest. Few academics bring money to their universities on such a scale.

Closing comments

This chapter shows substantial activity over spin-offs and start-ups in UK universities, and also that these universities have nothing to fear from comparison with the USA. Even so, the UNICO Survey makes a crucial comment, pointing out that the current number of scientific and technological research projects in British universities must be 'in the tens of thousands'. It follows that even the 175 companies spun off by UNICO members in 2001 is a very modest total relative to the total number of discoveries currently being made by university researchers. A promising start has been made but there is much more to be done in establishing and supporting both spin-offs and start-ups.

This chapter supports the belief that a significant increase in the number of spin-offs is both necessary and possible in the next phase of the process of commercializing university research. If this is to happen, the innovative imagination of those formally employed in technology transfer by universities and the more entrepreneurial ventures of individuals like the three highlighted here will need to be emulated by many more. And, outside that, universities will need to link themselves as positively as they can into the informal networks of support that are developing in wider communities outside them.

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3

Are Research Spin-offs a Local Phenomenon? Empirical Findings from Germany

Jürgen Egeln, Sandra Gottschalk, Christian Rammer and Alfred Spielkamp

Introduction

New business ventures stemming from universities or public research organizations have attracted increasing amounts of interest in innovation policy over the last years. Significant contributions to knowledge and technology transfer are expected from such public research spin-offs. They are regarded as hubs that transfer research results into new products, new processes or new services (OECD 2001; Callan 2001). Regions that are sites for public research facilities are hoping that spin-offs will strengthen the local economy and increase innovation activities in the region. Spin-offs that stay in the region may benefit from linkages to and cooperation with their incubator. At the same time, they may build up links to other regional firms and thus contribute to spillovers of new knowledge into the regional economy.

Silicon Valley or the Greater Boston Area are presumably the most prominent examples of such type of regional knowledge transfer through public research spin-offs (Bania *et al.* 1993; Saxenian 1994). But is this typical for an economy as a whole? Do public research spin-offs really stay close to their incubators, or do they leave the region? In this chapter we address the following research questions:

- Do public research spin-offs cluster around the institutions they have been associated with?
- What determines a spin-off's decision whether to stay in the incubators' region or to move away?

- Which location characteristics attract spin-offs, and do these characteristics differ in comparison with non-academic firm creations?

Most of the literature on research spin-offs stresses the spatial proximity between public research spin-offs and their incubator (Carayannis *et al.* 1998; Chiesa and Piccaluga 2000; Colyvas *et al.* 2002; Siegel *et al.* 2003). In a recent OECD compilation of spin-offs (OECD 2001), it is stated: 'The spin-off phenomenon is at base a local phenomenon, as local innovation networks play a major part in it. These firms are linked to their home laboratories, to a few close customers, to support from local authorities' (Mustar 2001, 169f). In this chapter we will investigate this assumption using data that cover the whole spin-off activity in an economy over a five-year period. This representative database overcomes a basic shortcoming of previous studies on research spin-offs and their location, which almost entirely gathered information from the incubator organizations and may thus be biased towards spin-offs that are 'in sight' of the incubator's location (Steffenson *et al.* 1999; Clarysse *et al.* 2001; Massing 2001; Matkin 2001; Mustar 2001; European Commission 2002a and b; DiGregorio and Shane 2003; Lockett *et al.* 2003).

There are several arguments why spin-offs from universities or public research organizations will cluster around the location of their incubator. First, proximity to the incubator facilitates collaboration in research and the flow of tacit knowledge and lowers transaction costs associated with such type of activity. Typically, spin-offs commercialize – at least to some degree – new knowledge produced at the incubator. Thus, they might depend upon further research results from the incubator and use contacts for learning and appropriating new technologies and scientific findings into their business practice (see Cohen and Levinthal 1989, 1990; Grabher 1993; and Cowan and Foray 1997 on the role of face-to-face interaction for tacit knowledge exchange). Spin-offs should therefore be interested in maintaining personal links to their former colleagues in order to ease knowledge exchange.

Secondly, researchers who establish their own enterprise might attempt to keep some formal relation to their university or research organization that might range from cooperation in research projects, subcontracting in research or lectureships to further part-time occupation at the institution. Such formal relations provide some amount of income to the firm founders and might ease a subsequent return to public research in the case of failure of the spin-off. Thus, formal relations reduce the risk of the business venture. As such relations demand some degree of personal presence at the institution, a location close to the incubator will be preferred. New ventures most often lack capital at the time of starting the business. High uncertainty about their commercial success restricts access to external finance. At the same time, public research spin-offs may require laboratory equipment, high-level computer facilities and other types of physical research infrastructure. In order to minimize investment in fixed capital they might attempt to use the infrastructure of their incubator, at least in the first phase of business activity. Furthermore, especially in early stages of business activity demand for new products will vary considerably over time, and a large number of permanent employees may represent a severe financial burden. Proximity to the incubator also eases the temporal employment of students or young researchers and allows for reducing fixed costs as well.

Finally, one may expect individual preferences by the founders of spin-offs to stay in the region they have worked so far. They may have built up social relations they want to maintain, and costs of migrating to another region may be perceived as too high.

There are, however, some good reasons why public research spin-offs may leave the region of the incubator. First, they need to establish customer relations in order to sell their products and services. As spin-offs often introduce products and services that are new to the market, close contacts to users, and redesign of products and services to meet specific demands is required. There might be only a few key users for the spin-off's innovation in the market, and it is rather unlikely that they are located in the same region as the incubator. Location decision of spin-offs can thus be described as the optimization problem to minimize the sum of costs of interacting with users, interacting with the incubator, and acquiring factor inputs, first of all high-skilled labour. If the demand for user interaction and high-qualified labour that provides complementary skills to that of the founders is high – and is expected to rise over time – spin-offs are more likely to locate in a region different from that of the incubator.

The following section describes the database of our analysis in more detail. The third section analyses the location pattern of spin-offs and the spatial distance between spin-offs and incubators. The fourth section discusses the determinants of a spin-off's decision to locate away from the incubator, using different threshold values. The fifth section deals with the determinants of location decisions of spin-offs that either move away or stay in the incubator's region and identifies differences in location determinants between spin-offs and other start-ups in the same business sectors.

Data

To identify the number and characteristics of public-research spin-offs we carried out a telephone survey (using a computer-assisted telephone interview technique) of more than 20,000 firms that have been established in the years 1996 to 2000 in Germany. The database is a stratified random sample of the Mannheim Foundation Panels, which are constructed from firm-level data made available by CREDITREFORM (see Appendix 1 for details). Stratification criteria are the year of establishment, the economic sector and the type of region.

The survey is restricted to 'knowledge-intensive industries'. These cover R&D intensive manufacturing, technology-oriented services such as software, telecommunication and engineering services, and knowledge-intensive services such as management consulting, teaching, research and other producer-oriented services (see Appendix 2). The relevant population contains about 322,000 start-ups, which is about 20 per cent of all start-ups in Germany in the respective period of time. We assume that the vast majority of spin-off activity takes place in knowledge-intensive industries. Prior data analyses showed that the overwhelming share of self-employed graduates work in these sectors. Moreover these sectors account for almost all R&D activities in Germany (Stifterverband 2002).

Each start-up had to state during the telephone interview how many of its initial founders were or still are working in public research institutions, and at which institution(s). A public research spin-off was then identified as a start-up with at least one founder who worked or is still working in a public research institution. Public research institutions consist of universities (including technical colleges, so-called 'Universities of Applied Sciences') and public research laboratories in Germany but also comprise institutions abroad.

Out of 20,241 complete observations we identified 2,218 public research spin-offs: i.e. about 11 per cent of all start-ups in knowledge-intensive industries in Germany in the second half of the 1990s are spin-offs from public research institutions. The majority of public research spin-offs belongs to the service sector, the share of R&D intensive manufacturing is less than 20 per cent (Table 3.1). With respect to the total population, public research spin-offs are represented above average in technology-oriented services.

The information gathered from all start-ups had to be restricted to a few main firm characteristics in order to keep total interview time low and match the costs available for the survey. The questions referred to

Table 3.1 Survey on start-ups in knowledge-intensive industries in Germany (1996–2000): number of surveyed spin-offs and start-ups by sector

	Public research spin-offs	*All start-ups*	*Share in all start-ups*	*Shares by sectors*
R&D intensive manufacturing	395	4,506	8.8	17.8
Technology-oriented services	923	7,661	12.0	41.6
Knowledge-intensive services	900	8,074	11.1	40.6
Total	2,218	20,241	11.0	100.0

Source: ZEW Spin-off-Survey 2001.

the relevance of new research findings from public research for starting the business, current links to public research institutions, R&D activities, and size and economic activity.

Location patterns of public research spin-offs

One may assume that the location behaviour of public research spin-offs differs significantly from that of other start-ups. There might be special, close links to their incubator institution that suggest choosing a location nearby the incubator. Just as the location pattern of incubators is very likely to differ significantly from the location pattern of all start-ups, so will that of spin-offs differ. But location decisions of spin-offs have to take into account criteria other than that of minimizing the distance to the incubator. The utilization of localization and urbanization economies essentially influences the possibility of market entrance, and hence the cost structure and sales prospect of firms. Knowledge-intensive industries with high access to production and sales factors have better possibilities in agglomeration centres than in rural regions: a wide range of qualified personnel, diversified business structure, a high demand for high-quality products and services, high purchasing power of the population, high share of research and knowledge-intensive enterprises and excellent traffic and technological infrastructures. Disadvantages of agglomerations such as high rents and cost for land should be less important for public-research spin-offs.

Table 3.2 presents the location pattern of public research spin-offs in comparison with that of all start-ups, of start-ups in knowledge-intensive industries and of the spin-offs' incubators. For each category of start-up, the share of firms located in agglomeration centres, other urban centres, suburban regions and rural areas is presented. The location pattern of incubators refers to the regional distribution of institutions that have been stated as incubators by public research spin-offs, weighted by the number of spin-offs. Table 3.2 shows that the location pattern of public research spin-offs lies in between that of their incubators and that of other start-ups in knowledge-intensive industries. While incubators are heavily concentrated in agglomeration centres and urban centres (80 per cent of all institutions), start-ups in knowledge-intensive industries are mainly to be found in suburban regions and rural areas (62 per cent), i.e. they show a location pattern similar to all start-ups in Germany. This pattern reveals the regional distribution of demand in Germany.

About every second public research spin-off is located in an agglomeration or other urban centre. This is significantly lower than the respective share of incubators, but significantly higher than the same share for other start-ups. Location decisions of public research spin-offs thus seem to be driven both by the access to knowledge at their incubator and by the access to demand.

There is obviously a significant portion of public research spin-offs that do not locate very close to their incubator but move at least to another type of region. Table 3.3 shows the share of spin-offs located at different distances from their incubators. If a spin-off has more than one incubator, which is the case for about every second spin-off, the distance to the nearest incubator is used. More than one-quarter of public research spin-offs are located at least 75 kilometres (km) away

Table 3.2 Distribution of all start-ups, start-ups in knowledge-intensive industries, public research spin-offs, and incubators of public research spin-offs by type of region (in per cent)

	All start-ups (i.e. start-ups in all types of industries)	*Start-ups in knowledge-intensive industries*	*Public research spin-offs*	*Incubator institutions*
Agglomeration centres ≥ 300,000 inhabitants	29.9	31.7	41.4	61.2
Urban centres < 300,000 inhabitants	6.5	6.0	9.3	18.7
Suburban regions	39.5	42.1	34.9	14.9
Rural regions	24.1	20.2	14.4	5.2

Source: ZEW Spin-off-Survey 2001, Mannheim Foundation Panels. All information is expanded for the German statistical population of knowledge-intensive industries.

from their incubators, while only 55 per cent are within a 25 km distance from their home institution. About a third of the public research spin-offs in Germany are located 50 or more kilometres away from the incubator's location. Spin-offs are not as much a local phenomenon as many case studies have suggested so far.

To leave or to stay at the incubator's region?

In this section, we investigate the determinants of a spin-off's decision to leave the region of the incubator. The term 'region' refers to the area around the incubator within which face-to-face contacts may take place on an ad hoc basis, i.e. travel distance is less than an hour. We use alternative radiuses of 25, 50, and 75 km, respectively, to demarcate an incubator's region. All spin-offs from an incubator that are located within this radius are regarded as having stayed in the region, while all the other incubator's spin-offs are regarded as having left the region.

The decision to leave or stay is assumed to depend on five groups of determinants that represent different types of costs and benefits associated with the location decision:

1. *Urbanization economies* in the incubator's region reflect the level and quality of local demand. A high level of demand and economic activity are incentives to stay in the region rather than to leave. Urbanization economies also cover the diversification of the labour market. Spin-offs will require high-qualified labour and thus tend to locate in regions with a high supply of well-trained labour, which can be found most easily in large agglomeration areas.
2. *Localization economies* in the incubator's region cover the potential for business relations for the spin-off. A high-tech orientation of the local economy, and a high number of start-ups in the same sector as

Table 3.3 Distribution of public research spin-offs by distance to their incubator (in per cent)

Distance between firm and incubator	*Public-research spin-offs*
Less than 25 kilometres	55.1
25 to 49 kilometres	11.4
50 to 74 kilometres	6.0
75 kilometres and more	27.4

Source: ZEW Spin-off Survey 2001. All information is expanded for the German statistical population of knowledge-intensive industries.

the spin-off provide a favourable base for user–producer interaction and supplier links, and represent a competitive environment for the spin-off.

3. The *type of incubator* affects to some extent the way of cooperation and the organization of linkages between the incubator and the spin-off (see Beise and Stahl 1999 on the types of public research institutions in Germany). At universities, researchers are often strongly occupied with basic research, teaching and administration tasks that may leave rather little time for collaboration with spin-offs. Technical Universities often engage in technology transfer activities with large, established companies that may also limit their capacities. Technical Colleges are strongly teaching-oriented but typically own separate resources for transfer activities, including contacts to spin-offs. Public laboratories consist of several different institutions (see Harding, Chapter 7) but are similar in having a strong research orientation and sufficient resources for cooperation with spin-offs. Interacting the incubator's institutional affiliation with the technology specialization of the spin-offs covers some additional aspects of the attraction of the incubator as a source of knowledge for the spin-off.
4. *Characteristics of spin-offs*, such as size, age and sector of economic activity, control for firm heterogeneity and corresponding effects on location decisions. In this respect, the time span between quitting the public research institution and establishing the spin-off firm is of special relevance as it increases the opportunities for future business contacts to potential customers as well as to other public research institutions, and may thus increase the likelihood of starting the business at a location outside the incubator's region. Actually, only 47 per cent of all public research spin-offs in Germany start their business immediately after quitting universities or public labs (including spin-offs with researchers who still have an occupation in public research). The remaining share had independent or wage employment in between.
5. Type and intensity of *knowledge transfer* through spinning off is expected to affect the spin-off's demand for later interaction with the incubator or other knowledge sources. We distinguish the relevance of new research results obtained at the incubator, the relevance of special competencies appropriated during work at public research, and the relevance of concrete demand by firms for spinning off. Furthermore, the *knowledge intensity* of the spin-off, i.e. carrying out R&D and having formal knowledge interactions with

public research, will influence the significance of transaction costs for keeping in contact with the incubator and thus affect location decision.

The effects of these variables on the spin-off's decision whether to stay or leave their incubator's region are estimated by probit regressions (Table 3.4). For each public research spin-off we measure the distance between its location at the time of surveying (Autumn 2001) and the location of its incubator. If there is more than one incubator, the distance to the nearest incubator is used. Distances of 25, 50, and 75 km, respectively, are used as threshold values to separate leaving from staying spin-offs. The analysis is restricted to spin-offs from German public research institutions. A total of 2,077 observations are available.

Spin-offs tend to move away from their incubator's region if urbanization economies in the region are less pronounced. All three indicator-variables for the type of region show a positive sign, i.e. the probability to leave an incubator's region is higher if it is not the centre of an agglomeration. Incubators located in smaller and more peripheral regions thus have a lower probability that firms spinning out of their institutions will stay nearby, i.e. spin-offs tend to transfer knowledge out of the region. Spin-offs from incubators that are located in rural areas tend to move away less than 75 km, while spin-offs from incubators in suburban region show a high propensity to move to a rather distant location. But spin-offs are also more likely to leave their incubator's region if the local level of income is high, but moving distance tends to be less than 50 km. This variable may grasp the effect that spin-offs avoid high land and living costs in agglomeration centres and move to suburban regions.

Localization economies play no major role in explaining a spin-off's decision to leave or stay. While a high level of start-up activity in the spin-off's sector is an incentive to stay, the R&D intensity of the local business sector does not attract spin-offs. This is in contrast to the importance some strands of literature assign to local knowledge networks within R&D oriented firms as a major location decision.

The propensity to leave the region increases with the size of the spin-off and the time-span between quitting public research and starting an own business. The older a spin-off is, the more likely it is that it has moved away from the direct neighbourhood of the incubator, but the age does not affect the decision to leave the more extended region of the incubator. Spin-offs with an economics or business administration background leave the region significantly more often while all other

Table 3.4 Determinants of spin-offs' decision to leave the incubator's region (Germany, 1996–2000): parameter estimates of weighted probit regressions for different distances between a spin-off and its incubator

	Distance to incubator > 25 km	*Distance to incubator > 50 km*	*Distance to incubator > 75 km*
Urbanization economies in incubator's region			
Urban centre with population < 300,000	0.417 **	0.298 **	0.190 *
Suburban region of an urban agglomeration	0.350 **	0.326 **	0.401 **
Rural area (urban centre < 100,000 population)	0.385 *	0.374 *	0.264
Level of new firm formation	–0.019	0.021	0.052 *
Income level (purchasing power per inhabitant)	0.037 **	0.007	–0.004
Localization economies in incubator's region			
Level of start-ups in the spin-off's sector	–3.59 **	-2.296 *	–1.961
R&D intensity of the business sector	–0.632	–0.418	–0.321
Share of high-qualified employees	0.002 *	0.002	0.003 °
Spin-off characteristics			
Ln(number of employees in starting year)	0.115 **	0.101 *	0.086 *
Ln(age)	0.125 *	–0.032	–0.017
Ln(years between leaving incubator and start-up)	0.116 **	0.148 **	0.170 **
Discipline natural sciences	–0.113	–0.090	–0.059
Discipline engineering	0.105	0.168 *	0.070
Discipline economics and business administration	0.206 *	0.208 **	0.143 *
Discipline social sciences	–0.161	0.007	0.013
Spin-off carries out R&D on a permanent base	–0.072	–0.123 *	–0.016
Share of researchers among spin-off founders	–0.317 **	–0.211 *	–0.158
Type of incubator by spin-off's sector			
Technical University & R&D int. manufacturing	–0.058	–0.081	–0.296 *
Technical University & technology-orient. service	0.171	0.096	0.095

Table 3.4 Determinants of spin-offs' decision to leave the incubator's region (Germany, 1996–2000): parameter estimates of weighted probit regressions for different distances between a spin-off and its incubator *continued*

	Distance to incubator > 25 km	*Distance to incubator > 50 km*	*Distance to incubator > 75 km*
Technical University & knowledge-intensive service	0.382 **	0.397 **	0.374 **
Technical College & R&D int. manufacturing	–0.348 *	–0.723 **	–0.797 **
Technical College & technology-orient. service	–0.050	–0.248 *	–0.149
Technical College & knowledge-intensive service	–0.020	–0.072	–0.172
Public Laboratory & R&D int. manufacturing	0.514 *	0.782 *	0.950 **
Public Laboratory & technology-orient. service	–0.207	–0.451 *	–0.256
Public Laboratory & knowledge-intensive service	0.497 **	0.461 *	0.538 *
Interaction between spin-off and incubator			
New research results essential for spinning off	0.118	0.089	–0.034
New research results important for spinning off	0.049	0.111	–0.012
Special competencies essential for spinning off	0.118	0.077	0.024
Demand by firms important for spinning off	–0.135	–0.083	–0.065
Spin-off uses incubator's infrastructure	–0.387 **	–0.228 *	–0.375 **
Joint R&D projects with public research institutions	0.095	0.010	0.027
Contract research to public research institutions	–0.215 **	–0.169 *	-0.153 *
Public research institution are clients of spin-off	0.059	0.100	0.034
Training of spin-off employees at public res. inst.	–0.194 **	–0.136 *	–0.097
Employing students from public research institutions	–0.047	–0.141 *	–0.236 **
Constant	–0.573	0.030	0.091
Number of observations	2,077	2,077	2,077
Wald chi^2	134.86**	145.86**	139.19**
Pseudo R^2	0.063	0.062	0.060

** (*) indicates significance at the 0.01 (0.5) level.
Source: ZEW Spin-off-Survey 2001, calculations by the authors.

disciplinary backgrounds show a similar effect upon the location decision.

Spin-offs in knowledge-intensive services (such as management consulting and teaching) are more likely to leave the incubator's region, especially if the incubator is a Technical University or a public laboratory. These spin-offs offer services that often demand face-to-face contact with clients for selling the service and therefore may prefer locations with high demand for their services. As Technical Universities and public laboratories are often located outside the main agglomerations in Germany, these spin-offs tend to move to more central locations. Spin-offs from public laboratories that specialize in high-tech manufacturing also tend to leave their region, while high-tech manufacturing spin-offs from universities (which are the majority) are more likely to stay close to their incubator.

Spin-offs tend to stay in the incubator's region if

- they use infrastructure of the incubator,
- they place contract research to public research institutions (both to the incubator or to others),
- they use public research as a source for training their employees.

Moreover, the higher the share of researchers among those who established the spin-off, the higher the propensity to stay near to the incubator. Carrying out joint research with public research institutions does not affect, however, the decision to leave or stay. The same holds true if public research is a client of the spin-off. Spin-offs that employ students tend to stay within a 75 km circle of the incubator.

A striking result of the analysis is in relation to the knowledge intensity of the spin-off and the relevance of transferring new research results to the market by spinning off. All variables that measure these aspects are insignificant. The decision to locate close or further away from the incubator is not driven by the extent to which knowledge transfer is at the centre of the new firm formation. The demand by firms, which might be expected to be a force that pulls a spin-off away from its home institution, is insignificant, too.

Determinants of start-up location: are public research spin-offs different?

The main concern of this section is to examine which factors affect the regional distribution of start-ups in research and knowledge-intensive branches of manufacturing and services. We attempt to explain the number of such start-ups in German districts (*Kreise*) by looking at district-specific variables. Only some of all relevant factors are observable and considered in our analysis.

We distinguish between the two groups of start-ups: all start-ups in knowledge-intensive industries, and public research spin-offs. The latter is separated in those spin-offs which are located in their incubator's region (i.e. less than 25 km distance from the incubator) and those which are located outside their incubator's region (i.e. more than 25 km distance from the incubator). All figures are related to the number of start-ups in the time period 1996 to 2000. The analysis is carried out for all 439 German districts.

The exogenous variables may be categorized into four groups. First, a region's size is controlled for by the logarithm of the population in the employment relevant age from 15 to 65. Other aspects of agglomeration economies are modelled by the employment density (employees over population) and the travel distance in hours to the next international airport. Secondly, the district's knowledge and research base is represented by the number of inhabitants with a university degree over total regional population, the number of researchers in private firms over total regional population, the number of researchers in universities over total regional population, and the number of researchers in public research laboratories over total regional population. Thirdly, the socio-economic structure of the region is covered by age structure, the share of employment in research-intensive manufacturing in all manufacturing employees, an index of purchasing power per inhabitant, and the unemployment rate. To control for the effects of regional stratification in our sample and for regional differences in the response behaviour we use control variables that basically represent the probability that a start-up in a certain region is covered by our survey.

The results of a negative binomial regression to explain the number of start-ups in German districts for each of the four start-up types distinguished are given in Table 3.5. We find that both public research spin-offs and all start-ups in knowledge-intensive industries are founded more often in agglomerated districts. The population between 15 and 65 years can be interpreted as the district's potential of firm founders. The coefficient of this variable is to be interpreted as the elasticity of the number of start-ups and spin-offs, respectively, in the district to the employment relevant population. For start-ups and for spin-offs the coefficient is significantly greater than 1, and thus the number of foundations increases more than proportional with the founders' potential. This is also true for the spin-offs that locate near to their incubator, but not for those which leave the incubator's region. For the latter group we find the opposite relation. They leave the agglomerated regions which are the locations of their incubators not to locate in another agglomeration but in a smaller region, i.e. regions with a lower level of start-up activity.

But what determines the location decision of the spin-offs to leave their incubator's region? Looking at the results for the knowledge and research base variables we find that it is not the search for high-qualified staff which leads them to do so. The number of all start-ups and of the staying spin-offs depends positively on the intensity of high-qualified persons. This is not the case for leaving spin-offs. We also find that the intensity of researchers in private firms has a significantly negative influence on the district's number of all start-ups and staying spin-offs but not on the number of leaving spin-offs.

High capacities of private research in a district lead to high opportunity costs for researchers who want to establish their own firm because there are a lot of attractive jobs in industry for them. Moreover, the wage level for research jobs, often in big firms, is high in such regions, and so it is expensive to hire researchers. This argument does not seem to be true for leaving spin-offs. Our results suggest that for them it is not relevant to locate in a university area (with a high intensity of researchers in universities) but to locate in the neighbourhood of public research laboratories (with a high intensity of their researchers). In Germany these institutions are often in suburban regions and not in the centres of agglomerations.

The most important factor in explaining the location pattern of all start-ups and all research spin-offs is the purchasing power variable. It seems to be the case that the level of regional demand is a very important determinant of the location decision. The main share of research spin-offs belongs to technology-oriented or knowledge-intensive service sectors. Firms in these sectors often serve local or regional demand of manufacturing or other service firms. For the district's overall level of start-up activity in these sectors the research orientation of the local manufacturing industry is a major determinant. The higher the share of research-intensive sectors in total manufacturing, the higher the number of all start-ups in knowledge-intensive industries. However, this relation does not hold for public research spin-offs. Here, the share of research-intensive manufacturing has no significant influence on the number of spin-offs located in the district.

Table 3.5 Negative binomial regressions for determinants of the number of start-ups in German regions 1996–2000, differentiated by types of start-ups

Variables	*All start-ups in knowledge-intensive industries*	*All public research spin-offs*	*Research spin-offs staying in the incubator's region*	*Research spin-offs leaving the incubator's region*
Agglomeration indicators				
Ln(population from 15 to 65 years)	1.1050 **	1.0515 **	1.2396 **	0.8981 **
Employment density	0.4422	–0.0697	–0.9401	1.3144
Travel distance to nearest intern. airport	–0.0015 **	–0.0014	–0.0026	–0.0008
Knowledge and research base				
Intensity of high-qualified persons	0.0001 *	0.0001 **	0.0017 **	0.0001
Intensity of researchers in private firms	–0.0952 **	–0.0112 *	–0.0228 *	–0.0106
Intensity of researchers in universities	–0.0010	0.0035	0.0126 **	–0.0108 **
Intensity of researchers in other public research institutions	0.0174	0.0806	–0.0106	0.1613 **
Socio-economic structure				
Share of persons aged 25 to 50	0.4307	–0.0580	0.3397	–0.2509
Share of employees in R&D int. manuf.	0.5294 **	–0.2239	0.0328	–0.0650
Purchasing power per inhabitant	0.0372 **	0.0546 **	0.0525 *	0.0644 **
Unemployment rate	–0.0283 **	0.0028	0.0274	–0.0327 *
Control variables for response behaviour and stratification effects				
Control 1 (dummy)	0.3843 **	0.3610 *	0.1206	0.6176 **
Control 2 (dummy)	0.1049	0.3507 **	0.8575 **	–1.1352

Table 3.5 Negative binomial regressions for determinants of the number of start-ups in German regions 1996–2000, differentiated by types of start-ups *continued*

Variables	*All start-ups in knowledge-intensive industries*	*All public research spin-offs*	*Research spin-offs staying in the incubator's region*	*Research spin-offs leaving the incubator's region*
Control 3 (dummy)	0.0372	0.1804 *	0.5698 **	–0.0531
Constant	–2.7915 **	–5.6690 **	–8.0395 **	–5.7134 **
Number of observations	439	439	439	439
LR chi^2	998.87 **	565.77 **	373.05 **	353.66 **
R^2 adjusted	0.236	0.240	0.227	0.205

** (*) indicates significance at the 0.01 (0.5) level.
Source: ZEW Spin-off-Survey 2001, calculations by the authors.

Conclusion

Based on a representative survey of start-ups in Germany in 1996–2000 in knowledge-intensive industries, we found that about 55 per cent of all research spin-offs, i.e. start-ups founded by one or more person(s) that previously have worked or are still working in a university or public research organization, are located rather close to their incubator organization, i.e. within a 25 km circle. However, their aggregated location pattern differs significantly from that of their incubators. Almost 50 per cent of all research spin-offs are located outside the centres of agglomeration and urban regions. At the same time, 80 per cent of their incubators are located in centres of agglomeration and urban regions. This balance can be regarded as a flow of knowledge from the centres to the surrounding and peripheral areas.

The fact that the majority of spin-offs still set up in the same region as the incubator is not necessarily due to their choice to be located close to the scientific institution. Most of the incubators are located in highly attractive regions in terms of economic activity and infrastructure, i.e. in the cores of agglomerations or in urban areas. These are locations where knowledge-intensive companies find favourable conditions, such as proximity to customers, a highly qualified workforce, high-tech infrastructure and excellent transport connections. We can therefore expect that spin-offs – but also other companies active in research and knowledge intensive industries – are attracted by locations of this kind. Disadvantages typical to agglomeration areas such as high prices for buying land or renting space or high transport costs due to traffic jams are generally less relevant for small businesses.

Our results suggest that the location behaviour of research spin-offs is strongly demand driven. If the incubator's location is less attractive in terms of urbanization economies, spin-offs are likely to move away. However, if they have strong formal relations to public research institutions and heavily rely on high-qualified staff they tend to stay in the incubator's region, i.e. if they use infrastructure of the incubator, or if they place contract research to public research institutions, or if they use public research as a source for training their employees. Spin-offs with a lower need for academic qualification and a lower level of cooperation are more likely to leave their incubator's region. They typically locate in suburban districts with a research environment, e.g. in regions with public research laboratories.

Spin-offs in high-tech manufacturing, which most often have a natural science background, tend to rely on technology pushes from science and locate rather close to their incubators while service-oriented spin-offs that typically have – among others – an economics or business administration background are those most likely to move away. Because the latter are by far much larger in number than the former, spin-offs contribute to interregional and not only to intra-regional knowledge transfer. In the literature, however, analysis of spin-offs often focuses on high-tech manufacturing. This may explain the widespread view that spin-offs are a local phenomenon.

Summing up, one should not neglect the role of 'pull' factors for the spatial allocation of public research spin-offs as well as other start-ups in knowledge-intensive industries. They seem to influence location decisions as much as 'push' factors such as the human capital base and the regional level of research and science.

Appendix 1: ZEW Foundation Panels and definition of business foundations

In cooperation with the German credit-rating agency CREDITREFORM, the ZEW has developed panels on firm foundations in West and East Germany since 1989. CREDITREFORM is Germany's largest credit agency and has the most comprehensive database of German firms at its disposal. Its main business objectives are to provide information regarding firms' financial situation, and to handle collection orders. For the ZEW foundation panels, CREDITREFORM provides the base data every six months, which are obtained from corporate information that is regularly collected by its approximately 135 regional offices. The ZEW integrates these data into a panel structure, carries out quality controls and analyzes the number of start-up figures for different kinds of sectors and regions (see Almus *et al*. 2000; Engel and Fryges 2002).

In the ZEW Foundation Panel all business foundations are regarded as new business foundations in legal terms if

- they perform corporate activities that have not been carried out before, and
- they are economically active on the market to such an extent that it corresponds at a minimum to the full-time activity of one person ('economically active new firms').

Company conversions, the establishment of associated companies, new business establishments due to relocations, secondary occupations, bogus self-employment, etc. are not regarded as business foundations. For the purpose of this study, self-employment (doctors, lawyers, architects, etc.) is not defined as a business.

Appendix 2: Research and knowledge-intensive industries

Research and knowledge-intensive sectors cover three groups of industries:

1. Branches of industry with intensive research and development (R&D), e.g. chemicals and pharmaceuticals, mechanical engineering, electronics and communication equipment, computers, automobile and transport equipment, precision and optical instruments, technology-intensive sectors in traditional sectors such as technical textiles, technical ceramics, technical plastics, special metals, etc. (high-tech industry).
2. Service sectors which strongly rely on the use of new technologies, e.g. software/IT consulting, technical offices, physical and chemical analysis, research services, telecommunications, media technology (technology-oriented services).
3. Service sectors where highly-qualified staff or generally the exploitation of (new) knowledge are decisive for a competitive edge, e.g. business and tax consulting, education, media and publishing, health services, advertising (knowledge-intensive services).

In the second half of the 1990s one-quarter of all start-ups were established in research and knowledge-intensive sectors.

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4

Academia and Business: Links and Lags in Spain

Javier Alfonso-Gil and Antonia Sáez-Cala

Introduction

Knowledge, understood as the systematic search for the laws of nature and society, is a relatively recent phenomenon in the history of humanity. Except in extraordinary but isolated instances, it is not until the conjunction of the eighteenth and nineteenth centuries that the practice of science acquires an incipient critical mass. Moreover, it is only in the nineteenth century that we can begin to witness the integration of science and technology (North 1990). Integrating science and technology (S&T) requires that those institutions involved in creating S&T (mainly universities and institutions of upper learning) and those involved in the application of science and technology to the marketplace (mainly firms) reach out to each other to achieve benefits for society from their interrelation and cooperation. The progressive integration of S&T is in direct relation to the level of applied knowledge and, ultimately, growth in the economies, and these have tended to generate asymmetrical development processes in various countries.

Universities existed long before the dates mentioned above. The first European universities were established at the beginning of the second millennium, but their concern was generally directed toward fields of knowledge considered important to society at that time, far removed from what we understand today as scientific practice. Despite the common view that the university has been the temple of knowledge and the creator and trustee of a society's knowledge throughout its history, it was well into the nineteenth century when this knowledge began to systematically move into the field of S&T. The temple of knowledge was involved in simply increasing knowledge *per se*, a far cry from the needs of a today's industrial fabric.

Although some societies took steps toward a greater presence of academia in industry, their universities maintained most of the structures and objectives they were born with, structures and objectives of little relevance to the world of enterprise. It is not our purpose here to appraise and evaluate the possible objectives of the university, but rather to establish the historical non-concerns of academia relative to the productive fabric of a country. One reason for that historical non-concern is that the university, as the millennial institution that it is, shows clear signs of path-dependence and, consequently, of difficulty in changing its behaviour (David 1985; Arthur 1989).

Since the beginning of firms and particularly since the appearance and later consolidation of capitalism, firms have been creating and incorporating the technological assets necessary for survival into the productive process. Entrepreneurs are the ultimate creators and, with their incentives and objectives, they have wagered all to overcome the risk and uncertainty accompanying all entrepreneurial performance. The ultimate ideal is the Schumpeterian entrepreneur, who resides in dynamic environments where the creation and destruction of firms is high. Today, these dynamic environments are to be found in the field of high-knowledge content activities. It is important to emphasize that until the recent times mentioned above, firms have mainly performed independently of the university and, therefore, their technological task has progressed with certain disregard for formal science. Method, observation and imitation, and on-the-job learning have historically been the tools of creation and diffusion of entrepreneurial technology, guided by the entrepreneur's search for profit. Thus, technology is an essential variable for firms, an inseparable part of the productive function and, as such, should contribute to the basic objective of survival in the market.

Universities may be trustees of knowledge, but they do not always know how to transfer it to the industrial fabric even though this may be of vital importance to the welfare of citizens in a society. On the other hand, the firm demands and accumulates technological knowledge, but due to its structure or design it is unable to increase knowledge if it is not aligned with its main objective, the search for profit. One institution possesses knowledge, but has difficulties transferring it, while the other knows how to transfer knowledge, but has problems acquiring it. Is it possible that the two institutions might converge?

The foregoing is a heroic hypothesis on both accounts, university as well as enterprise. We know that from the late nineteenth century and particularly in the twentieth century on, large firms do actually carry out research (Rosenberg and Birdzell 1986) and therefore acquire and accumulate knowledge, which could cause doubts on their need for the university. However, this independence is only apparent. One of the characteristics of pure knowledge is its uncertainty of potential applications. Compatibility with other knowledge, which may or may not be available at a given time, is unpredictable, as is the field or firm which may eventually apply the knowledge. Thus, the possibilities of generating knowledge in firms are severely limited to only one production unit, no matter how large or important that unit may be. The search for ideas, knowledge and their application is still – and will continue to be – an essential variable that transcends the firm, its research centres, its size and its resources.

The hypothesis is also heroic as applied to the university in that some (US) universities and public research centres have a long tradition of creating firms, called 'spin-offs', which will be analyzed in this chapter. In Europe it is only since the beginning of the 1990s that firms of this type have been appearing. In the case of Spain, the experience is even more recent and, as will be seen below, only now getting started. This article will attempt to explore the problems that both institutions are encountering in their attempts at minimizing their differences. First, relations between universities or research organizations and the firm in Spain will be investigated. It will then go on to describe the recent appearance of firms in science and technology-intensive industrial sectors, backed by universities and formed by research personnel from the university or research centre. We will not describe existing private or public tools (called 'technological institutes', 'parks' or 'centres') with or without direct participation of universities that are involved in the creation, transfer and diffusion of innovation in firms, as there is quite a lot of literature for the Spanish case (Cotec 2000). However, we will particularly focus on the so-called '*science parks*', understood as intermediate or interface organizations created by universities and public research organizations to serve as firm incubators of spin-offs in knowledge-intensive industrial fields. The technological and commercial or financial uncertainties and risks that these firms supported by university or public research organizations face will then be reviewed in an attempt to give the reader a panoramic view of the current situation of spin-offs in Spain. Finally, some conclusions will be drawn looking at the potential and limitations of relations between the academic and entrepreneurial worlds in Spanish society.

Institutional framework: the lags

If we were to define the university as the institution directly or indirectly designed by the public authority, in which the ideas governing society and, by extension, the world, are created, contrasted, accepted or rejected, then whatever the university does is of interest to all, whether we are aware of it or not. That is, we are dealing with an organization which basically shares the characteristics of a public good (non-rival and non-excludable) as defined in the literature (Samuelson 1954). As a result, the output of university research done for society is too low when it is primarily relegated to private initiative. Market failure to provide this kind of goods is well known and well documented. A society not supporting the creation of universities or public research and development (R&D) centres with adequate budgetary policies will neither be able to start a knowledge pathway nor to follow on a path once started. This is true not only if the country is a follower having to catch up, but also for leading countries with a need to maintain their position.

Looking at costs and benefits of universities' output, private and social rates of return deviate. There is evidence that the option of investing in human capital is profitable at the individual level, but not always at the aggregate level for society (Pritchett 1999). In this respect, the Spanish case shows distressing signs of disjunction between the effort made in human and budgetary resources assigned to research and the results obtained for society. Although a rigorous appraisal and evaluation of the research system in Spain is not yet available, there is some data that tends to show its poor returns.

Table 4.1 shows the technological balance of payments in Spain from 1994 to 2000 in OECD countries where Spain's balance is clearly in the red with one of the lowest coverage rates in the sample and practically constant in the sign over time. This underlines the outer technological dependency of the Spanish economy. Table 4.2 shows the total researchers employed in R&D in OECD countries and their distribution by activity in the public and private sectors (firms, higher education and state). The most obvious fact is that 74.4 per cent of the total personnel involved in research in Spain are in the public sector (university and state), a figure far above averages in the other OECD countries. Finally, Table 4.3 shows the effort (expenditure) made by Spain in R&D relative to total GNP and its distribution by private and public sectors. The expenditure parameter is much lower than that of the rest of countries shown, but what is even more significant is that the proportion of expenditure by sectors once again contrasts with the averages for the countries of the EU-15. Do the figures in these tables support our doubts about the profitability of public research in Spain? Is it relevant to ask what part of Spain's scientific production is actually diffused in the market?

It is true that there are certain areas of both basic and applied research where Spanish researchers are increasingly affirming themselves internationally. They participate in hundreds of research projects and the situation has improved considerably.

However, from the point of view of this chapter, there is much to be done to improve the transfer of knowledge from the university and higher research centres to the industrial fabric (Cotec 2002). Table 4.3 on R&D expenditure in EU-15 indicates that something is awry in the transfer of knowledge to industry. The 15 countries spend on average 1.9 per cent of the GNP on R&D while Spanish expenditure is only 0.9 per cent of the GNP. This figure clearly demonstrates that the effort is still insufficient.

Table 4.1 Technology balance of payments (OECD countries); cover rate (GDP/TBP)

	1994	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*
Canada	1.30	1.27	1.34	1.18	1.63		
USA	4.56	4.38	4.14	3.50	3.09	2.75	
Japan	1.25	1.43	1.56	1.90	2.13	2.34	
EU-15							
Germany	0.80	0.80	0.76	0.84	0.85	0.77	0.73
Austria	0.88	0.89	0.83	0.78	0.79	0.87	1.00
Belgium	0.94	1.22	1.32	1.29	1.22	1.20	...
Spain	0.10	0.07	0.08	0.15	0.19	...	...
Finland	0.24	0.15	0.14	0.19	0.26	...	...
France	0.73	0.73	0.75	0.71	0.83	0.87	...
Italy	0.58	0.77	0.57	0.79	...	...	...
Portugal	0.26	0.26	0.34	0.36	0.37	0.38	...
UK	1.17	1.19	1.60	1.72	1.80	...	...
Australia	0.47	...	0.37	...	0.46	...	...
Hungary	...	...	0.84	0.63	0.44	0.43	...
Mexico	0.16	0.24	0.34	0.26	0.31	0.14	...
Norway	0.58	0.51	0.83	0.66	0.68	0.74	...
New Zealand	...	2.48	...	0.57	...	2.14	...
Poland	0.98	0.99	0.57	0.48	0.35	0.19	...
Czech Rep.	...	...	...	0.73	0.56	0.50	...
Switzerland	2.31	2.20	1.89	2.45	2.23	0.78	...

Source: OECD (2002).

Table 4.2 Total R&D personnel

	Total of researchers		*Distribution on the national total 1999 ([b])*		
	1999	*1998 ([a])*	*Enterprises*	*Government*	*Universities*
EU-15	*932,257*	*890,091*	*48.8*	*14.0*	*35.9*
Germany	255,260	237,712	58.8	15.0	26.1
Austria		18,715	62.6	5.1	31.8
Belgium	30,219	28,149	54.5	4.0	40.4
Denmark	18,438		46.5	21.2	31.0
Spain	*61,568*	*60,269*	*24.7*	*19.4*	*55.0*
Finland	25,398	23,745	41.6	16.2	40.9
France	160,424	156,857	47.0	15.7	35.4
Greece	14,828		15.6	13.5	70.6
Netherlands	40,623	39,081	47.7	19.8	31.4
Ireland		7,825	65.1	3.9	28.7
Italy		76,056	36.3	18.0	45.7
Portugal	15,752		12.7	21.9	52.3
UK		158,671	58.2	9.1	30.9
Sweden	39,921		57.2	6.1	36.6

[(a)] Data of 1997 for Ireland and Italy, (b) 1998 for EU-15, Austria and UK; 1997 for Ireland.
Source: OECD (2002).

Moreover, an even more significant figure can be found in the distribution of expenditure (if state and universities are considered together as public) between public and private expenditure for the EU-15. There the average is 66 per cent for private expenditure versus 34 per cent for public, which clearly contrasts with the Spanish case.

These figures tell us that the largest part of future increased expenditure on R&D in Spain ought to be applied directly or indirectly to research in the private sector (around 78 per cent of the increase) if Spain is to reach the average of the EU-15 member states. Although these figures only provide us with a static version for one year, this is no good news for public research or researchers hoping to move into the public sector. Table 4.2 shows that employment of researchers by sector is biased towards the public sector where only 24.7 per cent of personnel employed in R&D are in firms, as opposed to an average of 48.8 per cent in the rest of the OECD countries. Not only should more expenditure on research be directed toward enterprise, but by the same token firms should also accelerate the incorporation of research personnel into their industrial activity.

Effort in research in Spain shows a weak structure. While it is true that the public sector should be the basic platform for research devel-

Table 4.3 R&D expenditures

	Expenditure (per cent of the GDP)			*Expenditure distribution*		
	2000	*1999*	*1998(a)*	*Enterprises*	*Government*	*University*
EU-15	*1.90*	*1.92*	*1.87*	*66*	*14*	*20*
Germany	2.46	2.44	2.31	70	14	16
Austria	1.79	1.83	1.81	...	...	...
Belgium	...	1.98	1.90	72	3	24
Denmark	...	2.00	2.02	63	16	21
Spain	*0.90*	*0.89*	*0.90*	*53*	*17*	*30*
Finland	...	3.19	2.89	68	12	20
France	2.15	2.19	2.17	65	18	17
Greece	...	...	0.51	26	24	51
Netherl.	...	...	1.94	54	19	27
Ireland	...	...	1.39	74	7	19
Italy	...	1.04	0.98	54	21	25
Portugal	...	0.76	...	25	31	43
UK	1.84	1.87	1.83	69	11	20
Sweden	...	3.80	3.75	75	3	21

(a) 1997 for Greece and Ireland.
Source: Eurostat.

opment due to theoretical reasons put forth above, it is also true that the results of research should be measurable in improvement of the welfare of population, ultimate goal of all human activity. Greater equilibrium between public and private research does not mean that public research must be reduced *per se*, but rather that its activity and contribution to society should, at some point, be submitted to appraisal and evaluation. That effort in expenditure on public research should be balanced with greater participation in private research, which seems to be better designed to transfer knowledge to society. Why is private research better designed to transfer knowledge and its fruits to society? A significant part of the answer to this question has to do with the incentives that the various agents who intervene in the process of increasing knowledge in the university, are faced with. It is possible that there are many researchers whose goal is to increase knowledge and, in turn, benefit society without concern for monetary incentives for their academic activity. But the structure of basic incentives is to be found in the laws and norms that govern the organizations and their agents in whatever society (Alfonso-Gil, 2001). And these formal 'rules of the game' tend to be inflexible because a significant majority of the population created, accepted and complied with them. Therefore changing shared mental models is hard. Under these conditions, the norms of public universities lack necessary flexibility and tend to reflect a static and centralist world.

In the Spanish case, the performance of its agents and the environment of public academia are ruled by these laws and, although they have slowly been modified in their methods and objectives, universities are still defined as something self-centred, isolated from the industrial fabric. This university design is born of the logical, although primitive, search for stability and security on the part of individuals. Therefore, the incentive for individuals entering into this organization is manifested *ex ante* – that is, to reap the fruits of such advantages as secure jobs for life, little monitoring, strong labour rights and a lax hierarchical structure compared to the rest of the workforce. These incentives are reduced once the individual is within the system, and this fact has long-term effects on society in the form of low productivity. There are no incentives for increasing productivity in terms of wage policy, protection of their intellectual property rights (IPR) or patenting of the fruits of their research. There is still a flexible legal framework missing, and no new fields of knowledge are incorporated. There is not even agreement on whether the university should bond more with industry and society. This might explain the gap that is consistently detected between high personal productivity (high human capital in university positions with their advantages and privileges) and low aggregate productivity for the country. Since the system does not motivate, or, rather, does not correctly motivate, 'once one is inside the organization', any contribution to growth tends to rapidly decrease simply because individuals are rational beings.

Technological framework: the links

In spite of the foregoing, the university is still the place with the greatest density of knowledge in any country and it will continue to be so. The task facing the institution, then, is to apply its accumulation of knowledge to the daily practice of society and particularly to the industrial fabric through the world of enterprise. Otherwise, consciously or not, we would be proposing a world of elites, isolated and distant from all that is most dynamic in the nation. How can this be done? The most significant barriers to stimulating and transferring knowledge that which have to be overcome are the shared mental models of those agents and management of the institution believing that the university should somehow be isolated and protected from the environment that surrounds it. US experiences in the so-called 'new economy' (Romer 1986; Lucas 1988), defined as the product of the union between S&T and therefore intensive in qualified human capital, stress the crucial role of universities once successful links have been established. But as Table 4.4 shows, in the production and export of high-technology goods and income from manufacturing licences, Spain is among the countries with the poorest values. Moreover, according to the European Commission, there are no Spanish firms among the Top 100 firms in Europe investing in R&D.

One of the most promising formulas for encouraging universities and their researchers to participate in the adventure of transferring technology to the industrial fabric is through intermediate organizations or incubators initiated or accompanied by universities themselves. The objective of these organizations is to encourage research personnel to create firms in knowledge-intensive industrial fields.

'Spin-offs' are production units created by university scientists to open up new markets and opportunities with their activity. In contrast to spin-offs, 'start-ups' are also created by university staff and students, but are not actively supported (see also the chapter by Hague). Spin-offs become an important instrument designed by universities to trans-

Table 4.4 High-tech exports and income and payments by licences in EU countries

	High-technology exports		*Royalty and licence fees*	
	$ millions	*Per cent of manufactured exports*	*Receipts in $ millions*	*Payments in $ millions*
	1999	*1999*	*1999*	*1999*
Germany	75,176	17	3,017	4,405
Austria	6,384	13	120	623
Belgium	11,115	8	757	1,138
Denmark	6,493	20	…	…
Spain	*6,945*	*8*	*344*	*1,831*
Finland	8,547	24	648	375
France	55,834	23	1,983	2,297
Greece	484	10	0	58
Netherlands	39,917	33	2,388	3,426
Ireland	27,929	47	415	6,943
Italy	17,240	8	563	1,382
Portugal	1,062	5	27	292
UK	66,942	30	7,942	6,301
Sweden	15,100	22	1,386	1,147

Source: World Bank (2001).

fer their intensive human and technological capital to the industrial system. Let us define the basic profile and fundamental agents that intervene in this new kind of firm.

The anatomy of spin-offs

An influential minority in Spanish universities is aware of the increasing interdependence between S&T and the industrial fabric as well as the need to take measures to render legislation more flexible and motivate their most dynamic scientific personnel. The creation of interface organizations is encouraged, normally foundations that act as incubators for future entrepreneurial projects based on industrial application of researchers' S&T knowledge. The relations established between the university and its researchers are of great importance in this context. Although recent modifications are appearing, it is common practice for the university to be the owner of research products obtained by its personnel. In fact, until well into the twentieth century, researchers at universities had rarely been asked about the commercial exploitations of their labour. Becoming an entrepreneur did not normally fall into their plans (Samuelson 2001). The legislative change in the USA after 1982 – the Bayh-Dole Act – caused radical change in the understanding of relations between the university and its researchers (Evenson and Westphal, 1995). This new law allowed firms and entrepreneurs to exploit future patents and even already existing patents in the hands of public organisms to accelerate their introduction into the market. Encouraging the university to hold a more favourable view of commercial exploitation of its knowledge requires the creation of flexible organisms. These would depend directly on the university, but they would have the same organization and management as firms and be removed as far as possible from the bureaucratic centralism of the university. With the creation of their science parks, university foundations were able to avoid academia's diffused and unfocused objectives as well as its rules. Although there is no single model to describe relations between the university and its researchers as to the product of their work, some progress is being made in the area of ownership of IPR. Those scientists obtaining results may receive recognition and IPR even though these results were obtained during their employment with the university. In this way, the university allows the intellectual property of the patent or design to be in the name of the researcher(s) in exchange for possible returns on a future commercial exploitation. The patent not only becomes the basic instrument that boosts incentive among researchers in the university but also protects research products from the rest of the academic world and possible predatory practices.

In Spain, patents are not seen as an optimal tool for industrial exploitation. Table 4.5 testifies to this fact. Comparing the relation between the number of R&D personnel and patent outcome for EU countries between 1994 and 1998, Spain is always at the bottom of the ranking. The Spanish system does not create incentives for researchers to use their work for applications in the industry fabric. An evaluation of the National Plan for R&D for the years 2000–3 corroborates this fact. Only 13 per cent of the 15,000 scientists and researchers answer that they are interested in developing patents.

And only 27 per cent are interested in the development of industrial know-how (Table 4.6). This table also brings to light the bias of researchers towards publication with the objective of receiving academic promotion. These are incentives for (more scientifically oriented) research *ex ante* in order to enter into the university system, but there is only very little motivation to research *ex post*. Thus, incentives must be redesigned in function of desired objectives.

These new relations between universities and researchers, aimed at improving the transfer of knowledge to the industrial system and changing the incentive structure of researchers, are channelled through interface organisms or 'science parks'. The task of these interface organizations involves making researchers aware of existing market possibilities in their field, providing the potential firm with physical space and temporary technical and administrative support and negotiating patents at the international level.

Since researchers are not always competent entrepreneurs, incubators offer consultancy services and affect the incentive system of the researchers by shareholder and stakeholder governance systems. The capital structure of spin-offs is usually divided among university, researchers, specific government support and shareholders. The university's share is minor and generally in the form of support in the start-up of the firm. Researchers are the majority shareholders since they bring knowledge and sometimes a patent on the industrial product to be marketed. Government support is kept to a minimum to avoid the possibility of converting the spin-off into a state firm. Other shareholders should contribute the majority of financial capital to launch the manufacturing project and place it in the market. Their participation is decisive although it is usually temporary.

The difficulty and complexity of this kind of firm is not in the capital structure that we have described but rather in the type of activ-

Table 4.5 Patents requests, R&D staff and patents/R&D staff ratio (1994–8)

	1994			*1995*			*1996*			*1997*			*1998*		
	Patents requests	*R&D staff*	*Requests/ staff*	*Patents requests*	*R&D staff*	*Requests/ staff*	*Patents requests*	*R&D staff*	*Requests/ staff*	*Patents requests*	*R&D staff*	*Requests/ staff*	*Patents requests*	*R&D staff*	*Requests/ staff*
EU-15	*32,117*	..	..	*34,447*	*1,591,675*	*0.0216*	*36,469*	*1,608,516*	*0.0227*	*38,094*	*1,612,297*	*0.0236*	*39,996*	*1,661,856*	*0.0241*
Germany	12,954	..	..	14,075	459,138	0.0307	14,848	453,679	0.0327	16,101	460,411	0.0350	17,090	461,539	0.0370
Austria	755	..	..	807	..	..	793	..	..	841	..	..	997	31,308	0.0318
Belgium	910	38,779	0.0235	952	39,846	0.0239	956	42,548	0.0225	1,013	44,220	0.0229	1,106	46,428	0.0238
Denmark	591	..	..	626	30,213	0.0207	683	32,148	0.0212	659	34,187	0.0193	629	..	..
Spain	*462*	*80,399*	*0.0057*	*476*	*79,988*	*0.0059*	*511*	*87,263*	*0.0059*	*545*	*87,150*	*0.0063*	*618*	*97,098*	*0.0064*
Finland	789	32,331	0.0244	893	33,634	0.0265	891	..	..	890	41,256	0.0216	998	46,517	0.0214
France	5,260	315,159	0.0167	5,585	318,384	0.0175	5,773	320,805	0.0180	5,807	306,178	0.0190	6,227	309,515	0.0201
Greece	35	..	..	43	17,571	0.0024	48	..	..	49	20,173	0.0024	50	..	..
Netherl.	1,732	78,980	0.0219	1,809	79,256	0.0228	2,109	80,789	0.0261	2,237	83,967	0.0266	2,167	85,486	0.0253
Ireland	93	8,654	0.0108	133	9,662	0.0137	142	10,838	0.0131	134	12,030	0.0111	144	..	..
Italy	2,539	143,823	0.0177	2,635	141,789	0.0186	2,904	142,288	0.0204	3,004	141,737	0.0212	3,104	..	..
Portugal	22	..	..	16	15,465	0.0010	15	..	..	24	18,035	0.0013	20	..	..
UK	4,486	..	..	4,609	..	..	4,829	..	..	4,736	..	..	4,823	..	..
Sweden	1,451	..	..	1,761	62,635	0.0281	1,926	..	..	2,002	65,495	0.0306	1,977	..	..

Sources: Eurostat (2002); OECD (2001).

Table 4.6 R&D staff and reasons to develop projects within the Spanish National Plan (2000–3): percentage of researchers who have shown interest according to knowledge area

	Areas of knowledge							
	PGC	*CV*	*RN*	*Q*	*TEC*	*FIS*	*SE*	*Total*
To generate knowledge scientist-technical	98	96	95	97	94	97	98	96
To solve problems of scientific character	94	94	92	86	81	100	86	91
To solve problems of technological or industrial character	24	28	67	85	84	40	26	51
To form researchers and/or technical personnel	84	81	82	86	84	88	75	83
To acquire equipment/ infrastructure	48	36	38	38	52	35	52	45
To develop patents of industrial interest	7	16	16	39	22	6	0	15
To develop know-how of industrial interest	10	18	38	63	59	8	15	31
To collaborate with other groups of centres or companies	57	53	67	64	77	65	59	64
To publish	88	89	81	79	80	80	93	85

PGC: General Promotion of Knowledge. CV: Quality of Life (Biomedicine, Biotechnology, Socio-sanitary). RN: Natural Resources; Q: Processes and Chemical Agents. TEC: Technological Priorities (Design, Industrial Production, Materials, ICT, Aeronautics, Automotive, Energy, Space, Transport and Territorial Arrangement). FIS: Physics (Astronomy, Astrophysics, Physics of Particulars, Accelerating and Thermonuclear Physics). SE: Socio-económy.
Source: Evaluación (2003).

ity and the novelty of the industrial sectors. By focusing on fields of new knowledge with little market experience, uncertainty about technological and commercial results is very high and poor survival rates are characteristics of a highly dynamic world of Schumpeterian creation and destruction. Studies carried out in UK show that only 10 per cent of firms created obtain profits (Hague and Oakley 2000). As a consequence, spin-offs are financially at very high risk. This leads them to depend on atypical capital sources, such as private venture capital (VC) where lenders seek returns in accordance with the risk assumed. Or they may turn to capital supplied by 'business angels', defined as persons or organizations with financial resources and altruistic objectives willing to finance this type of firm independent of the risk of the capital investment. The number and scale of VC funds has risen extraordinarily in recent years, but even in those countries where it has most developed, the subentry of 'seed money' (capital specifically directed toward the funding of new ideas, trials or prototypes) is in the minority (National Science Foundation 2002). Naturally, this particularity causes additional problems in countries like Spain where the growing market of VC maintains the tendency of more advanced countries in discriminating against spin-offs for their investments. The size of the seed-capital market as well as 'business angels' is extremely small and insufficient to meet the needs of emerging fields in the new economy (Cotec 2002; Martí Pellón 2001).

Spin-offs in Spain

In the last 25 years, Spanish universities have undergone an unparalleled process of growth since their beginnings in the Late Middle Ages. From hardly a dozen public universities, the country now has more than 50 university headquarters throughout its territory. It is one thing to inaugurate a university, and quite another to provide it with the necessary endowment of knowledge to be able to carry out research and obtain the results required by the integration of S&T today. Thus, of the more than fifty existing universities, only a handful is capable of carrying out the kind of initiative being analyzed in this chapter. History weighs heavy and research is an accumulative process, in which the density and quantity of scientists determines the capability of producing S&T on the part of each university.

The figures on expenditure on R&D by regions in Spain (Tables 4.7 and 4.8) help us in identifying where research is being done and how much expenditure and personnel are involved in it in each Spanish region. They also indicate where the greatest contribution to S&T is in Spain; 46.3 per cent of research personnel and 52.7 per cent of total expenditure of the Spanish state on R&D are located in Madrid and Barcelona, regions with fairly long trajectories of higher education centres in S&T. That is, universities located in these areas are the best

Table 4.7 R&D staff by Spanish regions (1994–2000)

	1994		*1995*		*1996*		*1997*		*1998*		*1999*		*2000*	
	Total no.	*Per cent*	*Total no.*	*Per cent*	*Total no.*	*Per cent*	*Total no.*	*Per cent*	*Total no.*	*Per cent*	*Total no.*	*Per cent*	*Total no.*	*Per cent*
Total	*47,867*	*100*	*47,342*	*100*	*51,633*	*100*	*53,883*	*100*	*60,269*	*100*	*61,568*	*100*	*76,670*	*100.0*
Andalucía	4,978	10.4	5,870	12.4	6,432	12.5	6,690	12.4	7,634	12.7	8,660	14.1	9,210	12.0
Aragón	1,418	3.0	1,459	3.1	1,254	2.4	1,487	2.8	1,674	2.8	1,638	2.7	1,948	2.5
Asturias (Principado de)	938	2.0	1,033	2.2	784	1.5	1,015	1.9	1,064	1.8	1,072	1.7	2,106	2.7
Baleares (Islas)	178	0.4	294	0.6	570	1.1	332	0.6	415	0.7	394	0.6	439	0.6
Canarias	1,289	2.7	1,278	2.7	1,661	3.2	1,374	2.5	2,045	3.4	1,785	2.9	2,380	3.1
Cantabria	522	1.1	439	0.9	633	1.2	457	0.8	883	1.5	472	0.8	570	0.7
Castilla y León	2,882	6.0	2,152	4.5	2,943	5.7	3,140	5.8	3,271	5.4	3,409	5.5	3,992	5.2
Castilla–La Mancha	438	0.9	518	1.1	554	1.1	621	1.2	855	1.4	773	1.3	1,070	1.4
Cataluña	7,616	15.9	8,814	18.6	9,611	18.6	9,544	17.7	11,469	19.0	11,844	19.2	14,812	19.3
Comunidad Valenciana	3,750	7.8	3,553	7.5	3,850	7.5	3,728	6.9	4,012	6.7	4,070	6.6	6,122	8.0
Extremadura	746	1.6	402	0.8	493	1.0	734	1.4	884	1.5	774	1.3	1,163	1.5
Galicia	1,562	3.3	1.963	4.1	1,750	3.4	3,433	6.4	3,505	5.8	3,304	5.4	3,982	5.2
Madrid (Comunidad de)	13,215	27.6	14,603	30.8	14,985	29.0	15,520	28.8	15,778	26.2	16,812	27.3	20,715	27.0
Murcia (Región de)	925	1.9	901	1.9	871	1.7	1,007	1.9	1,044	1.7	1,066	1.7	1,185	1.5
Navarra (Comunidad Foral)	1,054	2.2	761	1.6	1,594	3.1	1,125	2.1	1,352	2.2	1,423	2.3	1,601	2.1
País Vasco	2,665	5.6	3,108	6.6	3,405	6.6	3,486	6.5	4,160	6.9	3,790	6.2	5,039	6.6
Rioja (La)	150	0.3	196	0.4	245	0.5	190	0.4	224	0.4	282	0.5	337	0.4
Not regionalized	3,544	7.4	..		..		..		..		..		..	

Source: INE (2001).

Table 4.8 R&D expenditures by Spanish regions (1994–2000)

	1994		*1995*		*1996*		*1997*		*1998*		*1999*		*2000*	
	MPTA	*Per Cent*	*MPTA*	*Per Cent*	*MPTA*	*Per Cent*	*MPTA*	*Per Cent*	*MPTA*	*Per Cent*	*MPTA*	*Per Cent*	*MPTA*	*Per Cent*
Total	*548,154*	*100*	*590,688*	*100*	*641,024*	*100*	*672,017*	*100*	*784,513*	*100*	*831,158*	*100*	*951,560*	*100*
Andalucía	45,088	8.2	57,350	9.7	63,084	9.8	65,865	9.8	77,436	9.9	78,988	9.5	90,207	9.5
Aragón	13,514	2.5	14,558	2.5	14,490	2.3	14,188	2.1	19,917	2.5	22,324	2.7	22,324	2.3
Asturias (Principado de)	8,011	1.5	9,600	1.6	10,598	1.7	10,174	1.5	11,384	1.5	12,386	1.5	19,065	2.0
Baleares (Islas)	1,944	0.4	2,781	0.5	3,556	0.6	4,292	0.6	5,749	0.7	5,472	0.7	5,799	0.6
Canarias	13,357	2.4	11,922	2.0	14,372	2.2	13,667	2.0	17,662	2.3	17,436	2.1	19,872	2.1
Cantabria	4,729	0.9	5,023	0.9	5,069	0.8	5,831	0.9	9,114	1.2	7,001	0.8	5,980	0.6
Castilla y León	25,878	4.7	22,333	3.8	23,979	3.7	24,995	3.7	26,394	3.4	33,609	4.0	37,073	3.9
Castilla–La Mancha	4,684	0.9	11,081	1.9	11,113	1.7	15,019	2.2	14,958	1.9	10,832	1.3	19,730	2.1
Cataluña	109,748	20.0	124,308	21.0	135,562	21.1	146,047	21.7	178,923	22.8	187,976	22.6	210,007	22.1
Comunidad Valenciana	34,642	6.3	34,757	5.9	40,674	6.3	43,971	6.5	52,228	6.7	55,271	6.6	71,632	7.5
Extremadura	4,690	0.9	3,558	0.6	4,658	0.7	5,513	0.8	6,411	0.8	6,435	0.8	9,407	1.0
Galicia	14,070	2.6	19,661	3.3	20,511	3.2	23,639	3.5	25,438	3.2	27,469	3.3	34,851	3.7
Madrid (Comunidad de)	203,251	37.1	200,716	34.0	213,453	33.3	216,480	32.2	242,323	30.9	264,456	31.8	291,505	30.6
Murcia (Región de)	7,357	1.3	8,451	1.4	8,813	1.4	10,090	1.5	11,606	1.5	14,061	1.7	17,340	1.8

Table 4.8 R&D expenditures by Spanish regions (1994–2000) *continued*

	1994		*1995*		*1996*		*1997*		*1998*		*1999*		*2000*	
	MPTA	*Per Cent*	*MPTA*	*Per Cent*	*MPTA*	*Per Cent*	*MPTA*	*Per Cent*	*MPTA*	*Per Cent*	*MPTA*	*Per Cent*	*MPTA*	*Per Cent*
Navarra (Comunidad Foral)	7,788	1.4	9,219	1.6	10,015	1.6	10,404	1.5	12,713	1.6	15,166	1.8	15,739	1.7
País Vasco	42,635	7.8	53,412	9.0	58,851	9.2	59,463	8.8	68,931	8.8	68,898	8.3	76,474	8.0
Rioja (La)	1,340	0.2	1,958	0.3	22,226	0.3	2,378	0.4	3,322	0.4	3,377	0.4	4,555	0.5
Not regionalized	5,428	1.0	0		0		0		0				0	

Source: INE (2001).

endowed with intensive knowledge and thus most likely to build bridges toward the new industries of the future based on knowledge. The legislation currently in force for universities (*Ley Orgánica de Universidades – LOU*) opens timidly new possibilities for technological transfer to firms. Likewise, university statutes currently being revised to introduce modifications from the LOU are expected to allow for more flexible frameworks than in the past. However, they may not be sufficient to permit development and consolidation of spin-offs.

Current legislation restricts the participation of researchers belonging to the university roster and full-time employed with the university. Due to problems of incompatibility, universities may only share at a maximum of 10 per cent in firm capital and may not hold positions on the governing boards of these firms. In the following, we present some of the most important ongoing projects in Spain in this context.

The Science Park of the University of Barcelona

Research carried out in this park is multi-disciplinary and embraces a great variety of research fields in experimental, human and social sciences. One of the most important scientific areas under study in the park is biomedical research. The new spin-offs of the University of Barcelona and the Institutes and Centres of the Consejo Superior de Investigaciones Científicas (CSIC – Council of Higher Scientific Research) carry out their activities in the fields of bio-pharmacy, linguistic engineering (communication, publishing materials and education) and new materials. The services provided to these firms by the park include physical infrastructures, administrative support and financial and entrepreneurial consulting.

In 2002, a Bio-incubator was launched to facilitate the start-up of new firms in the field of biotechnology by providing scientific and technological infrastructures, entrepreneurial management services and financial support. Currently in the first phase, the bio-incubator occupies 500 m^2 with capacity to incorporate seven firms (seven laboratories and from four to six offices). The maximum time firms may occupy space is three years, during which the firm receives economic aid from the park and from the Centro de Innovación y Desarrollo Empresarial (CIDEM – Center of Entrepreneurial Innovation and Development). The latter is part of a programme by the regional government to support the creation of technology-based firms with a strong focus on biotechnology (30 per cent of the funding). As of May 2003, seven spin-offs have been created, six of which are still in the bio-incubator. The annual forecast is for two or three new spin-off projects, of which one or two will set up in the bio-incubator. All of the new firms have a patent, which was initially negotiated by the patent service of the interface organism, the Science Park of Barcelona, at the instance of the University of Barcelona, who is, according to present legislation, the owner of the IPR of its employees. Once the spin-off is constituted, the university surrenders the patent to the firm in exchange for a small share, at most 10 per cent, of the firm's capital. As other investors purchase shares in the firms, the university's capital share becomes diluted. Most partners in the spin-offs are researchers from the university itself and other Catalan universities and from centres of the CSIC.

At the end of 2002, the park introduced a seed-capital fund for the spin-offs. The seed-capital society is led by the CIDEM, and the university is symbolically present to give continuity to the initial capital stage. It can contribute up to 30 per cent to a spin-off's capital, while co-funding is required where entrepreneurs or promoters must contribute at least 40 per cent of the capital. Once the initial stage is completed, the development and consolidation of the spin-off continues with the search for new partners through VC funds and other regional and local institutions. Such is the case of Barcelona Activa (Agency for the Local Development of Barcelona), whose presence in the financial structure of the firm amounts to 30 per cent. Due to the recent launching of the project, there is as yet no study on the success rate of these spin-offs in the market, and park authorities are still cautious about the potential for market success of this knowledge-transfer instrument.

The Science Park of Madrid

The park is expanding around two groups of strategic research fields: first, biotechnology and biomedicine with particular emphasis on genomics and proteomics, food science and technology and animal health, and secondly, materials science and nano-technology. Existing and newly created research institutes are available as well as centralized or on-line infrastructures and a centre for the development of technological firms. These organisms will coordinate with each other to achieve the goals of the park.

In 2001, the Foundation Science Park of Madrid was constituted, whose board of trustees includes the promoting universities (Autónoma and Complutense), the Banco Santander Central Hispano, the CSIC, the Centre for Energy, Environmental and Technological Research (CIEMAT), the Community of Madrid and the Chamber of Commerce and Industry of Madrid. In this same year, the first selection of spin-offs to be located in the firm incubator was made. In 2003, the patent centre was opened and a VC fund was constituted. At present, ten firms are installed in the incubator and it is hoped that another 30 can be created throughout 2004. This rather rapid creation of spin-offs is not spectacular, if we consider that the park is designed to take in all initiatives arising not only within the sponsoring universities, but also from other sponsoring institutions such as the CSIC.

As in other parks, working staff in spin-offs is between three to six persons, including researchers and a professional administrator, whose presence is required by the park's terms. All the firms own patents. Those belonging to some of the centres of the CSIC are licensed to the firms, while the universities relinquish the patents in their possession to the firms in exchange for approximately 10 per cent of the shares in the firm's stock. The idea is to maintain the university within the capital of the firm so that it can obtain some income from the dividends, which will in turn be integrated into the institutional funding system in an attempt to diversify their sources. Therefore, the model can be considered as mixed and depends on who owns the IPR. Common and integral services are offered to the entrepreneur including practical training, with personalized tutoring, specialized professional services in all legal, fiscal and economic and financial aspects as well as those specialized in the protection of industrial and intellectual property (Centre of Documentation and Patents), and help in seeking external funding. Resources for the park come from the Central Administration (Contract Programme with the Ministry of Science and Technology), from the European Commission (European Fund for Regional Development – EFRD) and from contributions of the sponsors. In the near future a higher level of self-funding is expected through the exploitation of the firm incubator.

Initiatives of the University of Santiago de Compostela

The Sociedade Xestora de Intereses da Universidade de Santiago de Compostela, S.L. (UNIXEST) was created in 1998, and one year later, the Sociedad para la Promoción de Iniciativas Empresariales (UNINOVA) and the Sociedad de Capital Riesgo de Galicia (UNIRISCO Galicia). Constituted by the University and the City Hall of Santiago de Compostela, the objective is to incubate academic spin-offs through university research projects. This is one of the first Spanish experiences of this type. UNIRISCO's participation is usually temporal (from three to ten years) and minor (from 30,000 to 120,000), although it can provide other financial instruments – loans and syndicated shares with other VC entities in case of higher investment needs – and it provides consulting services both in the negotiation process and once the firm has been constituted. UNIRISCO's investment strategy is aimed at all sectors except the financial sector, although there is particular interest in technology-based projects (life sciences, biotechnology and biopharmacy) and projects which generate employment and are originated in universities and, particularly, Galician universities. At present UNIRISCO has a fund of three million euros. It has participated in a total of ten firms of the 16 created since the beginning of UNINOVA, which has been an important source in selecting investments for UNIRISCO.

On average, five or six spin-offs have been created a year and this figure is expected to be maintained in the future although only two or three projects are actual technological-based spin-offs. Two of these experiences have already left the incubator and show signs of success in the market. At first, none of the firms normally have products likely to be patented since they are only patented once they are placed in the market. The patents are usually negotiated and belong to the University of Santiago, who can sell it to the spin-off. Or it may belong to another university, or the right of use may be licensed to the firm in exchange for shares, thus becoming a partner. There is no standard model and few guidelines for the capital structure of these spin-offs. At present there are no examples in which the university is a direct partner in the spin-off, and any share-buying is done through UNIRISCO. The university participates in the social capital of incubating firms with a minority and temporary share only as long as the firm is in the incubator. Nevertheless, the most common form of capital structure in these spin-offs is participation by the promoters, which varies from 30 to 60 per cent, external capital (UNIRISCO or other VC societies) with around 30 per cent, and other investors, whose shares range from 10 to 15 per cent.

Steps taken in Valencia Region

The Parque Científico del Mediterráneo (MEDPARK), a project of the University of Alicante, was set up to use its research potential to promote relations between the university and firms and facilitate technological transfer to the private sector. Therefore, the future park will have an incubator, an area to locate consolidated R&D firms and installations to house services. At present, four new firms in the fields of chemistry and computer science have been created and market success is promising. An annual growth rate of two or three spin-offs is foreseen when the project is launched. This entrepreneurial initiative arose from a group of researchers from the university itself and was more a personal than institutional project. Only four employees formed the initial workforce, one of whom was an administrator from outside the university. However, members of research teams from other collaborating public research centres could become partners as well in the future. These firms have patents either owned by the firm, if the idea came from outside the university, or by the university. In the second case, the university may relinquish the patent – that is, the firm buys the licence – or it may keep the property by tendering exclusive exploitation rights to the firm.

The Ciudad Politécnica de la Innovación is an initiative of the Universidad Politécnica de Valencia. The foundation of this science park was constituted in 2002 on the university campus. Besides the university, the founding partners are the regional government (the Generalitat Valenciana) and the entrepreneurial confederation of Valencia. Entrepreneurs hold 51 per cent of the shares while bringing to the firm only 5 to 15 per cent of the budget resources, the Generalitat Valenciana holds from 12 to 15 per cent, and the major contributor is the university although it holds only 4 per cent of the shares. The park provides services such as administrative support, financial and entrepreneurial consulting, training and locales, to installed firms and in particular to the spin-offs. Their incubating activities go back to the beginning of the 1990s when initiatives were launched to stimulate enterprising attitudes by promoting knowledge-based firms. The results, in number of firms created, were poor for the period 1992–5 due to requirements such as the presence of a professor in each firm project.

From 1996 on, this barrier was eliminated and more firms were created. Now 340 firms have been launched (start-up phase), of which 96 are currently operating outside the incubator. The annual rate of creation averages about six to eight firms, which move into the incubator. Of 18 applications, five or six firms will remain in the incubator. The high number of firms created includes not only academic spin-offs, but also 'start-ups' since most of them are initiatives of last-year students and first-year graduates. In the spin-offs there is a greater presence of university researchers and professors and these firms have a patent, something start-ups often lack. The interface organization negotiates the patent through its patent service or through the service involved in transferring research results. The property of the patent usually belongs to the public centres when their personnel are involved. This property is normally licensed to the firm in exchange for capital shares (approximately 10 per cent in the university). Where administrative costs of negotiating a patent are too high, as often occurs in the field of biotechnology, the university seeks out external partners to co-share in the patent.

The average funding structure in these firms varies depending on the entry barriers in the activities. The university initially contributes 5 per cent of the capital through their foundation in the first three years, obtaining a greater share in the Board of Trustees (initially 20 per cent), which is relinquished after seven years. The rest are contributions by the researchers themselves and external capital (25 per cent), such as seed capital for smaller initial investments and VC. The most frequent fields of these firms are biotechnology, plant genomics, computer science, automation, design, microscopy and chemical technology. They have an average workforce of four workers and a manager/administrator, whose expenses are co-financed for the first two years through the public programme. The potential for success of these firms in the market is seen as high.

Experiences in the Universidad del País Vasco

In the Basque Country, there are two models for the creation of spin-offs in the scientific-technical field. On the one hand, in the Vizcaya case, the university has its own firm nursery, where the whole process from the very idea of constitution of the firm is supported directly by the university through several services. Among these are physical infrastructures to establish firms. On the other hand, the Guipuzcoan model, also applied in Àlava, does not have its own nursery, but when a firm needs physical space the university helps to find it in existing incubators of the scientific-technological infrastructure of the province. At present 13 spin-offs have been created at a rate of two or three entrepreneurial projects a year and it is hoped that this rate can be maintained in the future through association with the strongest and most relevant R&D groups in the university. Currently, three firms are not located in the incubator, but rather in the technology park of Bizkaia. As in the spin-off model, the partners are researchers and personnel from the university itself (members of the research team, ex-alumni and professors). Only 20 per cent of these firms' inventions are protected, particularly those projects arising from relevant research groups. In general, the university negotiates the patents except when firms own the patent, in which case the promoters themselves negotiate it. The activities of these spin-offs are mainly in the fields of ICT and environment. Although infrastructure is inadequate, some research groups are forming in the field of biotechnology in collaboration with the technology park. These firms have an average of only four employees, although the workforce can consist of more than ten in firms located in the technology park.

Conclusion

One of the most important problems all societies must solve is the transfer of increasing knowledge that research systems (laboratories and universities) generate to private firms converting this to products and services. Spain has much to learn in the area of knowledge transfer. Despite some indications of institutional changes, its public research system is still weighed down with an out-of-date institutional framework unable to adequately respond to the needs and requirements of modern S&T. The disparity between public and private research is evident, which leads to the conclusion that both financial and human resources should in the future be more biased towards the private sector. At present, Spanish firms are neither willing nor have the capacity to carry out the research necessary to participate in the most dynamic sectors of today's and, more important, tomorrow's industry. But besides improving the absorptive capacities of private firms, links have to be created between universities (originator of knowledge) and the entrepreneurial fabric of the economy (natural transmitter of knowledge). These tools must help to reduce a lack of incentives of academic researchers. Transforming researchers into shareholders of their own firms or spin-offs will promote the search for ideas and their diffusion and application to the productive system. This would, at least partially, increase incentives throughout the researcher's academic career, since their IPR and ultimate industrial exploitation will lead to greater financial reward for their work. An alternative solution to the problem is the creation of intermediate organisms acting as incubators for the development and consolidation of spin-offs in industrial fields of high applied knowledge. The objective is to link academic knowledge to industrial fabric and change the traditional institutional rigidity of the university. Since spin-offs focus on relatively new fields of knowledge, their industrial activities are submitted to a high degree of institutional, technical or financial uncertainty and risk. Consequently, survival rates are very low and – due to the high risks – access to funding is limited even though investment returns may be high. It is still too early to appraise and evaluate the Spanish experience in the creation of spin-offs. The positive note of this chapter is that the universities seem to be increasingly aware of the need to transfer knowledge to society and, consequently, there are groups within the institutions who are searching for ways to do this.

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5

Measuring and Funding the 'Third Mission': The UK Policy Debate

Jordi Molas-Gallart

Defining the Third Mission: a new role for universities?

Over the past decade, the social and economic role of universities has been the object of intensive reassessment. Many academic studies have addressed the linkage between university activities, particularly university-based research, and economic performance and societal needs. In their often-cited book, *The New Production of Knowledge*, Gibbons *et al.* (1994) argued that the model in which knowledge is generated within self-contained disciplines and away from the social and economic context of application is breaking down. The new emerging model of knowledge production is more fluid and dispersed. The traditional distinction between academic and non-academic work becomes blurred. Universities interact with other knowledge producers and carry out research closer to the context of application.

In a similar vein, Etzkowitz *et al.* have argued that universities are freeing themselves from public control and taking a more proactive role in the knowledge marketplace (Etzkowitz, Webster *et al.* 2000). The result is an 'Entrepreneurial University', adept at raising funds from private and public sector organizations and individuals, and more closely linked to its economic and social milieu. It is further argued that the Entrepreneurial University promotes economic development through – among others – its commercialization activities and the links it establishes with industry (Clark 1998). The academic analysis of the new university models thus moves from a discussion of trends and patterns of change to providing a normative framework to guide educational and research policies. Analysts have argued that creating new research opportunities through commercial consultancy or research contracts can benefit both university and industry. Ormerod, for instance, argues that teaching, consultancy and research can stimulate each other in a virtuous circle (Ormerod 1996).

This emerging view coupled with corporate calls to make the work of universities more responsible to the technical and scientific needs of industry and the service sector (e.g. CBI 2003) provides the background to a growing interest by government to stimulate the 'Third Mission' of universities. As we will see below, the term 'Third Mission' can be interpreted in different ways, but it broadly refers to the engagement of university with societal needs: a role to be added to the two traditional missions of teaching and research.

Government focus on the Third Mission

UK government has, for some years, deployed a range of initiatives to support the Third Mission of universities. The support of these activities is providing universities with a 'Third Stream' of funding, to be added to the other two streams of funding supporting teaching and research. In general, funding for UK higher education institutions (HEI) is channelled through the Higher Education Funding Councils, operating in the different regions (see Stiles 2002 for an analysis of this funding system) – Higher Education Funding Council for England (HEFCE), Higher Education Funding Council for Wales (HEFCW), and Scottish Higher Education Funding Council (SHFEC). Since 1999, these councils and the Department of Trade and Industry have allocated Third Stream funding through programmes mainly supporting entrepreneurial activities and based on calls for tender. These initiatives include the Higher Education Innovation Fund (HEIF), the Higher Education Reach-out to Business and the Community (HEROBC) initiative, and the University Challenge and Science Enterprise Challenge schemes.

As the emphasis on the importance of such Third Stream of funding increased, there was a widening perception that such project-based resource allocation would prevent universities from developing long-term Third Mission strategies. Third Stream funding is not only very small in relation to the other two streams, but is targeted to specific well-defined sets of projects and short-term strategies. Once a project has been completed, the receiving university has to seek additional funding for other related activities from other support programmes.

To enable longer-term planning of Third Mission strategies, universities, government and other stakeholders are exploring the possibility of developing permanent Third Stream funding mechanisms. It is hoped that continuous funding streams will reduce the dependence on discrete project bids and the uncertainty associated with such procedures. The objective of permanent funding strategies would be to provide core funding to help HEI develop organizational practices to promote the transfer of knowledge and skills, and improve their connections with business and society at large. The provision of permanent funding could also provide a further incentive for universities to take a more serious look at Third Stream activities.

Yet moving from a 'project and bidding' form of funding to the establishment of new forms of permanent support is not straightforward. New criteria have to be developed to assign resources, and to do so on a long-term basis. It is important that such criteria are based on evidence of needs or performance of Third Mission activities, or both. Data is needed to support such evidence-based policy implementation.

The need for sets of metrics to support funding decisions was soon perceived as an early requirement to deploy a permanent Third Stream of funding. Different metrics are already used to determine funding levels for teaching and research activities. Teaching funds are determined by a complex formula taking into account the number and type of students. Core funding for research is based on the Research Assessment Exercise (RAE); this is a less mechanistic approach, by which expert panels assess the performance of university departments on the basis of submissions that focus mainly, although not solely, on academic publications. In practice, panels in different disciplines will take different approaches to quality assessment, ranging from the rather mechanistic counting of articles in academic journals, which are themselves rated according to their perceived quality, to more qualitative assessments. At the end of the process each department is assigned a rating, and funding is then distributed through a formula that takes into account this rating (Bessant, Birley *et al.* 2003). In 2001, government agencies were considering how to approach Third Stream measurement as a way to support decisions on Third Stream funding level. This is therefore a two-level problem: first, adequate indicators of Third Mission activities need to be developed; second, once these indicators are translated into reliable data, such data needs to be used to inform funding decisions. Two groups of related questions emerge:

- What indicators of Third Mission activities can be feasibly defined and developed?
- How will quantitative indicators be used within the processes required to make funding allocations?

At the beginning of this process, however, government agencies were taking a rather optimistic view of the difficulties inherent in these processes. Public officials were gearing themselves to implement a system of indicators and an accompanying funding formula within a relatively short period of time (a few years to identify indicators, define, collect and use them to determine funding allocations). This rapid track to a permanent Third Stream of funding was based, however, on a narrow view of what constituted the Third Mission and what indicators could therefore be collected. The trend was towards implementing a simple set of indicators based mainly, if not uniquely, on indicators of downstream Intellectual Property (IP) commercialization. This was a field where considerable experience already existed. In the US, the Association of University Technology Managers (AUTM) has been carrying out surveys of commercialization activities in US universities for many years and has established a solid approach with a set of clear definitions and questions targeted, naturally, at the US context. In Europe the AUTM survey has been adapted, most notably in the UK through the survey carried out by the Nottingham University Business School (NUBS) in association with the University Companies Association (UNICO) and the Association for University Research & Industry Links (AURIL). The NUBS-UNICO survey has been supported by the Economic and Social Research Council, and has already been applied twice to a selection of universities (see also Chapter 2 by Hague). Its promoters plan to turn it into an annual monitoring exercise. At the time of writing there are also European-wide initiatives to develop common approaches to the development of indicators of university–business interaction with the EU-funded 'Proton' project as a leading example.

Yet these approaches focus on a narrow set of indicators, particularly on those activities (patenting, licensing, business ventures, etc.) that can directly lead to the generation of resources through the commercialization of inventions generated within universities. But university–industry relationships are more complex and extend to collaborative links involving not only research but also teaching activities, access to facilities, and consultancy, among many others. Further, the Third Mission is rarely seen *only* as becoming more 'user-friendly' for business, or becoming part of this business community, but includes also, in most views, a key facet of 'support to the community', in the form of other non-academic activities oriented to the solution of social and political problems. From this point of view, the generation of indicators and metrics for the measurement of Third Mission activities becomes a much more difficult problem.

Measuring the Third Mission: some fundamental difficulties

As UK government departments became closer to the development of a system of indicators, concern grew that an unbalanced system could be put in place. For instance, some university managers of technology transfer offices and industry links became critical of simplistic approaches that would equate their role with that of a commercial office for university-generated innovations. In late 2001 the Russell Group of Universities, an informal grouping of UK leading research universities, invited tenders for a study to develop a system of indicators for Third Stream activities. The study we conducted at SPRU, University of Sussex, stressed the need for a comprehensive definition of Third Mission activities, which would necessarily result in a more complex system of indicators than initially envisaged (Molas-Gallart, Salter *et al*. 2002).

The need for a slow, progressive approach to the establishment of a system of indicators emerges from the fundamental difficulties that such an initiative faces. This section briefly discusses two of the most relevant problems: the diversity of ways in which the Third Mission can be conceptualized, and the debate on the role of universities within the educational and research system.

Defining the Third Mission

The term 'Third Mission' is being increasingly used and has become common in the policy debates in the UK. Although it is broadly recognized that the term refers to the engagement of universities in non-academic activities, its scope is seldom explicitly defined. Implicitly, however, the term is used in many different ways. Take, for instance, the following definitions of Third Mission or Third Stream:

- In his book, *Creating Entrepreneurial Universities* (Clark 1998), Burton Clark explicitly defines the three streams in terms of income sources. The First Stream refers to the *public* core funds that state universities receive to support their teaching responsibilities. The Second Stream refers to funds received from governmental research councils to support research. Finally, the Third Stream refers to income from all other sources including companies, philanthropic foundations, the European Union, student fees, endowments, etc. From this point of view, the different streams refer to different sources of income. This is consistent with the approach taken in the book: the entrepreneurial university is characterized by its proactive

approach to fund-raising, whether from consultancy projects, endowments, alumni gifts, or the income received from fee-paying students.
- As we have discussed above, UK government departments have tended to see the Third Mission (and the associated Third Stream of funding) as being related to the commercialization of university resources. The assumption here is that universities possess a broad array of capabilities that are not being exploited outside non-academic environments. Through commercial exploitation these capabilities will be released for wealth creation and benefit the regional and national economies. From this perspective the Third Mission is seen as being linked to technology commercialization, patenting, licensing and the generation of spin-off companies. This is a much narrower approach to the view taken by Burton Clark.
- Other experts have used slightly different concepts to refer to the additional extra-academic mission of universities. For instance, Ian Gibson, Chair of the House of Commons Select Committee on Science and Technology, has used the term '*community stream*' to refer to the effort to be made by universities to engage with their local communities for their mutual benefit. In this 'social view' of the Third Mission, universities will strive to bring their work closer to disadvantaged local communities. They will for instance establish initiatives to recruit students from these environments, and work with local organizations to solve local problems. Note that this approach is very different from the other two. Although again the focus is on non-academic activities, it is well understood that a substantial segment of such social activities would not generate extra funds. The other side of the same coin is that fund-raising activities, like consultancy, will not necessary support the local community.

Such a variety of approaches can be translated into a variety of policy goals. For instance, UK government ministers and officials have variously described different Third Mission objectives including the support to small and medium-sized enterprises, the promotion of regional development, the involvement in community and social development, urban regeneration, the creation of wealth, and the improvement of economic competitiveness. Yet when a system of funding to support these initiatives is under consideration, it is crucial to determine what is the set of Third Mission activities in need of support. If a funding system is linked to a set of metrics without careful consideration being given to policy objectives, such objectives will be inadvertently determined by the composition of the set of indicators being used. From this point of view, the process of defining Third Stream, and devising metrics, is a major strategic exercise with profound impact on how universities see their missions, and ultimately, on the distribution of public funds, and the definition of policy objectives.

The balance across missions and the role of universities

Beyond defining the scope of the Third Mission, a further policy issue is the way in which this set of objectives is combined with the more traditional university tasks of teaching and research. As new demands are made of them, universities have to find a balance between a wide range of different roles and responsibilities, from teaching and research to economic development and societal impact. For instance, the UK White Paper on Science and Innovation sees universities playing a central role as 'dynamos of growth' in the emerging knowledge-driven economy, 'not just creators of knowledge, trainers of minds and transmitters of culture, but ... also major agents of economic growth' (Department of Trade and Industry 2000, p.27). But how these roles are to be combined with the traditional missions is the object of much heated debate.

The discussions about the role of universities are by no means new, but they have taken on immediate policy relevance. Some question the premise that universities should have an economic contribution, and see their role as providing a 'liberal education'. Such education is a value in itself and should not be justified in terms of other alleged economic benefits (Maskell and Robinson 2001). Although the view of an elitist university concerned only about the generation of knowledge for its own sake does not carry much weight nowadays, there is a more widely sustained view among academics that the concentration on use and problem-oriented research may undermine the quality of both research and teaching. Some authors, like Richard Florida, have argued that commercialization pressures are generating tensions between public and private interests and undermining the long-term economic impact of universities. Focusing on commercialization may shift the universities' attention away from their 'primary missions' of research and teaching, thus undermining rather than supporting their contribution to economic development (Florida 1999).

However, the extent to which commercialization interferes with other university activities is far from clear, and its impact on teaching, research, staff morale, and university budgets is likely to depend on other contextual variables. A review comparing different types of universities concludes that there is no clear relationship between the user orientation of university research and teaching activities and the quality of the basic research it conducts (Martin and Etzkowitz 2000). Further, the discussions on the merits of commercialization have tended to ignore the wider social impact of universities' Third Mission activities. As discussed above, universities can make social and economic contributions that are not channelled through commercial avenues. A balanced view of the different conduits through which non-academic communities can engage with the work of universities would lead to a holistic approach to the assessment of Third Mission activities. Otherwise, attention would focus on only one of the mechanisms through which universities engage society and on the limited set of academic disciplines that are commonly associated with commercialization activities (like biotechnology and information technology) to the detriment of other disciplines that make their societal contributions through different channels (like political science, mathematics, and many others).

An approach to the measurement of Third Mission activities

Following the above discussion, we have proposed that any approach to measuring Third Mission activities has to start with an acknowledgement of the variety of ways, many of them indirect, in which research and other university activities affect economic performance and society at large. The need to take a broad view of university–society interactions has to be backed by an appropriately broad definition of what constitutes the Third Mission. Our report to the Russell Group of Universities defined Third Stream activities as those concerned with the generation, utilization, application and exploitation of knowledge and other university capabilities outside academic environments (Molas-Gallart, Salter *et al.* 2002).

It must be noted that this approach will exclude some of the activities that were considered as Third Stream (or Mission) in the definitions reviewed above. For instance, not all 'community stream' work is concerned about the generation and utilization of knowledge and capabilities outside university environments: the effort to recruit students from underprivileged backgrounds aims at broadening the appeal of academic pursuits to a wider population, but does not directly pursue the application of university capabilities to the solution of societal problems. In a similar vein, seeking endowment and alumni contributions will be part of the Third Stream of university funding as defined by Burton Clark, and may be characteristic of many entrepreneurial universities, but are not Third Mission activities according to our definition.

Our approach focuses rather on the engagement of university capabilities outside academic environments. In other words, we are paying attention to a specific type of 'outreach activities', including, among many others:

- consulting and contract research by university for industry;
- joint research where both university and industry are involved;
- spin-off firms, innovation centres, incubators, science parks, etc.;
- traditional commercialization activities including licensing and patenting;
- the development of teaching curricula aligned with specific needs as defined by social groups, and training programmes targeted to professionals in industry, government, and the service economy;
- the development of informal contacts between academics and their potential 'non-academic users';
- contributions by academics to non-academic publications.

We propose an analytical framework based on a principal distinction between what universities have (capabilities) and what they do (activities) (Molas-Gallart, Salter *et al.* 2002). Universities have capabilities in two main areas: (a) knowledge capabilities embodied in their academic staff and (b) physical facilities including laboratories, libraries, and teaching rooms and equipment. These capabilities are developed as universities carry out their core functions of teaching and research. Using these capabilities, universities carry out three main sets of activities: (i) teaching, (ii) researching, and (iii) communicating the results of their work.

All these capabilities and activities can be considered to contribute to the Third Mission when they engage non-academic communities. Following this framework, our study identified 12 different categories of Third Mission activities accompanied by 65 different potential indicators.

A feasible approach to data collection cannot conceivably cover each one of these indicators. Yet, a system of Third Mission measurement must be based on a carefully selected battery of indicators, covering all potential areas of activity. The fact that in some areas it is easier to develop indicators than in others (compare for instance the monitoring of commercialization activities with trying to account for informal networking activities outside academia) may lead to some areas being inadvertently prioritized. This is an area where the danger of looking for our lost keys only where there is light available is ever present. Yet, although a comprehensive approach can be easily justified on the basis of comprehensiveness and balance, it generates important implementation difficulties. Setting up comprehensive Third Mission metrics is a task fraught with dangers, some obvious, some less so.

Measuring the Third Mission: some practical problems

Were universities required to collect data on Third Mission activities in a systematic manner, several issues would need to be resolved first. Some are methodological problems related, for instance, to the definition of the concepts being used, while others relate to the practicalities of implementing yet another complex system of performance monitoring. The main issues to be addressed include the following.

(1) The definition of categories and concepts

In many Third Mission areas there are no well-developed data collection instruments and no substantial experience in data collection. Many of the concepts are not clearly defined and will need to be clarified. The potential for misinterpretation is substantial, and attempts to clarify the terms in questionnaires may result in complex long-winded forms. New concepts will also require new data collection structures and mechanisms, and, as a result, data may be initially very costly to collect.

(2) Centralization of management

Many Third Stream activities are carried out without any central university leadership or control. Consultancy projects, contributions to the media, and advisory work are conducted by small teams and individuals. Often individual academics collect some income from such activities. If the elaboration of new university-wide indicators implies the creation of new centralized reporting requirements, an incentive may be created to centralize the management of Third Mission activities. An emerging centralized managing culture may clash with individualistic entrepreneurial academics used to engage in Third Mission activities without the interference of university managers. It could be argued that a heavy bureaucratic approach to management may stifle the activities it was designed to promote. It follows that data requirements must be designed to take into account the type of organizations and procedures necessary for data collection, making it possible for flexible and decentralized management systems to operate data collection and management functions.

(3) Differences across disciplines

The ways in which academic disciplines can contribute to economic and social development vary from area to area. Naturally, applied disciplines like engineering, medicine or business studies are likely to find direct channels of application. In contrast, the impact of fundamental theoretical disciplines (like theoretical physics or philosophy) is bound to be indirect and, often, longer term. Further, some disciplines like biotechnology and information technologies are linked to emerging sectors with low entry barriers and direct links between scientific developments and technological innovation. In these areas, mechanisms like university spin-offs provide a direct avenue for the exploitation of scientific research outputs. In other sectors with higher barriers to entry, patent and patent commercialization will be the preferred exploitation avenues (see, for instance, on the pharmaceutical sector, Mowery, Nelson *et al.* 2001). These differences across disciplines present substantial practical problems when trying to develop metrics to assess and compare Third Mission activities across all sectors and disciplines, or when comparing universities with different disciplinary focuses.

(4) Differences across universities

The differences across universities do not only depend on their varied disciplinary make-up. Martin and Etzkowitz refer to different 'species' of universities (Martin and Etzkowitz 2000) to indicate the variety of forms and orientation of universities. Different intellectual, economic and social contexts lead to different types of university, each with its own balance between teaching, research and Third Mission activities. How this variety can be captured by a single set of indicators and addressed by a single performance-based funding mechanism, remains a difficult problem. A stream-based system of funding could increase the specialization of universities into different 'streams': some would be mainly teaching organizations, others centres of research excellence, and yet others would specialize in engaging their local and regional environment. By specializing, they could maximize their performance in a given area and attract public funding. This outcome is seen with concern by most academics and university managers. In a highly hierarchical university system like the British, such specialization could result in a *de facto* rigid hierarchy between centres of international research excellence, teaching institutions outside the elite research centres, and lesser institutions receiving less funds and constrained to focus on engaging their local and regional environment. In this sense, a system of indicators designed to support such a system could hardly be described as a neutral tool for comparing performance across a wide variety of organizations.

(5) Measurement fatigue

The UK university system is already subjected to several monitoring exercises requiring substantial investments of time and resources. Teaching is being assessed through the Teaching Quality Assessment (TQA), and research through the Research Assessment Exercise (RAE). There is no enthusiasm for yet another additional reporting and monitoring system. Further, present and projected levels for Third Stream funding are bound to be low when compared to the teaching and research streams, and a comprehensive system of indicators is likely to be broad and complex. New indicators will have to be designed so that their collection is less labour-intensive, or they have to provide useful management tools for the universities, or both.

(6) Unintended effects of applying metrics

The measurement of activities, particularly when connected to a system of financial rewards, is likely to generate unintended effects, as organizations and individuals adapt their behaviours, sometimes in an opportunistic manner. For instance, organizations are likely to respond by pursuing performance in the selected indicators rather than developing strategies to address the areas in need of improvement. In the case of universities, the organizations may focus in the pursuit of a narrow set of indicators (say number of patents, industrial spin-offs, press appearances, etc.) instead of developing a Third Mission strategy. A traditional response to this problem is to deploy a system of indicators that is so complex that cannot be easily manipulated by opportunistic behaviour. There is, however, evidence suggesting that further complexity does not in practice diminish attempts to engineer responses (Loch, Pich *et al.* 2001). Complexity does not get rid of opportunistic behaviour.

This set of problems relates to the implementation of a measurement system. When aligning such a system with a funding mechanism an additional set of issues and difficulties emerges:

(7) Problems with impact measurement

To be able to account for the 'quality' of an activity, and to avoid measuring 'inputs' rather than the more significant results of an effort, there is a trend in the construction of indicators favouring the use of output and impact indicators. For instance, instead of focusing on the number of patents granted to an organization, it is assumed that the income generated from a patent portfolio will provide a more accurate estimate of the success and performance of the organization's commercialization strategy. Yet, the distribution of the impacts of research and innovative activities is always skewed: a very small number of activities or performers account for most of the impact (Scherer and Harhoff 2000). If an indicator displaying a skewed distribution is used to guide budgetary allocations, the distributions of funds will also tend to be skewed: a very small number of organizations will receive most of the support. Although some current policy proposals favour skewed resource allocations to support 'excellence', the resulting concentration of funds in a small number of organizations reduces diversity and generates additional difficulties (Molas-Gallart, Salter *et al.* 2002). Further, a skewed distribution of Third Stream funds may also concentrate funding in specific localities and within a very limited number of sectors and activities. In addition, the use of impact indicators presents other problems, like the difficulties in identifying additionality and the sensitivity of measurement results to the moment in which the measurement is conducted (sensitivity to timing; see, for more detail, Molas-Gallart, Tang *et al.* 2000; Molas-Gallart, Salter *et al.* 2002).

(8) Interdependence between Third Mission and research activities (second stream)

It is not surprising that a relationship may exist between good academic research and the capacity to engage in the solution of practical problems: the capacity of organizations to engage with non-academic users is dependent, among many other factors, on their ability to generate new knowledge. Studies have shown, for instance, that excellent academic research appears to have a direct impact on innovation (Hicks *et al.* 2000). Yet, if the capacity to engage in Third Mission activities is dependent on research performance, Third Stream funding may be related to research capabilities and therefore be positively correlated with Second Stream funds. Although this observation does not affect the development of indicators to measure performance in Third Mission activities, it is an important consideration when such indicators are used to inform funding or, even further, develop Third Stream funding formulas. If the

Second and Third Stream funding allocations appear to be correlated, this could be interpreted as double counting performance in some specific areas when developing performance-based funding allocations.

(9) Public support of commercial work

It could be argued that a system of Third Stream funding rooted in indicators of commercialization performance would use public funds to support commercial activities unfairly. It could appear as if direct financial rewards are being offered for commercial performance. There is, therefore, a need for a system of indicators that is broad enough to include all types of Third Mission activities, and an approach to manage Third Stream funds in which these are not seen to be allocated as a reward for pure commercial success, but rather as a system to promote beneficial activities that could not, at least at an early stage, be set up as self-financing operations.

Developing a system of indicators and a funding allocation process

The problems identified in the section above are only a selection of a broad set of difficulties facing the implementation of a permanent system for Third Stream funding informed by robust data. Although a definitive solution for many of the issues discussed here does not exist, the problems need to be addressed explicitly when developing a system of indicators. Our study suggested a conceptual framework on which to 'hang' a set of potential indicators. The conceptual framework (Molas-Gallart, Salter *et al.* 2002) works as a guide to check the comprehensiveness of the selected set of indicators (we suggested that no category should be left unattended, and no category should be over-represented). Yet the price to pay for comprehensiveness is a complex system of indicators, which, in many cases, have not yet been properly defined, let alone 'operationalized' through questionnaire instruments.

The prospect of batteries of indicators to be collected to inform Third Stream funding decisions will be daunting for any university manager that may be put in charge of compiling the data. The development of a system of indicators for the Third Mission is bound to take considerable time and resources. A balanced approach, and its linkage to a funding system, are best developed in a staged manner, and through a process that gives voice to all stakeholders. The objective is not so much to reach consensus, but to build a system that is supported by the experience of managers and academics, and that can be adapted to learn from experience.

A staged approach is an iterative process, with an initial phase of indicator definition, followed by collection, analysis and feedback of results into the refinement of the system of indicators. Through this process data becomes robust over time and can play an increasingly important role in informing funding decisions. One of the issues to be discussed is whether such funding allocations will remain the decision of expert panels informed by, it is hoped, increasingly sophisticated data sets, or the process will reach a stage in which the elaboration of a funding formula emerges as a feasible alternative. Short of determining funding levels, it is conceivable that a formula could be used only to assist the decisions of a panel. One way of using a formula-based approach to inform funding decisions would be to group universities on a scale according to the scores achieved by applying the formula. Funding would then be distributed to each group following processes similar to those currently applied in the RAE. This approach does not remove judgement in the allocation process. The formula itself would be based on judgements about what is important, and the panel would oversee its development, application and change.

In any case, the discussion of a funding formula when there is not yet a set of widely accepted indicators, or even definitions of Third Mission activities, is rather premature. The UK policy process is recognizing the complexity described in this chapter and, as a consequence, policy rollout is being delayed. In December 2002, the Higher Education Funding Council for England (HEFCE) launched an expert consultation on the issue. Meanwhile, Third Stream funding will continue to be project-based rather than permanent. HEFCE is, for instance, planning a second round of HEIF funding 'to help [HE] institutions increase their ability to respond to the needs of business and the wider community'. This second round of HEIF is expected to provide the transition towards a permanent third stream of funding by 2005/6 (HEFCE 2003). Meanwhile HEFCE is engaged in further consultations on the approach to Third Mission data collection.

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6

The Role of Intellectual Property Rights Regimes for R&D Cooperation between Industry and Academia

Ulrich Blum and Simone Müller

Motivation

An increased cooperation between universities and industries is seen by many politicians as an ultimate remedy against economic underdevelopment by fostering regional growth in a world in which the know-how content of products is ever increasing. Furthermore, this know-how is increasingly separable from the goods and, thus, can be developed into an Intellectual Property Right (IPR). As we well know, technological development was historically often linked to the machinery in which this specific technology was used, and enterprises tried to keep implicit knowledge within their firms, protecting it against diffusion into economic space. The more that know-how became public, for instance through the development within publicly financed research units, such as universities, the more a general diffusion process became possible. It was in the nineteenth century that nation-states started to found their universities of technology, their royal research institutes, etc. in order to promote technological development. The necessity to protect generally accessible know-how that was privately developed became of strategic importance and, thus, international regulations on trade marks, patents, their licensing, etc. developed.

Know-how then increasingly became a tradable good; i.e. the ability to transfer its contents from one place to another, given its understanding, became possible. This ability to understand, however, technically called the absorptive capacity, mostly depends on technological status. In his seminal book on economic development, List (1848) pointed out that countries in the course of catching up should invest in human capital and send their workforce to other countries to learn, understand and bring home the latest technologies. Today, this notion of absorptive capacity becomes ever more important in the technological race. In many cases, only those who also do specific research can understand the results produced by others. Following today's view, know-how comprises in most cases a bundle of goods, and these goods are public, club or private. The use of public goods, however, may be restricted because of rights that grant exclusive use, such as patents or licences. Complementary implicit knowledge components may limit the use of publicly available technology.

In many cases, a clear-cut delimitation between basic research and market-oriented research is developed to position the role of academia and industry in the process of knowledge production. However, this distinction is not always very helpful, because market potential can be directly developed out of basic research, as we see in life sciences. Thus, we will distinguish between horizontal and vertical research. *Horizontal research* produces a knowledge platform, and competition in this category tends more to research results than to market performance. As a consequence, it is oriented towards research markets. In sharp contrast, *vertical research* is motivated by the foreseeable market potential of the results envisaged, and these results must be private goods. As private goods, exclusion of third parties from using the results is possible. This implies that the information content of research becomes a decisive criterion in the process of categorization of market conduct and incentive structures. On the horizontal level, the economic market in most cases will be more distant than in vertical structures. Information sharing will be more open between specific groups that are able to evaluate the content of the implicit knowledge produced. This implicit knowledge is made explicit, but only for a limited audience in the academic market constituted by publications, etc.

In the following section, we will categorize R&D according to different criteria and precisely filter out those areas of interest to be pursued here. Then, in a more theoretical section, we will focus on the information structure of R&D cooperation within the context of a principal–agent model. This will, in the fourth section, enable us to design a policy-adaptive methodology of cooperation. In the final section we will summarize our findings.

Definition of the area of interest

R&D processes can be categorized according to many dimensions. Figures 6.1 and 6.2 illustrate two different categorizations each with three criteria to categorize, the first dealing with the choice of instruments and the second showing different institutional settings. The idea is to trace 'white spots', i.e. combinations of categories that are not, but should be, covered by programmes. Generally speaking, the six-dimensional characterization of research may be employed as a filter for creating new and eliminating obsolete programmes.

The first cube (see Figure 6.1) relates to the institutional side of research, because the type of research unit, the goods structure of outcomes and the respective financial support are important success factors. The second cube (see Figure 6.2) contains firm size, which is important for the delimitation of incentive programmes as well as the ability of firms to carry out research and development themselves. In fact, the two other dimensions, namely reasons for failure and innovation policy, are not entirely independent. Especially small and medium sized firms (SMEs) have problems in obtaining sufficient financial support from outside sources. Furthermore, they often lack a systematic R&D programme. This relates to the instruments used with respect to a given institutional set-up. Again, the dimensions are not entirely independent as universities tend to produce more public goods (within a system of horizontal co-operation) and are strongly supported by public funds, in strong contrast, for instance, to profit-oriented private institutions.

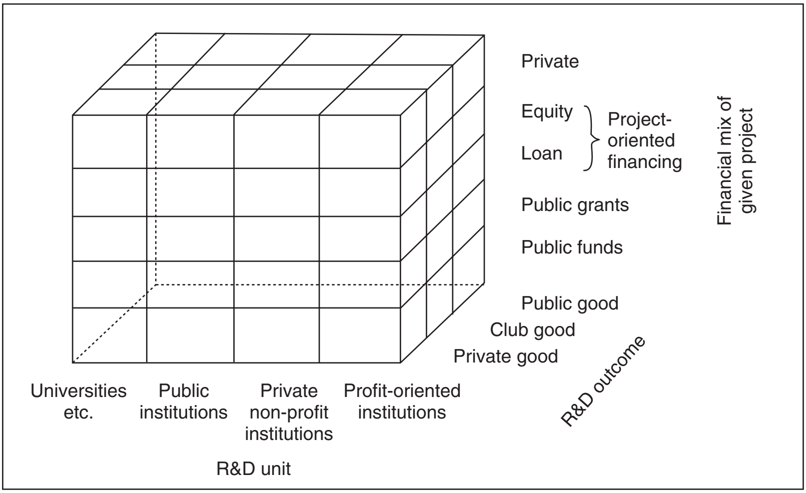

Figure 6.1 The cube of instruments

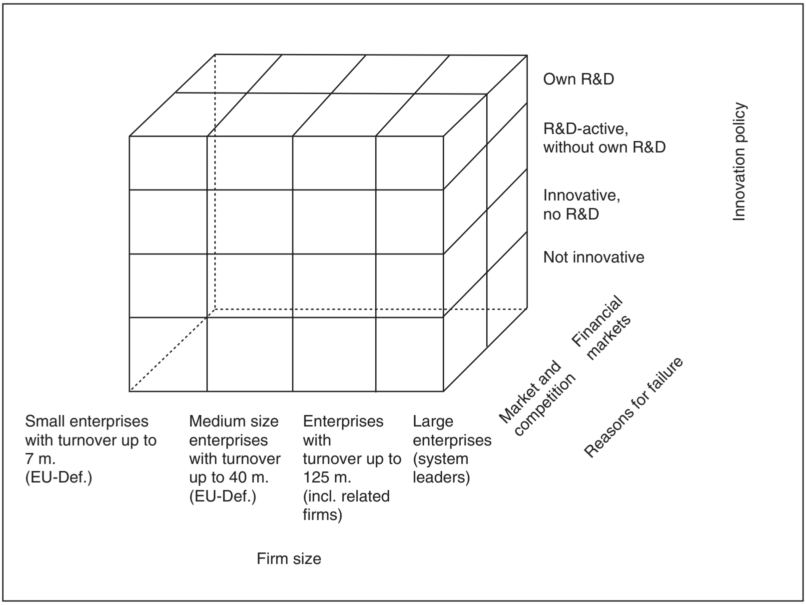

Figure 6.2 The cube of institutional arrangements

The two cubes make it clear that the structural gap between academic research institutions on the one side, and private, profit-oriented institutions on the other, is vast with respect to the institutional architecture, the accessibility of financial support or the pressure to produce results. This implies that the incentive systems between academia and enterprises must be bridged. We consider information asymmetry and different goods structures as the most important aspects. The following section will provide theoretical underpinnings for an information theory approach to public research. The fourth section will then concentrate on the institutional implementation.

University–industry cooperation from a theoretical perspective

Cooperation as problem of efficient institutional arrangements

A cooperation design that links academia and industry has to address the following four problems:

1. *What are the incentives?*
   As shown earlier, incentive structures vary vastly between academic institutions and industries. Among the major problems are different markets (research markets versus product markets) that exist in the two institutions but with different levels of importance.
2. *What are the characteristics of the research and development products?*
   Research results possess private, club and public goods properties. This implies an incentive-compatible financing: results that are public and where exclusion of users is impossible must be financed by the public unless exclusiveness can be granted through patents. Club goods, i.e. insider knowledge, must be paid for by the insiders. Private knowledge must be paid for by entrepreneurs, finally by the market.
3. *How is risk allocated?*
   Cooperation is also a venture of risk allocation. It has to be decided which side takes which risks and how this relates to the rewards of cooperation.
4. *How is information distributed?*
   Cooperation is based on incomplete contracts and thus carries a considerable degree of insecurity. Institutional arrangements have to be defined that compensate for or overcome these diversions.

These four points imply that cooperation between industry and academia has to be addressed within the context of information economics, especially of opportunistic behaviour.

Opportunistic behaviour and kinds of transaction

Information economics analyzes cooperation designs with respect to the risk of opportunistic behaviour by whichever of the two parties involved in the contract has more information. Opportunism follows from bounded rationality, i.e. people have limited information and limited ability to process it, and self-interest. If transactions are categorized according to market uncertainty caused by opportunistic behaviour, two types of goods emerge, according to Williamson (1985):

1. *Exchange goods*: These goods comprise the transfer of property rights to resources that do not involve promises or latent future responsibilities (Pauly 1974). These transfers are completed at time of transaction and, thus, the quality of goods cannot be influenced by either seller or buyer. No party involved in the transaction has to engage in specific investments.

2. *Contracts*: In sharp contrast, a contract promises future performance, typically because one party makes an investment the profitability of which depends on the other party's future behaviour. In this case, the product to be exchanged only emerges with the closing of the contract and may even vary hereafter. As a consequence, at least one party to the contract has to sink specific investments without having a guarantee of a full use of the product, which is thus incomplete in nature.

This is the typical case when parties agree on a technology, the potential of which is still unknown. The extent of uncertainty faced by the parties of a transaction is thus determined by two criteria (see Figure 6.3):

- determination of behaviour prior to the completion of the transaction, and
- observability of behaviour after completion of the transaction.

By combining these two criteria, four types of market uncertainty theoretically emerge that are caused by asymmetric information. Thereby, observable and not observable characteristics of behaviour can be combined to hidden characteristics. They are the only source of market uncertainty for exchange goods where the behaviour before closing the contract is determined. Contracts as future promises of performance, like university–industry cooperation, where at least one party usually has scope for deviating behaviour, are exposed to all three types of opportunistic behaviour: quality uncertainty, hold-up and moral hazard. We will analyze these three types in more detail below.

		Behaviour after closing of the contract	
		Can be observed	Cannot be observed
Behaviour before closing of the contract	Is determined	Hidden characteristics (quality uncertainty)	
	Is not determined	Hidden intention (hold up)	Hidden action (moral hazard)

Figure 6.3 Basic types of market uncertainty

Quality uncertainty

Quality uncertainty refers to asymmetric information on the above-mentioned characteristics of the good, if they are already determined at the time when the contract is closed, but may not all be apparent to the less informed party of the contract. The extent of uncertainty is determined by two dimensions: the ability to evaluate goods characteristics and the time of evaluation – before or after the transaction (see Figure 6.4).

- If quality evaluation is possible by inspection before purchase, we obtain a *search characteristic*, i.e. a characteristic for which the identification of its properties is possible. This, for instance, is the case if know-how is licensed and this know-how is already in use; the interested party may thus identify the properties of interest by inspecting the licensed technology or product.
- If the ability to evaluate quality is impossible before purchase but given after purchase, *experience characteristics* are obtained. The user may identify the properties at worst over a certain period, i.e. gain experience. This is the case of a newly developed licence where the user experiences all characteristics of technology over time.
- If quality evaluation is impossible even after purchase, because the less informed party does not possess the necessary knowledge or skills to evaluate, or the costs of evaluation are assessed as to high, a *credence characteristic* emerges. This is the case of basic know-how, whose potential lies far in the future.

The risk for the less informed party increases the more the contract contains experience and credence characteristics. Akerlof (1970) described possible market failure caused by quality uncertainty on the market for secondhand cars where only ‘lemons’ are traded because of

		Ability to evaluate quality characteristics	
		Possible	Impossible
Period of quality evaluation	Before purchase	Search characteristics	Experience, credence characteristics
	After purchase	Search, experience characteristics	Credence characteristics

Figure 6.4 Classification of quality characteristics

adverse selection. There are two types of mechanism that reduce quality uncertainty: self-selection and signalling.

In the case of *self-selection* the less informed party creates its offer in a way that enables it to capture the necessary quality information. This is possible if the arrangement is so structured that lying is not in the interest of the better informed. Self-selection is appropriate for contracts where the demand side has more information than the supply side. This is the case in health insurance schemes where the insurer offers different contracts such that higher risks choose contracts with higher premiums and a higher coverage rate. The mechanism of self-selection is appropriate for cooperation between university and industry where the demand side, i.e. the industry, has more information about the profitability of a patent or licence because it has more information about the future demand on the product market. The contract between university and industry thus may contain different fixed and variable components, e.g. depending on future sales volume.

The second mechanism to reduce quality uncertainty is *signalling* and goes back on Spence (1973). Here the supplier whose quality surmounts the average quality in the market creates a credible signal that enables the less informed demander to identify him and to pay a higher than average price. This price premium covers more than the cost of the signal emitted by the supplier. Theory suggests that signals are credible if those sent by the better risk are less expensive than those sent by the inferior risk. Such a credible signal could be a guarantee or an obligation to take back the contracted good. Reputation as an investment in a relationship is another type of signal (Allen 1981; Shapiro 1983). In this case, the less informed demander obtains knowledge about the supplier's past behaviour from former contract partners. This allows an established research unit, i.e. an incumbent, to dominate and successfully compete against an unknown market entrant.

Hold-up

Hold-up goes back to Goldberg (1976) and refers to a situation in which the behaviour of one party, i.e. a hidden intention (see Figure 6.3), clearly appears and inflicts a damage on that party – i.e. one party opportunistically exploits a loophole in an incomplete contract where not all precautionary contractual terms could be specified.

Alchian and Woodward (1988) find composite quasi-rents caused by specific investment as the reason for hold-up. Composite quasi-rents are the portion of the excess return of resources that depends on the continued association with some other specific, currently associated resources. If one party of the contract has sunk costs in specific investments, the recovering of these sunk costs depends on the fairness of the other party. It would be tempted to expropriate the quasi-rent by refusing to pay or serve. Fairness implies that, in the case of hold-up, a specific kind of behaviour is expected but not explicitly contracted. Thus, the claim is only implicit. Examples of this kind of implicit claim are career promises for an employee made by its employer or service announcements or the expectation of cooperation between a licenser and a licensee. If the risk of hold-up cannot be excluded by precautionary contractual terms it can only be overcome by vertical integration and ownership. Thereby, the incentive of exploitation of quasi-rents is prevented because they rest in one hand.

What does this imply for the cooperation between university and industry? If the risk of hold-up caused by specific investments and incomplete contracts becomes too high, the researcher must be included in the future utilization of his knowledge by shareholding, being part of a spin-off, etc. This is the way successful American universities transfer knowledge to the market. We will extend this idea in the fourth section.

Moral hazard

In contrast to hold-up, in which the less informed party (principal) observes the behaviour of the informed party (agent) after closing the contract, this is not possible in the case of moral hazard. The notion of moral hazard comes from insurance market theory (Pauly 1974), in which the insurer cannot observe whether the damage was caused by a third factor, i.e. state of nature, or the insured. This example describes the cause of moral hazard: the less informed party cannot differentiate between an external factor and the behaviour of the informed party, i.e. effort, diligence or carefulness. The exogenous factor gives room for opportunistic behaviour by the agent. Thus, moral hazard occurs in a situation where ‘nature’ makes control impossible. For instance, it is impossible to enforce the creativity of a researcher: slack cannot be distinguished from effort! The researcher will always be tempted to attribute research failure to adverse and unfortunate circumstances, if, in fact, he did not work sufficiently hard. Moral hazard is analyzed within the context of agency theory (Holmström 1979; Grossman and Hart 1983) and solved by incentive contracts. The principal offers a contract to the agent that he can accept or reject (see Figure 6.5). If the agent accepts, he obtains a reward for the production of an effort that makes the principal benefit. This implies that the distribution of risk between principal and agent becomes of high importance. In most cases, the principal is considered to be risk neutral whereas the agent is considered to be risk averse. The incentive problem is solved by appealing to the self-interest of the agent to be cooperative and design incentive-compatible contracts.

The results tend to vastly differ from those obtained under conditions of neoclassical theory. The latter would suggest paying the agent according to his marginal effort. However, if this cannot be verified, it will be advisable to punish the agent for bad results with reduced income in order to encourage him to report favourable conditions. Thus, the risk-averse agent will therefore have to bear a share of the risk, which is neoclassically inefficient.

This risk has to be compensated by a risk premium that would not have been necessary if the risk-neutral agent bore all risk. Thus, the benefit of incentive contracts is overcompensated by the additional costs of the risk premium if the actual impact of the contractual incentives on the agent's behaviour is only weak compared to a situation without incentive contracts. Under these conditions, the moral hazard problem cannot be solved with an incentive contract. The principal may then pay a supervisor that controls whether the agent engages in the contracted effort. Here, the cost of the supervisor has to be overcompensated by the gains from monitoring the agent. In this category of models, the supervisor, furthermore, has to be prevented from colluding with the agent. The supervisor thus obtains an important role

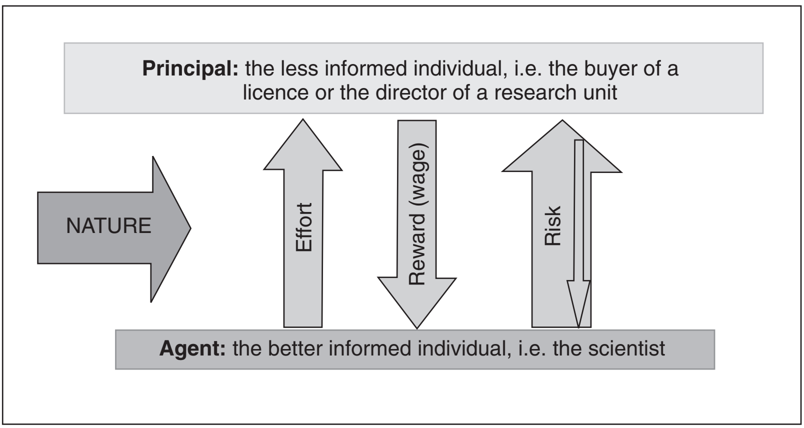

Figure 6.5 Agency problem

under conditions of increased information asymmetries, especially if the state of nature is detrimental to verification. However, the investment into a supervisor has to be worthwhile, i.e. the principal, once freed from control, should benefit from scale economies.

In the following, we will show what implications our findings of how to reduce contractual uncertainty will have for the cooperation between university and industry.

Institutional framework of cooperation

The treatment of IPR in industry

If an employee invents something, the respective know-how belongs to the company, which, for instance, may look for patent protection. The company will then allocate a certain premium to the employee that gives sufficient incentives to be creative. If the company is not interested in the know-how, the employee can fully take possession of these intellectual property rights (IPR).

Professors' privilege 'before 2002'

In sharp contrast to the legal regulation in industry, know-how produced at universities was, before 2002, in the sole possession of the respective scholar, who could thus also engage in industry contracts without violation of any university law. This was even extended to the content of theses, for instance masters' theses, as they are written under the academic supervision of a professor. However, in the 1990s masters' theses were considered to have their own copyright law (as do PhD theses, which are the sole possession of the author) and, thus, the intellectual property was considered to be that of the student. Often, this led to contracts between the professors and their students relating to the ownership of intellectual property included in the theses. Problems arise in contract work, formidably in engineering, when a firm, e.g. a car manufacturer, contracts work to a university institute that splits it up into academic work chunks, i.e. separate theses that address specific problems.

In February 2002, the professors' privilege was abolished and replaced by a regulation similar to that in industry: inventions within universities have to be declared to the university which then has to decide within a three-month period whether to make use of it or not (see Figure 6.6). If the university makes use of it, the respective professor obtains a premium; if not, he may market the content of his invention himself, i.e. look for patent protection. The basic idea was to follow the approach used by American universities that generate income by selling off technology or trigger spin-offs.

Evaluation of the institutional change

We will not engage in an evaluation of the regulations with respect to the treatment of IPR in industry. The regulation in universities was considered to be very one-sided in favour of the scholars who, if lacking market knowledge, were said not to develop their know-how sufficiently in order to trigger economic development. Furthermore, the financial pressure of universities tempted politicians to squeeze out money from the selling of technologies. However, the old situation had tremendous benefits. It left the professors with a proper evaluation of the risk of developing their technology or looking for patent protection, which is not cheap. Furthermore, know-how, whose potential was not realized by the scholars, was available at no cost to industry.

The new situation has at least three very adverse results:

1. If universities and industry cooperate, the legal status of know-how developed is not entirely clear. The scholar cannot, as historically done, sign a contract by which he hands over all rights of inventions to the industrial partner. Thus, any contract today has at least three sides: industry, university and scholar. This has reduced flexibility and increased the risk of disputes. This is a result of the change of the general institutional arrangement.
2. Universities have a strong problem in evaluating the potential of know-how produced in their institutes. These results, to a large extent,

	Before 2002	After 2002
Universities	'professors' privilege'	results from research belong to the university that compensates individual unless no claim is made*
All other	results from research belong to the firm that compensates individual unless declared of no use	unchanged

*this implies that a university, if taking IPR, **must** develop it!

Figure 6.6 New regulation of intellectual property rights relate to experience and credence characteristics. Thus, next to the inventor or developer, a competent expert ('supervisor') has to be installed, who is able to position the results in the market – be it a research or an economic market. As a consequence, federal states have set up new institutions outside university – evaluation bureaus – that should finance them in the long run from income generated by selling off technologies. This, however, has reduced the incentive of universities because only parts of these funds are channelled back to the universities. As a consequence, the 'reward' side of the principal–agent problem remains unsolved.

3. Finally, the regulation is not incentive-compatible for the university scholars. We will try to elaborate this problem a little bit further.

The incentive-compatibility of the new regulation

We assume that the professor or his network is able to evaluate the potential of an invention. If he were not, he would have left the knowledge to all those interested, and it would then constitute a public good, and the benefit of dissemination would be to the general public. The rewards would be reflected in increased taxes and thus be beneficial to all – unless the ability for detecting and unveiling, evaluating and assessing, and finally, producing and marketing these results does not exist outside university. Then, a more general problem arises, which remains unsolved under all institutional frameworks.

In the first case, the scholar could be honest and declare all inventions to his university. If the university takes up the invention and protects all IPR, he obtains a premium and the story is closed. If the university turns down the invention it is left to the scholar for further development. If the university takes over the right of the invention and does not develop it, it risks that scholar filing for failing to exploit his invention, which could generate a right for compensation.

The rational scholar would thus hand over all research results without market potential to the university, or even flood it to cause a breakdown of universities' capacities. Either, the university takes it up but will find it hard to market it, in which case the scholar has reduced the risk of his own marketing cost and could even file for compensation if the university is not sufficiently eager or turns down the invention and it falls back to the scholar, who now has learnt more about market potential, thus profiting from reduced information asymmetries; or, he could harbour interesting and high-potential inventions within his own research company that he runs with other individuals, which thus makes it very hard for the university to prove that he has been dishonest. The only solution lies in a screening procedure under which a self-selection system forces the scholar to unveil his knowledge of potentials, i.e. a choice between fixed and variable components of participation.

How should cooperation be organized?

To sum up, there are three prerequisites to be followed if cooperation between university and industry wants to be efficient:

1. It must be in the interest of university personnel to reveal the market potential of its research results, at least to enter cooperation with other institutions that are able to produce a proper evaluation. Market orientation – whether in terms of research markets or economic markets – must thus become an important issue in research. As a consequence, the dissemination of knowledge should not be taken out of the hands of universities and handed over to third parties. The university should not be reduced to a supervisor with incentive-incompatible contracts.
2. It must be in the interest of universities to make research economically attractive for their personnel. This could be in the form of additional revenue; in the context of the typical scholar it would be more likely that he is motivated by the higher budget and better equipment of his institute. As a general rule, the remuneration – whether personal or institutional – should relate to screening techniques (self-selection), which offer alternative revenue schemes that differ in total percentages as well as a split into fixed and variable amounts.
3. Clear-cut rules have to be established with respect to the IPR of inventions produced in cooperation projects.

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Part II

Academia–Business Linkages and Industrial Development

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7

Why Invest in Biotechnology? German and British Biotechnology Policy Compared

Rebecca Harding

Introduction

This chapter is an attempt to answer the question as to why governments across the world commit so many resources to biotechnology, by comparing German and British policy development over the ten-year period since 1992. Britain and Germany represent interesting cases within a wider European effort to catch up with United States. They have, respectively, the largest and the second largest biotechnology sectors in Europe. Both have strong regional biotechnology clusters around world-class universities, and both countries invest the largest amounts in Europe of private and public sector money in biotechnology. Their biotechnology policies at a government level are strongly supportive of establishing and developing robust biotechnology research and, accordingly, have the most policy and infrastructure attributes that are either supportive or strongly supportive of biotechnology (Senker and Zwangenberg 2001).

What makes the comparison especially interesting, however, is the way in which the two countries have moved towards this position during the last decade. Britain's biotechnology sector is strongly established and has emerged out of high-quality research and strong commercial involvement in that research in and around the Cambridge area in particular. Awareness of the significance of biotechnology as a scientific area was first raised in the 1970s and 1980s by a government-commissioned report, and subsequent policy sought to increase general awareness, particularly amongst private sector companies, about its potential. Government policy has worked over recent years to extend the cluster-based activity beyond Cambridge, to other regions of the

UK. Thus, for example, policies like University Challenge (UC) and the Higher Education Innovation Fund (HEIF) have attempted to stimulate the flow of seed-corn finance to university research-based spinouts and encourage academic entrepreneurship generally and, as a corollary, biotechnology in particular.

In contrast, Germany's biotechnology sector was substantially less developed than UK or US biotechnology at the beginning of the 1990s. Although the capacity to audit trends in biotechnology did exist within the Fraunhofer Society's technology foresight programme, Delphi, research activity was limited to three Gene Research Centres at Cologne, Heidelberg and Munich. Real awareness of the importance of biotechnology as an area of research and commercial activity did not really become widespread until the latter half of the 1980s (Wörner *et al.* 2001). Historically-based mistrust of biotechnology because of its association with genetic manipulation and legal restrictions on R&D in this area contributed significantly to its relatively backward stage of development in comparison to the UK in the early 1990s (Harding 1999, 2001). With the amendment of the Genetic Engineering Act in 1993, legal barriers to biotechnology research were removed. The subsequent government-led BioRegio programme was set up in 1995 and has arguably been a central driver behind the development of a systematic and positive approach to biotechnology research and commercialization. It was supported by a strong political commitment to increasing funds for basic research in biotechnology.

The two countries provide examples of two different approaches to the development of biotechnology, then. Both countries have marked similarities according to Senker and Zwangenberg (2001). For example, both have favourable knowledge and skills regimes and strong science bases with an active emphasis on technology transfer (TT) between the research base and commercial application. Both have strong multinationals operating in the pharmaceuticals and chemicals areas. Furthermore, the public in both countries is generally positive about biopharmaceutical research and development although more wary of the application of biotechnology techniques such as genetic modification in the agro-food areas. Yet in the UK the structures are largely market led. Policy works to facilitate market operations where any gaps are apparent, for example in funding or in research and development. In Germany, biotechnology as a legitimate area of scientific investigation and of commercial enterprise has been developed to a significant extent by policy effort to create markets where none existed. This has been done through support for research network development and for biotechnology start-up finance. Much of the development in Germany is still embryonic – it has a much larger number of start-up companies established for less than three years, for example, while in the UK the biotechnology sector is more established. However, the sheer pace with which Germany has caught up in terms of biotechnology research and entrepreneurship warrants further investigation in its own right, as it arguably represents an extension of the base of the 'business system' to incorporate this type of activity and, hence, to allow its industrial structures to adapt (Casper 2000). We will turn to a closer look at the UK and German specificities and experiences in developing biotechnology as a science-driven industry after characterizing the main affected policy fields.

Biotechnology as a policy focus

There are clearly some factors associated with biotechnology that warrant public sector support. In particular, two factors have to be highlighted that mean it cannot survive alone. First, there is a general reluctance by private sector investors to invest in the early stages of bio-businesses because of the inherently risky uncertain outcomes – the 'Finance Gap'. Secondly, biotechnology is itself highly technical, inter-disciplinary and based on networks of researchers that make it hard for non-specialists to understand the business concept and, hence, to make investments. This is termed the 'Knowledge Gap'. In themselves, however, these may not justify the large policy emphasis that is being put on biotechnology research in all industrialized economies. In order to examine this, it is necessary to see biotechnology in the context of competitiveness in wider science-based industries.

Biotechnology, as an area of research and commercial activity, is derived from the public sector research base in life sciences on the one hand and the research activities of the chemical and pharmaceutical sectors on the other. Increasingly, the pharmaceutical industry is the core sector underpinning R&D in biotechnology. These pharmaceutical companies spend very high proportions of their total turnover on R&D, as this is where the competitive advantage in that sector originates. The research intensity of the sector has increased with combinatorial chemistry (inter-disciplinary chemistry) and molecular biology now working together to develop new diagnostic and drug delivery mechanisms as well as long-term gene-based solutions to diseases or, in the case of agro-environmental biotechnology, crop development.

These tools and techniques are developed in-house in large company research laboratories, but the risks associated with the research are high since the 'critical mass' in research effort discussed above applies as much to large companies as it does to small. As a result, brand new areas of biotechnology research, which are not likely to lead to new products or processes in the immediate future but which may have commercial potential in the future, are often strategically 'outsourced' to smaller research-based companies with strong links to research institutions in the public sector science base (Gambardella *et al.* 2000). It is essential that structures to support this type of activity exist to maintain the competitiveness of the pharmaceutical industry in a country.

Gambardella *et al.* (2000) point to the declining competitiveness of the European pharmaceutical sector and argue that one of the core reasons for this is the under-development of its networks and support infrastructures in the science base relative to the US. Germany and the UK are leaders in the European market, but there is still a competitive gap between them and the US, which is potentially extremely damaging to the future competitiveness of the whole sector. They point to the global mobility of researchers in this area since all belong to international networks of scientists and experts. Increasingly, they argue, local 'innovation clusters' are globally competitive with one another as locations for science-based businesses and it is here that the scale of the US science system as well as its links with the commercial base far exceeds that of Europe (Gambardella *et al.* 2000; see also Cooke 2001). Biotechnology is core to the competitive success in pharmaceuticals because of this reliance on research outsourcing and excellence in the science base. It is no one clearly defined area (Webber 1995) and, instead, appeals to three major policy areas explained in the following.

University–industry links

The first area is science policy generally and university–industry links in particular. Biotechnology requires a strong basic science research base in the life sciences if concepts or ideas with any commercial potential at all are to be developed. This means that firms tend to cluster in 'knowledge sources' (Cooke 2002). And since the research and commercial effort in biotechnology is so internationalized, these 'knowledge sources' compete and collaborate with one another nationally and globally. This 'symbiotic tension' where research and industry compete for and collaborate in research projects but are ultimately mutually interdependent in the transfer of technology from the science base through to industrial application is well documented for the German system and regarded as a source of competitive advantage for German innovators (Harding 2000, 2001). Gambardella *et al.* measure the extent and scope of networks between the public and the private sector science base for pharmaceuticals in the US and Europe and argue that the concepts of competition and collaboration in technology transfer (TT) are important in understanding competitive advantage in the pharmaceutical industry (see also Senker and Zwangenberg 2001; Cooke 2001; Kaufmann and Tödtling 2001; Love and Roper 2001). Further, the transfer of knowledge in biotechnology is tacit in nature and relies substantially on the relationships between scientists in research institutions and private sector laboratories making the spatial concentration in TT at a regional level especially significant in driving the propensity to innovate (Zeller 2001, Kaufmann and Tödtling 2001).

What policy-makers in Europe generally and in Germany and Britain in particular should be aiming to stimulate in the biotechnology sector, therefore, is the development of strong university–industry research networks in the interests of enhancing their attractiveness as locations for global R&D, either by large companies or as the home of international research-based firms. This is the source of national comparative advantage in TT. 'Symbiotic tension' is key to understanding the viability, sustainability and competitiveness of the biotechnology sector. It is this process that enhances the development of vibrant university–industry links nationally and, hence, that facilitates the location of international R&D in one country as opposed to another. It is no longer possible to regard the national and the global innovation system or network as independent of one another (Archibugi *et al.* 1999) since research is internationally mobile and will locate around specialized 'centres of excellence'. Policy has to ensure that strong university–industry networks and linkages enhance research specialization if it is to create attractive locations for global biotechnology R&D.

Regional policy

There is a substantial body of literature to suggest that, in a world where R&D is mobile internationally, competitive innovation advantage is generated at the regional rather than at the national level (Cooke *et al.* 1997; Sachsenian 1997; Harding 1999; Cantwell and Iammarino 2000). This is because technological specialization, being so critical to the symbiotic tension relationship within TT, is best developed at a regional level. Regional universities have scientific specialization and resources to support that focus, any spinout companies from university research are likely to be within the areas of scientific excellence developed within the university and large companies are more likely to locate and, hence, to transfer knowledge where such excellence exists. Learning and adaptation to changing market and technological conditions is more likely to be effective and sustainable at a regional level since tacit knowledge is transferred more easily between actors in close spatial proximity with clear links to the cumulative skills and attributes of the regional labour market (Cooke *et al.* 1997; Porter 2002). As expertise starts to build, specialist financiers, accountants and lawyers are established to support the science base and any start-up businesses are provided with appropriate and readily accessible advice and consultancy. The evolution of this type of regional 'innovation system' is said to go some way in explaining the development of Silicon Valley and Route 128 in the US (Sachsenian 1997).

The attractiveness of the 'cluster' approach (Porter 1998) to policy-makers is clear, especially for biotechnology. Since biotechnology research and commercial activity is interdependent with scientific and commercial networks, since tacit knowledge transfer is behind the symbiotic tension at the heart of competitive success in this industry and since firms cluster close to knowledge sources, it makes sense to operationalize biotechnology policy at a regional level. Universities, as identified above, are 'magnets' of biotechnology activity, but a true innovation system at a regional level is created for biotechnology through the combination of research hospitals and 'chains of transactions between scientists, entrepreneurs and various intermediaries including inventors and lawyers' (Cooke 2002). Only by systematizing this set of interactions will regionally generated knowledge add value through the cumulative learning process to create the specialization that is so important to international competitive advantage in research-led sectors such as biotechnology.

Evidence suggests that such regional 'centres of excellence' or 'clusters' and their intra-regional links (both within a country and globally) are necessary preconditions for creating attractive locations for global biotechnology R&D. Interestingly, the national, regional and sectoral systems of innovation are peculiarly interdependent for biotechnology because of its knowledge-intensive and research-led nature (Senker and Zwangenberg 2001, Gambardella *et al.* 2000, Owen-Smith *et al.* 2002; Malerba 2002; Freeman 2002). For policy-makers this is a complex message – regions are important as the point of delivery but the sources of learning and added value actually rest in the networks that individual researchers have nationally and internationally. In other words, national science policy and regional cluster policy should be mutually reinforcing and formulated to 'promote network building among firms and other actors of a regional innovation system and to interlink these intra-regional networks with national and international knowledge sources' (Koschatsky and Sternberg 2000).

Finance policy

Technology-based firms are both more suited to venture capital (VC) investment and more likely to seek VC investment. They require significant amounts of capital but, because their business is based on an innovation rather than a proven business concept, investments in them are inherently more risky. In theory, at least, this ought to be the domain of risk-takers and, hence, also the domain of VC investors. But as Table 7.2 illustrates, both Germany and the UK are behind the US in terms of VC investments, particularly in biotechnology, and this is a clear challenge for policy.

German and UK policy compared

The previous section identified three areas around which biotechnology policy is built: university–industry links (particularly support for basic research and TT), regional development ('clusters' or 'centres of excellence') and finance. None of these areas are mutually exclusive, however, and, given the multi-disciplinary and networked nature of biotechnology itself, it would not be appropriate to construct a single policy towards this sector. Further, since the whole area of biotechnology is interwoven with the Public Understanding of Science (PUS) as well as with strong ethical considerations, any policies tend to cross department and legislative boundaries.

Finance policy in both countries is woven into policies towards support for TT and regional cluster development. Thus, this area of policy is not examined in its own right but instead integrated into the wider discussion and analysis (for further reference, see Harding 2000).

The legislative, regulatory and policy framework

Nowhere is the complexity of biotechnology more obvious than in the legislative and regulatory framework that underpins policy formulation and delivery. Germany and the UK each have one central department broadly responsible for the research and training agendas – the Bundesministerium für Bildung und Forschung (BMBF) and the Department of Trade and Industry (DTI) respectively. In both countries the remit of these departments is extensive and covers the guidance and advice, access to funding and general policy formulation (see Table 7.1). In addition to this, the DTI is also responsible for biotechnology legislation since the biotechnology directorate and the Office of Science and Technology sit within that department.

Germany's legislative and regulatory framework is far more embedded within a wider departmental structure than in the UK. There are 17 different departments or organizations involved with biotechnology at a national level (compared to 11 in the UK). The Environment Ministry (BMU), the Federal Ministry of Consumer Protection, Food, Agriculture and Forestry (BML) and the Federal Ministry of Health (BMG) control legislation, for example, while the BMBF is responsible for policies that enable researchers and small businesses to get guidance and advice on ethical, regulatory and research matters. The Federal Economics and Labour Ministry (BMAW) also provides funding for biotechnology, as do the state governments and the KfW/DtA (two now-merged Federal development banks with special focus on small and medium-sized enterprises – SME), while research and consultancy is provided by a plethora of establishments within the science base of the German economy including the Max-Planck Institutes (MPG), the Fraunhofer Institutes (FhG) and public and private sector research laboratories, universities and research establishments. Monitoring and ethical guidance is a clear responsibility of the Robert Koch Institute and the Central Advisory Committee for Biological Safety (ZKBS) and forms part of Germany's wider policy to ensure that technology assessment is fully integrated into any R&D activity (Harding 2001).

Departmental responsibility for biotechnology within the UK rests with the DTI, the Department of Culture, the Ministry for Agriculture, Fisheries and Food, the Department of Health (DoH), the Department for the Environment, Transport and the Regions (DETR – now the Deputy Prime Minister's office) and the Home Office. It is only the DTI that has an explicit role towards biotechnology in the form of legislation, funding or regulation; for the other departments biotechnology is integrated into wider policy frameworks. The Health and Safety Executive (HSE) and the European Standards Office play a strong role in monitoring and regulation while the General Medical Council (GMC) has a bioethics committee, which assesses the ethical implications of any biotechnology research. R&D is funded by the DTI and the DoH. By far the largest budget is with the DTI since it controls the research council budgets as well. Interestingly, charity funding for research forms an important, if small, part of the total funding for biotechnology R&D.

There are three marked differences between the German and the UK legislative and regulatory structures. First, the German framework is to a large extent embedded within its wider S&T system. This means that the responsibilities for pure (basic or blue sky) research as opposed to applied or commercial R&D are clearly delineated at the point of delivery (Harding 2001). Thus, for example, a Max Planck Institute would not be involved in the front line of commercialization research since this extends beyond its remit, although the Fraunhofer Institutes may well be. There is a strong 'blue sky' element within the dedicated 'Blaue Liste' research institutes like the Hermann von Helmholtz Gemeinschaften (HGF) and its post-1995 successor in the Eastern states, the Wissenschaftsgemeinschaft Gottfried Wilhelm Leibnitz (WPL). All these institutes are largely supported by the federal government, but a token 10 per cent of funding comes from the regions (Länder) to ensure that long-term public interest projects are fully investigated.

This regional role in the biotechnology framework is a second key difference between the UK and Germany. The role for regional-level governance and funding for research is not clearly defined in the UK, while in Germany a critical part of the remit of state governments is to formulate regional science policy based on regionally defined interests and needs.

Finally, the third key difference is in the financing of biotechnology. Again, in Germany, this is embedded within the existing institutional framework of the social market economy, meaning a clear delineation between national, regional and local responsibilities in the funding of public interest research and of commercial activity. Pure research is largely funded by the Deutsche Forschungsgemeinschaft (DFG), which had in 1999 a total research budget of DM 2,278 billion, 36 per cent of which was dedicated to life science research. Alongside this, the KfW-DtA has responsibility for facilitating loans, mezzanine and equity type finance and work with regional and local banks and VC firms to operationalize this. The UK funding system, as it is depicted in Table 7.2, is largely responsible for basic research in biotechnology and comes predominantly from the research councils, charitable trusts (around 7 per cent) or from government departments. Where research is applied and likely to lead to commercial exploitation of the science base, finance is through policy initiatives like University Challenge (UC) and has a strong private sector dimension to it.

The spread of biotechnology across so many departments and non-governmental organizations (like, for example, the GMC) is illustrative of a wide dissemination of biotechnology awareness at a policy level. It is interesting to note, however, that, although both governments do pay some attention to the importance of raising public awareness and understanding of biotechnology, the extent to which this is explicit within the above framework is limited.

There are three things that are immediately obvious from Table 7.1. The first is the sheer size of the German effort in the area of biotechnology policy in comparison with the UK. Policy has sought to raise the profile of the technology amongst scientists and businesses alike, and simultaneously has put in place a framework for informed public debate about the issues in biotechnology research. The second feature of the German system is its heavy reliance on competitions as a way of providing funding to research (basic and applied R&D, TT) as well as to network building at a local, regional and national level. Applicants for funding through these routes have to demonstrate a clear and established track-record and evidence that they are already following the strategies they propose in their bid for funding. In other words, the structures and systems for delivery have to be in place and some progress has to already have been made if a bid is to be successful. The final feature of the system is its embeddedness within the overall framework of the German science system: that is, the clear delineation between basic scientific and applied research, the integration of TT and commercialization and, as a logical extension, the capacity to build clusters relatively easily on the back of existing institutional structures that support competition and collaboration in R&D.

The UK system similarly reflects the intrinsic nature of its science system. It relies heavily on a competitive process for funding of any kind and, similarly, has sought to engage private sector money on a matched basis at all stages of research and commercialization beyond pure, or basic research. This is especially the case for any product development work as well as for cluster development. Collaboration in the system comes from specific policies to support partnership (for example the biotechnology exploitation platform) and from broader policies to support university–industry partnership. These latter policies, such as UC, HEIF and the Science Enterprise Challenge are not purely for biotechnology, however. Public understanding is facilitated through BIO-WISE (although this is technically to explain the commercial potential of biotechnology and not to widen public understanding).

Table 7.1 The biotechnology policy framework in Germany and Britain

	Germany	*UK*
Basic research	*Deutsche Forschungsgemeinschaft:* research council funding prioritizing biotechnology research. *Max-Planck Gesellschaft:* national networks of basic research institutes with research specialisms at regional level. *Blaue Liste Institutes:* regional research institutes with Länder funding. *Regional Gene Centres*. *National initiatives* include specific funding for nanotechnology, proteomics, bioinformatics, German Human Genome project & sustainable bio-production. *BioFuture*: competition to provide young scientists with resource-base to develop high-powered research and commercial careers in applied biotech research.	*Biotechnology and Biological Sciences Research Council, Medical Research Council* and the *Natural and Environmental Research Council* provide funding for basic science in universities.
Applied research	*BioFuture*: also provides support for commercialization and incentives to stay in Germany. *Fraunhofer Institutes* work with companies on applying biotechnology research.	*Biotechnology Exploitation Platform Challenge*. *DTI funding for partnership research*.
Technology transfer	*INSTI:* national network of patenting search organizations linked with technology transfer structures like AN-Institutes and Fraunhofer. *Centres of Competence*: tech transfer centres within the BioRegio structures to facilitate university–industry links. Various other programmes including *Innovation-Market, Innovations Partner & German Economy*.	*Biotechnology Exploitation Platform Challenge:* to encourage universities and businesses to work together. *University Challenge:* not specific to biotech but a seed fund for university technology spinouts.

Table 7.1 The biotechnology policy framework in Germany and Britain *continued*

	Germany	*UK*
Commercialization	*BioChance*: competitive access to development finance for established start-up biotech firms conducting high-risk R&D.	*Bioscience Unit* (DTI) champions commercial exploitation including IPR agreements, regulation and tech transfer. *Biotechnology Mentoring and Incubator Challenge Fund* to create high-quality sustainable biotech companies. *Trade Partners UK*: to encourage exports in biotechnology.
Cluster development	*BioRegio:* Competition between regions to develop clusters around biotechnology generally. *BioProfile*: Competition-based extension finance for BioRegio regions to develop focus and specialize in dedicated area of research.	*Public–private sector partnerships* to stimulate biotechnology R&D and commercialization in the regions following report by Minister for Science in 1999. *University Challenge* to stimulate science and commercial networks through universities.
Regulatory framework	Regulation falls under three categories: *national environmental policy (BMU), agricultural biotechnology* (BML) (including animal testing and research) and *health* (BMG) that govern genetic engineering. The *Robert Koch Institute and the Central Advisory Committee for Biological Safety* monitor health and safety issues and develop guidelines.	Responsibility spread across a number of different government departments and guidance notes are prepared accordingly. Advisory Committees provide health and safety and ethical advice, Department of Health has responsibility for medicine licensing.
Public understanding	*Science Live*: 'science touring truck' equipped with research facilities to allow scientists to run experiments where resources might otherwise not exist & trained personnel to raise profile and understanding of biotechnology. Web-based reference centre for bioethics. *Safety Research and Monitoring*	*BIO-WISE*: explaining the commercial potential of biotechnology to businesses. *Department of Culture* provides information courses. *Public Understanding of Science*.

Support for university–industry links

Biotechnology relies heavily on the efficiency and effectiveness of the science base to develop products with any commercial potential at all. And, similarly, the process of biotechnology development, which transfers pure science know-how into industrial application, is dependent upon collaborative and communication channels with business. So, if government is to be successful in promoting the industry, it has both to ensure the adequate funding of the science base and, critically, develop support structures to facilitate the effective transfer of knowledge from basic scientific research into product development.

The first thing to examine, then, is the overall level of science funding in Germany and the UK in order to understand the scale of differences between the two countries. Funding for the science base as a percentage of GDP is given in Table 7.2. For comparative purposes, the US is included in the next two tables.

Germany spends more as a percentage of GDP than the UK, although does not spend as much as the US. However, Germany has a much larger GDP than the UK and this translates into a higher level of overall expenditure on Science, Engineering and Technology (SET). For example, the UK SET budget expanded by 7.5 per cent to £6,734 million between 1999 and 2000, but Germany still spends more than twice the UK amount in real terms on its science base and expanded its funding by 14 per cent over the same period. This is shown in Table 7.3 indicating government budget allocations for R&D (GBAORD) in current $US prices for comparative purposes.

Another point is worthy of note here: German reliance on the private and governmental sectors for funding of R&D in comparison to the UK. This is illustrated in Table 7.4, which shows the sources and modes of funding in the two countries.

Germany's funding for R&D is largely from government or business. The UK in contrast has a lower level of private expenditure on R&D

Table 7.2 Overall levels of science spending in Germany and the UK (per cent of GDP)

	1993	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*
Germany	2.42	2.32	2.31	2.3	2.31	2.32	2.44	2.46
UK	2.15	2.11	2.02	1.95	1.87	1.83	1.87	-
US	2.62	2.52	2.61	2.66	2.7	2.77	2.64	-

Source: OECD (2001).

Table 7.3 Total government budget allocations to R&D (million current PPP $)

	1994	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*
Germany	14,952.4	15,696.9	15,879.4	15,595.7	15,625.0	15,991.5	16,224.6
UK	8,058.4	8,628.1	8,942.7	9,055.7	8,603.7	8,879.6	-
US	68,331.0	68,791.0	69,049.0	71,653.0	73,569.0	76,886.0	75,415.0

Source: OECD (2001).

Table 7.4 Overview of different sources and modes of funding for R&D in selected countries, 1999

	Aus	*Can*	*Fin*	*Fra*	*Ger*	*J*	*Sw*	*UK*	*US*
R&D performer									
Business enterprise	45.1	59.8	71.1	63.1	*70.0*	70.7	75.1	*67.8*	75.7
Government	23.4	12.0	11.1	17.9	*13.7*	9.9	3.4	*10.7*	7.2
Higher education	29.4	26.9	17.8	17.6	*16.3*	14.8	21.4	*20.0*	14.1
Private non-profit	2.1	1.2	0.7	1.5	*0.7*	4.6	0.1	*1.4*	2.9
Source of funding									
Business enterprise	39.7	44.7	66.9	53.5	*65.1*	72.2	67.8	*49.4*	66.8
Government	47.8	31.2	29.2	37.3	*32.3*	19.5	24.5	*27.9*	29.2
Abroad	2.5	16.7	3.0	7.4	*2.3*	0.4	3.5	*17.6*	-
Other national sources	4.7	7.4	0.9	1.8	*0.3*	7.9	4.2	*5.1*	4.0

Source: OECD and national documentation.

and lower levels of public expenditure on R&D. Funding from abroad as well as funding from other UK organizations, often charities, is a sizeable proportion of total funding. This is particularly important for biotechnology since much of the 'other national sources' category is accounted for by large national medical charities such as the Wellcome Trust.

Actual expenditure on biotechnology is hard to derive on a comparative basis (see also Senker and Zwangenberg 2001). The reason for this is that, as can be seen from Tables 7.3 and 7.4, the reach of biotechnology research and application extends far beyond one government department and is interwoven with the structure of the science system itself. However, the German government claimed to spend something in the region of £750m on biotechnology in 2001 across all government departments. In the UK the three research councils with the most explicit remit for funding biotechnology are the Biotechnology and Biological Sciences Research Council, the Natural and Environmental Research Council and the Medical Research Council. Their combined budget is £567.1m, although this is a general budget allocation and not for biotechnology specifically. Since it is so difficult to establish exactly how much is being put into biotechnology in the two countries, and since much of the effectiveness of biotechnology as a vehicle for commercial application and, hence, innovation-led growth, rests in the relationship between universities and industry, it makes sense to dwell on this area a little longer. This is broadly 'technology transfer' although the relationships between universities and industry at local or regional level are core to specialist cluster development too. Table 7.5 examines policy priorities in Germany and the UK in this area. There are a number of points that can be drawn out from this table.

1. In Germany, funding for teaching and research in higher education establishments comes from regional and national level governments. Thus teaching, for example, is broadly funded by regional governments beyond a token 'core' funding from the national

Table 7.5 University–industry policy priorities in Germany and the UK

	Germany	*UK*
Policy priority (2001/2)	Enhancing efficiency of science system; ICT, biotechnology; health research, sustainable development, physics chemistry and materials sciences, nano-technology, energy, transport and mobility, space, marine technology.	Increased infrastructure funding, research in key technologies, boost to science budget to build on university research; commercialization of public sector research.
Formulation mechanism	Federal Government, Joint Commission of Federal and Regional Government on Research Support, and Science Council. Delphi programme to advise on future scientific trends (through *Fraunhofer* but also in conjunction with MITI).	DTI, POST, OST, Chief Scientist, Foresight Programme and Foresight Fund.
Implementation mechanism	Federal and regional funding initiatives and programmes; foundations and institutional structure. VC Innoregio and Bioregio programmes.	Government departments, research councils, universities, research and technology organizations in private sector, Faraday Partnerships Programmes and initiatives; VC through University challenge & HEIF, R&D tax credits.

Source: Modified from Harding 2001.

government. However, research is funded by both the regional and the national governments (through the DFG and Blaue Liste Institutes in the case of national interest research). This means that regional governments can set research funding priorities to reflect regional economic priorities and that cluster development policies can build on this to develop sectoral specialisms and networks.
2. The UK government has prioritized funding for the science base generally and for biotechnology in particular and there are more resources available for research in this area. The commercialization strategies are reliant on the engagement of private sector businesses through 'matched funding'.
3. Both countries have mechanisms for anticipating technological changes and formulating policies and strategies accordingly. In Germany the mechanism for evaluating biotechnology developments through the Delphi programme is based in the Fraunhofer Society. The UK's Foresight Programme is run through the Office of Science and Technology and is based on committees of scientists and business people who evaluate the commercial potential of technological change as they occur.
4. At the point of implementation, the German policy mechanism reflects the institutional structure and responsibilities of the science system generally. The UK in contrast has a much more decentralized delivery system alongside a centralized funding system and is reliant on private sector partner involvement.

The highly contested research market in the UK makes collaboration more difficult, even in an area where it is essential to collaborate. In contrast, the strongly collaborative nature of the German science system means that collaborative science is easier; this may go some way to explaining the speed with which Germany has caught up in terms of patents.

University–industry links and academic entrepreneurship

Both governments have put a large effort into raising the profile of academic entrepreneurship as a driver for technology transfer and commercialization. Policies are similar in both countries and include strategies to stimulate incubators, science parks and VC, and, critically, to streamline intellectual property agreements so that universities, researchers and businesses can profit from research. Evaluating the effectiveness of these types of policy in any rigorous sense is extremely difficult since there is a multitude of different ways in which the relationships between academics, academic entrepreneurs and business are built.

Within the context of this research it was neither necessary nor appropriate to attempt such an evaluation. However the Global Entrepreneurship Monitor study interviews entrepreneurial experts across a number of countries of which Germany and the UK are two. This study uses an identical methodology to speak to these experts, and asks them questions around 'entrepreneurial framework conditions', including R&D transfer, education and training, culture, policy, government programmes and finance. For the purposes of this chapter, the German and the UK expert surveys have been used to draw out any general messages on university–industry links generally and biotechnology in particular. The results are shown in Table 7.6.

It becomes clear from this table that problems in the relationship between universities and business exist in both countries. Specifically:

- There is too much regulation. In Germany the experts focused specifically on patenting requirements and technology assessment regulations in biotechnology, while in the UK the regulation was seen in the broader context of labour market regulations and taxation.
- The support structures that help R&D to commercialize are seen as too expensive in both countries. This includes patent searches and access to professional business support (for example, accountancy firms and legal practices).
- The R&D transfer system does not always work as effectively as it might – there is still mistrust between industry and the science base in both countries.
- The patenting and IPR systems in both countries are viewed as unwieldy or ineffective.

There are a number of stark differences between the two, however:

- *Government programmes*: In Germany interviewees were very positive while in the UK UC was seen to have excluded non-university bio-innovators. It was also pointed out that UK policies are not focused explicitly on biotechnology and that this might restrict the potential for biotechnology exploitation.
- *Finance*: Seed and early-stage funding for biotechnology in Germany was seen as good. Respondents in the UK argued that there is still a shortfall in equity-based funding for biotechnology.

Table 7.6 Attitudes towards university–industry links in Germany and the UK

Entrepreneurial framework condition	*Germany*	*UK*
Finance	• Banks seen as not having skills to evaluate research-based business proposals. • '*Neuer Markt*' was important in getting culture of technology-based businesses going. • Access to venture capital for university projects good but this is less the case in the eastern states and there is a perception that the money is 'public' money and therefore not commercial. • Development finance for university projects is good.	• Persistent risk aversion on behalf of UK investors towards university start-ups. • Equity gap for university projects because financiers do not have the skills to evaluate, especially in biotech. • Finance is hard to come by unless it matches with a priority area.
Government policy	• Too many regulations from government. This is particularly severe for biotechnology businesses.	• Regulation, especially in areas of employment law, make growth very hard, especially for science start-ups.
Government programmes	• Programmes effective and logical. • Incubators work well to transfer technology. • Finance measures are used well. • Programmes have increased awareness of science venturing. • Regional policies excellent – especially BioRegio.	• Programmes tend to favour entrepreneurs within universities and not those from outside the university sector • Incubators work well..
Education and training	• Lack of business education in schools, especially for the life sciences. • There is a strong supply of well-qualified people. • Germans prefer not to work across scientific disciplines which is an issue for biotechnology.	• 'Anti-science ' culture in schools. • Lack of business education throughout the system. • Major skills gap in critical scientific areas.

Table 7.6 Attitudes towards university–industry links in Germany and the UK *continued*

Entrepreneurial framework condition	*Germany*	*UK*
R&D Transfer	• Patent protection is not always effective and is over-complex especially for biotechnology. • It is not easy to find the best support for patenting searches as there are so many of them. • Under-utilized potential in research base. • Entrepreneurship in universities is increasing but more is necessary.	• Universities have real problems with SME. • There is more entrepreneurship at universities but there is still too little. • University scientists have no concept of what it means to set up a business.
Commercial professional infrastructure	• There is a tight network of support agencies. • Commercial support is expensive.	• Variable quality across the company. • Duplication is an issue. • Commercial support expensive.
Physical infrastructure	• Excellent.	• Major source of competitive disadvantage.
Market openness	• When big pharmaceutical companies are involved they are strongly supportive of start-up biotech companies.	• Flexibility in labour market. • Strong support from large pharma companies.
Culture	• Scientific entrepreneurship is a popular career choice increasingly because of the intellectual freedom it gives researchers. • Negative attitude to failure. • Working hours culture is changing in Germany and this will be positive. • Public understanding of science could be improved. • Heavy reliance on government programmes	• Persistent 'anti-science' culture in the general population made worse by media coverage. • University–industry links still generally weak and not based on mutual understanding.

- *Universities*: These were seen in the UK as still having real problems in dealing with spinouts as well as with small and medium-sized businesses (SMEs) in their local communities. In Germany the attitudes were generally more positive – that universities were developing along the right lines but that there is still under-utilized potential.
- *Physical infrastructure*: This was seen by experts as 'awful' in the UK but excellent in Germany.

The regions

The UK's market-based policy contrasts with Germany's 'engineered' cluster development policy through BioRegio. BioRegio rests on an analysis by the German government in the early 1990s that concluded, first, that biotechnology was likely to be central to future economic growth (prompted by the Delphi programme) and, second, that mechanisms had to be established to facilitate a quick and effective catch-up. The best way of doing this was seen as being through the regions. Regions with established biotechnology sectors (through the Gene Centres) along with other regions with strong biological or biomedical research universities competed for funding in a competition launched in 1995. The BioRegio programme assessed proposals against four criteria:

- The networks should create a motor for biotechnology 'catch-up'.
- The proposal should stimulate biotechnology start-ups.
- The proposal should grow existing biotechnology R&D.
- VC provision should be an integral part of the cluster design.

The overall aim of the programme in 1997 was to make Germany 'number one' in Europe by the year 2000 (for further reference on BioRegio, see Dohse 2000). Seventeen projects were approved, although three were selected as 'models': Munich, Rhineland and Rhine-Neckar. These model regions received more public money and priority access to future competitions. None of the regions received more than a maximum of 50 per cent of public sector funding; however, being a model region provided greater leverage to private resources.

Dohse (2000) argues that cluster development in Germany was strongly influenced at a policy level by the literature on regional innovation systems as drivers for national technological specialism and competitiveness. Similarly, UK policy has been influenced by the literature and by policy and practice in other countries – especially the US and Germany (DTI 1999). The theory behind cluster development in the two countries is very similar. Therefore, this translates into a very similar set of critical success factors against which the policies can be assessed.

Table 7.7 looks at biotechnology clusters in four regions – two in Germany and two in the UK. Cambridge and Munich are compared as models of 'best practice' in the two countries. Alongside this, Jena and Manchester are compared as examples of regions with a strong historical research base but weaker economic and infrastructure support at the outset. The material in these tables is based on publicly available material and further research would be necessary to assess or evaluate the actual performance of these biotechnology clusters. In all regions, the biotechnology cluster strategy appears to have created jobs, attracted private capital, stimulated HEI spinouts and created research specialisms.

Combining the common critical 'success factors' for UK and Germany, a number of conditions for successful regeneration provides some initial analysis of the success of the strategies in the two countries against five criteria:

1. *Actual research and patents*: This gives an indication of the strength of the science base and its potential for production of the critical mass of research necessary for developing commercial products in the future. All four of the regions have strong research universities and specialisms with active patenting activity in core biotechnology areas. Cambridge, Manchester and Munich have attracted R&D capacity from large multinational firms, while Jena has developed its own commercial R&D strength through *Jenoptik*.
2. *Numbers of large companies*: This gives an idea of the private sector networks and investment that has been leveraged through an initial public sector investment. The market is most developed in Cambridge, although Munich also has a strong track-record in recent years for attracting private investment. Manchester and Jena have also been successful in attracting some large company investment, especially in related technological areas.
3. *Private finance raised and numbers of VC firms*: Venture capital (VC) is seen by policy-makers as a means of stimulating start-ups and science-based entrepreneurship and, although it is by itself not enough to guarantee this, evidence from the US suggests that it is a necessary if not sufficient condition. All regions have been success-

Table 7.7 Regional clusters in Germany and the UK

	Size of the biotech community	*Other regional facts and figures*			*Market areas*	
		Biotech companies	*Employment*	*Research*	*Biotech companies*	*Specialized service providers*
Munich (Bio-Regio Munich)	• Number of biotech companies grown from 36 in 1996 to 107 in 2000. • 2001: 130 biotech and pharma-companies (of which 110 are SME) • 10 international pharma-companies including Glaxo-SmithKline, AGFA, AUDI, LINOS, Rodenstock, OSRAM	• 50 VC financed biotech companies • 5 *Neuer Markt* listings • 85 start-ups	• 500 per cent growth in direct employment • 2,500 employed in biotech SME • 5,500 employees in Bio-Photonics	• 82,000 students • Ludwig-Maximilians University • Technical university • 2 teaching hospitals • 2 applied science universities • 13 non-university research centres • 3 biotech-oriented Max Planck Institutes • Society for Health and the Environment	• Microop-tometry • Materials • Optical communi-cations • Photonics	• Seed financing of biotech start-ups • Hub of Munich biotech network (includes VC fund) • 10 dedicated VC firms • 1 dedicated consulting co. • 4 knowledge transfer consultant • International business consultants • Munich Business Angel network • International investors

Table 7.7 Regional clusters in Germany and the UK *continued*

	Size of the biotech community	*Other regional facts and figures*			*Market areas*	
		Biotech companies	*Employment*	*Research*	*Biotech companies*	*Specialized service providers*
Cambridge	• 175 biotech companies • 250 specialist service providers • 30 research institutes • 20 multinationals (pharma, agro-bio and food) • 4 leading hospitals	• 1995: 5 quoted companies (£400m market cap) • 2000: 20 quoted companies (£7bn market cap) • 20 per cent of Europe's publicly traded cos. • 7 of top 15 LSE quoted biotech cos. • 25 per cent of Europe's top 50 publicly quoted cos. • £1bn in VC funds	• 10,000 employed directly related to biotech • 20,000 in life sciences • 20,000 in network membership	• 11 Nobel Prize winners • 3,500 students • 350 research groups • 6 of top US biotech cos. with operations in region • Large company research – AstraZeneca, GlaxoSmith-Kline, Dohme	• 30 per cent develop biopharma products • 28 per cent pharma services • 15 per cent diagnostics and reagent supplies • 11 per cent with agro-bio development • 12 per cent biotech instrumentation and equipment	• 40 per cent offer technical services • 9 per cent offer financial services • 5 per cent offer legal services • 15 per cent offer dedicated consulting services • 31 per cent offer other related services (e.g. biotech centre of excellence)

Table 7.7 Regional clusters in Germany and the UK *continued*

	Size of the biotech community	*Other regional facts and figures*			*Market areas*	
		Biotech companies	*Employment*	*Research*	*Biotech companies*	*Specialized service providers*
Jena	• Large firms: Jenoptik, Carl Zeiss, ABS, AGFA, H&W optical instruments, OSRAM semiconductors • 56 members of Bio-Regio Jena • 50 members of Bildverarbeitung Thüringen (training oriented) • 34 BioInstruments start-ups • Opthalmoinnovation Thüringen • 60 members of OptoNet Jena	• 31 new biotech companies since 1995 from Bio-Regio	• Bildverarbeitung Thüringen: worldwide turnover of companies – DM 80m + 850 jobs • BioInstruments: 350 jobs; 170 patent registrations; DM 98m in Jena biotech companies • Turnover of DM 1bn worldwide in OptoNet + 6,000 direct jobs created	• Friedrich-Schiller University Jena • Erfurt University • 2 FE colleges of applied science • 11 non-university research centres including Fraunhofer, Steinbeiss & 2 Max Planck Institutes • 1 government laboratory	• BioInstru-ments (platform technologies) • Optometry and opthalmics • Cellular & molecular biology • Drug targeting • Materials	• 4 venture capital firms • 4 banks • 1 consulting firm • 4 kompeten znetze – networking structures to provide mentoring and support as well as international links

Table 7.7 Regional clusters in Germany and the UK *continued*

	Size of the biotech community	*Other regional facts and figures*			*Market areas*	
		Biotech companies	*Employment*	*Research*	*Biotech companies*	*Specialized service providers*
Manchester & NorthWest *Public funding package for BioNow:* £24.5m (DTI, NWDA & ERDF) *Manchester Incubator*: £15.4m total project funding from ERDF, University of Manchester, Wellcome Trust and Hulme Regeneration Ltd	• 120 biotech & biomed companies in region • 60 dedicated biotech in region • 15 listed companies in NW • 9 funded companies in Manchester incubator • 5 companies in Manchester Science Park • 5 multinationals (AstraZeneca, Aventis, Bristol Myers Squibb, Eli Lilly, Novartis Powderjet)	• 8 biotechnology companies in total	• £25m VC funds • 75,000 sq ft incubator building (fully occupied May 2001)	• 9 'biotech related' depts in NW universities (at 5 or 5* 2001) • 8000 S&T graduates from Uni of Manchester • AstraZeneca's largest world R&D centre • NHS networks • DTI networks (MerseyBio, BioNow)	• Vaccines, immuno-therapy and gene therapy • Molecular diagnostics • Sensor technology • Speciality chemicals • Instrumentation and spectrometry • Pharma companies • Wound healing and tissue engineering	• Specialism in biomanufacture

ful in attracting large amounts of VC funds. The key difference between Germany and the UK, however, is that these funds have been leveraged by strong policy efforts through the KfW/DtA, while in the UK the government has played a minimal role.

4. *Numbers of start-ups and SME*: This gives an idea of the 'lead generation' of growth businesses in the cluster. All regions have been successful in creating spinouts and start-ups. Cambridge is the most established region and has the largest number of publicly listed biotech businesses. The other regions are still in the 'catch-up' phase and have more embryonic life science businesses (ELISCOS). Evidence on the sustainability of these tiny businesses is sparse.
5. *Jobs created*: All regions record job creation through life science and biotechnology-based businesses. Cambridge, where the cluster is arguably most developed, attributes 10,000 jobs to the biotechnology sector and Munich has a similar number.

Jena is slightly different from Manchester in that it already had a large and established life-science-based business before BioRegio and hence claims that 6,000 jobs have been created as a direct consequence of growth in biotechnology.

Concluding remarks

We can learn a lot from the analysis here. The market-based strategy in the UK and the more 'engineered' strategy in Germany cannot be compared directly in terms of their effectiveness or suitability outside their national context. Germany has a networked science system that is characterized by the 'symbiotic tension' under which firms and research institutions compete for and collaborate in research projects. The BioRegio contest and the spread of other related initiatives through the institutional system of German R&D and technology transfer has produced a rapid catch-up in biotechnology. This in itself has been impressive to watch – especially for those who judged the German system incapable of rapid change!

In contrast, the UK's more market-based system would not be effective in Germany but has merits within the context of the UK economy. Universities are used to competition in research and this ensures that the quality of research conducted remains high. There are issues around the extent to which the system can be adapted to further technology transfer, and maybe some of the reduction in the competitiveness of the UK biotechnology sector relative to Germany in the last couple of years stems from the difficulties that UK scientists and businesses have in collaboration – there is 'tension' but no 'symbiosis' between the users and the producers of science.

The issue of sustainability is key, especially for Germany where criticisms of its strongly public sector approach centre on the small size of many of the biotechnology start-ups. Where the UK's structures are more established, for example in Cambridge, the sustainability of the sector can be taken much more for granted. However we can learn three key points from the speed with which Germany has caught up. Specifically these are:

1. Regions are important as vehicles for appropriate policy formulation and delivery.
2. Substantial funding is critical.
3. Funding is key – needs a lot of money because biotech is expensive and networked.

Finally, there is scope for understanding much more about the way biotechnology works from the standpoint of a more detailed Anglo-German comparison, and further research should concentrate on addressing the following issues:

- First, policy has been a 'leap of faith' and measuring effectiveness has been hard. We need new measurements that incorporate the role of the tacit knowledge transfer and network development intrinsic to biotechnology research. In short, we need to be able to measure 'symbiotic tension' and its effect on the development of biotechnology.
- Secondly, Germany has a higher number of 'platform technologies' – i.e. equipment and supplies or drug delivery systems with clear commercial potential as opposed to the UK, which is still more research oriented. This may be because of differences in the applied research funding structure and in particular the use of equity-based finance in the early stages of biotechnology start-ups. The area of biotechnology finance warrants further investigation since it may well be that the form this takes fundamentally alters the trajectory along which biotechnology research develops.
- Finally, the management of small biotechnology firms is an interesting area for further comparative research. This has been conducted for Germany in some detail (Wörner *et al.* 2001) but there is scope for expanding this on to a much more extensive level in order to examine the impact of networks on the trajectories along which biotechnology develops.

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8

Geographical Proximity and Circulation of Knowledge through Inter-Firm Cooperation

Delphine Gallaud and André Torre

Introduction

The production of scientific and technological innovations has become essential for many firms, but the latter are seldom in possession of all the knowledge needed for this activity because of the increasing complexity of knowledge bases or because R&D departments are too small. As they do not possess internally all the skills they need, firms wishing to innovate have recourse to external sources, such as cooperation with other firms or public organizations of research. However, acquiring external knowledge is not sufficient; one must also be able to use it in a specific process of production, to transform it into organizational routines, because it is important not only to integrate this knowledge, but ideally to use it to produce new knowledge.

This process of creation, re-creation or imitation of new resources is a complex operation that not only necessitates several technical and organizational adaptations, but also requires frequent relations of cooperation and partnership. The integration of new knowledge cannot be done in one go, but progressively during the course of the innovation projects, which implies that relations must be sustained for a period of time. But the interests of the participants in this interactive process, as well as their opinions concerning technical issues, sometimes vary or diverge. This is why cooperation is also a source of tensions and conflicts that jeopardize the adaptation of knowledge produced externally, or even completely hinder the innovation process.

In this chapter, we try to provide some answers to the following question: What is the role played by geographical and organized proximities in the context of these external acquisitions of knowledge? In other words, can they help reduce the intensity of conflicts and thus facilitate the interactive process of innovations?

The structure of this chapter is as follows. First, we present the shortcomings of innovation theory and works on spillovers that claim the importance of geographical proximity for circulation of knowledge without considering the necessary organizational prerequisites for this. Having explained the relevance of permanent as well as temporary geographical proximity, we will then turn to a discussion of conflicts between cooperators within innovation processes from a theoretical as well as an empirical perspective. The empirical study is based on a case study of French biotechnology firms and will serve to prove our hypothesis that temporary geographical proximity plays an important role in preventing and resolving conflicts between innovators.

The spatial dimension of the external acquisition of competencies to innovate

Firms wishing to innovate rest on a knowledge base that they possess internally and/or must obtain from their competitors, neighbours or partners (Cohen and Levinthal 1989). Studies on districts or innovating milieus (Becattini 1990; Saxenian 1994) as well as recent developments in the innovation theory refer to the spatial dimension in the relations of acquisition of external knowledge, whether they are inter-firm relations or relations with research laboratories. They postulate the beneficial effects of geographical proximity, which would seem to be due in particular to the possibilities offered by face-to-face (F2F) relations between local actors, relations which facilitate the transmission of knowledge, in particular of tacit knowledge (Lundvall 1992).

In light of recent research and applied studies carried out on the matter (Vedello 1997; Dahl and Pedersen 2003), this thesis needs to be seriously re-evaluated. In the following paragraphs we show the limits of the analyses in terms of localized knowledge spillovers, before presenting recent breakthroughs in the field of economics of proximity, in particular concerning the possibility of moments of temporary proximity during the interactive process of innovation. We end this section with a conclusion on the importance of relations of proximity in the process of external acquisitions of technology.

Localized knowledge spillovers and their limits

One of the characteristics of innovation is to produce externalities. Due to the peculiar nature of this activity that is sometimes compared to the production of a (semi) public good, the results cannot be totally appropriated by the innovator, as part of the knowledge is diffused into the economy without the innovator being able to prevent it, or even being aware of it. When innovation (or R&D) is likened to information, there is a leakage of results that concerns the overall economy, but the approach in terms of knowledge leads one to analyze the possibility of diffusing this knowledge, as well as the geographical area it covers. From an empirical point of view, the fact that there is a high concentration of innovative activities contradicts the hypothesis of a complete diffusion of R&D results, which would allow activities to be equally distributed throughout the territory. The polarization of innovative activities, which is even greater than the production activities (Audretsch and Feldman 1996), is then often accounted for by the characteristics of the externalities that are assumed to have a limited geographical extension. Autant-Bernard and Massard (1999) have compiled four types of studies dedicated to calculating the externalities of knowledge (or spillovers) and their spatial area, respectively based on:

- the use of patents as markers of externalities (Jaffé *et al.* 1993),
- the geographical concentration of innovations (Feldman 1994; Audretsch and Feldman 1996),
- the geographical coincidence (Jaffé 1986; Anselin *et al.* 1997), and
- local interaction (Anselin *et al.* 1997; Wallsten 2001),
- to which one may add (Feldman 1999) knowledge incorporated in capital or investment goods.

All these works come to the conclusion that externalities exist and that their geographical extension is limited. This explains the concentration of firms in certain areas and supports the idea of geographical proximity being an important factor in the diffusion of knowledge.

However, the measurement of geographical extension of localized knowledge spillovers is still debated. Some of the above-quoted studies do not really propose an estimation of spatial externalities: the authors use a predefined geographical area, which presupposes, but does not prove, the existence of externalities. Thus, the first three methods (patents, concentration, coincidence) do not offer a true measurement of externalities (no calculation of the elasticity of R&D expenditure in relation to the innovation capacity of the company of reference) and even less of the distance they are supposed to cover. Assuming that externalities exist, they model their effects and, in actual fact, measure agglomeration phenomena. These methods generally postulate the role of local dimensions by using predefined geographical areas: states (Jaffé 1989; Feldman 1994), metropolitan areas (Jaffé *et al*. 1993) and counties (Anselin *et al*. 1997 in their first evaluation). Notions of distance, when they are introduced into the gravity and coverage indicators used by these authors, are predefined. For instance, according to Anselin *et al*. (second measurement), R&D may have been carried out within a radius of 50 or 75 miles around the county of reference.

More recent studies are making use of *Geographical Information Systems* (GIS) in order to model the range of technology spillovers and provide an indication for measuring distance. Thus, Wallsten (2001) makes use of GIS to analyze the probability for a firm whose neighbours received government support for innovation, of also benefiting from such assistance. It locates firms without using a predefined geographical zone and shows that firms receiving financial support are situated close to each other, in a radius of one-tenth of a mile, often on the periphery of urban areas. Even if these are strategic externalities linked to information rather than R&D, and even though participating in a government programme is liable to introduce a different angle, one sees nevertheless that the distance retained, if it is not predefined, still varies noticeably from one author to another (from 50 miles to one-tenth of a mile), which allows extrapolation. Finally, it was not until the publication of Orlando's work (2000) that distances and research externalities could be simultaneously calculated thanks to these methods.

Geographical proximity and organized proximity

Literature on the economy of proximity generally refers to two types of proximity (Gilly and Torre 1999; Kirat and Lung 1999; Rallet and Torre 2000):

- *Organized proximity* lies on two types of logic, *a logic of similitude and a logic of belonging*. According to the logic of belonging, actors are close when they belong to the same space of relations (firm, network…), i.e. actors between whom interactions of different natures take place. According to the logic of similitude, actors are close when they are alike, i.e. when they possess the same space of reference and share the same knowledge, so that the institutional dimension is also important.

- *Geographical proximity* refers to a great extent to the location of firms, and integrates the social dimension of economic mechanisms, or what is sometimes called *functional distance*. In other words, the reference to natural and physical constraints is an important aspect of geographical proximity, but other aspects are equally important in its definition: the aspect of social structures such as transport infrastructures that facilitate accessibility, or the financial mechanisms that allow the use of certain communication technologies.

It is necessary to take this definition of geographical proximity further by distinguishing *permanent* geographical proximity, which corresponds to the co-localization of firms, from *temporary* geographical proximity, which lies on momentary F2F interactions enabling actors to meet without necessarily requiring co-localization.

This type of proximity is related to a phenomenon that is currently spreading: the increasing mobility of individuals, information and goods. Indeed the professional mobility of individuals has increased with the development of transports (improved accessibility, increase of speed, reduction of costs) and the technological revolution in telecommunications (improved forms of long-distance processing and transfer of information in comparison with the telephone era, low costs of information transfer). The complementarities of transports and communication (the more individuals telecommute, the more they need to meet others, and vice versa) increase this mobility, so that an increasing number of actors no longer have a permanent workplace. But there is a wider mobility, which crosses territories: the travelling of a sales representative, the visits of a consultant auditing a firm for several days, the participation of a researcher in a national or international congress, the temporary visit of an engineer to the laboratory of a firm or university with which his/her firm cooperates. Thanks to this developing mobility, the constraint of geographical proximity can be fulfilled temporarily through travelling without the interaction leading to the permanent co-localization of the partners.

The need for geographical proximity is generally not permanent. It affects certain phases of the interaction: the phase of negotiation in a transaction, the definition of the organizational framework and guidelines of cooperation, the realization of its initial phase in the case of a technological alliance, the necessity to share equipment in the experimental phase of a common research project or to exchange knowledge and above all to know personally the researchers (colloquium) belonging to a scientific community, etc. Short or medium-term visits are then sufficient for the partners to exchange – during F2F meetings – the information needed for cooperation. As a result, permanent co-localization is not necessary even for activities where physical interaction plays an important role in the coordination (services co-produced by the provider and the user, knowledge-intensive activities such as innovation and R&D activities). This is what we call the need for temporary geographical proximity.

Indeed, the possibility of moments of temporary proximity puts into question one of the most widespread theses in the regional analysis, according to which firms have a strong tendency to settle near one another because of frequent and repetitive interactions requiring F2F relations. This idea can be found in particular in the research carried out in the field of innovation geography (Feldman 1999). According to some authors, firms need geographical proximity to exchange knowledge concerning their production, commercialization, and above all R&D activities. The thesis is based on the tacit nature of part of the knowledge, the transmission of which requires F2F relations (learning by imitation, informal exchanges, intuitive solutions to problems, etc.), whereas codified knowledge is transmitted more easily through ICT or physical supports (articles, books, instruction manuals, etc.), which are independent from the individuals or organizations that produced them.

This thesis must be qualified (Rallet and Torre 2000). The equation of the sharing of tacit knowledge and geographical proximity on the one hand, and codified knowledge and long-distance relations on the other, is indeed simplistic. Firstly, it is difficult to separate the uses of both types of knowledge and therefore to translate them with different geographical terms. Secondly, F2F relations, and therefore geographical proximity, are not the only possible supports for the sharing of tacit knowledge (Freel 2002). Thanks to the collective rules and representations that they produce, organizations offer powerful mechanisms of long-distance coordination (or organized proximity). Thirdly, ICT also make the long-distance sharing or co-producing of tacit knowledge possible thanks to the technological evolution of computer sciences, which offer possibilities such as informal or visual communication (association of the image, written support and voice) or written communication that has become close to oral communication (e-mails, forums, chats, etc.). There is no denying that F2F relations remain indispensable for certain types of interactions (Dahl and Pedersen 2003), in particular to solve problems related to the heterogeneity of reasoning modes or those related to the processes of deliberation and negotiation. However, the intensity of the need for F2F relations varies according to the phase of the process (Gallaud and Torre 2003).

External acquisitions of technology and their spatial dimension

External acquisitions of knowledge have for a long time been considered as essential for a firm's production of innovation, whether the knowledge is acquired through firm-to-firm relations or relations of an academic nature (Lundvall 1992). A firm wishing to acquire external knowledge can get information made public through conferences, trade fairs, publications, symposia, exhibitions, etc., but most knowledge it wishes to acquire is private (or semi public) and can only be acquired from other firms or organizations. These acquisitions range from commercial transactions (the markets of technology) to research cooperation. The latter can be more or less formalized, whether it concerns relations with public research organizations (contracts between universities and industries) or with other enterprises (vertical cooperation, which corresponds to relations with clients or suppliers, and horizontal cooperation with the competitors, the complementary firms belonging to the same sector or other types of enterprises). In cases where knowledge is public, geographical proximity has no impact because knowledge can be acquired wherever the innovating firm is located in relation to the productive source of knowledge. Things are different when the information is not divulged: it can be beneficial for the firm that seeks to acquire it to be located in the proximity of the productive organization.

The need for geographical proximity varies according to the type of cooperation undertaken by a firm. The latter depends mainly on the difference between the knowledge bases of the organizations that cooperate. The bigger the difference between knowledge bases the more necessary are interactions of proximity: interactions implying temporary meetings and/or a localization of proximity.

Generally, for most cooperation projects, interactions are frequent during the phase dedicated to the search for partners and the cooperation contract negotiations. Repeated interactions allow the mutual evaluation of the initial competencies and resources as well as those, which will have to be produced during the cooperation. Later in the frequency of interactions, proximity might drop for two reasons: (i) the organizations know each other better and can therefore exchange through communication technologies, (ii) the closer one gets to the production process, the more information organizations possess internally, which limits the need for exchanges.

The relations between external acquisitions of knowledge and forms of proximity can be systematically classified according to the following five channels generally found in the literature.

(a) Informal interactions

Considered as being the basis of the daily functioning of districts and milieus (Becattini 1990; Camagni 1991), informal interactions, above all, enable local actors to exchange general information and tacit knowledge, mainly through former work colleagues or fellow students (Dahl and Pedersen 2003). Because this type of knowledge transmission is not easily carried out when the actors are geographically distant, co-localization or permanent geographical proximity plays an important role in this case. As for organizing occasional meetings between geographically distant actors, this option would precisely be outside the informal nature of the type of interactions discussed here.

(b) Patents and licences

This highly codified type of knowledge transmission does not generally imply any relation of geographical or even organized proximity, with the exception of licences of know-how which imply the obligation for the firm granting the licence to commission the installation on the site of the client firm or to train its staff. Thus Tyres and von Hippel (1997) have studied the purchase by firms of new machines, the installation of which necessitates on average three trips by the engineers of the innovating firm. The geographical proximity mobilized here, of a temporary nature, also proves relatively limited in time.

(c) Industry–university cooperation (Carayol 2003) concerning research operations

Informal interactions of cooperation, often used as support to development, must be distinguished from formal interactions. As shown above, geographical proximity is important in the case of informal relations. Indeed the co-localization of organizations facilitates exchanges of information concerning the techniques and competencies available (know-who). In its permanent form, it also plays an important role in situations where a firm makes use of university buildings and when material and equipment are used in common by the university and the firm.

In the case of projects of formal cooperation, interactions occur during the stage of (fundamental or applied) research. The need for geographical proximity is then only temporary, as these interactions occur less frequently than informal interactions. However, the bigger the difference between the knowledge bases of the organizations the more frequent and necessary interactions of proximity will be.

(d) Formal interaction in the form of vertical cooperation

Cooperation within a supply chain helps to define the characteristics of the innovations and therefore reduce the risk associated with the introduction of new products or processes of production on the market (Tether 2002). Cooperation with clients, which concerns above all the stages of applied R&D, makes it possible to reinforce the adequacy between product and demand (Lundvall 1992). Defined as the lead user, a client will help – as early as the design stage – an innovating firm to adapt its innovation to the needs of the market. Interactions of proximity play an essential role in this case: interactions are frequent during the stage of research but their frequency progressively drops during the different stages of development. Cooperation with suppliers can be of two types. It is important to distinguish the suppliers who participate in the production of the innovation from those who only intervene at the industrial stage (at the time of mass production):

- Suppliers who belong to the first category will have to adapt their products to the demand of the innovating firm. Interactions of proximity will therefore take place at all stages of the process, according to the modifications of the innovation project. In this case only temporary geographical proximity is necessary for the good progress of these operations.
- The suppliers of the second category only need to modify their products once the R&D process is over. The interactions – less frequent than in the previous case – occur at the stage of mass production. Here again, only moments of temporary proximity are necessary.

(e) Formal interactions in the form of horizontal cooperation

Three cases must be distinguished:

- 'Classic' horizontal cooperation, i.e. with firms belonging to other sectors of production, generally concerns specific moments of the research project. Permanent or temporary, geographical proximity is used to solve development problems.
- Cooperation with competitors is regulated in order to avoid the collusion of products on the market and the formation of oligopolies.

This is why cooperation is often limited to the research stage. However, firms try to limit the leakage of their know-how in these exchanges. Indeed, Dahl and Pedersen (2003) show that in some clusters the work contracts of engineers contain a clause of non-disclosure of the information related to R&D projects to engineers of rival firms, which limits informal interactions. Firms are in this case confronted by a contradiction: they can choose co-localization in the hope of benefiting from their neighbours' knowledge while trying to limit the leakage of information concerning their own productions. This illustrates quite well the ambiguous nature of permanent geographical proximity. It is simpler to set up occasional meetings in the context of cooperation contracts during the stages of research, meetings that both limit the risks and opportunities of obtaining external knowledge.

- Cooperation with firms of the same sector with complementary activities also occurs during the stage of research but can go as far as setting up of prototypes. Because the division of labour is high, interactions of proximity occur less frequently than in the case of academic cooperation, firms trying to limit interactions to the stage when the 'modules' of the innovation are assembled.

Thus, the need for geographical proximity remains relatively important in the processes of external acquisitions of knowledge, even though temporary geographical proximity is generally needed more than permanent proximity, and therefore the co-localization of activities of innovation seldom seems essential. This result contrasts with theses of innovation theories, which tend to overestimate the role of geographical proximity and to advocate the co-localization of firms or research laboratories. Contrary to these predictions, external acquisitions do not generally occur in the context of permanent geographical proximity but of temporary proximity, and mainly between distant organizations, which are not situated in the same geographical area. The division of labour enables innovators to individually carry out the stage of production for which they possess the most competencies and to limit interactions with other parties to the stage of assembling of the innovation. However, the density of interactions strongly depends on the respective competencies of the firms engaged in the innovation process, while all innovations do not require the same density of proximity interactions nor their concentration at the same moment of the process.

The introduction of the conflict dimension

Innovation theories and the works on spillovers claim that permanent geographical proximity has beneficial effects on the development of innovation at the local level, because it allows a high and regular frequency of interactions. But this idea is currently disputed. The first reason for this refers, as mentioned above, to the important role of temporary geographical proximity in the process of innovation. Secondly, it has also to be considered that permanent geographical proximity produces negative effects seldom discussed in literature. In particular it is the source of conflicts of access to scarce resources (increase of the prices of plots, access to qualified labour) and conflicts of interests between co-localized actors (Saxenian 1994).

However, conflicts occurring during the interactive process of production of innovation do not only concern the disadvantages of geographical proximity. They are more related to the tensions that emerge between actors, as technical differences, interpersonal disagreements, issues of power, property rights, etc. We shall see below, based on the example of French biotechnology firms, that geographical proximity plays a complex role in attempts to solve conflicts. Permanent proximity enables neighbouring actors to meet and have informal relations. Temporary proximity has an important role in the prevention and resolution of conflicts emerging during the process of production of innovations, whether they are conflicts related to the organization of labour, to technical characteristics of the innovation, or to property rights.

Economic analyses of conflicts

Economic analysis has dedicated little time to the study of conflict relations because this notion poses methodological problems, which often prove in contradiction with the core of theoretical elaborations. The field of analysis is generally confined to conflicts of interests or conflicts related to the distribution of wealth between actors, which excludes conflicts of passion (which are a matter for psychology) as well as the relations of power (reserved to political sciences). Thus the classics have privileged the conflicts related to the distribution of wealth, thinking that strong inequalities led to recurring revolts (and therefore to open conflicts), while the neo-classics have focused more on the problems of conflicts of interests, proposing to solve them by designing instruments that would enable actors to represent the gains of exchange. Later on, *Game Theory* considered conflicts as a central object of analysis, its research focusing on the determination of possible solutions and resolutions depending on whether they are cooperative or non-cooperative games (Schmidt 2001). However, in these works, conflicts never reach the stage of commitment behaviour (verbal or physical aggression) and do not even lead – in the non-cooperative approaches – to any communication between the actors who agree on the set of solutions, represented by artifacts such as the matrix of gains. Even credible threats do not go beyond 'polite declarations' calling for 'rational' reactions from the opponent, and never degenerate into acts of violence.

Most heterodox approaches adhere to this idea of relations without serious conflicts (i.e. not leading to acts of violence) and try above all to highlight the mechanisms of conflict prevention, just like the School of Regulation, which emphasizes the notion of compromise enabling the different institutional forms to build up a system (for instance the Fordist compromise). The evolutionist approach prefers to analyze routines – defined as control mechanisms that are sufficient to prevent conflicts, and resulting from an organizational truce between managers and employees (Nelson and Winter 1982) – rather than explain how the conflict is resolved. It does not deny that intra-organizational conflicts do exist – 'it is not however of our intention to ignore the divergence of interests between organization members' (ibid, p. 107) – and that actors can resist from automatically carrying out the task prescribed by the firm. On the contrary, it emphasizes that employees work in the framework of 'de facto contracts', which imply a certain propensity to not carry out tasks being controlled by the managing staff. In itself this routine activity dissuades actors from pursuing their personal interests and keeps conflicts within limits that are bearable for firms.

Thus, the economic management of conflicts concentrates generally on the search for mechanisms of conflict prevention and resolution and neglects the relations of power between actors as well as the conflicts concerning access to scarce resources. Only the *Marxist Theory* has considered conflicts as the driving force behind economic and social change, with the class struggle being a form of open and violent conflict between members of different social groups, aiming to modify the distribution of wealth. The main difficulty currently consists in producing a theory of conflict that would make it possible to take into account the heterogeneity of actors and the fact that the latter interact in order to find solutions to conflicts.

Cyert and March (1963) were among the first authors to reintroduce the notion of conflict in the analysis of the firm, by studying conflicts between shareholders and managers, i.e. between the owners of the firm and those who exercise their decision-making powers daily and whose strategies are liable to affect the distribution of the value added. Other works on management then focused on taking into account intra-organizational conflicts and something close to the common definition: interpersonal disagreements.

A conflict is defined as a process in which one of the parties feels that its interests are opposed or negatively affected by the action of another party (Wall and Callister 1995), a process which goes on in time and can lead to the escalation or the reduction of tensions. But authors diverge on the identification of the very objects of a conflict, whether they are goals, values, access to resources (Putnam and Poole 1987), needs, interests (Donohue and Kolt 1992), or aspirations (Pruitt and Rubin 1986). The causes of conflict found in literature also vary and include individual characteristics of the different parties, difficulties or type of communication, power-seeking behaviour (Ferguson and Cooper 1987; Blalock 1989), self-fulfilling prophecies concerning the reaction of other actors in relations to one's own objectives, structure of organizations, or earlier interactions, as a previous conflict is likely to reoccur, especially if it has left one party unsatisfied (Tjosvold and Chia 1989).

Nowadays, the temptation to limit conflicts is being replaced by attempts at valorization (in particular in the case of innovation projects) in order to increase the performance of the participants. Three main modes of conflict resolution have been observed (Wall and Callister 1995): (i) in some cases solutions are found by the actors themselves – possibly because the conflict has become too expensive – with solutions ranging from compromise to the imposition of a point of view by one of the parties, including assertion through force; (ii) in other situations the hierarchy imposes a solution; (iii) in others a third party intervenes (mediation or arbitration): some parties may hope that their gains will be higher if they use arbitration rather than compromise with other parties. Finally, the managers might decide to wait for the conflict to solve itself. This is the so-called solution of avoidance (Gobeli *et al.* 1998). Innovation situations, in particular when there is constructive interaction, facilitate the emergence of conflicts, the participants in a project often having partially divergent interests or objectives that generate tensions during the process of innovation.

Conflicts in the process of acquiring knowledge and types of proximity

One of the central limits of economic theory is that it ignores the conflicts related to the process of production (and even more of innovation). But these conflicts sometimes cause the failure of innovation projects, in particular when they are carried out in cooperation. Oppositions concerning property rights for example are an important cause of failure of technical cooperation. The mobilization of geographical and organizational proximities is an asset in the resolution of these conflicts.

When organizations exchanging knowledge are localized in the same area, interactions can be repeated. But when they are not, interactions are less frequent because of costs related to travelling, which can be divided into transport costs and the time necessary to meet the other innovators. This is why the participants to a project will then try and limit the moments of geographical proximity, by attempting to rationalize the need for temporary geographical proximity, making F2F interactions only possible when they are necessary. Indeed, it is important to make the distinction between:

- *firms entering a sector (start-ups*), who must simultaneously decide where to locate themselves and possibly choose cooperation partners. They might find it in their interest to locate in the proximity of other firms or organizations in order to take advantage of a pool of qualified labour or knowledge externalities within a single region. This case is limited – with the annual entry rate into branches being low – and also refers to the setting up of new production or R&D units.
- *firms, already localized,* wanting to cooperate with other organizations in order to innovate. These firms will not decide to relocate in the proximity of organizations with which they wish to cooperate due to the cost of such an operation. This is the reason why surveys such as CIS (Community Innovation Survey) (Freel 2002) find an important part of the relations of cooperation occurring between firms belonging to different regions or even different countries. The creation of a joint venture, consisting in building a new laboratory in a location approved by all participants, is not the most used solution because it is also deemed too expensive.

For these reasons, the process of innovation in the case of external acquisition of knowledge often proves different from what is predicted by Innovation Theory presenting the density of interactions and their regularity during the process as factors to explain performance of innovation projects. Indeed studies show that participants in a project of innovation tend to meet only once a term, and the frequency of these meetings is generally stipulated in contracts (Gallaud 2003). The division of labour between innovating firms remains high, i.e. each firm carries out the tasks for which it has the most competencies and the innovators meet essentially in order to assemble the different modules and/or to manage conflicts. Thus permanent geographical proximity is not necessarily beneficial to firms when it is associated with the idea of co-localization. Furthermore, a firm deprives itself of its competencies, sometimes for long periods of time, when it sends staff away. Temporary geographical proximity makes it possible to avoid this expensive solution when firms have the capacities to develop an innovation in common although they are not co-localized. They develop the project by only moving some staff, mostly in the context of a formal cooperation like a contract.

The analysis of benefits of (temporary or permanent) geographical proximity in the case of conflicts can be listed according to the modes of resolution of conflicts emerging during the development of innovation projects. They are first of all (Dyer and Song 1995; Gobeli *et al.* 1998):

- *avoidance*, in which the project manager waits for the conflict to solve itself, at the risk of causing the project to fail, leading to separation. If innovators do not recognize the conflicts, they will not travel to resolve it.
- *the imposed solution*, associated with a relatively low geographical proximity. It is not necessary for all the participants to the project to meet when this solution is chosen.

Two cooperative solutions necessitate geographical proximity more because they require the participants meeting in order to negotiate a compromise:

- *the 'give and take' solution*, whereby the hierarchy proposes a solution that is acceptable for all participants concerned. It differs from mediation – which refers to disagreements between an institution and a user more than to firms – in that one of the parties (the hierarchy) is both judge and party and proposes concessions elaborated with the workers. Co-localization facilitates the finding and acceptance of this type of solution.

- *the concerted solution*, in which all participants meet and find, together, a mode of resolution specific to their problems. The advantages of permanent geographical proximity are obvious here, as it enables the parties involved to hold repeated deliberations and negotiations and facilitates the quick mobilization of actors after latency periods. We shall see below that temporary geographical proximity also has merits.

But geographical proximity alone is not sufficient to solve conflicts: it is always associated with organized proximity. The relative failure of Japanese transplants into Silicon Valley shows that interactions are not generated by co-localization alone, but that institutional mechanisms are necessary (integrating a network by being introduced by an actor who already belongs to it). In other words, geographical proximity must be activated by organized proximity (Filippi and Torre 2003). The studies carried out on 'epistemic' communities (Steinmueller 2000) also reveal the importance of standards, rules and a common culture, which enables actors to interact. These factors correspond to what we understand by organized proximity, defined by a certain degree of similarity between actors (as discussed earlier in this chapter).

While standard theories highlight the mechanisms of conflict resolution by making the hypothesis that actors agree on the set of solutions, the treatment of conflicts in innovation projects consists for the actors in building a common space, which contains the (temporary or definitive) solution to the conflict as well as the common rules, which will enable them to debate and possibly reach a compromise. The practical cases of innovation projects show that the innovators solve conflicts of representation when they have built a common language (Latour 1989; D'Adderio 2001), or forms of organized proximity, i.e. when they are sufficiently similar to understand a problem in the same terms. From our point of view the role of organized proximity varies according to the forms of conflict resolution chosen: it is nil when the solution of avoidance is used, low when the solution is imposed, and it increases significantly when the 'give and take' and concerted solutions are mobilized. Temporary geographical proximity and organized proximity are then complementary and enable the actors to find processes of negotiation and compromise.

Conflicts and proximity in the biotechnology sector

Far from being a homogeneous and coherent sector (Porter 1990), biotechnology can be defined as the set of techniques and knowledge related to the use of living organisms in processes of industrial production (Ducos and Joly 1988). Biotechnology is essentially used in chemistry, agro-chemistry, pharmaceutical and agro-food industries, and very occasionally leads to a few applications related to the environment or the control of pollution. In France, a production chain made of firms which are specialized in these activities or complementary activities, is emerging: manufacturing of specific instruments and equipment, technical consulting and expertise, and specific modes of financing (Lhuillery 2002).

Biotechnology is characterized, generally and more specifically in France, by cooperation between distant firms, to such an extent that firms being co-localized in science parks do not appear to cooperate locally very much. Distance does not seem to penalize these firms and does not stop them from developing their projects. But this does not mean that geographical proximity plays no role in their functioning. Indeed, although co-localization is not sought for, the benefits of geographical proximity are mobilized, but in a temporary manner, through occasional meetings between the participants of the projects. Thus, most contracts of cooperation concerning innovation activities make provision for at least one meeting per term in order to examine the progression of the project. One of the objectives of these meetings is to defuse, reduce or attempt to find solutions to conflicts that may emerge during the process of innovation.

Conflicts in biotechnology are related to property rights, to the technical content of the cooperation (disagreements concerning the objectives and/or the technical characteristics of the projects), to the organization of labour or to interpersonal disagreements. Problems related to property rights are likely to increase in the coming years because approximately 50 per cent of the patents covering the main medicines will have become public by the year 2005 (Depret and Hamdouch 2001), which is going to increase the competition between firms and probably the cooperation between big laboratories and start-ups of biotechnology. Problems concerning conflicts of representation are important because cooperation takes place between different organizations, for example firms and universities. Interpersonal disagreements influence the performance of innovation projects (Souder 1987), even if arrangements are often possible. Thus, in cooperation with public organizations or universities, innovators emphasize the fact that they knew the researchers with whom they now cooperate before the cooperation project was launched. Interpersonal networks serve in these cases to reduce conflicts (Depret and Hamdouch 2000).

In the following, we refer to a questionnaire survey of 60 biotech SME (Gallaud 2003), where people in charge of innovation projects have been interviewed. The innovation projects had to have been carried out in cooperation with other firms and/or public organizations of research. The content of the cooperation covered all forms of technical cooperation with the exception of purchases of patents and licences. The geographic area covered by the survey included the regions of Alsace, Auvergne, Brittany, Ile de France, Rhône Alpes and Midi Pyrénées. Firms localized in science parks as well as outside any specific group were included. The main activities of the firms surveyed are related to agriculture and the agro-food industry. The objective of the interviews was to look for the role played by relations of proximity in the modalities of anticipation and resolution of conflicts emerging during processes of interaction for the external acquisition of knowledge. One of the main questions referred to different types of conflicts experienced and whether they had been solved through geographical proximity (with at least one trip of the innovators) or only by using different channels of telecommunication. The central hypothesis was that the different types of conflicts led the firms to mobilize temporary proximity with different intensities.

The results show that the types of conflicts during innovation projects in biotechnology were related to:

- *property rights of the innovation and gains drawn from future innovation*. These conflicts occur more often in cases of cooperation than for any other form of acquisition because the knowledge does not yet exist when the contracts are signed (incomplete due to the uncertainty of the innovation process: see Chapter 6 by Blum and Müller). They oppose firms and public organizations of research more frequently; possibly because the modes of valorization of knowledge are different and French public organizations were only authorized in 1999 to create private valorization structure. Firms with experience on conflicts of this type have a higher-than-average propensity to experience once again a conflict relation, possibly due to a climate of distrust between participants. Temporary geographical proximity is mobilized to resolve these conflicts, the innovators travelling (generally between four and five times) in order to solve conflicts related to the distribution of gains of the innovation. The relations of power and the threats will be more effective and credible than in the case of utilizing telecommunications.

- *the objectives and/or technical characteristics of the innovation*. If innovators share neither the same knowledge nor the same 'professional culture' they have different representations of the objectives and/or the technical characteristics of the innovation (Latour 1989). It is this type of conflict inherent in any innovation project that geographical proximity is most able to solve. It is easier for innovators to reach an agreement on the technical characteristics through F2F interactions than through distant interactions (e-mail or telephone), probably due to problems of translation between the different professional cultures.
- *the organization of labour during the project*. Conflicts of this type do not occur frequently. Temporary geographical proximity (i.e. travelling) is seldom used, with most conflicts being managed through telecommunications. This might be due to the fact that the organization of labour in innovation projects remains highly divided.
- *interpersonal disagreements between innovators*. These conflicts seem to be the most frequently solved through telecommunication, but the results of our survey do not enable us to draw any clear conclusion in this regard.

Thus, whereas conflicts of access to scarce resources are partly caused by permanent geographical proximity, it is the content and the progress of the interactions themselves which lead to conflict during the process of innovation. Temporary geographical proximity can help solve these conflicts, through occasional meetings, facilitating discussions, negotiations and the elaboration of compromise.

Biotechnology firms use most modes of external acquisition of knowledge and above all cooperation with other firms. Most cooperation takes place between distant firms. In this case geographical proximity is temporary (one meeting per term on average). It is often mobilized before the projects are launched in order to solve conflicts related to property rights. On the other hand, its role appears more limited during the project. Above all, organized proximity makes it possible to limit the conflicts related to the organization of labour and differences of representation on the characteristics of the innovation. However, it is more limited than what literature predicts with the division of labour remaining high in cooperation projects.

Conclusion

Contemporary theories of innovation overestimate the positive effects of permanent geographical proximity by considering the co-localization of organizations as a key factor in the success of interactive processes of innovation. This chapter examined the role played by geographical proximity in the circulation of knowledge, by focusing on those moments of the process which more particularly imply its mobilization.

An examination of cooperation relations reveals that the firms involved in this type of project use permanent geographical proximity only moderately. This does not mean that geographical proximity plays no role in the external acquisition of knowledge, as the example of French biotechnology firms shows. Indeed, our research shows that French biotechnology firms mobilize temporary geographical proximity in order to acquire external knowledge with the help of cooperative projects. Moreover, although most cooperation takes place between geographically distant organizations, temporary geographical proximity is often used before the beginning of the project to anticipate conflicts related to property rights. It has a more sporadic role during the course of the project, because meetings are planned from the beginning of the operations. However, it plays a role in the resolution of conflicts, by enabling the participants to meet occasionally, and discuss, negotiate and elaborate compromise to solve conflicts related to the organization of labour, technical characteristics of innovation and property rights.

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9

Evaluating the Future Impact of New Technologies: The Case of Biophotonics in Germany

Michael Kraus and Guido Benzler

Introduction

The successful application of new technologies in products and services is considered to be one of the key driving forces of economic development. However, the definition and identification of those new technologies having the strongest impact on economic development remains a challenge for both industry and politics. Over the last decade of the twentieth century, the concept of 'Technologies for the Twenty-First Century' was introduced and investigated globally. In Germany the notion has been sponsored by the Ministry of Research and Education (BMBF). This concept is based on the observation that the classical segmentation of economy in industrial branches and products, as given for instance by the NACE (Nomenclature générale des activités économiques dans les Communautés Européens) or the STIC (Standard International Trade Classification) code, is no longer appropriate to describe the developing segmentation of products by the technologies involved.

A good example for this latest development is laser technology, which became a key element in a variety of products which are traditionally associated with totally different industry branches: the automotive industry (laser welding, etc.), medical industry (laser cutting, skin treatment, diagnosis, etc.), and data processing (fibre communication, optical data storage, etc.) all depend on the availability of the latest know-how in laser technologies to achieve a competitive advantage. The need of these companies to share R&D, cooperate, etc. imposes a strong technological link between different industry branches and justifies the introduction of a 'Technology Concept' supplementing the existing 'Branch Concept' based on the requirements during the first half of the twentieth century.

Along with the progress in the individual technologies, it can now be observed that the combination of different key technologies like Biotechnology *and* Optical Technologies, Neuro-Science *and* Information Technologies opens up a new field of classification, labelled 'integrating technologies' such as Bio-Photonics, Neuro-Informatics and Nano-Biotechnology. This transformation process has to be considered a quasi-natural development evolving together with progress in R&D. However, besides all the technological challenges and questions, the concept of integrating technologies also imposes a variety of new aspects in terms of business development, evaluation issues and funding policy.

Biophotonics

According to the National Science Foundation – Centre for Biophotonics (2002): 'Biophotonic is the science of generating and harnessing light (photons) to image, detect and manipulate biological materials. Biophotonics is used in *biology* to probe for molecular mechanisms, function and structure. It is used in *medicine* to study tissue and blood at the macro (large-scale) and micro (very small scale) organism level to detect, diagnose and treat diseases in a way that are non-invasive to the body' (NSF 2002).

A closer examination of the term 'biological material' reveals that there is also a variety of new products being developed or already available on the market, dealing with ecological and agricultural issues such as pollution monitoring, food monitoring, crop identification, fertilizer optimization, etc. Last but not least, optical technologies play an important role in the development of new pharmaceuticals. Figure 9.1 depicts the intersection between the different technology fields of Biotechnology, Photonics (Optical Technologies) and Medicine.

Common to all the fields of application of biophotonics is that a successful new product requires the appropriate combination of *both* profound knowledge in life science *and* optical technologies. A good example for this requirement may be the optical coherence topography (OCT), which allows the non-destructive and remote imaging of very small structures at smaller spatial resolutions order of magnitude than ultrasound and computer tomography. OCT can be applied (among a huge variety of other applications) for instance to detect malfunctions in the human eye at a very early stage, thus allowing for cost-efficient therapy. The application of OCT yields information about a possible disease by cross-sections of specific regions in the human eye.

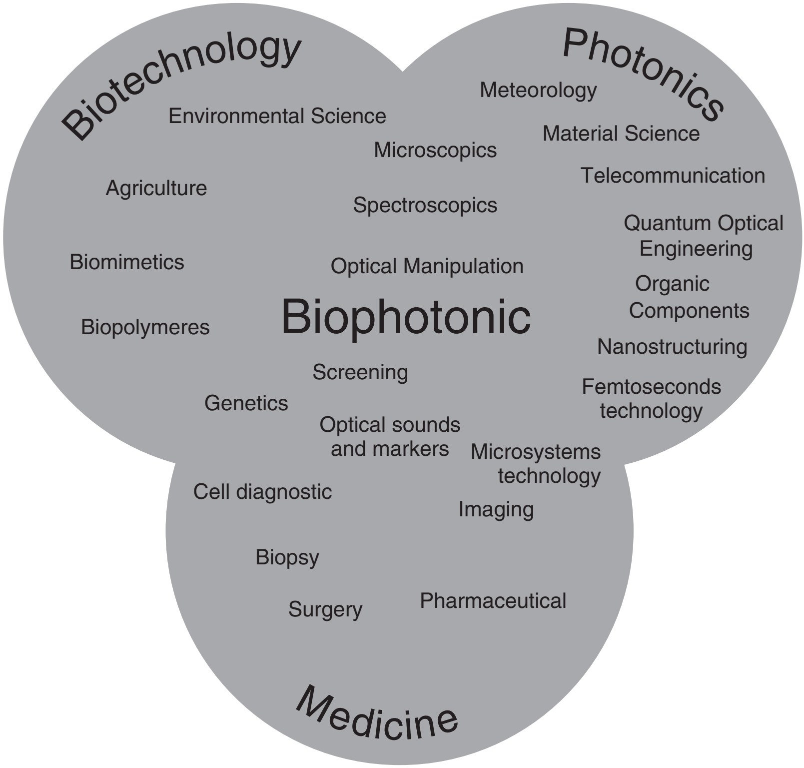

Figure 9.1 Biophotonic at the cross-section of technologies

Here, a twofold challenge becomes obvious. On the one hand, the expert in optical technologies has to develop this non-destructive method and supply the ophthalmologist with clear and crisp images of the patient's eye. On the other hand, the ophthalmologist must communicate to the optics experts which part of the eye should be analyzed and what appear to him as the most relevant facts in order to improve his diagnosis. Therefore, the ophthalmologist has to understand the surgery principle and the possibilities that OCT can offer in order to design a meaningful specification list on what is important to analyze. Vice versa, the optics expert has to develop a close understanding of the tissue properties, the working principle and many further ophthalmologic details in order to be able to provide the best method of analysis, data processing, and result presentation.

It is obvious that OCT is a very ambitious technique and only a team of medical and optical experts can refine such an analysis tool to a degree that allows commercial application. Both the medical and the optical experts are working at the state-of-the-art limit of their individual technology and science. Both expert groups have to reach beyond the existing limits of documented knowledge, thus producing a highly innovative product or process within their field of 'integrating technology', i.e. biophotonics.

This example is substantiated by the results of a current study on biophotonics in Germany (Deloitte and Kraus 2003). An overall analysis of the possible limiting factors for growth in biophotonics reveals that the most prominent issue is 'lack of the need of the users', as is shown in Figure 9.2. These issues are perceived as even more salient than the issue of 'cost pressure in the German health system'. Fifty-seven per cent of all companies claim that the lack of understanding of the true requirements of the end-users is a limiting factor in the field of biophotonics. In addition, still 37 per cent claim that lack of understanding of the potential of biophotonics in general is also a limiting factor, along with other issues.

It can also be assumed that other integrating technologies like Neuro-Informatics, Nano-Biotechnology, etc. may also be affected by the multi-disciplinarity required to remain competitive.

Success factors

Lessons learned from the transformation from industry branch to technology field, and from technology field to the now upcoming integrating technologies, refer to the importance of changing driving forces for both scientific and economic success compared with the past. With regard to the individual personal profile of scientists, researchers, developers and

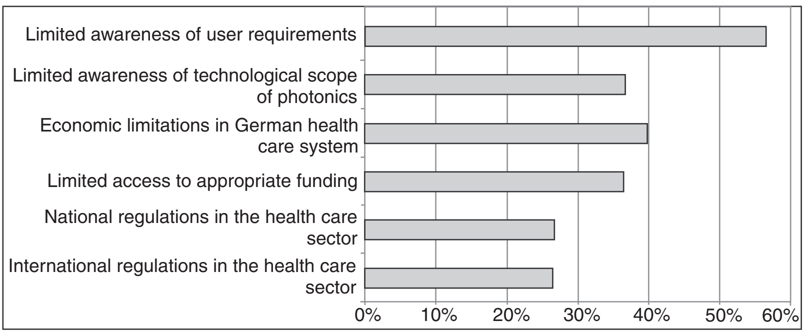

Figure 9.2 Limiting factors in biophotonics

managers, enhanced communication skills are necessary in addition to profound technological know-how. Success stories will be based more on team success and less on individual capabilities. To avoid any misunderstanding, this is *not* a farewell to individual top performance but an additional challenge for each member of the team. This challenge implies that personal communication skills become increasingly important and will be a critical factor in the recruitment of employees. It also raises questions on current academic education, where personal skills are becoming a more and more established part of the academic curricula. However, the scientific segmentation is still very prominent.

In terms of management concepts, it is obvious that the classical approach of 'concentration on core competencies' cannot be applied when managing a technology-driven company in the field of biophotonics. On the contrary, the management here will be required to promote and set a good example on an open-mind policy: new products may require an emphasis on non-core competencies, and future products may be within an entirely new market.

Therefore, an in-depth understanding of the achievements and questions with respect to other technologies, the development of a common 'language', and the availability of experts from different technologies will be some of the success factors in biophotonics. The rather classical factors like effectiveness, business processes, labour cost, tax issues, etc. do not lose any of their relevance, though.

The strong future orientation and dynamic development is mirrored by the expectation of the staff development according to our study. Approximately two-thirds of the companies under consideration are expecting to maintain the same number of staff in the field of biophotonics. However, 30 per cent expect an increase in the number of staff

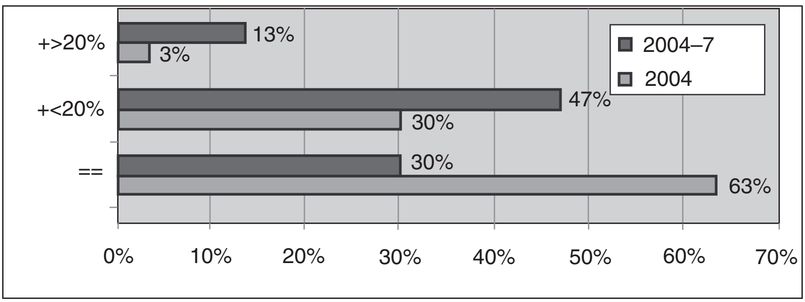

Figure 9.3 Expected growth in biophotonics staff

within 2004. Three per cent are even expecting to increase staff by more than 20 per cent. Even more striking is the companies' expectation for the future. As indicated in Figure 9.3, only 30 per cent of the companies are expecting a steady number of staff, and 70 per cent expect to increase their number of staff.

According to our findings, shown in Figure 9.4, currently about one-third of the companies are still in the preparation stage to generate turnover with biophotonics products or services. Usually, the number of staff increases once the rollout of product and services starts. It can be expected that interdisciplinary aspects will function as key criteria in the future staff selection in these companies.

Evaluation issues

Besides the factors relevant to the internal structures of biophotonic companies or research entities that are devoted to biophotonics, other managerial and infrastructure aspects become increasingly important. Where the scientific back-up necessary for a high-tech start-up company is concerned, the selection of the most suitable location to start a business in biophotonics is determined by the availability of local expertise in various science and technology fields.

For regional planning entities like ministries, regional development and innovation promotion agencies the task of analyzing regional profiles becomes increasingly demanding, as more complex structures have to be considered. Therefore, the required qualification and skill

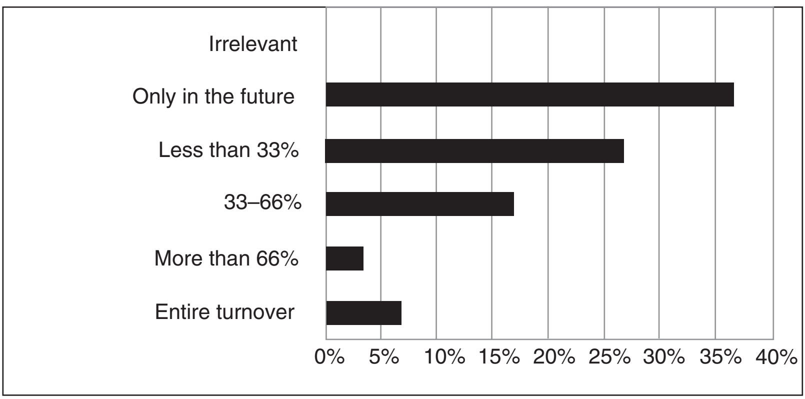

Figure 9.4 Contribution of biophotonics to overall turnover

level of technology transfer experts will rise substantially or, vice versa, interdisciplinary skills will become an important factor in every serious evaluation. Following the path of economic development, the production of 'classical' goods, for which technology has a less significant impact, is characterized by classical evaluation aspects like economies of scale, ROI, market share, sales methods, etc. Proceeding to technology-driven companies and products, issues like publications, patents, conference contributions, functional models, and proof-of-principle have to be added as evaluation criteria.

Finally, in the case of integrating technologies like biophotonics, even more parameters are important in drawing a meaningful picture of a company's SWOT (Strength, Weakness, Opportunities, Threats), like density of technology patterns, capabilities and access to 'network', knowledge sharing, application of publications and patents, as well as the understanding of customer needs. This shift in evaluation parameters should not only be applied in the case of evaluation of start-up companies but also in the case of other companies or business units which are promoting technology and innovation. However, the current set-up of the Basle II rating system offers almost no systematic consideration of this set of changing parameters.

Funding issues

The public R&D funding scheme is also adapting to the changing needs and framework of various technologies. While some classical industry branches are being supported due to lacking competitiveness, economic crisis, and historic structural change, technology-driven companies can take advantage of public funding within the framework of 'joint research projects', funded by ministries like BMBF in Germany in order to perform R&D on specific project contents.

However, in recent years BMBF has recognized that direct project support can only be one main pillar to foster technology and innovation. The second main pillar of technology promotion in Germany is the funding of, first, network structures, secondly, communication platforms, and, thirdly, time-wise limited joint ventures that consist of specialists with an interdisciplinary background. Thus, ultimately, support of classic projects that focus on only one technology will be reduced. One example of these changes is a broad initiative by BMBF on 'competence centres'. Meanwhile, about 80 of such competence centres are operating in Germany, each focusing its expertise on a specific technology. The availability and access to

Table 9.1 Summary of the relevant factors in the development of technologies

	Industry branches	*Key technologies*	*Integrating technologies*
Example	Steel, Coal, Mining, Farming, Chemistry, Construction Industry…	Biotechnology, Laser, Nano, Micro, Superconductivity…	Biophotonics, Neuro-Informatics, Nano-Biotechnology…
Characteristic	Application of established methods, materials and mind-sets, small R&D activity, large number of workers, mass production, tight price corridor, international competition.	Specialized expert groups with high technological skills to harness the challenges of the individual technology.	Combination of two or more key technologies, successful application based on the expertise of at least two experts from different technology fields.
Success factors, challenges	Efficiency, business processes, labour cost, tax issues.	Academic fortune, teamwork with technology experts.	Deep understanding of the achievements and questions within the respective other technology, common language, availability of experts from differ ent technologies.
Evaluation issues	Mainly economic issues, ROI, market share, sales methods.	Publications, patents, conferences, functional models, proof-of-principle.	Density of technology patterns, capabilities to network, knowl edge sharing, application of publications and patents, understanding of customers' needs.
Business issues	Concentration on core competencies, strong international competition.	Concentration on core competencies, market technology driven, key application still open.	Open-minded policy required, new products may need to handle non-core competencies, product may be within a totally new market, market driven by needs.
R&D funding scheme	Not applicable, funding only in the case of economic crisis.	Classical project support.	Financing of network structures, stimulating joint ventures, reducing classical project support that focused on only one technology.

such network structures is an important factor in an assessment of a company's likelihood of participating in the steady growing knowledge in the various technologies.

In the case of biophotonics, public funding in Germany in terms of specific R&D projects amounts to 30 million Euro over a period of five years. Currently, a new biophotonics programme is in its very early stage. This new programme is expected to amount to the same sum. With this total sum of the two programmes, biophotonics funding reaches a similar level to the US-funding of the Centre for Biophotonics by the NSF.

At present, only approximately 25 per cent of the funding total is directed to industry. The majority of 75 per cent is used to support universities and research institutions. This distribution indicates that a large number of fundamental questions about biophotonics are still under investigation and that industry is showing increasing interest in the results as they come closer to a potential application.

Direct project support is accompanied by a variety of competence networks in the field of biotechnology and optical technologies. This development strongly supports the specific demands of biophotonics to stimulate both project work and close exchange of knowledge and views in order to develop new products and applications.

Summary

Biophotonics, the combination of optical technologies and the broad spectrum of life-science technologies, was used as an example for a new type of technology cluster where at least two state-of-the-art technologies are used to create new applications and products. Table 9.1 depicts the relevant factors. The factors that determine success or failure in these 'integrating technologies' have been derived and the classical assessment scheme for technology-oriented companies has been extended. Future observation will allow the drawing of further conclusions.

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10
The Matrix INT (Instruments and Needs of Technology) and the Evaluation of Innovation Policies

Riccardo Cappellin

Introduction

Innovation – both technological and organizational – is a fundamental ingredient of economic growth, and it has a crucial role in enhancing the positive potentials of the process of international integration. However, the perspective of the 'knowledge society' raises risks of exclusion, which may reduce the benefits of international integration and lead to further divergence and segmentation between economically strong regions and countries and less developed countries and regions. This chapter focuses on the case of small and medium size firms (SME) and on the medium and low-technology industrial sectors representing the crucial specialization in the industrialization process of less developed countries. Innovation affects the capabilities of SME to survive and to grow in the actual process of liberalization and openness to the international markets. In particular, innovation in SME has to be broadly defined as extending beyond research and development activities and also beyond the adoption of new technologies, in order to include more incremental developments, such as the adaptation of product and services to meet the changing needs of customers and markets and the adoption of new organizational methods both internally and in the relations with other firms in a sectoral or regional framework.

The methodology described in this chapter aims to evaluate the gap between the characteristics of the demand and the supply of technology transfer (TT) services to SME in a wide international framework, comprising both developed countries and less developed countries. It considers the factors determining innovation according to three complementary perspectives: types of industry/technology, types of firm and types of region. It emphasizes that the problems and opportunities of innovation with specific reference to SME are different in various individual countries and that that determines a different structure of the demand of innovation policies. It also classifies a wide set of instruments in innovation policy according to three policy-making models: government, market and multilevel governance. Finally, it illustrates a new model defined as Matrix INT (Instruments and Needs of Technologies), which allows the measuring in a rigorous and quantitative way of the complementarities and the trade-offs between various policy instruments in innovation policies. This model reveals the joint effects of the policy instruments on specific factors and needs of the innovation process and the relevance of these specific needs in a typology of industry/technology, firm and region.

Problems and needs of firms in the innovation process

The design of the innovation policy and the identification and creation of specific policy instruments requires that each specific policy case study to be considered (i.e. individual firm, sector, cluster, national or regional economy) is analyzed according to three dimensions (see Figure 10.1):

- the typology of industries/technologies
- the typology of firms
- the typology of regions

as that allows some of the major problems and needs in the field of innovation policy to be identified.

First of all, the evolution of the technological bases in the various fields of production affects the need of modern policy instruments in innovation policies. That underlines the importance of analyzing the process of technology convergence and the increasing interdisciplinary integration of modern technologies and also the parallel process of increasing specialization and diversification of the various industries.

Building upon Pavitt's taxonomy of innovating firms, Archibugi and Orsenigo (2002) propose to group industries in five large categories (Pavitt 1984; Marsili 2001). Individual firms are included in each category according to the sources of innovations (Pavitt 1984; Winter 1984; van Hippel 1988; OECD 1992; Archibugi *et al.* 1999; Breschi, Malerba and Orsenigo 2000) and the technological trajectory they

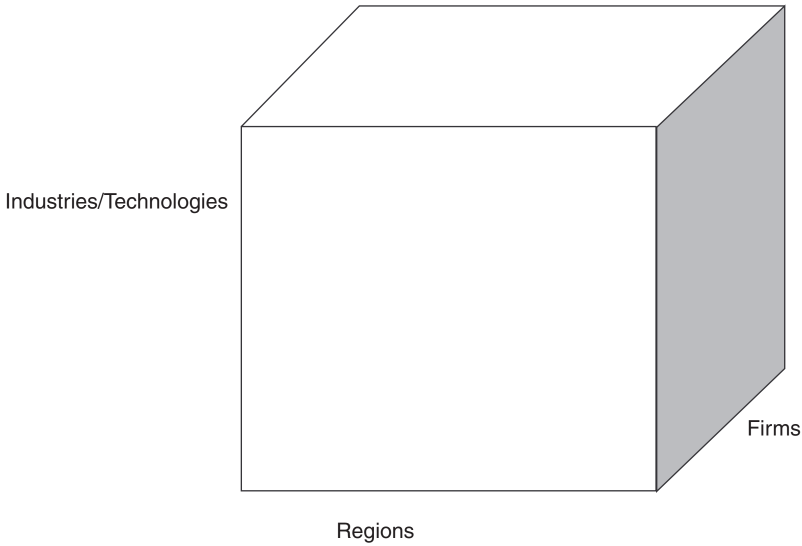


Figure 10.1 The combination of three dimensions in the design of innovation policies

follow rather than according to the characteristics of the prevailing product, as in the usual statistical classifications.

The *science-based* regime characterizes innovative activities, where the universal nature of scientific knowledge technologies generates a continuous stream of new products. They are characterized by high technological entry barriers, which originate in the high specificity of knowledge applications across production processes, and in high cumulativeness of innovation. Innovative activities are principally devoted to product innovation and benefit from the direct contribution of scientific advances in academic research.

The *fundamental-processes* regime characterizes activities where technological entry barriers are high and especially related to scale advantages in innovation and strong persistence of innovation. Innovation is mainly process innovation and, although affiliated firms and users represent the main external source of knowledge, it benefits from the quite important and direct contribution of scientific advances in academic research.

The *complex (knowledge) system* regime presents a knowledge base that combines mechanical, electrical/electronic and transportation technologies. The distinctive feature of this regime is the high degree of differentiation of technological competencies developed by firms, especially in upstream production technologies, and of external sources of knowledge, including an important, although indirect, contribution of academic research.

The *product-engineering* regime includes the bulk of capital goods firms. This regime is distinguished by the high diversity of technological trajectories explored by firms. Innovation is in products and benefits from external contributions of knowledge, mainly from users.

The *traditional industries* regime includes a variety of production activities, which mainly benefits from upstream sources of capital-embodied knowledge, as the knowledge base is characterized by the acquisition of technological expertise from specialized suppliers. However; these activities are also characterized by strong innovative capabilities in product design and vertical and horizontal differentiation, often have a direct contact and knowledge of large national and international markets and are quick to introduce product incremental innovations and customization.

Table 10.1 schematically reports the most important needs of SME in terms of technology transfer, when the process of knowledge creation and of innovation adoption is analysed according to the typology of industries/technologies. These needs differ between the types of industries/technologies, and the list within Table 10.1 demonstrates factors which determine these differences (Archibugi *et al.* 1999; Archibugi and Orsenigo 2002).

Secondly, the process of technological innovation is related to the development of a learning process and to the accumulation of knowledge within the individual firms. The issue of the organizational structures and dynamics within the firms then needs to be addressed, in order to design policies that aim to enhance the internal production of know-how, the competencies of the human resources and the creative and entrepreneurship capabilities. According to Orsenigo and Decastri (2002), SME may be classified in four major types:

- *'Schumpeterian' fi*rms, i.e. companies which are born on the basis of an innovation and try subsequently to develop it.
- *'Marshallian' firms*, i.e. SME that are active in a specific geographical area (clusters, districts, productive and innovation systems, etc.). They are typically extremely specialized in some stage of the value chain and/or in a product niche. They entertain close – often socially shaped – linkages with the other firms in the area and they learn largely via informal processes, acquisition of capital goods, exposition and

Table 10.1 Typologies of industries and factors influencing their needs on learning

Typology of industries/technologies
1. Science based
2. Fundamental processes
3. Complex knowledge system
4. Product-engineering
5. Traditional industries

Factors influencing needs by typology of industries/technologies
1. Promote codified knowledge, through support to basic research, higher education and university–industry cooperation and also international transfers and cooperation.
2. Promote tacit knowledge and enhance internal skills and competencies through specialized professional training and lifelong learning and tight client–supplier collaborations.
3. Promote combinatory/complex knowledge through interdisciplinary research, exploration of new technological potentials and new combinations of different technologies.
4. Promote prescriptive knowledge and applied research through 'normative' or 'demand pull' approaches in industrial application, exploitation of existing technological advances and the development of 'transfer sciences'.
5. Promote innovation networks and access to complementary technologies and capabilities through cooperation with other firms of different sizes, sectors and countries and partnership between private and public institutions.
6. Promote the imitation of innovation in other countries and firms.
7. Promote the appropriability of technological discoveries.
8. Promote the protection of 'infant industries'.
9. Promote international openness and competition.

solution of immediate, specific problems, and interactions with other companies. Their technological strength derives essentially from the processes of knowledge sharing and by the dense knowledge flows that take place in the geographical area where they are located. In many cases, such knowledge flows are largely informal.

- *'Smithian' firms*, i.e. firms based on processes of division of labour and specialized in the supply of intermediate products and components to other (often larger) companies, often on the basis of organized sub-contracting relations and hierarchies. Their participation in the network of sub-contracting relations is a fundamental source of technical knowledge and skills.
- *'Marginal' firms*, characterized by low technological skills and little effort explicitly devoted to learning.

The main problems that these types of firms face in their innovation and learning activities and therefore the scope for potential policy action may be indicated as in Table 10.2. Again, criteria are given to distinguish the needs of firms according to their innovation and learning capabilities and strategies (Guilford 1959; Galbraith 1982; Geroski *et al*. 1997; Nonaka and Konno 1998; Perrin 2000; Orsenigo and Decastri 2002).

Thirdly, the innovative potential of firms depends not only on internal capabilities, but also on their relations with other firms and their embeddedness in a local environment. Thus, innovation and

Table 10.2 Typology of firms and factors influencing their needs on learning.

Typology of firms

1. Schumpeterian firm
2. Marshallian firm
3. Smithian firm
4. Marginal firm

Needs by typology of firms

1. Promote accessibility to a variety of technological sources and to foreign markets, through interaction with external actors, cooperation schemes, intermediaries, infrastructures, logistics, information systems.
2. Promote receptivity or openness, through improved human capital, well-designed learning processes, the development of tacit knowledge and the development of proactive rather than reactive strategies toward technological change.
3. Promote common identity, the sharing of common values, creation of teams, alignment with company's strategic objectives and consensus on a joint clear strategy.
4. Promote internal creativity both by individuals and by interactive groups of people, through greater autonomy, empowerment, internal mobility and intensive interaction between different capabilities and through the development of a strong internal technological base and the persistence of innovative activities.
5. Promote internal entrepreneurship capabilities, through the development of internal organizational capital, launch of new projects, adoption of new management methods, new production processes, re-engineering projects, spin-offs of innovative start-ups and access to innovative finance.
6. Promote local embeddedness in the external environment or 'relational capital', through stronger relationships with suppliers, and improved relations with other firms and the suppliers of modern equipment.
7. Promote the access to skilled labour and attract or retain qualified workers.
8. Promote market orientation and shareholder value, through customer satisfaction, strong relations with clients and the explicit management of the intellectual assets, internal core competencies, brands and patents.

development policies should have different characteristics according to the type of regions considered.

Regions can be classified according to different perspectives (Cappellin 2002b), such as their development and technology level (i.e. *developed regions, intermediate regions and economic lagging regions*), the level of urbanization and the structure of their urban system (i.e. *metropolitan regions, intermediate regions and rural regions*), the diversification of their sectoral composition (i.e. *high-tech clusters, diversified industrial regions, specialized industrial districts, rural areas*), the dynamism of their industrial sectors and the bounds to a past structure (i.e. *dynamic industrial regions, old industrial and re-conversion regions, transition economies*), or the geographical position (i.e. *metropolitan regions, border regions, internal small rural areas, large peripheral areas*).

According to the approach of territorial networks (Cappellin 1998 and 2003b), it is possible to identify a limited set of factors (see Table 10.3) which have a key role in the process of innovation and development within various regions. It should be emphasized that these factors assume a different importance and priority in regional policies according to the specific characteristics of each region (Porter 1998; Steiner 1998; Maillat and Kebir 1999; Cappellin 1998 and 2003a).

The various needs identified in relation to the three dimensions indicated above can be quantified according to a tentative scale from 1 (not important) to 5 (very important). Thus, each of the industries/technologies, firm types and region types indicated above has a different profile, which may be represented as in Figure 10.2 on page 176.

Policy-making approaches and instruments of innovation policies

The analysis of the role and characteristics of the individual intermediaries in technology transfer policies should be defined in a wider framework of various instruments of innovation policy. In particular, the design and implementation of innovation policy must tackle the problem of the architecture of the institutional framework and solve those policy issues which occur in the relationships between the centre and the periphery, the public and the private sector, the firms, the workers and the various external stakeholders, the world of production and that of financial intermediaries, the public technology transfer centres and the private consulting companies, and last but not least, the integration of an economic and technological perspective with a social and institutional perspective. In this regard, the debate in Europe

Table 10.3 Typology of regions and factors influencing their needs on learning

Typology of regions

1. High-tech clusters
2. Metropolitan regions in developed countries
3. Diversified and dynamic industrial regions
4. Specialized industrial clusters
5. Intermediate regions
6. Old industrial and re-conversion regions
7. Transition economies
8. Economic lagging regions
9. Metropolitan areas in economic lagging regions/countries
10. Border regions
11. Internal small rural areas
12. Large peripheral areas

Factors influencing needs by typology of regions

1. Promote external openness, accessibility, exports and external investments.
2. Promote territorial quality, territorial planning and infrastructure.
3. Promote institutional thickness, decentralization, self-organization, social capital and multilevel governance.
4. Promote local identity and consensus on a common development strategy.
5. Promote SME birth rate and entrepreneurship capabilities.
6. Promote sectoral diversification and spin-offs of new firms.
7. Promote the access to credit and diversification of financial intermediaries.
8. Promote the vertical/horizontal integration, subcontracting networks and firms specialization.
9. Promote interactive learning processes, diversity, creativity and knowledge networks.
10. Promote skilled human capital, receptivity and labour mobility between firms.
11. Promote productivity growth, adoption of innovation and R&D investment.
12. Promote employment growth and a lower unemployment rate.

on industrial and innovation policies allows us to identify various alternative approaches in public policy-making:

- the centralist model of sectoral planning ('government')
- the free market model
- the public–private partnership model of 'multi-level governance'.

Both the recent evolution of technologies and the process of increasing international integration of national economies seem to underline

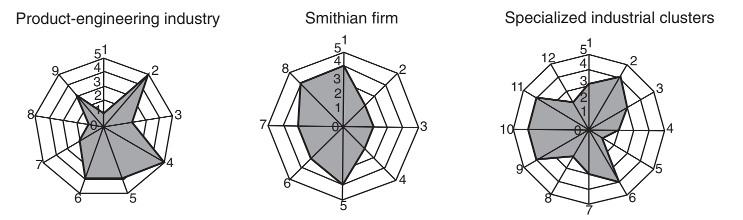


Figure 10.2 The profile of individual industries/technologies, firms and regions

the usefulness of the model of 'multilevel governance'. In fact, most programmes designed and implemented at the European level have focused on stimulating the process of institutional building and aimed at the creation of 'national or regional systems of innovation' by promoting the creation of inter-firm networks in innovation. Especially in the economic lagging regions, various EU programmes have been designed to promote an evolution from a traditional hierarchical model ('government' model) to models where public–private partnerships have assumed a crucial role.

The 'multilevel governance' model allows a flexible combination of bottom-up initiatives and top-down coordination and financing. Thus, it is possible to distinguish within it two different types, which can be indicated as 'governance model 1: public–private strategic partnership' and 'governance model 2: local networking and cooperation'. In the first type, a crucial role is assigned to national public authorities in promoting and steering the innovation networks made by different firms and actors. On the other hand, the latter type is characterized by a stronger autonomy of the different economic and social stakeholders. It may represent the case of a 'complex adaptive system' characterized by a high capability of self-organization and by national authorities providing incentives for local and international networking (Holland 2002).

In Figure 10.3, these four models of policy-making are described according to their respective position within two major dimensions: 'hierarchy vs. autonomy' and 'isolation vs. integration'. The first dimension measures the power of the central authorities vs. the freedom of the various firms and individuals. The second dimension measures the level of explicit economic interdependence, the sharing

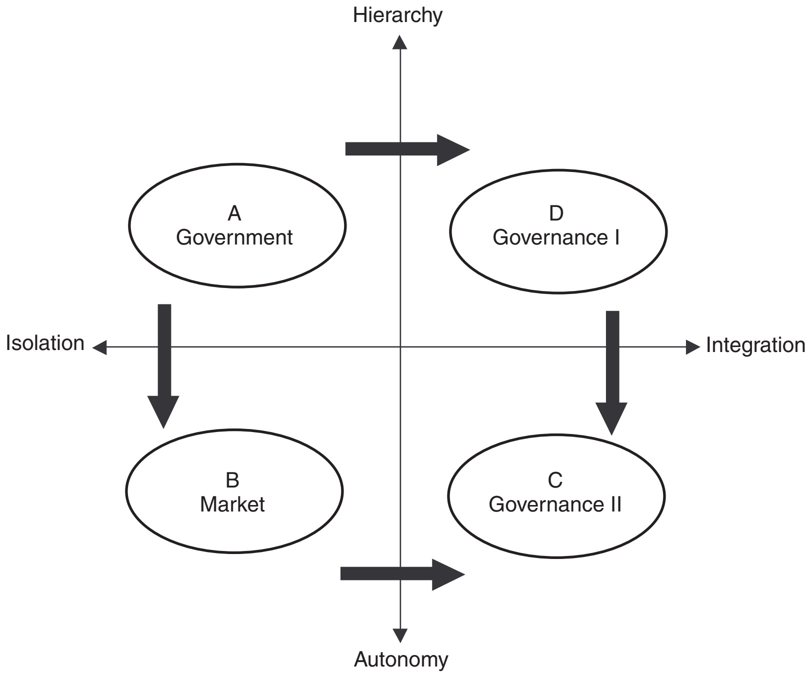


Figure 10.3 Four decision-making models

of common values and the sense of belonging vs. the absolute isolation of each individual confronted with the law designed and enforced by the state or confronted with the overall market price and conditions as in a perfect competitive market. When these two dimensions are considered, recent evolution in technology and industrial organization seems to indicate both the need to increase the autonomy of the various firms and actors and the need for a greater integration of the individual actors, due to their increasing interdependence, the increasing complexity of the factors determining the innovation processes and the need to integrate complementary technologies.

Thus, in Table 10.4, the different instruments adopted in innovation policies are grouped according to the above-indicated four policy-making approaches for facilitating an international comparison. The first class of instruments ('government' model) considers the case when the national government intervenes directly in order to promote 'national champions' or to protect 'strategic industries'. A crucial role

Table 10.4 Policy-making approaches and instruments of innovation policies

(A) 'Government' model strategic partnership	*(C) 'Governance' model 1: public–private*
1. Public-owned industries	1. Strategic planning contracts with large firms
2. Subsidies to strategic private industries	2. Territorial pacts with local actors
3. National agencies of sectoral industrial plans	3. Regional technological parks and centres
4. Public funding of R&D	4. TT centres and programmes (partially nationally publicly financed)
5. Regional offices of national agencies or departments	5. University–industry liaison offices
6. Public demand and fiscal incentives	6. Professional continuous education centres
7. Large public R&D institutions	7. National programmes for R&D and innovation networks
8. Science parks	8. National networks of TT service centres
9. TT service centres (fully publicly financed)	9. National financial trusts for financing innovative firms
	10. International networks of TT centres
(B) 'Market' model	*(D) 'Governance' model 2: local networking and cooperation*
1. Privatization of public industries	1. Cooperative research projects between SME (CRAFT)
2. Market deregulation	2. Autonomous (non-governmental) research institutions or foundations
3. Liberalization and MNE attraction	3. Business Innovation Centres (BIC) and Innovation Relay Centres (IRC)
4. IPR regulation and national patent offices	4. TT centres of industry associations and chambers of commerce
5. Private professional services	5. Local incubators of innovative firms
6. Private technology brokers	6. Regional/local development agencies
7. Private venture capital	7. Local stakeholders coordination tables
8. Private research companies	8. Regional Innovation System (RIS)
9. Technological education centres	9. Territorial knowledge management (TKM)
10. Public information and benchmarking centres	10. Regional innovative start-up funds

in this case is played by national ministries and agencies created by the national government, although these latter may be regionally decentralized. Thus, also the cases of large science parks and research institutions and of technology transfer (TT) centres totally publicly financed are considered in this class. These types of innovation policies instruments seem to be the most diffused at the international level and they can still play an important role in many less developed and also developed regions and countries. A second and opposite class of instruments ('market' model) considers the case when the crucial role to promote innovation is left to market forces. Certainly, general measures in industrial policy, such as privatization, liberalization and market competition regulation, as well as specific regulations of intellectual property rights (IPR), may have an indirect but powerful impact on innovation performance of regional and national economies. According to this approach, private TT intermediaries, such as professional services, technology brokers, venture capitalists (VC) and specialized new research start-ups play a crucial role. However, even within this model public authorities are still important, especially in facilitating the circulation of information and in enhancing a higher level of formal education of the labour force.

The third class ('governance' model 2) encompasses those policy instruments which are based on the concept of public–private partnership, when the leader role is played by public authorities. This is the case of national planning contracts with large private or public firms or of territorial pacts for employment bringing together many local actors. Specific instruments, such as university–industry liaison offices, TT co-financed by private industries, technology parks focusing on specific sectors and clusters, will lead to a tight integration between public and private institutions. Moreover, the concept of cooperation is the key element in programmes aiming to create networks at the national and international level between the various actors and intermediaries active in a regional or national innovation system.

Finally, the fourth class ('governance' model 1) encompasses those policy instruments which are often supported by public resources but have been created by a bottom-up initiative of private actors, groups and citizens. A crucial role in this case is played by the cooperation between firms and especially between SME, by the incubators of new firms and by independent foundations or research institutions. Local stakeholders are grouped together around an industry association or chamber of commerce. 'Business Innovation Centres' and 'Regional

Development Agencies' can be very helpful instruments in promoting local cooperation. Within this approach some innovative instruments, such as 'Regional Innovation Systems (RIS)', which have been widely experienced in European countries, also have to be classified. Another, similar methodology is 'Territorial Knowledge Management (TKM)', which aims to facilitate the relationship between local firms within territorial networks (Cappellin 2003a). SME barriers to financial markets will be overcome with the help of start-up funds (seed capital and VC) by regional organizations.

The various instruments in innovation policies have different capabilities for responding to the problems and needs indicated in Tables 10.1, 10.2 and 10.3. Thus, policy-makers have to identify those policy instruments which may be more effective, and improve the internal organization of public institutions by comparing the policy instruments locally available with international benchmarks. Table 10.5 indicates the relative importance of four specific policy instruments according to the various policy needs which have been earlier considered in an industry/technology, firm type and region type perspective. Thus, a score has been assigned to each combination of instrument and innovation need. This scoring system highlights the different qualities of instruments required within the four policy-making models to satisfy the needs of SME.

Table 10.5 Problems and factors influencing needs of innovation policies

Needs by industries/technologies	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
A Large public R&D institutions	3	0	3	1	2	2	2	1	0
B Private venture capital	0	0	0	2	2	1	2	0	2
C TT centres and programmes	0	0	0	1	0	0	1	1	0
D RIS – regional innovation system	1	2	1	2	2	2	2	2	1

Needs by firm type	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
A Large public R&D institutions	3	1	1	2	1	0	2	0
B Private venture capital	1	1	0	3	1	0	1	2
C TT centres and programmes	1	1	2	0	0	1	1	0
D RIS – regional innovation system	3	2	3	2	1	3	2	2

Needs by region type	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
A Large public R&D institutions	2	1	1	2	0	1	1	0	3	1	3	1
B Private venture capital	3	0	1	1	2	2	3	0	1	0	2	0
C TT centres and programmes	2	2	2	2	3	3	1	3	2	2	2	1
D RIS – regional innovation system	2	1	2	3	1	2	1	1	3	1	2	1

Note: The numbers of the columns correspond to the number of factors influencing needs in Tables 10.1, 10.2 and 10.3.

The model of Matrix INT

The following model is based on the idea that the choice of the most appropriate policy instruments in innovation policy should take into account the various needs which characterize the different firms, the respective sector and regional environment, and the different capability of the individual policy instruments in responding to these specific needs. The model, Matrix INT (Instruments and Needs of Technology) is characterized by a wide flexibility and is able to consider different types of regions, industries and firms to be combined in multiple solutions. The approach adopted in the Matrix INT model is illustrated in Figure 10.4.

The model starts with the identification of the various problems/needs in the process of innovation. These latter may be classified according to the three dimensions of industries/technologies, of firm organization and of regional characteristics, as indicated in Tables 10.1, 10.2 and 10.3. Then a set of 29 scores describe the problems/needs with respect to the industry/technology specialization, the prevailing firm characteristics and the characteristics of the region of localization. The value attributed to these scores increases with the intensity of the need within a given predefined range (for example 1–5). These scores are indicated in vector B of Equation (1).

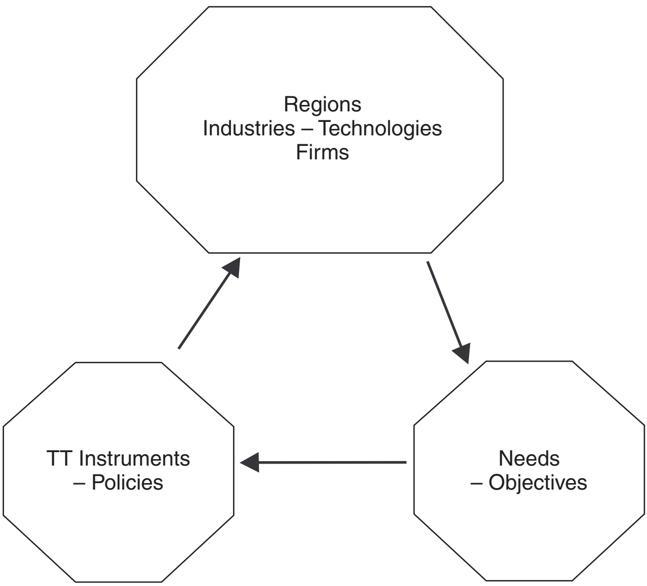
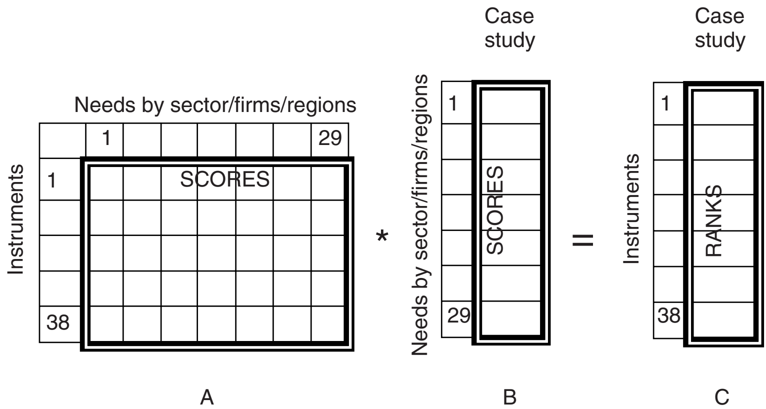


Figure 10.4 The approach of the Matrix INT

Equation (1) The approach of the Matrix INT

(1)



As explained above, the various policy instruments in innovation policies which have been listed in Table 10.4 have a different capability or effectiveness in tackling the needs of SME. This is described with a set of scores which have a greater value the more effective the instrument is considered to be on the specific need and have a nil value when no relationship can be identified between instrument and need. Also these scores are evaluated within a given predefined range (for example 0–3). These scores are indicated in the matrix A of Equation (1). The final result of the matrix multiplication gives a vector C, which indicates the ranking of various policy instruments according to their overall effectiveness with specific reference to the case study to be considered.

The approach adopted in the model of Matrix INT is also described in Figure 10.5. In fact, the identification of the industry/technology characteristics, the firm types and the local environment characteristics of a selected case studied (i.e. firm, cluster, sector, region) leads to the identification of specific needs in the innovation process. Then, based on those needs identified it is possible to rank the various policy instruments according to their respective effectiveness.

In order to simplify or guide the assignment of scores to various needs and policy instruments in innovation policy, it may be useful to follow a different procedure and to identify specific benchmarks based on international experience. Research (Cappellin 2002b) has identified various types of industries/technologies, firms and regions, which have been indicated in Tables 10.1, 10.2 and 10.3. Then, specific scores have been assigned to the various needs in each of these different types of industries/technologies, firms and regions. Moreover, on the basis of the results of a previous large survey conducted by the INSME network on more than 600 TT intermediaries in various countries, it has been possible to assign a score to various innovation policy instruments according to their ability to tackle the specific need to be considered.

The scores assigned in this research represent the result of the consensus reached within a group of experts with different backgrounds and competencies. However, these scores have to be adapted according to the specific case studies to take into account the specific needs and the relative efficiency of the specific policy instruments to be considered. The model of Matrix INT (Instruments and Needs of Technology) allows us to estimate the relative effectiveness of the various policy instruments by computing a set of scores through the following matrix multiplication, as indicated in equations (2.1), (2.2), (2.3):

(3) **A** (Instruments*Needs) * **B** (Needs*
Industries/Technologies–Firms–Regions)
=
C (Instruments*Industries/Technologies–Firms–Regions)

The procedure to compute the scores of the Matrix INT is illustrated with the following analytical expressions. Given the following indexes:

i: index of the need to be considered according to an industry/technology and to a firm and to a regional dimension (*i*: 1, …8, 9,….17,18,….29),

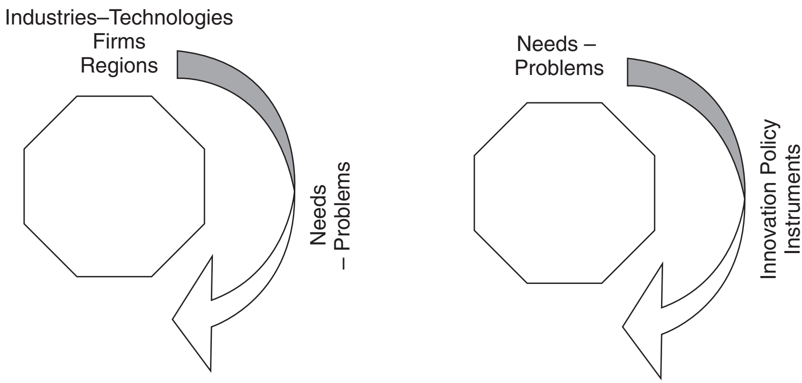
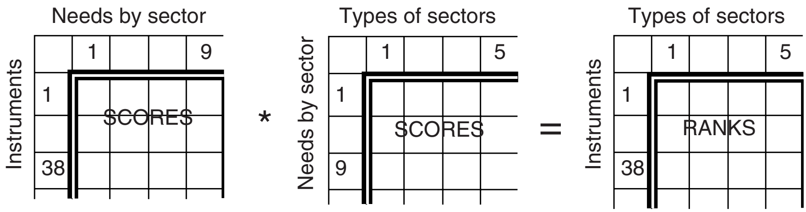
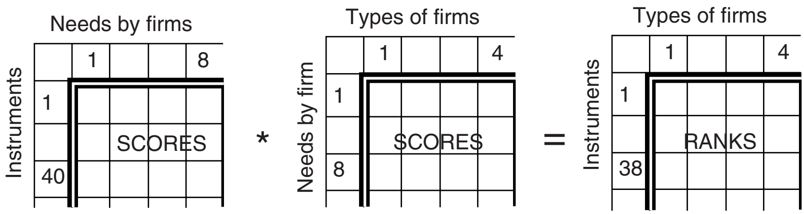


Figure 10.5 From case-study characteristics to innovation policy instruments

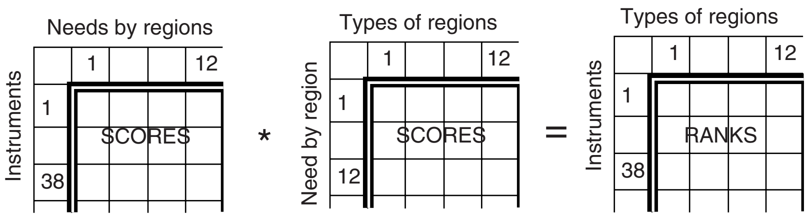
(2.1)



(2.2)



(2.3)



p: index of the policy instrument to be considered according to an industry/technology, a firm and a regional dimension (*j*: 1,…38),
t: index of various industry/technology types to be considered (*t*: 1,…5),
f: index of the various firm types to be considered (*f*: 1,…4),
r: index of the various region type to be considered (*r*: 1,…12),

we then define:

n_{it}, n_{if}, n_{ir}: scores of the need (*i*), respectively according to an industry/technology (*t*), firm (*f*) and regional (*r*) dimension,

x_{ip}: score of the policy instrument (p) in response to the need (i).

As indicated above, in the actual calibration of the model, the scores (n) have been defined with a value between 1 (low importance) and 5 (very important), with the constraint that the summation of the scores will be the same for each industry/technology, firm or region type to be considered. That obliges us to identify a well-defined priority between the various needs for a given industry/technology, firm or region type. On the other hand, it assures the possibility of comparing the numerical results obtained for the different types. Similarly, the scores (x) have been defined with a value between 0 and 3, where the value 0 indicates that a given policy instrument does not have any effect on a specific need, while the score assumes the value 3 when the instrument is particularly appropriate to respond to a specific need. The weights (W), to be assigned to a specific policy instrument (p) according to the three dimensions, industry/technologies, firms and regions (respectively indicated as: t, f and r), can be computed as the multiplication of the scores attributed to the individual needs for the specific scores expressing the effectiveness of specific policy instruments, according to the following expressions:

(4.1) $W_{tp} = \sum_i n_{it} x_{ip}$
(4.2) $W_{fp} = \sum_i n_{if} x_{ip}$
(4.3) $W_{rp} = \sum_i n_{ir} x_{ip}$

Then, an overall weight (W_p), referring to a specific policy instrument (p) to be considered, is computed through the following simple expression:

(5) $W_p = aW_{tp} + bW_{fp} + cW_{rp}$

where the parameters (a, b and c) are used to standardize the various scores or to assign a different importance to the industry/technology, firm and regional perspectives. The overall score for a specific instrument is then compared with the scores of other policy instruments. That leads to the identification of a set of 'appropriate' innovation policy instruments which takes into account three different perspectives: an industry/technology, firm and regional perspective. The results obtained depend on the opinions of an interdisciplinary group of experts, an international comparison of regional problems and regional policy instruments in various countries. However, these scores have to be adapted in other case studies to take into account the characteristics of the specific needs and the relative efficiency of the various intermediaries to be considered.

Looking at the contributions of the model of Matrix INT to innovation policies and their evaluation, first of all, it allows taking into account three different perspectives and it represents an operational instrument for reaching a coherent synthesis between the indications derived from different although related approaches in the analysis of the factors of innovation. Second, the Matrix INT allows including a variety of political instruments. Third, the Matrix INT makes it possible to measure in a rigorous and quantitative way the complementarities and the trade-offs between the various policy instruments, when the policy-makers aim to respond to various and interdependent innovation needs. In fact, the same need may be satisfied through various instruments and the same instrument may be adapted to respond to various needs. Thus, the model indicates the interaction between various innovation needs and policy instruments. Fourth, the model of Matrix INT helps the policy-makers to make explicit the priorities (the parameters: n_{it}, n_{if}, n_{ir}) of various needs to be considered as well as the expectation on the effectiveness of various instruments (the parameters x_{ip}). A specific policy instrument can be demonstrated to be superior to other policy instruments only when these parameters assume a specific level. That obliges the policy-makers to analyze the combination of industry, firms and regional typology characterizing a specific policy case study and to choose the instruments according to a comparison of their respective overall impact on a rather wide set of needs.

Fifth, the model Matrix INT can be used to describe the evolution in the set of the most appropriate policy instruments when the specific economy considered evolves from a specific combination of industry/technology, firm type and regional type to a new combination, as indicated in Figure 10.6. According to the results obtained in the INSME study (Cappellin 2002b), the instruments which seem particularly important in the case of the less technologically advanced industries, such as the ‘traditional industry’, are:

- Territorial knowledge management (TKM)
- Regional technological parks and centres
- National programmes for R&D and innovation networks
- University–industry liaison offices
- Cooperative research projects between SME (CRAFT)
- Public information and benchmarking centres

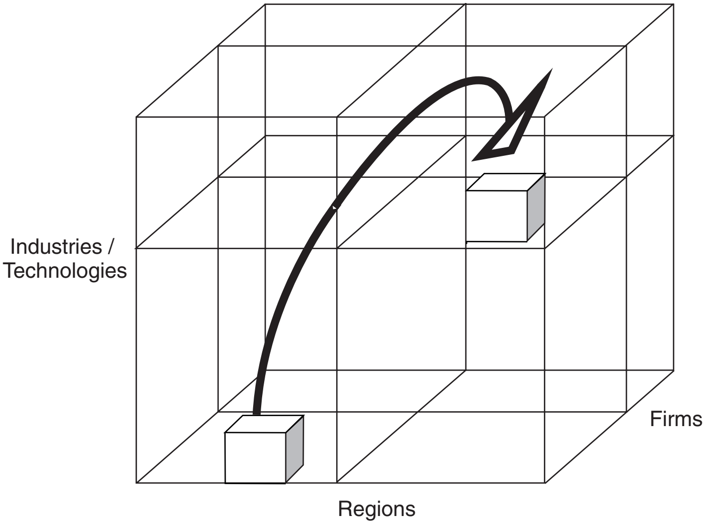


Figure 10.6 Shift to a new profile within the regions–technologies–firms space

- RIS (regional innovation system)
- Science Parks
- Strategic planning contracts with large firms
- Private technology brokers

The policy instruments which are mostly needed by the less technologically advanced firms, such as the 'marginal' firms, are:

- Territorial knowledge management (TKM)
- Local incubators of innovative firms
- Professional continuous education centres
- RIS (regional innovation system)
- Technological education centres
- Regional technological parks and centres
- University–industry liaison offices
- Public information and benchmarking centres
- TT centres of industry associations and chambers of commerce
- Science Parks

Finally, the less technologically advanced regions, such as the 'economic lagging regions', indicate a higher need for the following policy instruments than the more technologically advanced regions:

- TT centres and programmes (partially nationally publicly financed)
- Territorial pacts with local actors
- Regional offices of national agencies or departments
- Professional continuous education centres
- Regional/local development agencies
- Regional innovative start-up funds
- National networks of TT service centres
- Regional technological parks and centres
- TT centres of industry associations and chambers of commerce
- Science Parks

As indicated in equation (5), it is possible to compute an overall score when a specific case study has been defined according to the specific technology/sector, firm and region types, indicated in Tables 10.1, 10.2 and 10.3. As an example, the overall rank of the effectiveness of the various innovation policy instruments has been computed in two extreme cases (Table 10.6):

(a) Case study 1: Science-based industries + Schumpeterian firms + high-tech clusters
(b) Case study 2: Traditional industries + marginal firms + economic lagging regions

Case study 1 is more technologically advanced and underlines the demand for those innovation policy instruments which mainly contribute to the creation of 'codified knowledge', such as:

- Science Parks
- Autonomous non-governmental research institutions or foundations
- Large public R&D institutions
- IPR regulation and national patent offices
- Public funding of R&D
- Private research companies
- International networks of TT centres
- National programmes for R&D and innovation networks
- University–industry liaison offices
- Private technology brokers

In contrast, case study 2 is less technologically advanced and it indicates a higher demand for those policy instruments which mainly

Table 10.6 Matrix INT: comparison of two extreme cases

Policy-making model		*Instruments of innovation policy*	*Case 1: Science based ind. -Schumpeterian firms – High tech clusters*	*Case 2: Traditional industries–Marginal firms – Economic lagging regions*	*Difference of total scores*
A	8.	Science Parks	531.85	397.81	134.04
D	2.	Autonomous non-governmental research institutions	383.93	258.70	125.23
A	7.	Large public R&D institutions	398.13	282.82	115.30
B	4.	IPR regulation and national patent offices	278.09	191.90	86.19
A	4.	Public funding of R&D	354.59	276.99	77.60
B	8.	Private research companies	342.65	265.33	77.32
C	10.	International networks of TT centres	335.54	263.72	71.83
C	7.	National programmes for R&D and innovation networks	423.82	369.37	54.45
C	5.	University–industry liaison offices	501.19	451.00	50.19
B	6.	Private technology brokers	329.17	289.35	39.82
B	9.	Technological education centres	398.72	363.66	35.05
D	9.	Territorial knowledge management (TKM)	532.88	514.19	18.69
A	9.	TT service centres (fully public financed)	233.06	221.93	11.14
C	8.	National networks of TT service centres	270.36	259.37	10.99
B	7.	Private venture capital	287.06	278.64	8.43
D	5.	Local incubators of innovative firms	430.41	425.73	4.67
C	9.	National financial trusts for financing innovative firms	188.46	186.55	1.92
A	1.	Public-owned industries	221.50	226.48	–4.99
C	4.	TT centres and programmes (partially nationally publicly financed)	212.55	219.25	–6.70
C	3.	Regional technological parks and centres	466.60	473.54	–6.94
B	1.	Privatization of public industries	187.99	199.71	–11.72
A	2.	Subsidies to strategic private industries	121.70	140.53	–18.83
A	3.	National agencies of sectoral industrial plans	177.96	197.49	–19.53
B	3.	Liberalization and MNE attraction	331.03	352.41	–21.39
B	2.	Market deregulation	184.86	208.67	–23.81
D	8.	RIS (regional innovation system)	424.57	450.51	–25.94
A	5.	Regional offices of national agencies or departments	150.12	184.43	–34.31
D	7.	Local stakeholders coordination tables	168.81	207.85	–39.04

Table 10.6 Matrix INT: comparison of two extreme cases *continued*

Policy-making model		*Instruments of innovation policy*	*Case 1: Science based ind. -Schumpeterian firms – High tech clusters*	*Case 2: Traditional industries–Marginal firms – Economic lagging regions*	*Difference of total scores*
D	10.	Regional innovative start-up funds	276.63	316.49	–39.86
B	5.	Private professional services	210.16	251.15	–40.99
A	6.	Public demand and fiscal incentives	108.50	151.40	–42.90
D	6.	Regional/local development agencies	193.32	243.95	–50.64
C	2.	Territorial pacts with local actors	232.10	284.85	–52.75
B	10.	Public information and benchmarking centres	365.41	420.01	–54.60
D	3.	Business Innovation Centres and Innovation Relay Centres	301.84	363.70	-61.86
C	6.	Professional continuous education centres	315.50	387.92	–72.43
D	1.	Cooperative research projects between SMEs (CRAFT)	327.19	408.41	–81.22
C	1.	Strategic planning contracts with large firms	227.04	328.71	–101.67
D	4.	TT centres of industry associations and chambers of commerce	274.71	385.46	–110.75
		Total	11700	11700	0

enhance the development of ‘tacit knowledge’ and of interactive learning processes between the various SME and local stakeholders, such as:

- TT centres of industry associations and chambers of commerce
- Strategic planning contracts with large firms
- Cooperative research projects between SME (CRAFT)
- Professional continuous education centres
- Business Innovation Centres (BIC) and Innovation Relay Centres (IRC)
- Public information and benchmarking centres
- Territorial pacts with local actors
- Regional/local development agencies
- Public demand and fiscal incentives
- Private professional services

In particular, when the instruments of the four specific policy models described in Table 10.5 are considered, Table 10.6 indicates that they have a different relevance in the two extreme policy case studies. Case study 1, characterized by most technologically advanced industries, firms and regions, emphasizes the role of large public R&D institutions and private venture capital. In contrast, case study 2, characterized by the less technologically advanced industries, firms and regions, emphasizes the role of TT centres, programmes and RIS.

That may be interpreted as indicating that an appropriate combination of the 'government' and 'market' approaches may be more appropriate for the more advanced case study 1, and that the 'governance 1' and 'governance 2' approaches seem to be more appropriate for the less advanced case study 2.

Conclusion

This chapter serves to present a model of a Matrix INT (Instruments and Needs of Technology) characterized by a high flexibility capable of considering different types of regions, industries and firms. It represents a new method of evaluation similar to the multi-criteria analysis usually adopted in the choice of investment projects or in environment evaluation. According to this approach, policy-making processes should be structured into the following phases:

a) the identification of different dimensions of industries, firms and regions to be considered in a specific case study,
b) the identification of prior needs related to specific obstacles to innovation according to these three perspectives,
c) the selection of a complex set of complementary instruments most effective with respect to the identified needs.

The model of Matrix INT indicates complementarities and trade-offs between different instruments in innovation policy, as these latter have a different priority in various industries, firms and regions. On the other hand, each problem may be tackled by different types of innovation instruments and intermediaries, which are characterized by various degrees of effectiveness. Thus, the two major characteristics of the model 'Matrix INT' are:

- the adoption of a 'demand led' rather than a 'supply push' approach. That has led to focusing the analysis on the characteristics and needs

of innovation by various regions, sectors and firms rather than on the survey of potentials and problems of existing TT intermediaries;
- the identification of an intermediate step in the relationship between the analysis of characteristics of specific countries and the design of innovation policy instruments. That has led to focusing on the relationships between the specific needs ('demand') of various industries/technologies, firms and regions and the relative effectiveness of the types of innovation policy instruments ('supply').

The choice of TT intermediaries and innovation policy instruments is often made on the basis of subjective preferences of policy-makers or based on actual interests of already existing TT intermediaries in the region or country considered. That seems a less efficient approach than that indicated by the Matrix INT, which allows a choice of the most appropriate policy instruments by considering three complementary dimensions (types of industry/technology, firm and region), a large set of needs related to these dimensions and finally a diversified set of complementary policy instruments. Moreover, the 'Matrix INT' indicates a methodological framework suitable in an international comparative perspective. It may be useful in empirical studies and operative projects to carry it out jointly within international research and policy networks, aiming to elaborate comparative analysis and to identify specific benchmarks. This methodological framework will help in evaluating the gap between the characteristics of demand and supply of TT services to SME in a wide international selection of countries. It may also be used for the definition and the implementation of pilot projects to be elaborated in the framework of international cooperation. For example the model of 'Matrix INT' could be adopted as:

(a) a methodology for collecting statistical information on innovation factors,
(b) a methodology for defining a coherent set of priorities in policy-making,
(c) a methodology for the ex ante evaluation of the most appropriate policy instruments in innovation policies,
(d) a methodology for comparative analysis of the success or failures of given innovation policy instruments in various countries, or
(e) a methodology for comparative analysis of innovation problems and needs in various countries.

It must be underlined that the model of 'Matrix INT' does not propose a recipe, but a methodology that has to be handled with care and adapted to specific circumstances and problems. It does not indicate a unique best solution for many heterogeneous cases, but rather helps policy-makers to disentangle the various dimensions, variables and parameters to be considered and estimated.

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Part III

Academia–Business Linkages and the Regional Dimension

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11

The Territorial Development of Innovation Support Assets through University–Business Interactions: Towards a Dynamic Model

Paul Benneworth and Stuart Dawley

> There was at the turn of the 1980s a watershed in the history of technology transfer in the universities of the United States and in Western Europe … What is occurring is not only an increase in the volume of activity, but a transformation of the practice of technology transfer itself … It cannot be any more understood as a transmission of knowledge from the university to the receiver easily and usually with almost no follow-up … Technology transfer looks more like a game of soccer in which the university is a member of the team. (Gibbons *et al*. 1994, p. 87)

Introduction

We live in an age when learning, innovation and knowledge have become key drivers of economic development, and the institutions associated with promoting those attributes are regarded as vital to ensuring sustainable economic success (Robertson 1999; Cooke 2002; MacKinnon *et al*. 2002). This generally accepted belief is founded upon a wide range of examples of regions and economies where high levels of connectivity between universities, government laboratories, innovation agencies and firms have been associated with successful regional economic performance (Angel 1994; Storper and Salais 1997; Saxenian 2000; Wicksteed 2000). Intuitively, universities seem ideally placed to play a coordinating role within these knowledge networks, as their teaching and research activities have great potential for engendering and supporting innovation, learning and knowledge-promotion activities.

Recently, however, concern has been raised over the gulf between studies concentrating on highlighting these specific cases and those papers and commentators arguing that university–business interactions (UBI) *drive* territorial development. Uncritical readings of these relationships have given rise to what Autio (1997) called the 'growth myopia', in which a limited number of atypical high-science-content, high-economic-benefit and high-profile case studies have obscured and overshadowed the mundane reality of the majority of UBI (Benneworth 2003). Reading off from these exemplar cases to less successful situations presents an unrealistic set of expectations about UBI, how they operate and what they can reasonably achieve. In particular, there is a concern that specific activities might not always produce the more general improvements in competitiveness and productivity.

The importance of UBI is not without foundation, and it is accepted that UBI do have a vital role to play, rationalized at a number of scales. At a macro-level, some writers have argued that the type of knowledge required by businesses and governments has recently undergone a significant shift, and the most effective institutions are those best positioned to participate in these new modes of knowledge production (Gibbons *et al*. 1994; Etzkowitz and Leyesdorff 2000). At a meso-scale, the regional innovation systems literature has stressed universities' roles in engendering and supporting particular types of learning behaviours, whilst evolutionary economists have highlighted universities' roles in creating territorial collective assets (Maskell and Malmberg 1999; Cooke 2002). At a micro-scale, writers such as Jones-Evans *et al*. (1999) and van der Sijde *et al*. (2002) have taxonomized the particular activities in universities, that make knowledge more accessible to local businesses.

These frameworks do not directly address the issue of the growth myopia to examine how micro-level activities can be reconciled with the more systemic (meso- or micro-)shifts on which more general acceptance of the value of UBI is predicted. Addressing this problem necessitates building understandings based on a broader set of examples to analyze the processes by which 'particular activities' are translated into 'territorial collective learning assets' (Lawson and Lorenz 1999; Maskell and Malmberg 1999). In this chapter, we make sense of the way universities and firms together create innovation support assets, which can be used by a wider set of actors not involved in the original collaborative activity. We regard this asset creation in terms of 'densifying the techno-economic network (TEN)', i.e. providing enduring collective/territorial (meso-scale) innovation assets (Fontes and

Coombes 2001). This suggests a heuristic process model, whereas local businesses demand innovation support services from universities, which stimulates the universities to offer particular services on a one-off basis. The process of offering the service involves effort and learning, which in turn allows the universities to offer their services more easily to others.

In this chapter, we look at the micro-dynamics of this 'densification' process in one particular type of UBI, firm-based innovation. We report a set of findings drawn from a small study, which was concerned with all sources of innovation business advice for small firms in the North East of England. We consider the different ways in which firms work with universities in their innovation processes to sketch out a 'densification process'. We then argue that densification is a long-term process, initiated by highly sophisticated firms, but then carried forward as universities collaborate with less sophisticated innovators; the nature of particular innovation support services qualitatively changes as they become accessible to more firms, and capacity to effect substantive change is built up. We conclude by reflecting on whether densification as a process is sufficient under certain circumstances to be considered a significant improvement in the meso-scale regional innovation system (RIS). We begin by outlining the various approaches to making sense of UBI at a micro-scale.

UBI: from transactions to relationships

The micro-scale of UBI involves particular transactions between firms and universities with much recent academic debate focusing upon the responsiveness of universities to their clients' particular needs (Jones Evans *et al*. 1999; Martin and Scott 2000; Oakey *et al*. 2002). These various approaches are all micro-scale in the sense that they focus on the specificities of the particular transaction, and conceptually create a direct link between the activity and a particular set of outputs (e.g. van der Sijde *et al*. 2002). Although useful for mapping and quantifying particular situations, this offers no immediate bridge to understanding how the particular activities correspond to more systemic changes (at the meso-scale). This general problem of whether a micro-set of activities empirically demonstrates a broader systemic phenomenon is neatly exemplified in van der Sijde *et al*. (2002). They note that the University of Twente's spin-off programme created 920 jobs in 216 firms in the first sixteen years of its life (1983–98). At that time, Overijssel Province had around 330,000 employees (1996), so it is hard to argue that that programme – representing only 0.3% of all jobs in the province – has involved a significant systemic change (and indeed van der Sijde *et al*. held back from making such a claim).

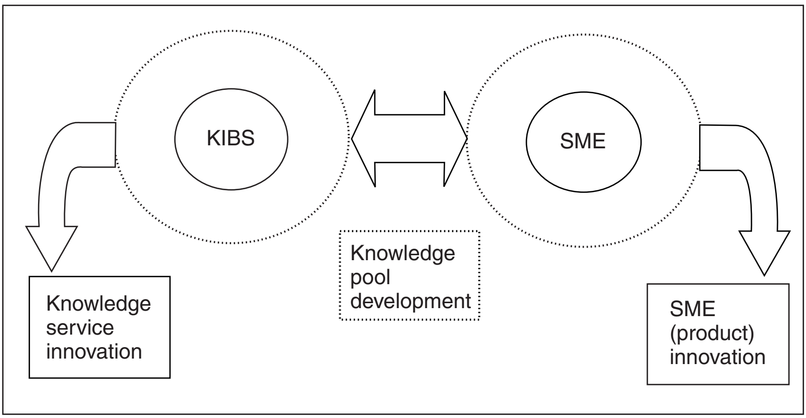
There is clearly an issue here of how it is possible to argue that meso-level changes have taken place (i.e. that activities are of regional benefit) on the basis of a set of micro-scale activities and outcomes. In the universities literature, this question has been finessed to a degree by arguing that universities have broader impacts on the socio-economic and cultural systems in their regions, which are transmitted through, but not contained by, particular activities and interactions (Robertson 1999; Valimaa 1999). An alternative way to bridge between the meso- and the micro-scales is to look at what endures in relationships between particular (micro-scale) transactions, and then consider if these enduring features can be regarded as territorially embedded (i.e. significant at a meso-level). In this way, the sum of territorial assets increases, which can be regarded as a net territorial (meso-)development.

Universities' capacities build up over time in ways that can be regarded as institutionally if not territorially embedded. Heydebreck *et al*. (2000) argue that as a consequence of this, universities have 'service bundles' of latent capacity which are partially activated in response to specific demands (p. 94). Benneworth (2001) extends this idea of a relationship to offer taxonomies of the different types of UBI which can co-exist in a single relationship between individuals in universities and firms. Each transaction in that relationship involves the requirement that partners share common interests in the transaction, even though the way each party regards the transaction may be very different. This necessitates a framework for understanding how particular learning transactions evolve into these enduring partnerships, in particular given that universities and firms do not always appear to have overlapping interests.

We argue that the knowledge-intensive business services (KIBS) literature provides a useful insight in understanding how relationships with very divergent benefits for various parties can act both as a solid basis for collaboration, and through these collaborations to yield more generalizable territorial assets. Wood (2002), for example, considers how technical consultancies build problem-solving knowledge which they sell to client firms, and which complement the client firms' greater technical expertise (cf. Creplet *et al*. 2001). Muller and Zenker (2001) argue that what happens in consultancy transactions is that both consultancy and client firm are each involved in their own innovation problem; clients solve their own problems, whilst the consultancy firm innovate in the field of 'profitably solving others' problems'.

Muller and Zenker argue that this dual interactive innovation represents a process of *co-evolution*; each party to the transaction gains a benefit from that relationship which directly furthers their own innovation needs. This relationship is thus a hybrid asset, which offers benefits to each party, and can be considered to exist in its own right. One way to conceptualize the relationship as a material asset is as a knowledge pool shared between the two parties. Because of the importance of tacit knowledge and interpersonal interaction to the relationship, there is a strong territoriality to these shared knowledge pools, and KIBS activity is important in the creation of region-specific economic development assets (Bryson *et al*. 1997). This process of co-evolution is shown in Figure 11.1.

University research, commercialization and technology transfer are by all reasonable measures knowledge-intensive business services in their own right (Wood 2002). This suggests value in focusing on the shared knowledge pools created when universities and firms work together to solve their innovation problems. Our hypothesis is that this co-evolution process produces shared, tacit and regional-specific knowledge pools. We can test this hypothesis by examining whether other firms can access this knowledge pool to solve their innovation



Source: Modified from E. Muller and A. Zenker, 'Business Services as Actors of Knowledge Transformation', *Research Plan,* 9, 2001, pp, 1501–16, with the permission of Elsevier.
Figure 11.1 The dual innovation spin-off loop in knowledge-intensive business services

problems (a spillover benefit). Although the benefits that each group derive from the particular relationship may differ, all parties (universities, initiator firms, successor firms) yield these benefits by accessing this co-evolved knowledge pool. Our argument is that territorial benefits arise because the spillovers allow subsequent firms to use the shared knowledge in the pool to meet their own innovation needs without replicating the sunk costs of the initial collaboration. From this review of UBI, we propose a three-stage conceptual process, which provides a basis for analyzing whether particular activities are densifying the TEN:

1. first, advanced firms work with universities, which also creates a shared knowledge pool,
2. less advanced firms work with universities, and this allows them to access the knowledge pool, then
3. the less advanced firms use the assets to innovate more effectively.

We focus our research on one group of firms who derive particular value from spillover knowledge, small and medium sized enterprises (SME). We now turn to examine the distinctive innovation requirements of SME, particularly in those regions with sparse TEN, where it is problematic to assume that all UBI follow the exemplar high-technology/high-growth models.

SME and innovation in less successful regions

In this chapter, our focus is on SME in less successful regions, for two reasons. First, SME have distinct innovation needs, involving a need to access external resources to reduce their vulnerability whilst innovating because of the uncertainty inherent in innovation. Kaufmann and Tödtling (2001) argue that the absence of particular resources in SME leaves them overly reactive to external changes. Martin and Scott (2000) highlight that SME are therefore more exposed to the risks of innovation, as they are often involved in fewer projects, and the failure of any one project is potentially disastrous for them.

These distinctive features of SME can be characterized as encouraging an *incremental* rather than a *rational-synoptic* approach to innovation (Simon 1945). A rational-synoptic approach is one in which each stage of the innovation process involves dispassionate evaluation of progress, only permitting the project to continue if it contributes to meeting the firm's technical, financial and commercial needs. By contrast, an incremental approach to innovation is one in which the future costs and benefits of innovation are not considered, with any kind of success the paramount goal. Even in very large firms, strategic projects can become subject to incremental innovation when they are deemed too important to be allowed to fail. One reason that this situation prevails in SME is that the firm lacks sufficient resources to have alternative strategies open if the development project fails, driving the pursuit of success over more rational evaluation (Jones and Stevens 1999).

Secondly, we focus on SME in a *peripheral region*, as these types of external resources which SME require are less likely to be present and easily accessible in less successful regions. Moreover, SME tend to be significant in shaping university responses only in sparse innovation environments, which largely correspond to less successful regions (Gomes-Cassares 1997). Fontes and Coombes (2001) argue that SME tend only to drive technological change where the resources they require are not already available, meaning in this case universities, which are not well-focused on meeting the needs of SME.

In resource-rich environments (dense TEN), there are fewer incentives for SME to expend effort in helping universities to be more open, because universities already tend to be adept at interacting with firms (i.e. the TEN is already dense). In the absence of these resources, however, SME can be central in encouraging public R&D institutions to increase their support for local businesses. Fontes and Coombes argue that high-technology SME are potential sources of expertise in 'adapting external technology for local use'. This provides a basis for a common knowledge pool between SME and public R&D institutions, helping those institutions to be more accessible to SME whilst at the same time shaping the universities' expertise (Nightingale 1998). By increasing the openness of universities, SME make it easier for other firms to access those resources, and improve the expertise of the university in working with other SME. These distinct requirements provide a conceptual framework for directly examining the emergence of the territorial shared knowledge pool, which UBI create. Knowledge pool assets are reusable at a lower cost than the original interactions, giving more choices to more SME, and reducing the pressure to act incrementally, which a lack of resources and choices engenders. Our hypothesis is, therefore, that in opening up universities to working more easily with SME, this activity makes it easier for other, less effective innovators to access the universities.

In this research, we are concerned with trying to understand the way in which firms and universities work together, the way this produces 'knowledge pools' (Gordon and McCann 2000) and whether others can access those pools to achieve the general benefits we highlighted at the start of the chapter. Our focus is purely on the dynamics of the assets created in the universities, and whether or not there is a recurrence, which allows more SME to access those assets. This in turn suggests three research questions, which this chapter explores:

1. How can we characterize the different ways in which firms work with universities in creating regional learning assets?
2. Is this a fair hypothesis and model of the 'densification process' for less successful regions?
3. What are the implications of this for the management of UBI?

Towards an operational methodology for examining knowledge pool formation

Our approach in addressing these questions is to look at how firms and universities have worked together, the creation of assets within universities, and whether the knowledge pool assets have a broader territorial scope than the original participants. From this, we consider whether particular firms' working with universities has made it easier for more firms to work with universities. In this research, although the ultimate subject is the territorial knowledge pool, we principally use the hypothesis developed above to look at how universities use these relationships and assets to improve their performance (i.e. increase their openness to 'firms').

Our argument above may be taken as an assertion that there is a simple dichotomy in approaches to innovation, between rational and incremental styles. However, we argue that this distinction obscures more general differences in the way in which firms undertake (and manage) innovation. We have, elsewhere, developed what we call the 'sophistication approach' for classifying firms' capacity for innovation management (Charles *et al*. 1998; Benneworth and Charles 2001; Benneworth and Charles 2002). We classify firms on the basis of three innovation variables: performance (how successful the firm was at innovation), practice (the systems the firms had in place to innovate) and self-awareness (the extent to which the firm thought about innovation in terms of broader business goals). Although some poor innovators may be lucky and succeed once in reaping some rewards from it, in the absence of effective management practices and systems, successes are rarely repeatable. The sophistication classification is based on four levels, whose main characteristics are:

- *Novice:* these are the firms with no systematic conception of innovation management and its relationship to other business processes in the firm;
- *Inexperienced/intermediate:* these are firms who have systems in place for innovation management but these systems are off-the-shelf and not necessarily well-developed for the company;
- *Experienced:* these are the firms who have tailored and matched their innovation management systems and company innovation culture, with the result that most innovation projects are successful;
- *Expert:* these are the acknowledged masters of innovation, and have managed to eliminate unnecessary barriers between working groups, whose teams reflect the products, services and techniques they are developing, and who actually improve the innovation management capacity of those with whom they work.

As improvements in sophistication correlate strongly with improved firm performance, one approach to the research might be to examine the way that firms use these collective territorial assets to move between levels, to improve their own sophistication (cf. Charles *et al.* 1998; Benneworth and Charles 2001; Benneworth and Charles 2002). However, in this research we are concerned with the converse of this – how universities use the knowledge pool to increase their effectiveness at working with firms, which we argue corresponds to a densification of the TEN.

Research method, analytic approach and study background

The method for the research involved semi-structured interviews with firms and those from whom they took advice to help in solving their innovation problems. The research was retrospective. In the firm interviews, firms were asked about what they had done in particular innovation projects, and how particular sources of advice had been used in solving the problems they faced in innovating. In the adviser interviews, the advisers were asked about their general expertise, and how working with particular clients in the sample had influenced the way they provided their sample.

Following Muller and Zenker's model (2001), each type of interview focused on the specific innovations and relationships in which the interviewees had been involved, to construct an understanding of the particular localized knowledge pool created through the UBI. The analysis involved three steps to investigate how particular transactions became institutionally and territorially embedded as general knowledge pools interaction between the relationships and the territorial asset:

- segmenting the firms according to firm sophistication level,
- analyzing differential uptake of the knowledge pool by firm sophistication level, and
- analyzing differential contribution to the knowledge pool by firm sophistication level.

The fieldwork involved interviews with 26 companies and 17 other advisers (including universities), with 43 interviews undertaken with a total of 48 interviewees between March and July 2002. The interviews were all undertaken within Tyne and Wear in the North East of England. The mix of interviews was divided thus:

- 26 interviews with innovating SME,
- 4 interviews with private sector business support providers,
- 6 interviews with public sectors support organizations, and
- 7 interviews with not-for-profit organizations (universities, enterprise agencies).

We chose the North East of England because of its economic situation as a less favoured region. The North East is the poorest and least populated of the English regions, although Tyne and Wear (the study location) is the richest of its sub-regions, at 82 per cent of UK average GDP (1998). Although the region has a high level of manufacturing, Tyne and Wear is predominantly a service-led economy, with only 18 per cent of employment in manufacturing, 15 per cent in business services, and 28 per cent working in public sector service provision. Much employment in the private service sector is in business service back-offices, call centres and customer relationship management activities.

Tables 11.1 to 11.3 provide some details of the sample, drawn up from companies which had sought public sector support for their innovation. Consequently, the sample does not reflect the business structure of the region, with a predominance of manufacturing companies and a relatively high number of spin-off firms (Table 11.2). We also classified the firms according to their innovation sophistication, and that classification is shown in Table 11.3.

The impact of firm sophistication on UBI

The first stage of the analysis involves looking at the direct provision of innovation support to SME from the universities, and how firms used that support in solving their innovation problems. In this first cut analysis, we focus predominantly on the firms and how they worked

Table 11.1 Size and formation date of firms interviewed in the sample

Description (employees)	*Firms*	*Formation date*	*Firms*
Micro-businesses (1–10)	16	Before 1988	4
Mini-businesses (11–30)	6	1988–1992	3
Small (31–50)	2	1993–1997	5
Small/medium (51–100)	2	1998–2002	14

Table 11.2 Reasons for the company's formation and company sector

Description	*Firms*	*Sector*	*Firms*
Liquidation bankruptcy spin-off	7	Engineering, R&D/architecture	6
'Intrapreneurial' start-up	5	Web design and computer services	5
Technology based start-up	5	Analytic software design	4
Professional services start-up	3	Light engineering & manufacturing	4
Hostile spin-off	3	Plastics, chemicals, pharma/biotech	4
Other	3	Retail	2
		Construction	1

Table 11.3 Number of firms at each sophistication level in the sample

Sophistication level	*Number of firms*	*Certain*
Novice	11	9 (81%)
Inexperienced	9	8 (89%)
Experienced	5	5 (100%)
Expert	1	1 (100%)
Total	26	23 (88%)

with the universities, segmented by sophistication level. This corresponds to how the firms *drew on the existing knowledge pool*.

Positive outcomes from novice firms

Although the eleven novice firms all found innovation exceptionally difficult, it should be stressed that the research covered only firms that were actively involved – sometimes unsuccessfully – in innovating. In the research, we identified that these firms faced four main barriers in innovating, which drove them towards an incremental approach to innovation (Benneworth and Dawley 2003). These four problems were a lack of time to consolidate ideas into products, a lack of credibility to champion radical changes to users, over-reliance on systems designed for large firm environments, and a lack of skill in winning finance for innovation. These problems are all very significant barriers to innovation, and, consequently, those firms required fundamental solutions to their problems, which were frequently so broad that UBI and knowledge pool assets were insufficient to meet their needs.

A characteristic of those novice innovators was their very diverse approach to accepting advice and support, which frequently did not conform to the models the advice providers had for the way their services should be used. Table 11.4 shows the diversity of the sources of advice which the 11 innovators in the sample used to address their innovation problems, and the infrequency with which they worked with universities is notable.

Even where universities had activities in place to encourage firms to draw on their expertise (such as placement programmes), novice innovators were not in a position to appreciate the value of the work, such were the breadth of their problems. Indeed, small packages of technical consultancy provided by universities were insufficient to provide them with a significantly greater number of choices, which would have enabled them to adopt a more rational approach to innovation.

Although comparatively few of the novice firms had relationships with universities, their relationships were qualitatively different from firms at other experience levels. Although a number of the firms (5 of 11) reported seeking advice from universities, their experiences tended to be predominantly negative, citing the long lead times for building collaborations and their lack of significance as SME to the university.

This lack of skill in accessing university services corresponded to firms being relatively reactive when approached by universities interested in working with them on particular activities. A number of the firms had contacts in particular universities, some of which were

Table 11.4 Range of innovation support organizations used by novice innovators

Public institutions	*Private organizations*	*Inanimate advice*
• The BIC	• Accountant	• Self-help books
• DTI (Victoria Street)	• Commercial lawyer	
• Small Business Service	• Patent lawyer	• Marketing tapes
• TPUK	• Suppliers	
• RSC	• Customers	• *The Times*
• Project North East	• Spouse/partner	
• Entrust	• 'Someone at the golf club'	• BL brochures
• Universities	• Cluster partners	
• Colleges	• Indep. financial advisor	• BL brochure
• 'A Civil Servant'	• Previous employer	
• Business Link	• Parent company	

Source: Firm interviews.

leading in the fields of research in which they were involved. Just as the novice firms were weak at articulating their service needs, they were also weak at shaping collaborative projects so the common interests served their own needs. Firms were typically approached by universities rather than vice versa.

Positive outcomes from inexperienced firms

The nine inexperienced firms can be characterized as much more stable innovators, and, consequently, the innovation problems they faced were far less totalizing than those faced by the novice firms. More generally, the research found that the inexperienced firms faced the same issues as novice firms – constrained finance, a lack of time, and being reactive to their partners (Benneworth and Dawley, 2003). However, these problems were manifested in qualitatively different ways for inexperienced firms; when the firms used university services to meet particular needs – finite element analysis, rapid prototyping, health and safety consultancy were listed by three firms – they were relatively skilled in using them effectively. The distinguishing feature between novice and inexperienced firms was that the inexperienced firms clearly interacted with universities through a reciprocal relationship.

In contrast to novice firms, the inexperienced firms were far more involved with universities, and had more intense relationships with those university collaborators. Table 11.5 outlines this, with inexperienced firms typically involved in universities in a range of ways, but also more selectively as part of a more strategic approach to building external linkages.

Table 11.5 Participation of inexperienced firms in particular forms of mutual innovation support activity

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Cluster activity		√							√
University	√	√	√				√	√	
Incubator unit	√	√	√	√				√	
Informal networks	√	√		√	√	√	√		√
Smart award winners		√	√					√	

Source: Firm interviews.

What Table 11.5 cannot show, was that in contrast to the novice firms, this selectivity constructively increased the technological and commercial opportunities that the relationships opened to the firm. In two cases, the firms had sourced technical services from dedicated university business service centres. Two of the nine firms were also involved with local universities as partners on EU (R&D) Framework Programme consortia, alongside a third firm which managed two thematic networks. These programmes provided access to the local universities (and the research funds), which was an important mechanism for the firms to develop their technology portfolios and help them to prioritize the development of particular products.

Finally, a number of the firms were developing relationships with universities in ways which were of direct benefit to themselves, increasing their technological and organizational options. When it was successful, the opportunities, that the relationship provided allowed the firms to be more selective about particular technological avenues they pursued and to choose projects that fitted best with their technological trajectory. Although two of them used services provided by university centres, which packaged services for SME, the two firms had not simply absorbed the service. Five firms reported – like the novice firms – that using universities was a long-term and tricky business, but they were more effective at accepting and dealing with the universities' time scales. However, not all relationships led to successful transactions or projects, and with inexperienced innovators, relationships were still to a degree underpinned by the timely availability of funding.

Positive outcomes from experienced firms

The difference between inexperienced and experienced firms was that the five experienced firms had begun to stabilize their innovation processes so that a number of the constraints faced by innovating SME were less applicable to their particular situations. All five of the experienced firms in the sample had been created as spin-off companies, in which the parent company had effectively incubated the assets from which the novel company had been created, but leaving a footprint from the culture of the large firm within the spin-off. A key element of the innovation process related to culture, taking a core group of staff from a parent company and placing them in a new business, and retaining their expertise without replicating the faults of the old company (and avoiding reliance on assets only available in large firms, such as steady finance).

As part of this, all the firms had close relationships with universities, and although the universities did well out of those relationships, the universities were undoubtedly important to the firms. The firms cited the relative inexpensiveness and independence of universities as central to what they could offer. Four of the five firms had very close relationships with the universities, each involving an overlapping mix of studentships, research programmes, placements, sabbaticals, and consultancy work. One firm specifically mentioned that the universities were favoured because they were a 'leveraged resource' (i.e. cheap), whilst others noted that universities were important because there were few other significant technological collaborators in the North East. The firms appreciated that the relationships built up over time, and required conditioning the universities to meet their needs and timescales. Indeed, one of the five firms initially had had a bad experience with a university collaboration, but they persevered and developed it into the most intense of the UBI.

Each firm had two sorts of relationships with universities, and the experienced firms were aware that they did segment those relationships to keep the two sets of transactions involved separate. The first type of relationships was speculative/discursive, when they would discuss future trends, technological developments and the needs of the universities as customers; these relationships were typically low-cost and evolutionary. The second type of relationships was consultancy, when the firms used universities to answer particular problems, which involved the high headline cash figures cited below. Interestingly, and in contrast to the less experienced firms, the experienced firms were effective at separating the two types of relationship even with a single member of academic staff to ensure that the relationship created benefits for the firm, as well as for the academic. The most obvious way in which this happened was their contribution to the universities. The benefit to two of the university departments with which experienced firms were working could be estimated at

£100,000 annually, and that of a third at £40,000. However, the benefits were not purely financial, and the universities benefited in numerous ways, and these benefits are shown in Table 11.6.

Characteristic of the experienced firms was that they were in a position to be constructively critical of the universities' expertise in supporting their innovation activity. Two of the five firms argued that their partner academic departments did not have the skills to innovate in a commercial environment. Indeed, those two firms themselves had to expend significant effort in ensuring that the universities could deliver useful consultancy services. Thus, although the firms knew they wanted to become world-class, and wanted to use the expertise in their partner universities to achieve that ambition, the universities were not always able to provide the appropriate support. By working directly with the universities, the experienced innovators did also contribute greatly to the creation of shared activities, which might in some way correspond to the concept of densifying the TEN.

Positive outcome from expert firms

There is a problem in this research in terms of the expert firms, because in contrast to previous research projects, we were only able to identify one of the firms as 'expert'. Although four of the five experienced firms had expert characteristics, only one of the 26 firms in the sample was unambiguously expert in all relevant areas. It therefore becomes very difficult to talk about expert firms in the generic sense. In the context of the research project, it is also problematic that the one expert firm that we did interview had developed incredibly well-formed links with universities. In many ways, our expert firm did resemble the experienced firms, having close relationships with universities, having different types of interaction within a single relationship and mixing the university interactions with other types of interaction.

Table 11.6 Ways in which local universities benefited from their linkages to experienced innovators

Financial	*Organizational*	*Prestige*
Consultancy fees	Status of department within university	Industrial collaborator
Studentship fees	Dealing with succession of senior staff	Referee
Matched time	Undergraduate student placement	Reference site
Collaborative research income		Papers
		'Research excellence'

In the previous section, we argued that experienced firms established discursive and functional relationships with universities in ways that kept the respective relationships independent. The expert innovator also demonstrated both of those types of relationships with universities, alongside a third form, which is potentially more significant for the generation of shared knowledge assets. Whilst experienced innovators concentrated their involvement with the academic departments in which they had a mutual knowledge-generation interest, the expert innovator involved itself in the universities in a more strategic manner. The expert firm in our sample had taken this strategic set of relationships to its natural conclusions, and was involved with universities and the regional development agency at the highest level.

The innovation plan for the North East is centred around the creation of five flagship centres of research excellence organizationally situated between universities and firms (ONE 2001). The expert innovator had been closely involved in both the development of that policy and its implementation in one particular 'Centre of Excellence'. The articulated reason for the expert firm's engagement with the process was that they appreciated that a centre of excellence closely aligned with their commercial focus would represent a considerable future innovation asset for their business. Their involvement with the Strategy for Success (ONE 2001) had developed as a long-term process facilitated through the many close linkages which the firm had with a range of university departments across the region. In the later stages of the development of the 'Centre of Excellence' idea, the firm had focused its work with one university to ensure that their particular sector was represented as a centre of excellence, and the firm provided its industrial reputation to ensure that the centre was developed.

The firms' contribution to the universities' innovation processes

The first step of the analysis was to consider the way the firms worked with the universities in solving their innovation problems. However, following Muller and Zenker, our interest is in the co-evolutionary process, and so we also consider what the universities drew from the collaboration in terms of their own innovation processes. Just as consultancies are continually innovating in 'providing consultancy knowledge', universities have to innovate in the provision of commercialization services, which may involve profound organizational innovation within the university, alongside the development of particular technical services (Jones-Evans *et al*. 1999). Just as it is possible to examine what each class of firm got out of collaboration, it is also possible to consider what contribution each class of firm made to the universities' innovation process, and how the firms were able to shape what eventually emerged from the universities.

The expert firm provided a range of strategic and critical assets for the development of the centre of excellence. As a strategic partner, the firm gave the particular centre an entrepreneurial imprimatur, an important political asset in the context of the North East of England. By articulating a vision for a centre of excellence wider than their own immediate interests, they acted as a proxy market demand for other less sophisticated innovators. By already funding ongoing collaborative research with universities, the firm gave universities confidence in the idea of the centre of excellence. If we consider the centre of excellence as the territorial asset, then the expert firm helped to solidify the idea into a tangible asset and to populate it with capacities which firms could use to support their own innovation processes. The expert firm's contribution to the development of innovation services in this case is best characterized as being a *strategic adviser*.

If expert firms help KIBS in a strategic way, then the experienced firms behaved as the *laboratories* for the universities in developing their services. The experienced firms were all high-technology firms with a real interest in using the services and knowledge available as effectively as possible, and were adept at critically evaluating the available provision on the universities' behalf. The experienced firms possessed the capacity to handle long-term relationships with universities, allowing the universities to experimentally test ideas for new services, but also to build research and technological expertise in novel fields. Experienced customers were a good source of sophisticated demand, returning repeatedly to universities with new ideas and problems, providing the universities with a stable market for those ideas. Thirdly, experienced firms supported universities in developing knowledge in new domain fields, by providing interesting environments in which to experiment, develop and test new knowledge.

If the experienced firms were the laboratories for universities' innovation processes, then the inexperienced firms were the '*laboratory rats*' (i.e. predominantly recipients rather than shapers), not directly involved in developing new services, but as constructive users of the services from which the universities could learn. Where inexperienced firms were problematic was in actively articulating sensible feedback, as they did not always realize the full value of the services they received; if the service involved problem diagnosis, for example, this diagnosis provoked defensive rather than reflexive behaviour from some of the firms. Where inexperienced firms were effective was in providing minor inputs to programme development or small improvements to existing services. The real strength of the nine inexperienced firms was that they generally had the capacity to absorb routine services, and in doing that, had an (unselfconscious) understanding of how those services could be improved. Moreover, they provided a market for those services once they were being offered, and hence in aggregate (as a market) they helped to fund the ongoing development of those services. In supplying consultancy to the inexperienced firms, the university staff/centre also benefited through becoming more innovative and professional.

If the inexperienced firms can be likened to laboratory rats, then the novice firms were akin to '*mice waiting for crumbs*'. Whilst the inexperienced firms were at least able to contribute effectively to the development of innovation support services in a positive manner, fundamentally, the novice firms in our sample were willing to use any solution to solve any problem. A number of them had tried to use a particular innovation service to solve a problem for which it was totally unsuited, raising doubts over whether the failure was because the service was intrinsically faulty, or that the firms were just bad service users. There is a broader problem if novice firms are allowed to disrupt the development of new support services and activities by being involved too soon in the process; the research suggests that they are best introduced at the late stage of the pilot, or in small numbers during the prototyping stage.

As a first cut analysis, this suggests that for any innovation support good provided by a university, firms at different sophistication levels need to be involved at different stages of the university's innovation process (i.e. in which the university learns how to offer its expertise as commercial services), and also in very different ways. Whilst expert firms are most able to give the best feedback, as sophisticated innovators they are the best placed to manipulate the relationships to disproportionately benefit from the services. Conversely, whilst novice innovators might have the most to gain from completed services, early involvement might significantly hinder the development of the particular innovation support service. In Table 11.7 we provide a more complete taxonomy of this situation.

Table 11.7 Firms' contributions to universities' innovation process segmented by firm sophistication level

Level	*Time*	*Involvement in development*	*Service use*	*Mode of use*
Novice	At time of launch	Highlight problems in the operation of the services offered by the centre	Consuming	Passive: use solution
Intermediate	At prototype stage	nvolved as early Iusers igiving sensible feedback and limitations	Testing	Active: test potential solution
Experienced	During programme design	Involved as good consumer of services who can make sense of a new idea, at early stage; also, a source of active demand	Shaping	Active: use solution as element
Expert	At strategic programming point	Approached by university to sit on strategic body to design the university's strategy for commercialization	Strategic	Passive: shaping strategic environment

From co-evolution to densifying territorial collective assets

In this research, we have observed a limited number of situations which might correspond in some way to densifying the TEN of the North East of England. Certainly, particular university activities were developed in concert with more sophisticated innovators and used by less sophisticated innovators. This suggests that the co-evolutionary innovation between firms and universities could densify the TEN under certain circumstances. Given the small scale of the project, it is impossible to definitely assert that these changes are a significant improvement – that is, to say that these individual activities collectively add up to a systemic change. However, from this study, it is possible to at least sharpen up some of the issues which were ambiguous at the start of the research process.

The first issue relates to the second of our research questions, as to whether the three-stage densification process we advanced is a fair model, and the implications of this for our hypothesis that densification is demonstrated by increasing numbers of firms being able to access the capacities within particular knowledge pools. The three-stage model appears to be more conceptual than a (more powerful) direct model of what people actually do (Dosi 1988). We found no evidence that anyone developed particular support services in that way, consciously beginning by working with the most sophisticated innovators, stabilizing a product or service, and then diffusing and refining it in concert with sequences of less sophisticated innovators. What can be said is that the services themselves developed in that way, but that different actors were involved at different stages of the process without being consciously involved through the process.

This does raise the question of whether the model is a good territorial model; the territory is the container in which many of the actors are located, but the evidence that densification takes place at the meso-scale is more equivocal. This research does suggest that particular activities are manifestations of the broader sets of relationships within which are embedded more general territorial knowledge assets. Although we have not observed systemic effects at a meso-scale, what we have observed is networks materializing into assets with a greater durability than the ephemeral transactions. This at least partly corroborates the initial assumption that universities have broader impacts than the pure provision of particular services (Robertson 1999).

One enhancement of our understanding of universities' roles refers to the conclusion that it is not just the universities that are the bridge for the knowledge – the firms are also important in creating and sustaining the territorial knowledge pool, rather than just as sophisticated users of particular discrete services. The relationships were important, and this raises a question relating to how relationships differ from the 'networks' which are commonly accepted as underpinning and providing benefits within RIS (Cooke *et al.*, 1998). The relationships provide a coordinating function over time and between separate partners, which allow conceptual connections to be drawn between activities in different partners. Over time, this coordination creates interdependence between the partners (in this case the interacting universities and businesses) but also other capacities, which themselves can be the basis for other collaborations. In that sense, the relationship acts to incubate these capacities, which lie latent within the relationship until they can be brought together with material assets and realized in new forms of activity.

Although this finding does not directly help to answer the third question, relating to the development of university management policies to support innovation services, it does help in building a bridge between particular activities and the meso-scale of the RIS. It also has implications for our understanding of the institutional forms which exist to promote UBI; from this, we can derive insights into the third question asked in this chapter. If the direct transactions are only one element of the benefits which exist to be exploited, then the optimal institutional forms for universities will be those which promote interactions but also help to realize the value of the internal/latent capacities generated through the UBI. Van der Sijde *et al.* (2002) do not directly reflect on the additional capacity which the TOP programme has created within the University of Twente. However, they do note *en passant* that the TOP expertise has been codified and commercially exported to Spain and Portugal, as well as being used to win European Framework funding for further research work. This suggests a need to shift from examining the institutional framework for the transactions to understanding the broader linkages between new institutional forms and existing activities in the universities.

Concluding discussion: latency and enactment in UBI

In this chapter, we have been concerned with recent increasing interest in the relationship between universities and economic success, and to explore this issue have focused on one dimension of that relationship – how universities contribute to supporting innovative companies. In our research, we concentrated on SME because of the distinctive needs that SME have, and which if met by universities, in turn make the universities a better source of support for more firms. We argue that this means that improvement in universities' reach-out activities can be regarded as a meso-scale change as long as it can be demonstrated that new capacities have been created.

Our central finding relates to the issue of capacity and activities in universities. Particular activities take place and draw on capacities within universities, but not all capacities are necessarily used at any one point in time, and the 'service bundles' offered to firms by universities are pulled together from all the capacities that universities have. The capacities are generated, developed and expanded through interacting with particular key firms, and once expanded, are more widely available to other firms. A key point is that this capacity – being latent – is not always immediately obvious, so that having an activity is not sufficient for universities, and it is the capacities reflected in those activities that are important. In particular, the development of that capacity is important in terms of increasing the openness of the universities to firms at decreasing levels of sophistication. Thus, in terms of developing a nuanced understanding of novel institutions for promoting university commercialization, this research suggests that what is important is not the institutions themselves *per se*, but the capacity they represent. Following Martin and Scott (2000), particular institutional responses may be well evolved to the needs of users, but this does not necessarily mean that they can readily be transferred between situations. Moreover, universities may require multiple responses to ensure that firms at all sophistication levels can access the capacities within the universities; possible responses are suggested in Table 11.8.

Table 11.8 Types of 'response' required by universities to supply technology transfer opportunities for firms at each sophistication level

	Reason for dealing with university	*Development of relationship with university*	*How the university can facilitate relationship*
Expert	Shaping the university's strategic decisions to the firm's own benefit.	Strongly interpersonal at high level: e.g. between MD and VC.	A willingness to engage with local firms.
Experienced	Accessing complementary research activities and exploiting low overhead rates.	Personal trust in research capacity of department, contractual relationship controlling funds and IP.	An IP management framework that allows collaboration; academics given freedom to explore opportunities.
Inexperienced	Accessing external research funds to shore up own internal R&D activities.	Someone has a plan for a big research bid, and the firm is approached to take part.	A research contracts unit to pull together big partnership bids and ensure the university has a range of bids.
	Consultancy services	One-off service or membership of specialist unit	Specialist consultancy units.
Novice	Getting the advice and credibility of an expert in writing a funding bid.	Contact 'expert' in response to recommendation from friendly adviser.	Rewarding individuals who give ad hoc support to novices.

A second institutional dimension to this point is the way in which universities themselves improve their 'innovation sophistication'. Although none of the improvements such as the Centres of Excellence were consciously developed and managed as innovation projects, there appears to be scope for managing the creation of novel knowledge-brokerage institutions as innovation projects. Heydebreck *et al.* note that service bundles evolve, and there may well be capacity to rationally manage the innovation process to drive forward that innovation process within the universities. Table 11.7 above suggests the different stages at which it makes sense to involve firms as universities develop novel institutions for supporting firm-based innovation processes. If there is a genuine innovation process (as part of the co-evolution between firms and universities), then there may be value in exploring whether different types of institutions are differently sophisticated. This would suggest investigating the barriers that universities at different levels experience in innovating, and possible strategies for improving the sophistication levels of universities. Our main avenue for future research in this area is to examine at a micro-scale the innovation process by which universities create technology transfer activities, and how universities improve their capacity to create new support activities. This is heuristically a pleasing direction to pursue, to look at the most understudied and over-expected group in SME innovation research, that of the university partner.

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12

Regional Innovation System Barriers and the Rise of Boundary-Crossing Institutions

Phil Cooke

Introduction

Accounting data in Dunning (2000) show that we have entered a new phase of global economic development in which '*Knowledge Economies*' are the most significant centres of growth and dynamism (Cooke 2002a). It was easier to argue this in the years leading up to the ending of the ICT 'bubble' early in 2001 and many unethical sources for the inflating of that bubble have since been identified (Cassidy 2002; Fusaro and Miller 2002). Nevertheless, paradigmatic change transcends stock market booms and slumps, and the industries that underpin the Knowledge Economy are not limited to dot.com businesses. Far from it, the Knowledge Economy includes some traditional as well as high-technology engineering industry, and some rather traditional public service industries like healthcare and education as well as R&D and media. Knowledge-economy sectors such as those identified by OECD (1999) and modified slightly in EU (2002) and Cooke and De Laurentis (2002) show it is knowledge-intensive services that play the most significant role in the designation of knowledge economies.

Having displayed a definition of 'Knowledge Economies' at the beginning, the chapter then moves in the next section to a consideration of the implications of this quite significant emergence of a differently composed, 'stylized' regional economy for the economic development 'industry'. Especially in less favoured regions, many persons are employed in public or semi-public agencies the mission of which is to vitalize or revitalize regional economies that have slipped behind either their comparators or their previous performance. They have a perspective on the nature of their task, the problems they must face and the useful as well as useless policy instruments implemented in their governance areas or those of equivalent agencies elsewhere.

We will engage in a brief 'sense-making' exercise to illustrate the paradigms, frames and schemas that require adjustment for such bodies and their enterprise and innovation support teams to be able to move ahead in synchronization with the changed economic trajectories. Moreover, attention will be paid to instruments deployed for so doing. In exemplifying this, the focus will be on building *Regional Innovation Systems* (RIS), a now popular regional policy instrument, having been the subject of research in at least fifty empirical studies (see Cooke, Heidenreich and Braczyk 2003) and policy in a range of regional and inter-regional settings (e.g. Northern Ireland: Cooke, Roper and Wylie 2002; 2003, and the more than 100 EU regions listed in Landabaso 1997. Øresund is the first international RIS to be built: Törnqvist 2002). Finally, we will briefly explore five 'boundary-crossing' institutions and instruments that have been mobilized in diverse settings to aid integration of distinct communities of practice or 'epistemic communities' for economic development (Haas 1992; Brown and Duguid 2001). These are: (i) Regional Science Councils, (ii) 'Lighthouse' Projects, (iii) Intermediary Technology Institutes, (iv) Innovation Accelerator-Incubators, and (v) Arm's-length Venture Capital.

Evidence suggests that they are relatively easily brought into interface contact in RIS that were established already in the 'Industrial Age' but require significant readjustment faced with Knowledge Economies even in such accomplished settings. In less-favoured regions, Knowledge Economy requirements create great strains on often public-led economic restructuring agencies, and some evidence of such difficulties is presented. It seems a major task – familiar to those operating in developing countries – that arises because academics and consultants, particularly, offer a beguiling strategy to be aimed at but few or no mechanisms by means of which policy actions that will reliably terminate in strategic goals achievement or 'implementation of the vision' can be formulated (UNIDO 2002).

The knowledge economy and 'knowledge economies'

It is increasingly accepted that we have entered the 'Knowledge Economy' and that this is different from the 'Information Age' because it refers to specific assets that consist in knowledge of 'how to', 'who to' and 'what to' deploy to create value. It is an active economic practice rather than a passive information space, upon which it nevertheless depends, but in ways that express value through the scarcity of 'knowledgeable' expertise. Manuel Castells (1996) speaks of the knowledge economy being one in which productivity derives from the interaction of knowledge upon knowledge rather than upon raw materials. Nonetheless, it is wrong to dismiss traditional or 'old economy' economic activity as not belonging to the knowledge economy, as for example the OECD does. Rather we can also usefully speak of 'pure' and 'applied' knowledge economy activity. The first is captured in genomics, software and, for example, 'futures' or derivatives trading in financial services, or conceptual art. The second is in many other sectors that conduct or use R&D even though it is applied to, for example, food production, fashion design, or fire insurance.

A key reason for believing that a significant shift has occurred taking us into a Knowledge Economy is that data suggest this to be true. Thus, the book value of intangible assets compared to raw materials has shifted from 20:80 in the 1950s to 70:30 in the 1990s. It is now routine (and controversial) for firms to include the value of such intangibles as 'goodwill' in their balance sheets (Dunning 2000). A dot.com business had in early 2003 to reduce its balance sheet asset value by $30 billion because of the downturn in the value of the sector's 'goodwill' compared to during the boom. Goodwill in those times was associated fundamentally with being seen as inhabiting a knowledge-intensive sector of the economy. We have seen many other firms in the 'knowledge' or 'new economy' sectors having to reduce their book value because of the over-valuation of such intangibles as perceived from the bottom of the growth curve as distinct from the top.

It is important to say straightforwardly that the deployment of knowledge in economic affairs is not a new thing. Making a fire is clearly a knowledgeable and, in the deep past, powerful, knowledge-based skill, as the Prometheus myth testifies. Hunting, farming, smelting copper, bronze and iron, later steel, are knowledge-based activities. In turn this knowledge became the basis for science and its application in early industrial technology. From coal-mining grew coal tar production, the origin of the German dyestuffs industry whose aniline products led to branching into pharmacology, the (re-)discovery by the Bayer corporation of Aspirin and the birth of modern pharmaceuticals. This industry is now shifting from its synthetic chemistry origins into post-genomics and other variants of molecular biology and the science-based biotechnologies of the future.

In the process, this gives us a clue about the possible core differences between the contemporary and future knowledge economy compared to the era when Aspirin was first marketed, which is often referred to as the 'Industrial Age'. In the Industrial Age, industry was centrally concerned with the recovery from nature of raw materials that could be processed into usable products like textiles, steel, ships, drugs, and so on. To a large extent, the sources for these natural resources determined the location of industrial activity. Thus, Bayer is located at Leverkusen, across the Rhine from Cologne with its established university training and research skills, and a short train ride from the Ruhr coalfields. The location was thus good for high-skilled labour recruitment and an ideal transshipment point for raw material inputs (coal tar and other coal-derived chemicals) and finished product outputs up or down the Rhine and via the extensive railway network centred in the Ruhr–Rhine region.

To stay with Aspirin for a while, when Bayer chemists first processed it industrially, they thought to market it best as a fever treatment, not a painkiller, since it had shown in trials some success in that regard. It was only by chance that patients later reported its effectiveness as a painkiller and this led to refinement of its target market. Surprisingly, it was as late as the 1990s that its powers as a supplement with positive effects upon blood flow and value as a therapeutic in cardiac health were discovered. But, even more recently, certain negative effects upon young people have also been discovered for the tiny minority prone to Rea's disease, and its properties as a wonder drug have been slightly undermined. The reason for this diversion into the evolution of Aspirin and its uses is to emphasize the 'chance discovery' element that normally accompanied scientific and technological progress in the Industrial Age. Even though Bayer and other German chemicals companies pioneered the concept of the in-house central R&D labouratory, an idea taken up highly effectively by American corporations like Dupont, AT&T and General Electric, research was and remains expensive and somewhat 'hit-and-miss' under the chance discovery method. In 2003, it has been discovered that Aspirin is now thought to offer protection against a number of types of cancer.

As hinted already, OECD (1999) defined Knowledge Economies as 'high-tech manufacturing plus knowledge-intensive services' share of regional employment'. Using source data of the European Commission (2001) *Eurostat* report entitled *Regions: Statistical Yearbook 2001* at NUTS 2 level reveals significant differences between urbanized and economically less favoured regions (see, for detailed discussion of the methodology and results, Cooke and De Laurentis 2002). Three things may be said from these results with confidence regarding the tasks of development agencies faced with the Knowledge Economy. First, the strong Knowledge Economies may rely more or less comfortably on market forces to facilitate their adjustment. Contrariwise, the lowest-scoring regions must find ways to integrate their main economic sectors, tourism and agriculture, directly into the Knowledge Economy. Finally, those in the areas relatively close to the margin between Knowledge and Non-Knowledge Economies have the difficult task of adjusting trajectories set on a more 'Industrial Age' curve, even including a re-industrialization curve involving attraction of high-technology production through Foreign Direct Investment (FDI) – e.g. S.W. Scotland, Rhône-Alpes and S.E. Ireland, N. Ireland, Saxony, Upper Austria and Navarra – towards Knowledge Economies. It is these kinds of regional economy that much of the rest of this chapter focuses upon.

Sense-making regional innovation systems

In this section, we will first distinguish between two types of Regional Innovation System (RIS) that emerged from research such as that reported in Braczyk, Cooke and Heidenreich (1998), Cooke, Boekholt and Tödtling (2000) and Cooke, Heidenreich and Braczyk (2003). These are, respectively, Entrepreneurial, and Institutional RIS (ERIS and IRIS). A RIS consists of two sub-systems. The first is the '*Knowledge Generation*' sub-system. The second is the '*Knowledge Exploitation'* sub-system. Most regions, and many nations, have poor linkage between the two sub-systems. Where nations or regions have overcome this barrier, it is either because of the successful working of market mechanisms, set in an appropriate regulatory environment, classically in the USA, or because market failure is overcome by the establishment of state entities that directly or indirectly seek to straddle the 'exploration' to 'exploitation' divide. Regional development agencies (RDA) have often embarked on the second of these to integrate necessary knowledge flows, since the first option is emergent but not yet mature. Indeed, by comparison with leading RIS in the USA such as that of Greater Boston and Massachusetts, or San Diego and Silicon Valley in southern and northern California, most European regions are constrained to public intervention if regional innovation is to function systemically. Of course, a majority probably do not have meaningful RIS, something that contributes significantly to the much touted 'innovation gap' identified by the EU and others between Europe and the USA.

The key mechanisms facilitating the flow of knowledge, whether intra-regional, inter-regional or international, are knowledge itself, resources (particularly finance), and human capital. In strong market systems, venture capitalists that are proactive in seeking and assessing knowledge competences in laboratories are crucial links across the exploration/exploitation boundary (Kenney 2000). They are increasingly highly attuned to the nuances associated with specific, advanced fields of research, the 'star' scientists associated with leading-edge research, and risk assessment associated with its commercialization. In systems such as Silicon Valley, some scientists and engineers are highly attuned to stock markets, prospects for venture funding and initial public offerings (IPO). It is clear to see that the systemic nature of the likely interaction between scientific research, i.e. 'knowledge generation' (itself involving exploration and *examination* knowledge, the latter involving trial and testing competences), and innovation or 'knowledge exploitation' is massively assisted by these 'boundary crossing' competences. To that must be added the prevalence of 'academic entrepreneurs' managing a spinout firm while keeping an academic post in a nearby university, and receiving business management support from venture capital (VC). These and their staff convey knowledge of distinctive kinds across boundaries too, and the micro-system of the firm operates as a seamless web. But added value comes from the fact that VC invests in portfolios of proximate and non-proximate firms among which, at the inter-firm and inter-research centre levels, comparable knowledge transfer occurs both formally and informally. It is this network form, embedded in market transactions and some 'untraded interdependencies', that typifies the 'open systems architecture' of the ERIS (Dosi 1988; Best 2001).

Where ERIS are underdeveloped, perforce ambitious regional administrations develop institutions to facilitate comparable effects through establishing 'boundary crossing' institutions that may forge an 'Institutional Regional Innovation System' (IRIS). The most fully researched of these is Baden-Württemberg in Germany, for which detail can be found in Herrigel (1996) and Cooke and Morgan (1998). To be brief, the key 'boundary crossing' institutions are, for larger firms, the Fraunhofer Institutes, of which there are fourteen conducting applied research, and for smaller firms the Steinbeis Foundation, now numbering some three hundred transfer centres based in higher education institutes and innovation centres. Fraunhofer Institutes conduct publicly subsidized, industry-funded research to solve technological or managerial problems, assess technologies and conduct foresight activities. They bridge the basic research function of the fourteen Max-Planck Institutes and the ten universities across to the commercial application requirement from firms. Steinbeis provides a similar subsidized consultancy function for SME. Neither engages in spinout activity, which again is seen as an innovation centre or incubator function in science parks located close to universities. Assessment of this version of an IRIS is that it works well where technology and innovation tends to be path dependent rather than disruptive (the latter being more typical of the ERIS set-up), where institutions have grown incrementally to meet needs in an evolving but well-understood sectoral innovation system (in this case automotive engineering), and where specialized in-house expertise familiar with technology application work is in place.

Thus, at key points where epistemic communities like 'academic engineers', 'civil servants' and 'business managers' must communicate on policy-related matters there are 'boundary crossing' *buffers* like Fraunhofer Institutes, business associations and science park incubator centres that interpret among distinct communities of practice thus enabling (international) regional knowledge flow from *exploration* through *examination* to *exploitation* knowledge categories. But this sophisticated externalized 'knowledge management' system is itself an 'epistemic community' since it has, despite its professional divergences, an industrial convergence around automotive engineering, given it is a regional economy that is inordinately dependent on its star auto firms like Mercedes, Porsche and Audi, not to mention major suppliers like Bosch, ZF and ITT (Cooke and Morgan 1998):

> An epistemic community is a network of professionals with recognized expertise and competence in a particular domain and an authoritative claim to policy relevant knowledge within that domain or issue-area. (Haas 1992, p. 3)

> Presented with incomplete or ambiguous evidence, members of an epistemic community would draw similar interpretations and make similar policy conclusions. If consulted or placed in a policymaking position, they would offer similar advice. Unlike an interest group, confronted with anomalous data, they would retract their advice or suspend judgment. (Haas 1990, p. 55)

This has happened on many occasions in the past when efforts have been made to shift trajectory into new industries like multimedia, solar energy, sensors and biotechnology. Somehow, when one examines change in the Baden-Württemberg regional economy it tends to show the emergence of more knowledge-intensive software design and engineering, greater engineering consultancy and other knowledge-intensive business services activities closely related to automotive engineering as the shifts in question. Thus this *Land* finds it hard to elaborate industries outside the core 'epistemic community' despite, or perhaps because of, its highly refined IRIS.

If we move to a different, less accomplished, but argued to be 'learning region' (Cooke and Morgan 1998), this time Wales, we find a rather poignant story in which 'boundary crossing' was orchestrated largely by a single, hierarchical IRIS, namely the Welsh Development Agency (WDA). While the private sector was leading the innovation effort, especially in the shape of inward investors from Japan, Wales was the only UK region in which manufacturing employment continued to grow and a good innovation profile was registered (see Cooke *et al*. 2000). But during 1998–2002, 44,000 manufacturing jobs disappeared as these innovators shifted production to Central and Eastern Europe and elsewhere while other firms went under. Although public agencies had worked closely with such firms – even assisting in the building of supply-chain clusters in electronic and automotive engineering – they seem to have learned little. Now, even an innovative public VC entity, established to compensate for market failure, is inducing 'rent-seeking' from interested equity-hunting innovators by requiring them to raise half the required amount from grant-aid first.

It is not difficult to engage in 'sense-making' regarding the WDA's efforts to realign the top-down regional innovation system that emerged with heightened FDI activity in the 1990s. That 'system' (for it had some but not all such features) involved the import of *exploration* and *examination* knowledge from abroad with FDI, embedding FDI by assisting construction of regional supply chains, supporting SME and their knowledge *exploitation* capabilities, linking in skills training to produce technicians and semi-skilled engineering workers, and encouraging investment in related R&D directly by FDI firms or indirectly to universities by earmarking 'Centres of Expertise'. This began to bear fruit up to around 1998 when FDI dried up, and worse, began to move offshore.

The new 'Entrepreneurship Innovation' approach has four main components that can be viewed as potentially systemic. These are:

- An Entrepreneurship Action Plan (EAP)
- Finance Wales (FW), a public–private VC and business loans fund

- A Knowledge Exploitation Fund (KEF)
- Technium, an incubator-building programme

Apart from private co-funding for the VC fund, everything else is public, a sign of 'market failure' in these respects, precisely the reason why IRIS arrangements are necessary. Assessments of performance regarding initiatives such as the EAP, KEF and FW are seldom published, but Shipton (2003) showed that for the financial year 2001/2, in return for an average £80 million per year expenditure in its first three years, the EAP was set a target of providing support to 4,600 new business ventures, but in fact only aided 1,800 – a deficit of 2,800. For 2002/3 EAP was set a goal of supporting 6,300 start-up businesses and 4,000 start-ups were assisted by the WDA from April 2002. Part of this expenditure is on *entrepreneurship* modules in colleges. A report on KEF's own website shows that despite budgets of well over £20 million per year being spent, only 5 per cent more entrepreneurship modules were being taught in universities and other higher education institutes, although 25 per cent more were taught in further education colleges. But 75 per cent of the latter had no or few mechanisms for knowledge transfer organizations, while the statistic for universities was 25 per cent. It can be concluded that there is a significant disconnect in this particular part of the entrepreneurship-driven renewal of the regional innovation system in Wales. Finance Wales, a vehicle designed to supply VC to innovative SME and start-up businesses because of a perceived market failure in private provision registers such disconnects in the far lower than targeted number of businesses coming forward in quest of equity investment. Accordingly, public VCs are redeployed on to firefighting co-funding grant packages. Further administrative expediency and risk aversion has resulted in equity now being tied to accessing regional selective assistance, thus educating entrepreneurs to becoming 'grant junkies' rather than weaning them off grant-dependence as modern investment theory advocates.

These may be teething problems, but they betray an absence of flexibility on the part of large public bureaucracies and their communities of practice. Thus, KEF is managed by the Skills and Learning Agency (ELWa), and even though the organization in question also manages the funding of Wales' universities, it is the community colleges to whom most resources are directed, for trivial training modules to and instrumentation access by SME. In March 2003, it was revealed that the CEO was only devoting one day a week to his university remit, that ELWa was to be split in two, with the university remit to be independently managed, and responsibility for KEF to be transferred to the WDA. However, while it may be preferable to have these key IRIS elements managed under one roof, it should be remembered that ambitions have been unfulfilled under WDA guidance in the three other spheres.

It is clear that this complex policy area is infused with boundary-crossing problems that cannot be solved within public bureaucracy alone. There is a clear danger of 'goal displacement' (Selznick 1949) of the kind exemplified by FW. Moreover, in the same way industry is legally bound to seek profits rather than donate gifts, and universities find profit-making activity hard to accommodate, so governments are ontologically challenged by the idea of financial risk, especially given the widespread presence of an 'audit culture' (Power 1997). Yet innovation systems policies are closely intertwined with financial risk, whether arising from empty incubators, failed loans, aids to subsequently bankrupt businesses or lost VC investments, to name a few. Auditing emphasizes a 'tick box' mentality and public incentive systems reward expenditure of resources but not losses arising from failures associated with such investment.

Regional innovation system boundary-crossing instruments

We have seen that constructing RIS nodes that interact among epistemic communities with different codes of ethics, such as those supposed to interlock according to the 'central dogma' of Triple Helix thinking, is difficult if directly orchestrated by government. Yet, in situations of market failure, such desirable policy action lines must be animated by the public sector unless generous trust or foundation resources can be assembled (as happened in Austin, Texas, according to Henton *et al*. 1997). So, to make concrete implementable proposals based on actual instances of establishing boundary-crossing institutions, the following five cases can be offered. The first concerns the Knowledge Economy issue of science engaging with economic policy at regional level, a situation where, in England, RDA have recently been deemed 'too immature' to foster innovation by themselves (Davis 2003). If generically true, this means serious problems for the broader EU aspiration to raise innovativeness to US and Japanese levels, but a solution lies in establishing buffer institutions such as the following.

Regional Science Councils

Science strategy is far more basic than applied science supporting and is something that has begun to develop in the UK since about 2001.

The Scottish Science Strategy was the first and targets e-science, bioscience and medical science, as described in Cooke (2002b). It was commissioned by the Scottish Parliament, advised by the parliament's Science Policy Unit and consistent with economic development strategy which evolved from the initiative of Scottish Enterprise, the RDA, to embark upon a cluster development strategy that included facilitating cluster development in, amongst other fields, ICT and biotechnology. The strategy identified Scotland's R&D spend from public sources at about $1.2 billion and identified an above average success in accessing UK research funds. It seeks to augment these by re-allocations from within the Parliamentary budget and encouraging integration of research strategies among different research laboratories that the Parliament funds.

This course has also been followed, despite the absence of a parliament, by the North West region of England. In the aftermath of the debate about the location of the UK's new Diamond Synchrotron (important for bio-imaging), which went to Oxford in the heart of southern England's biotechnology belt, the North West used $40 million of compensation funding to upgrade its nuclear-age synchrotron, build a National Bio-manufacturing Centre to conduct and train for bio-manufacturing, develop collaborative bioscience projects between Liverpool and Manchester universities, and establish a science council. The science council reported in summer 2002, recommending special efforts be made to augment basic research funding in six areas, including biosciences, aeronautics, chemicals and textiles. This science strategy also links closely with the regional development strategy of North West England, building upon piecemeal efforts to establish bioscience clusters in Liverpool and Manchester. Because of the link to the regional development agency, a bid for the UK Biobank could be mounted in competition with other regions. The $70 million Biobank facility is a 'hub' with regional linkages to store and make available for research and exploitation the genetic information from DNA samples and the medical records of 500,000 volunteers, aged 45–69. It is funded by the Medical Research Council, the Wellcome Trust and the UK Department of Health. A second English Regional Science and Industry Council was established in North East England in 2002.

In this way, according to key scientific advice given to the UK Office of Science and Technology and to the UK second chamber Science and Technology committee investigation into plans for a $150 million Higher Education Innovation Fund to be managed by RDA, there is a perceived low-trust relationship that would be moderated by regional science councils. In the North West, its regional science council consists of university vice-chancellors, business leaders and scientists from industry and other public bodies. Noticeable is the fact that, public research labs apart, government representation is minimal, but also that science and industry are well represented, reflecting a presumably stronger trust relationship. Though this advice may not carry enough weight to change government policy, it is indicative of a fear that 'goal displacement' may devour these special resources, as exemplified in the following remark from committee witness Professor Sir Gareth Roberts:

> RDAs were set up in 1999 to regenerate the regions and to build infrastructure ... Science was not mentioned in the RDAs three years ago. Universities are now very big businesses [*sic*] that know how to manage large research budgets. RDAs don't have that experience. There is a feeling that the RDAs in England are not mature enough to distribute the money. The North West science council has a full appreciation of what's required. The RDA is not fully equipped to do the role government hopes it will in the fullness of time. (Davis 2003)

As a growing phenomenon in the Knowledge Economy, implicit in which is the building of RIS, regional science councils may find themselves more actively involved in regional science policy than the advisory role they have adopted hitherto.

'Lighthouse' projects

Northern Jutland in Denmark has been at the forefront of mobile telephone infrastructure under the GSM standard, since the 1980s. Many of its more than 60 start-up businesses, spinning out from the technical departments of Aalborg University, were established on the university science park and were then often targets for equity stakes or acquisition by the likes of Amstrad and Bosch and Siemens. On this basis, the cluster in Northern Jutland has developed a leading technological position in wireless radio technologies more generally. Now research applications for 4G are being developed. Hence, the developing expertise within this small RIS that has as its governance system a core set of networks linking firms together using social capital and firms to the university for intellectual capital, is *wireless* telecommunications hardware and software. But key to innovative capabilities is foreknowledge of market applications for wireless telephony.

Thus, in February 2000, the Danish Ministry of Research and Information Technology designated Northern Jutland as one of two 'IT Lighthouses' (Brunn 2002). This was part of their 'Digital Denmark' initiative to make the country a 'network society'. A key measure involved perceiving the region as a 'developmental knowledge laboratory'. This meant conducting a large-scale regional experiment in Northern Jutland, one-third paid for by the Ministry and two-thirds by regional authorities, local government and business to the tune of some € 50 million. The lighthouse experiment operates as a technology programme that funds specific applications projects. Significantly, these projects have four streams: IT infrastructure, E-Science, E-Learning and Skills, and E-Administration. It thus involves not only the techno-economic networks of the university and IT firms, but the community networks of consumers of health, local government, retail, transport, etc. Thus, in Northern Jutland, knowledge transfer bridges the university-industry divide with government animating socially useful innovation through a 'Lighthouse' project. This means that instead of 'knowledge networking' being confined to the political and policy arenas as a means of engaging with the Knowledge Economy, the policy and technology arenas engage with the regional community, accessing their tacit knowledge to build a market for innovative products and services. Thus, there are 'Lighthouse' projects on wireless services for delivery of healthcare, administration, local government services, and project-based E-learning. The first round of funding brought forth 55 projects in these and more technology focused fields, and the second round raised this number to 94.

Intermediary technology institutes

Scotland is rebuilding its RIS in recognition of the unsustainability of an FDI strategy when cheap locations abound elsewhere. Earlier difficulty in inducing an indigenous ICT industry value chain led to founding of the Alba Centre, a facility aimed at attacking the upper reaches of the value chain by training and spinout in advanced software. With Alba as something of a prototype, new Intermediary Technology Institutes (ITI) are now planned for Bioscience, ICT and Energy exploitation and commercialization. Thus RDA Scottish Enterprise has learned, not least from ICT-rich Taiwan, about the importance for commercialization of innovation of an intermediary entity like Taiwan's Industrial Technology Research Institute (ITRI) founded in 1973. From the perspective of managing international knowledge flows, 'catch-up' in Taiwan was dependent less on basic research quality from indigenous higher education institutes, than on forging alliances with transnational companies like IBM and Motorola, then transferring technological knowledge to receptive SME for commercialization. Taiwan's current dominance in mobile PCs rests on the work of such public–private consortia that rushed product to world markets (Mathews and Cho 2000).

Adapted to the Scottish context, where the prospects for commercializing original, as distinct from cloned, knowledge are higher than they were in Taiwan, but where the university originators are, as elsewhere, inexpert at generic, swift-growth spinout incubation, and the innovative, technology-intensive SME sector is rather thin, ITI have a logic to them, given the knowledge transfer and translation imperatives of turning exploration knowledge (basic research) into commercially exploited innovations. Thus basic research will be transferred into ITI, where a small staff will draw up contracts for such exploration knowledge to be examined with a view to exploitation by other, applied research academics under competitive tendering. Thereafter, results are to be sold, licensed, or stimulate business start-up activity. ITI are thus aimed at meeting an important element of the challenge set by the Scottish Executive in its 'Smart, Successful Scotland' vision. This is the framework to which Scottish Enterprise works in the threefold strategy discussed above, linking the 'Global Connections', 'Growing Business' and 'Learning and Skills' action lines. As innovative Knowledge Transfer Organizations (KTO) ITI address the heart of the Knowledge Economy's boundary-crossing conundrum between university research and industrial commercialization.

Innovation-accelerator incubators

Oxfordshire BioTechNet bio-incubator is, first, a 'virtual' incubator networking some 70 'mentors' available to sell at or below cost (if subsidy is available) market services, and secondly, houses start-up tenants in hard accommodation owned by the bio-incubator as an affiliate of the Oxford Trust, a charitable foundation, itself arising from the profitable activity of Oxford Innovation, a successful scientific instrumentation business. To help set up the bio-incubator a € 600,000 grant was won under a UK government (DTI) 'Bio-challenge' scheme in 1997, which assisted investment in incubator buildings. Although initial plans were for 1,000 square metres at a hospital site, land was found at Yamanuchi Research, the Oxford home of Japan's third largest pharmaceuticals business. Other shareholders invested nearly double the 'Challenge' funding and space was opened at the end of 2000. Oxford is one of the

UK's leading biotechnology 'clusters' with some 50 core biotechnology businesses (in the early 1990s only three or four) and a further 70 support firms, located at various sites, including along the A34 'corridor' to Abingdon.

In the main, these are spinouts from Oxford University Life Sciences and Medical School centres and departments. The incubator has 12 tenants, mostly single-person companies moving towards second or third phase development. All are in biopharmaceuticals, ranging from reagents, to therapeutic sugars, gene therapy, cancer therapy, antibodies and bio-instrumentation. Most have UK government SMART innovation awards, following exhaustion of which – if Proof of Concept is validated – business-angel funding is intended to lead to product sales after some five years. One successful firm associated with the bio-incubator is Oxford Glycosciences, one of the UK's leading firms now in discussion on merger with either Cambridge Antibody Technologies, Celltech or Merlin Ventures as the UK's biotechnology sector begins to consolidate (see also Hague, Chapter 2). Thus, BioTechNet is a private, not state-funded, facility, though it has clearly benefited from state set-up funding. It lacks either the power or responsibility to seek a return for incubator services beyond rent. It provides market network access to private equity linking to, among others, Oxfordshire's University Enterprise Network. Firms coming to the bio-incubator are thoroughly vetted and validated by Oxford University's 'Isis' commercial office. Its strengths are its reputation, its image as a model to other incubators, its uniqueness in Oxfordshire and its strong university and mentoring links. Its weaknesses are small size, with only three staff, dependence on private income and absence of a seed fund of its own. Future plans are to grow and offer 'accelerator' and 'follow-on' space. It is anticipated that the Yamanuchi site will soon host a science park, which may meet the preceding aspirations.

Hadasit is an Israeli bio-incubator, comparable to BioTechNet but even more of a 'one-stop shop'. Hadasit is fundamentally a for-profit, incorporated company founded by the Hadasah Medical Organization (HMO), a women's health foundation that owns 100 per cent of Hadasit's shares. In this sense, it encompasses the 'Isis' Technology Transfer Organization (TTO) function, generating a royalty stream from its investment in spin-offs. In this way, it offers a more comprehensive service than its UK comparator. Hadasit's aim is to increase the revenue base of the incubator. Its procedure involves screening firm candidates, agreement for pre-Proof of Concept funds followed by an IPR assessment. If it is selected, a patent filing occurs conducted by

Hadasit, leading to a final prototype, preparation of a business plan and auditioning for VC.

Hadasit has made use of Israeli NOFAR funding of $120,000 for 12 months, funded 10 per cent by industry, which is given right of first refusal on technologies arising. Moreover, the Horowitz Foundation gives $1 million per year to Hadasit. The Hadasit business approach emulates that of the Hapto Inc. model of Delaware, USA. This, for example, allowed a start-up created by Hadasit to in-license tissue-engineering platform technology and commercialize its IPR on behalf of HMO. A VC fund made a $1.5 million pre-seed investment available to start the company and Hapto Inc. cooperates in management in the HMO-owned Hadasit premises, concluding with a 'trade-sale' to a pharmaceuticals firm. As well as US partners, Hadasit links to incubation facilities in Singapore and Australia. It offers firms the widest range of services and benefits from growth in its equity stake in incubated start-ups. The incubator has firms specializing in thrombosis, cancer care, rheumatoid arthritis and hormone research.

These incubators perform vital functions in KTO activity, crossing boundaries between professional communities of practice and the larger Triple Helix buffer zones with relative ease. While BioTechNet operates amongst abundant private innovation support service markets and fits into the RIS's 'knowledge value chain' between the KTO at Oxford University and the service providers in the market, Hadasit has to substitute for most of these market or university provided functions due to the absence of an ERIS. It is noticeable that while neither is a public body, and nor are they market actors, relying on foundation funding and public grants, which suggests provision of this key 'bridging' function, is not yet attractive to private innovation system service providers.

'Arm's-length' venture capital

We saw earlier how having in-house public venture capital funds may leave them open to capture by goal displacement motivations. That is, if the designed service is not capable of proactively seeking clients and insufficient are forthcoming, then, rather than close the service down another function is given to it thus saving jobs, resources and embarrassment. This has clearly happened in the case of Finance Wales. However, an alternative way of organizing such a service is as practised through arm's-length venture capital in Northern Ireland. Two VC firms 'in the market' were supported by public start-up investment from the predecessor of Invest Northern Ireland (INI) the province's

RDA. An illustrative case of the advantage of a private VC presence in an otherwise 'market failure' regional setting for such services is the case of Belfast electronics firm Andor's difficulty with the financial regime in Northern Ireland. This arose from an approach to a bank that advocated acquiring a grant to warrant a loan. A fruitless process of grant-seeking led Andor ultimately to Crescent Capital, a VC, who, for an equity-share, solved Andor's grant and more general funding problem as it 'cut through an old boy network'. Others with whom Andor had positive experiences include Enterprise Equity (see below), and Dublin's Delta Partners. Thus this high-performance firm perceived a bureaucratic hierarchy crossing the public–private divide as constraining growth, something, which would have been stifled without the presence of a private investor community.

Crescent Capital is a small (4–5 person) company but its experiences and practices are instructive of the manner in which the evolution of more systemic innovation might occur. Crescent was set up in 1995 initially with close links to Top Technology, the Hambro's Advanced Technology Trust group of venture funds. The firm manages a £14 million VC fund backed by £7 million from the EU Technology Venture Fund, pension funds, insurance companies and other UK investors. On the technology front, Crescent has close links to Belfast university incubator QUBIS and its start-ups when they reach the VC stage. Investments are also made in promising firms in traditional industries like sawmills and food businesses. The firm invests at between £250,000 and £750,000 and substantially larger investments are made in conjunction with other funds. Importantly, the managing director identified the activities of the firm as both investment in and management of firms, the latter occurring through placing a Crescent manager on the board of the firm being invested in, with the role of active adviser.

A fairly regular partner of Crescent in funding syndicates is Enterprise Equity, established in 1987 as a private limited liability company employing 3–4 people and presently backed by the International Fund for Ireland. Funding is thus foreign and UK sourced for investment in Northern Ireland. Investments of up to £1.5 million range from early stage to development and acquisition, management buy-outs and buy-ins. Larger investments are made through syndicates, and typical partners would include Crescent, 3i and AIB, the latter for bridging loan finance, often required as mezzanine funding when taking a firm public.

While VC investment in Northern Ireland rose from £3 million in 1987 to £35 million in 2000, a funding gap exists for investments of between £100,000 and £500,000. It is considered relatively easy for

University Challenge, a DTI/OST fund managed by Queen's and Ulster University research managers, or seed-corn funds like the Emerging Business Trust to mobilize up to £100,000, while VCs are more comfortable with investments above £500,000, and hence there are no Northern Ireland suppliers in-between. Partnering public bodies such as INI may become more common in tackling this problem if a permanent solution is to be found. But firms seeking investment need guidance towards venture capital sources rather than themselves having to learn about the complexities of public funding the hard way.

Despite the above implication of closer public–private partnership, an example of the difficulty with risk experienced by Northern Ireland's RDA INI and its predecessors is the following. In the early 1990s INI's predecessor made a loan of £3 million to an innovative start-up firm called BCO Technologies in Northern Ireland to increase its focus on optical devices for communications applications. The firm operated in a technology for which there was then an undeveloped market and the INI predecessor's fear was that the BCO start-up would collapse before repaying the loan. With a considerable struggle the loan was paid off with the assistance of Enterprise Equity. In 2003 Enterprise Equity offered INI a share in BCO, which because of its previous unhappy experience of risk, INI turned down. The US analogue chip supplier Analog Devices Inc. then purchased BCO, trading stock valued at $150 million, for the Belfast-based producer of integrated circuit wafers for micro-mechanical optical components. Enterprise Equity's share in BCO was valued at $13 million. The Analog Devices chief executive claimed that his company's advanced micro-machine technology, coupled with integrated analogue and mixed-signal IC technology integrated on the same devices, 'uniquely positions ADI to become an important vendor to the optical network market'. He said BCO, employing 90 people at its factory in Belfast, is a leader in thick-film bonded wafers and silicon-on-insulator (SOI) technology, which would further enhance Analog Devices' position. When asked what INI would have done with its windfall had it invested, along with Enterprise Equity, in BCO a senior executive said there were no clear rules on what to do with profits to a public organization (Cooke and Clifton, forthcoming).

Conclusion

This has been a contribution to an understanding of the difficulties caused for RIS by epistemic boundaries, of the kind that are central to the Knowledge Economy pressures that force engagement among historically incompatible communities of practice, notably the Triple Helix interlocutors, identified as universities, industry and government by Etzkowitz and Leydesdorff (1997) and recently asserted by Etzkowitz (2003) to have cybernetic system guidance. The analysis began with an in-depth exploration of the nature and implications for regional science and innovation policy of the rise of the Knowledge Economy with its significantly uneven spatial effects. This showed three policy-relevant problems. First, strong Knowledge Economies may rely more or less comfortably on market forces to facilitate their adjustment. Second, the weakest regions must find ways to integrate their traditional assets directly into the Knowledge Economy. Finally, those in the areas relatively close to the margin of being a Knowledge Economy have the difficult task of adjusting trajectories set on a more 'Industrial Age' curve given they may already have developed aspects of regional innovation strategy around now-disappearing FDI manufacturing, possibly in high-technology sectors.

Attention then turned to the nature of RIS in both strong and weak Knowledge Economy settings. Distinctions were made between Entrepreneurial and Institutional Innovation Systems, which – unbeknown at the time by this author – are comparable to distinctions between entrepreneurial and institutionalized technological regimes made by Winter (1984) and Audretsch (1994). Where Entrepreneurial Regional Innovation Systems (ERIS) are underdeveloped RDA develop institutions to facilitate comparable effects through establishing 'boundary crossing' institutions to forge government-initiated links towards an Institutional Regional Innovation System (IRIS). Boundary crossing is less problematic where government is absent, something clarified by later references to the inappropriateness of RDA managing scientific innovation funding in England. However, markets for innovation support services are often not at all well-developed away from metropolitan 'safe havens' so government initiation and animation of innovation support activities is often vital. What government does not, however, do well is dealing with risk and managing boundary-crossing knowledge flows more generally. Science and industry seem better equipped for that, perhaps because less rule-governed and flexible internally, albeit with external regulatory codes in their professional practice. This creates further problems but also opens doors to experimentation and solutions.

These were analyzed in the final section. This focused on five 'boundary crossing' institutions for RIS building. Each involved some kind of intermediary outside the public sector. This ranged from the regional science council managing interactions between universities and regional economic strategists, through 'Lighthouse' projects that facilitate market discovery by engaging users rather than producers of socially relevant technological innovations, thus bridging university, industry and society gaps by 'contextualizing' innovation (Nowotny *et al.* 2001), to Intermediary Technology Institutes for bridging the knowledge exploration to exploitation gap, which universities are generally perceived to be relatively ineffective at tackling, to Accelerator-Incubator facilities that cross numerous boundaries affecting the exploitation of new knowledge as commercially viable innovations in the market, and finally, arm's-length VC that can handle risk in ways public investors often seem reluctant so to do. Thus by scanning and learning, administrations that are faced with daunting problems in innovation system building may overcome these by judicious adaptation of boundary-crossing institutions that have been applied elsewhere or developing appropriate boundary-crossing institutions from new. The key feature of all such boundary-crossing institutions is that they should be outside direct public sector control, mainly because all involve some degree of risk-taking that public sector functionaries are by and large neither trained nor competent to perform.

Note

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13

Universities as Hubs to Global Knowledge Pipelines? A Strategy-Focused Perspective on Regional University Policies

Rüdiger Wink

Introduction

After decades with images of ivory towers and seemingly confused scientists with no notion of 'real life', three driving forces recently led to a high political relevance of university development (Etzkowitz and Leydesdorff 2000):

1. paradigmatic changes in technological trajectories with industries now more dependent on close linkages between basic and applied R&D and public more affected by science in daily life (Nowotny *et al*. 2001),
2. paradigmatic changes in labour markets causing a shift towards highly-qualified workforce in all modern 'knowledge economies' (Blundell *et al*. 1999), and
3. increasing spatial concentration of knowledge-intensive industries in regions with sufficient infrastructures for knowledge generation, examination, and exploitation.

In particular, the last development serves as a threat to many regions fearing to lose access to leading-edge knowledge, which marks the basic prerequisite for sustainable future growth (see e.g. Chapter 12, and Tödtling 1994). The term 'local buzz' is one of the typical catchwords implying the dependence of economic development on geographical proximity and access to leading knowledge groups (Storper and Venables 2002). Well-known centres of knowledge like Cambridge, Boston, San Diego, or Lund University are typical examples for these processes of spatial concentration. Simultaneously, internationalization of markets with worldwide information and communication technology (ICT) linkages and integrative organizational forces like multinational enterprises (MNE) and transnational research groups challenges these centripetal developments (Bathelt *et al*. 2002; Amin and Cohendet 2003). But global knowledge pipelines along internationalized markets might only connect the leading knowledge regions.

In the following, we look at those regions which currently or permanently do not share those characteristics necessary for attracting global leading-edge knowledge groups (Kaldor 1970 for the justification of public policies in these cases). In the European context, these are regions at the periphery or in EU accessing countries, but also industrialized regions in need of structural change (see Chapter 12). They need access to knowledge pipelines – the knowledge base in other regions and flows between them – as the necessary prerequisite for developing regional knowledge management systems or preventing lock-in effects in their existing systems. Benchmarking studies present successful cases, where universities serve as a nucleus for knowledge generation and processing and as linkages to knowledge from other regions. But simply imitating these success stories underestimates the prerequisites for transregional knowledge transfer and for enabling universities to be transregional knowledge intermediaries. Thus, we will focus in this chapter on (i) the strategic process to decide on the elements of trans- regional knowledge management in single cases, (ii) the role universities can play within this strategy, (iii) instruments to integrate universities into transregional knowledge flows, and (iv) criteria to evaluate the impact of knowledge management strategies. But first we will give a theoretical overview of the specific challenges caused by transregional knowledge management.

Transregional knowledge management

Relationships between knowledge and regional economic development have been analyzed from a great variety of methodological perspectives (see Chapter 14 for an overview). Common lines of argumentation refer to the relevance of agglomerations, the availability of knowledge and human capital and the networking effects of knowledge (Fujita *et al*. 1999; Malmberg and Maskell 2002). From a purely economic point of view, knowledge is the result of a production process, started with investments in the availability of human capital, patent licences and research labs, and leading to new products and production processes, implemented by ongoing increases of productivity driven by learning-curve effects (see de Solla Price 1984 to consider necessary feedback processes). But why are some companies more successful than others despite equal investments, and why do regions remain in a lagging position despite public investments in human capital, the attraction of modern Greenfield investments, and the infrastructure for university–industry–liaison networks? Formal and informal institutions seem to matter, but also cultural and subjective factors, stressing that knowledge production and diffusion processes are more affected by social constructions than other production processes.

A similar experience can be observed within companies. '*Knowledge management*' is a buzzword used by nearly every business consultant. Companies should secure access to know-how, know-why, know-what and know-who, which requires the availability of huge quantities of data and complex linkages between different knowledge bearers (Grant 1996; van Krogh *et al.* 2000). Sophisticated ICT infrastructures and software should solve these problems. But in reality, most systems fail to improve knowledge flows within companies, as employees are not motivated to document their knowledge, most documentations are restricted to codified knowledge and do not include the user-specific tacit experiences, and documented knowledge has to be translated before use, reducing the incentives of employees to use such a system. As in the case of regional development strategies, the simple provision of data and infrastructures is not sufficient to increase knowledge flows and to improve the knowledge base of single elements in the knowledge system. The social dimension of generating, examining, utilizing, and adapting knowledge has to be considered.

What does this mean theoretically? Models from learning psychology, cognitive and brain sciences try to link individual processes of recognizing and processing knowledge in the brain with social interaction and construction (Bara 1995; Rizzello 2000). Exchange of experiential knowledge and arguments has always a cognitive dimension not restricted to the pure content of a written text or spoken word. On the individual level, any new data recognized is framed – in most cases subconsciously – against the background of already existing cognitive patterns due to genetic heritage or previous experiences. These patterns decide how to proceed with new data, whether to store or reject them and how to prepare them for future utilization. It is comparatively easy for any scientist to comprehend and process contributions within her specific disciplinary background but risks of misunderstandings arise with increasing distance between disciplinary languages, tools and models and with increasing distance between framing conditions of sender and recipient (Ortmann and Gigerenzer 1997). This explains the specific difficulties within academia–business linkages, when scientists are interested in early disclosure, publication and scientific reputation, while companies look for profitability of applications (Siegel *et al.* 2003). Although advantages of interaction between science and academia seem to be obvious, in many cases barriers are too high to create sufficient incentives for reaping these potentials.

Thus, intermediation between sender and recipient is necessary, not only to prevent misunderstanding but to create incentives for interaction. Communication codes serve as connecting links between sender and recipient (Wink 2003a). Such codes are quite simple in the case of codified knowledge, where formal conventions offer sufficient information for translating data. Codes for transferring tacit knowledge can be developed within informal or formal communities-of-practice fuelled by job mobility, scientific background, or social peer groups, where social norms, personal qualities and capabilities play a decisive role (Brown and Duguid 1991). From an economic point of view, two characteristics of these codes are important:

- they serve as *network goods*, where economies of scale can be achieved on the demand side with every further user of this code with increasing benefits depending on the number and heterogeneity of compatible knowledge bearers and the exclusiveness of access to the knowledge base by the codes (Liebowitz and Margolis 1994; Uzzi 1996; Nee 1998), and
- they require *irreversible investment* due to the specificity of languages, norms, or necessary skills causing dangers of lock-in effects, if they are only utilized by individuals with homogeneous knowledge, thereby diminishing the scale economies.

Three terms often used in the context of knowledge management are relevant within these processes of interaction. The individual *knowledge base* consists of theoretical and experiential knowledge stored within certain patterns and related to conscious processes of gaining expertise as well as unreflected routines. Knowledge management should create systemic linkages within an organization or a region so that its knowledge base can be more than the sum of individual knowledge capacities, if there are common codes and values inducing interaction and the emergence of new ideas and experiences (Argyris and Schön 1978; Shrivastava 1983). The understanding of codes and ability to transfer communicated experiences into the individual (regional) knowledge base are the *absorptive capacity*, which describes the potential to learn, i.e. to increase the knowledge base intended or unintended, by receiving information – in any possible way – from other persons (Cohen and Levinthal 1990). Linking individual knowledge and absorptive capacities by common codes of communication and processing can lead to a *knowledge system* describing a multitude of diverse possible interaction within the system, enabling the participants to connect all necessary prerequisites for knowledge generation, examination and exploitation and safeguarding a separation from communication outside the system by restricting the codes and absorptive processes to insiders (Cooke *et al.* 1997).

But considering the irreversibility of investments into compatibility with codes and the network characteristics of these codes, individuals will only invest in compatibility if they expect sufficient additional benefits to compensate the costs. Thus, a critical mass of code users, sanctions for free riders, and competitive advantages of network membership are necessary. Further problems are caused by the intangibility and novelty of knowledge within academia–business linkages (Wink 2003a). Due to knowledge asymmetries on the quality of knowledge between scientists and companies, high transaction costs for companies to restrict options for opportunistic behaviour by scientific knowledge generators can prevent successful interactions (see Chapter 6 by Blum and Müller).

Thus, formal and informal institutional arrangements are needed to overcome uncertainties on the emergence and benefits of knowledge systems. Examples for such rules are intellectual property rights regimes as well as obligations of disclosure or compliance with oral agreements. Although communication codes have to be adapted with time, the institutional framework serves as an umbrella for all participants to define at least a minimum of behavioural rules to be expected within interactions. Within this umbrella, sub-groups – driven by temporary benefits of interactions – specialize in actual interactions with more specific codes and content. Thus, looking at experiences with 'organizational learning' in a company or regional context, knowledge management refers more to institutional incentives to feed and utilize knowledge pools than building up complex ICT infrastructures.

Geographical proximity within a region can provide common institutional frameworks due to cultural and social norms and repeated social control via face-to-face (F2F) contacts and reduce costs of adapting to communication codes due to common language, education, or motivation by F2F contacts (Gertler 2001; Storper and Venables 2002). By building up regionally specific and bounded codes and routines, regions are able to obtain '*unique selling propositions*' to attract mobile human capital of highly qualified individuals, thereby reducing risks of losing access to global knowledge flows. But what about regions which do not have these unique selling propositions and depend on knowledge input from other regions? Transregional knowledge management sounds like an answer to this problem. With the term 'transregional' we refer to connections between selected areas in space – there is no ubiquitous (globalized) flow of knowledge and no spillover of knowledge between neighbouring regions, but transfers between single regions in different countries and therefore with different communication codes and institutional routines and frameworks (Wink 2003b).

Within regional policies, this necessity of transregional knowledge input into lagging regions has been interpreted as a task similar to 'conventional' regional catch-up strategies by capital transfers (Camagni 1995; Cappellin 2003). Thus, the same instruments as in conventional regional policy have been introduced: infrastructure projects to build up ICT connections to agglomerations ('information superhighways' as analogy to road and rail networks) and intermediaries ('science parks' as analogy to technology centres) as well as financial incentives to allocate knowledge into lagging regions, e.g. via transnational projects in the EU R&D frameworks (as analogy to investment grants for real capital investments). But transregional knowledge management would require that common communication codes between individuals or organizations in different regions emerge and are utilized, which are compatible with the codes in use within the regions. Universities might be ideal candidates to serve as necessary transregional communication code interfaces, as

- they are geographically close to regional companies and inter-firm networks, while having the option to attract at least temporarily researchers and teachers from other regions (see Chapter 8 by Gallaud and Torre on the role of temporal geographical proximity),
- they can influence the emergence of new – less geographically dependent – communication codes by building up alumni networks (O'Neill *et al*. 1996), or
- they can influence the emergence of new geographically dependent communication codes by attracting spin-offs and spinouts from universities, companies and research organizations in other regions.

In the following, we will take a closer look at political options to improve the contribution of universities as transregional knowledge channels. In contrast to a general overview on policy objectives and instruments, we will focus on strategic perspectives to policy decision-making.

The strategic focus of regional policy

Besides conventional instruments of regional cohesion policy, the European Commission and OECD increasingly use benchmarking studies to present best practices of regional development strategies and instruments to enhance 'learning' between regions (European Commission 2001; OECD 2001a and 2001b; Cooke and De Laurentis 2002). Thus, many lagging regions attempt to set up science parks, university–industry–liaison offices, and development agencies with the task of paving the way for new firms to obtain financial and consultancy services and other instruments similar to the institutional settings in successful regions (Löfsten and Lindelöf 2002). Due to the lack of entrepreneurial experiences and capabilities, such a concerted approach of building up institutions – institutional regional innovations systems (IRIS), as explained in Chapter 12 by Cooke – should make sense. But besides general doubts on transfers of institutional models (Gertler 2001), simply copying institutional settings and supporting technologies and industries similar to success regions will not improve sufficiently the attractiveness as knowledge economies for investors and human capital, since necessary competitive advantages to other regions are missing.

Thus, we stress the relevance of a strategic focus to regional policy. Similar to observations in management sciences, many policy concepts are bound to fail, if too many contradicting objectives exist, instruments are not suitable for influencing objectives, institutional prerequisites for implementing instruments are missing, or lack of capabilities for achieving the objectives have not been taken into account (Benzler and Wink 2002; Cappellin 2003). Concepts like 'balanced scorecards' have been proposed to introduce three basic changes within decision-making processes (Kaplan and Norton 1996 and 2001):

- *Reduction of complexity*

There are many objectives indicating regional development and a multitude of factors influencing the achievement of these objectives. But in a world with mobile production factors and interregional competition, it is necessary to concentrate on objectives to create a *unique selling proposition* within competition, as this might serve as sustainable competitive advantage compared with other regions. For instance, attempts to create another 'gene valley' by attracting researchers on biotechnology can only be successful if there are other location factors to distinguish this region from other 'wishful gene valleys'. Therefore, concentration to objectives contributing to a differentiation of the region and to main factors influencing the achievement of these objectives should increase transparency of strategies and reduce costs of coordination.

- *Legitimacy of strategic processes*

In many organizations, formulation of strategies and implementation are separated, causing additional costs of coordination and risks of formulating unrealistic objectives. Therefore, key players have to be identified and integrated into the strategic process. How this can be achieved in a regional context – whether a regional development agency spawns additional bureaucracies or serves as an initiating driving force, inter-firm networks organize themselves or need the support by moderating consultants – will depend on specific conditions. The decisive aspect is the acceptance by the key players who decide how to implement any strategy.

- *Strategic evaluation as learning tools*

Models, like the balanced scorecard, have been criticized for being too simplistic and too narrowly focused to quantifiable criteria and therefore only serving as a tool supporting hierarchical power of the strategy formulation level against individuals on the implementation level (Worthen *et al*. 1997). These statements are particularly motivated by practical experiences, where organizations only picked out the scoreboard and evaluation of performance against objectives formulated in the board to improve controlling mechanisms. But, as already explained, we understand these models as tools to improve strategic decision-making, which means that the selection and utilization of evaluation criteria is also a strategic process. Criteria should not only measure the performance against objectives but also give evidence to the rationality of objectives and instruments themselves to help in improving the strategy and transparency of the whole process

(Kuhlmann 2003). Therefore, any proof of 'under-performance' creates incentives to analyze the correctness of expectations and causes for this under-achievement. Considering the multitude of regional examples of lock-in effects due to lack of institutional flexibility – the inability to abolish a new bureaucracy or to withdraw financial support – transparency seems to be a decisive prerequisite to reduce risks of institutional path-dependencies (Raco 1999).

A strategic focus on transregional knowledge management by universities

What is the message of these theoretical thoughts on the difficulties of diffusing knowledge across regional boundaries and on stressing the strategic aspect of regional policies? In the following, we will try to draw some conclusions for the decision-making of university managers and/or regional policy-makers on the necessity and design of activities to improve transregional knowledge flows. Three steps will be discussed: (i) the objective of transregional knowledge flows; (ii) the instruments of university policy; (iii) the evaluation criteria to improve the strategy.

The dimension of objectives

Ealier in the chapter, we presented specific institutional challenges caused by transregional knowledge flows. Any investment and institutional adaptation to promote these flows should be justified by answering the following two questions, as they refer to the expected regional demand:

- *What is the impact of geography on knowledge needed for regional development?*

Geographical proximity is not equally important for all sectors and all stages of technological development processes (Gilly and Torre 1999; Malerba 2000). Its importance depends on the tacitness, specificity and novelty of knowledge and communication codes. Codified knowledge can easily be transferred without further explanations and involvement into routines of use. Communication codes refer to literacy and common technological (disciplinary) languages, thus knowledge can be transferred via ICT or other media. Specificity and novelty of knowledge influence the uncertainty on qualities of knowledge and the expected market value. Therefore, specific institutional frameworks are needed to prevent opportunistic exploitation by better-informed individuals. These institutional frameworks can be introduced cheaper and faster if there is at least some kind of common social norms and social control via F2F, making geographical proximity more important. Typical examples for sectors depending on tacit knowledge refer to high-tech machinery clusters in Baden-Württemberg, while the film industry in Hollywood seems to be the classical example of specific knowledge (Scott 1998; Raco 1999). If there is only weak evidence that geographical proximity is important, cooperation between universities and enterprises will be possible regardless of their regional location.

- *What is the impact of universities to the regional knowledge base?*

The increasing importance of universities and research organizations for regional economic development is closely related to the emergence of new science-driven sectors like biotechnology, where boundaries between basic and applied R&D are no longer visible and scientific analytical knowledge is a decisive input to the development of new products and services (Blumenthal *et al*. 1996; Cooke 2003). But there are still other sectors that depend on other kinds of knowledge: like the machinery sectors depending more on technology-driven knowledge, acquired on the job, where technical colleges or inter-firm projects are more important than universities, or media and design sectors with more symbolic knowledge bases acquired from individual or firm-specific expertise (Asheim 2002; Feller *et al*. 2002; Grossman *et al*. 2001). Even if demand for transregional knowledge by the companies refers more to consultancy services for international financial and sales markets, compatibility of communication codes between university and companies is necessary, stressing again the relevance of identifying the kind of knowledge needed. If firms are only looking for knowledge not provided by universities, or are not able to process science-driven, abstract knowledge, the transregional knowledge flow will only reach the university and not other parts of a regional knowledge base.

The dimension of instruments

Different instruments can be introduced to support transregional knowledge flows via universities. Again, it depends on the regional context, which instruments should be chosen. We will discuss four instruments to show the variety of options:

Transregional appointments

As knowledge and communication codes are closely related to the individual, the import of 'brains' by offering researchers from other regions or countries university chairs or leading positions in associated institutes is a typical instrument to support transregional strategies (Straubhaar 2000; Pries 2001). New 'brains' can not only improve the regional knowledge base by sharing expertise with incumbent researchers and companies but also serve to attract other researchers or companies in technologically advanced sectors, thereby creating regional 'centres of excellence'. But, besides considering the necessary expenditures for raising the attractiveness for excellent and/or successful researchers, the availability of two main prerequisites has to be investigated: first, the compatibility of the additional knowledge with the need for science-driven knowledge, and secondly the compatibility of communication codes used by the new researcher with colleagues at the university and regional firms.

Transregional knowledge inflow by contractual agreements

These instruments refer to financial grants for research cooperation by university staff and spinouts with enterprises and universities in other regions (Blanc and Sierra 1999). These projects can lead to the emergence of new common communication codes by temporary research placings or job mobility. For regional knowledge networks, these activities are particularly interesting if those university researchers involved use their additional expertise and codes to extend their supply for regional companies, or even build up incentives for regional firms to be involved in these transregional contracts without violating requests for secrecy by partners in other regions. But these instruments can only lead to positive impact on the regional knowledge base if there are already experiences with regional academia–business linkages, and if the universities obtain competencies sufficiently attractive for partners in other regions.

Transregional knowledge inflow by franchising

The complete inclusion of the regional university within an international (transregional) franchising system marks another way of increasing transregional knowledge flows. Internationally oriented universities create systems of certified courses and degrees, which are managed centrally and offered under a common label. The university teachers are mainly recruited within the regions and integrated into common staff development policies. For an internationally oriented university, such a system offers the opportunity of cheap supply of basic courses in economically lagging regions, while securing international access to a common baseline of knowledge for graduates and postgraduates. For lagging regions, this strategy offers an option to internationally standardized knowledge as a starting point for further research and contacts for future highly skilled persons interested in cheap schooling costs during their undergraduate period (Wink 2003b). Such activities can be relevant for regional knowledge networks with temporary deficits in access to standardized technological or marketing expertise, e.g. old industrialized regions in Central and Eastern Europe. Personnel with standardized skills could improve the access to international value chain networks and further improvements of the knowledge base. But without existing regional knowledge networks and experiences these franchise universities will only serve as isolated suppliers of knowledge.

Transregional knowledge inflow by alumni networks

For many US universities, alumni associations, 'old-boys networks', are a common and attractive instrument to further the career prospects of students, to increase private funding and to contribute to education by offering practical experience. From a regional perspective, this could also open up the doors for transregional cooperation of firms, as common experiences within university could reduce barriers of first contacts, and common rules within the alumni networks could serve as reputation. But this requires, on the one hand, an active corporate policy of the university, including a mission statement with common guidelines, public image and implicit routines as well as the involvement of alumni within the organizational structure of the university. Therefore, only those universities which obtain a certain homogeneity and common internal culture will be successful in integrating alumni. On the other hand, alumni will only be relevant for regional economic development if graduates actually leave the region and are able to use the degree as an entry ticket to an international career, and if the university is integrated into regional knowledge networks at least by having an effect on regional staff development policies.

The dimension of evaluation criteria

From a strategic perspective, evaluations not only serve to control performance against the background of given objectives, but provide information on the suitability of objectives and strategies. Thus, a system of criteria is necessary to test the assumptions on which strategies and objectives are defined, the achievements on the implementation level, and cause-effect relationships between observed changes of behaviour and performance and overall regional economic development. In the context discussed in this chapter, this means first selecting criteria to analyze the relevance of knowledge as regional production factor, geographical proximity and science-driven knowledge and services, as prerequisites for the formulation of transregional knowledge management via universities as regional development objective (Geuna 1999; Anselin *et al*. 2000; MacPherson 2002). Performance indicators will depend on the selection of instruments:

1. In the case of *appointments*, scientometric criteria and the compatibility with knowledge needed within the region will be most important, followed by observations of output of the new researchers to the regions (income by private regional funding, career of graduates, etc.).
2. In the case of *contractual agreements*, income generated by regional and transregional projects, in particular their development with time, and the development of content within these projects will be most important (see also Chapter 11 by Benneworth and Dawley).
3. In the case of *franchising* strategies, criteria will refer to staff development in regional firms through graduates and mid-term involvement of firms into transnational value chains.
4. In the case of *alumni* strategies, the spatial distribution of graduates and their career developments will be important indicators, as well as the mid-term development of transregional cooperation with those firms where alumni are employed.

As a result of such strategic focused evaluation studies, the comparability between the regions will be reduced due to regional specific evaluation schemes. But this reduction of information will also increase transparency, as only actual strategic competitors striving for comparable regional location factors will use comparable indicators.

Final remarks

As no empirical study has been presented, the thoughts within this chapter might look very abstract for regional development strategies. But looking at practical experiences, such an abstract and general structure of decision-making might be necessary in order to overcome the danger of simply imitating observed success stories and overestimating the impact of universities on transregional knowledge management. Three basic aspects are stressed within this chapter:

- Enhancing the access to knowledge flows in other regions or even internationalized flows causes additional institutional challenges due to the necessity of adapting communication codes.
- Universities can contribute to this transregional task only if regional prerequisites – need for tacit or specific, science or technology-driven knowledge – are given.
- Explicit policies to enhance transregional knowledge flows via universities should only be implemented if suitable processes to develop, formulate and test strategies are given. Any regional strategy should be concentrated on assets, which can create unique selling propositions within relevant interregional competition.

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14

Enlarging the Scale of Knowledge and Innovation Networks: Theoretical Perspectives, Methodological Approaches and Policy Issues

Riccardo Cappellin and Michael Steiner

Competitiveness factors in the transition to the knowledge society

According to recent developments in economic theory, economic advantages – on both an international and a local level – have turned from 'comparative' (being relatively cheaper) to 'competitive' advantage relying on more qualitative elements. This shift resulted from a number of studies published in the 1980s and 1990s, which emphasized the importance of 'soft' factors – referring to good quality of life and good services such as leisure, recreation and health, customized labour training and business networks – in explaining the economic competitiveness of localities. The studies included the work on Italian *industrial districts* by Piore and Sabel (1984) and Pyke, Beccattini and Sengenberger (1990), the *competitiveness of nations* by Porter (1990) and *social capital* by Putnam (1993).

In addition, more recently, knowledge has been recognized as a major source of competitive advantage in an increasingly integrated world economy (Grant 1996; Foss 1999; Nonaka *et al*. 2000). The most successful regions are perceived to be those whose firms display innovative capacity, being able to adapt to a rapidly changing marketplace and stay one step ahead of competitors. In fact, 'knowledge represents the fundamental resource in the contemporary economy and the process of learning represents the most important process' (Lundvall and Johnson 1994). In developed industrial economies, producing for open world markets, innovation and sustained productivity growth is less based on material infrastructure and capital than previously (European Commission 1995 and 1999). This kind of economic set-up and restructuring was predominant in the post-war period through to the 1970s. This basically meant the introduction of modern machinery and equipment in order to realize physical productivity gains. This kind of restructuring was relatively easy and resulted in relatively fast catch-up or advances for Europe and the less developed countries of the world *vis-à-vis* the US but is now confronted by new challenges based on knowledge as the decisive production factor.

This process is now repeating itself at a European level with the EU economic lagging regions and the Central and Eastern European (CEE) countries preparing for accession to the EU. Yet these forms of catching up still leave a large and persistent 'innovation gap'. This may be explained by the fact that the process of catching up – after having reached a certain level through physical productivity gains – has to rely on other forms and processes, demanding more time and being based on additional strategies and instruments. In particular, the transition from a traditional model of industrialization, based on economies of scale and capital investment, to a modern model of industry characterized by flexibility and innovation represents a challenge both for the EU economic lagging regions and the accessing countries.

These challenges serve as a background for this chapter. We ask for necessary EU policies to overcome development barriers for EU lagging and accessing countries in the emerging European knowledge societies. In the next section, we start with an outline on the theoretical framework, aspects of clusters and the network model as a basis for innovation processes. In the following sections, we point to preconditions for the growth of the knowledge base through different forms of learning; discuss the role of institutions and social capital in knowledge creation; and emphasize openness as a factor of innovation and development. Then we give a short evaluation of the framework of European RTD and regional policies, and finally sum up some aspects for future research and policy considerations.

Geographical agglomeration factors within clusters and the local networks model

Since the 1980s, innovation processes in Europe have essentially been marked by different forms of innovative milieus and their supporting institutions. Innovation and productivity gains are based on subtle forms of cooperation, where the creation of new knowledge implies an intense process of interaction. In particular, the role of *clusters* deserves special attention.

Clusters may be defined as 'geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries and associated institutions in a particular field that compete but also cooperate' (Porter 1990 and 2000). The economic growth of particular regions has been attributed to such clusters of firms that benefit from cooperative links and experience rapid rates of innovation (Porter 1998). It is widely believed that industrial clusters can help to improve the performance of regional economies by fostering innovation and strengthening the competitiveness of firms, thereby generating growth and employment. Despite the frequent assertion that clusters raise competitiveness and innovativeness, little rigorous analysis has been presented to support this claim. The theory does not distinguish sufficiently between different kinds of forces that promote the spatial concentration of related activities. By conflating different phenomena it confuses the processes at work and may yield misguided policy prescriptions by an overemphasis on local collaboration at the expense of promoting external connections.

Most of the available literature on the relationships between technology, geographical distribution of innovative activities and international specialization has at its basis the concept of 'locally bounded knowledge spillovers' (in Krugman's 'new economic geography' 1991 and 1995, as well as in more heterodox approaches like Lundvall 1992). Yet, it would be extremely valuable to analyze in much more detail how exactly these spillovers occur in different areas and sectors. Attention has focused on innovation as an interactive process involving the sharing and exchanging of different forms of knowledge between actors (Lawson and Lorenz 1999). The key argument here is that the collaborative nature of innovation processes has reinforced tendencies toward geographical clustering because of the advantages of locating in close proximity to other firms in specialist and related industries (Storper 1995 and 1997). Despite the claimed ubiquity of access to information engendered by the rapid growth of telecommunications, access to tacit knowledge based on networks and face-to-face (F2F) contacts, which offer greater reliability and less risk, tends to be spatially concentrated. Clusters and networks, as a special form of spatially based access to tacit knowledge, relying on specific milieus, are based on various qualified links of cooperation. These links can emerge between firms, but also with public, semi-public and private R&D institutions. Within these clusters, the sense of belonging represents the basis of a 'associative governance' that leads to the creation of club, fora, consortia and different institutional schemes of partnership (Cooke 1998; Cooke and Morgan 1998).

The *network model* can be regarded as a critical component of economic development and knowledge generation, as knowledge is channelled by formal and informal institutions within networks (Kogut *et al*. 1993; Keeble and Wilkinson 1999; Amin and Cohendet 1999). Networks can refer to both social relationships among individuals and interactions among organizations. The nature of cooperative linkages and networks between firms has received increasing attention in the past decade. The social network model based on the work of Granovetter (1985) and other economic sociologists (Piore and Sabel 1984) place a premium on close collaboration and trust between firms and related institutions (Zucker 1986), so that market failure can be overcome. In fact, trust is strengthened by local common identity and tradition and spatial proximity.

The term 'network' refers theoretically to goods and services, whose production costs (utility) decrease (increases) with an increasing number of participants and increasing systemic connection between single participants (Katz and Shapiro 1994; Economides 1996). From an economic point of view, the output of the economy depends not only on factors of production, such as capital, labour and technology, but also on the very different forms of organization or cooperation within networks of the material and immaterial flows between firms, institutions and other actors involved in the economic system.

Yet, there is still the need to establish a link between the literature on industrial and geographical clusters (Aydalot and Keeble 1988; Audretsch and Feldman 1996; Steiner 1998; Gordon and McCann 2000) and a parallel, but so far largely divorced, strand of literature (O'Dell and Grayson 1998; Nooteboon 1999), which has focused mainly on organizational structures of firms and introduced concepts, such as 'loosely coupled' organizations, to denote specific mixtures of internal research capabilities, on the one hand, and on the other, reliance on research agreements, as a means to explore promising new research directions and/or to provide complementary competencies.

It is well known that networks are highly differentiated across sectors, regions and countries. Thus far, the literature has analyzed these networks mainly on the basis of case studies, and the term 'network' has been used somewhat loosely. Many network studies have focused on the hypothesis that strong networking activities will aid local economic performance through increased information and knowledge sharing between individuals, enterprises and organizations. Thus, it is important to arrive at a theory-driven taxonomy of clusters and some basic principles underlying their structure and performance as a theoretical tool and basis for policy.

Interactive learning and the process of knowledge creation

Growth of the knowledge base depends on intended and unintended individual processing of experiences, i.e. 'learning', while the interpretation, transfer and use of experiences is influenced by interaction between individuals and between organizations (Cohen and Levinthal 1989; Anderson 1995). Approaches solely referring to quantitative indicators to identify learning capacities and knowledge in society reach their limits when tacit and highly specialized knowledge serves as a decisive factor in using and adapting new ideas and experiences (see, for quantitative approaches, OECD 1999; Cantner and Pyka 1998). Secondly, besides formal institutions, trust and routines often are decisive prerequisites for successful emergence and sustainability of innovation and learning networks. This refers to the basic concept of social capital (Putnam 1993; Woolcock 1998; Grootaert 1998; Krishna 2000).

The generation of new knowledge has to be seen as a cognitive process, where own or foreign, intended or unintended new experiences are recognized and compared to already existing cognitive patterns within the human brain (McCain 1992; Laughlin 1996; Rizzello 2000). Three separate dimensions are affected by these processes: knowledge, competencies and product/process innovation (Arrow 1962; Mansell and Wehn 1998). Looking at the processing of foreign experiences, the creation of new knowledge implies an intense process of interaction (Knack and Keefer 1997; Nonaka *et al*. 2000; Ritzen *et al*. 2000; Spender 2001), which is characterized by the transformation of tacit into codified knowledge and a movement back to practice where new kinds of tacit knowledge are developed. The transfer of tacit knowledge requires F2F contacts and physical proximity, while explicit knowledge may be transferred through ICT at long distances. Tacit knowledge is often more important than widely and routinely available codified knowledge. The interactive processes of 'learning-by-producing' and 'learning-by-searching' between firms and various economic and social actors represent the major mechanisms for combining existing knowledge and introducing new knowledge into the economy.

The actual 'knowledge society' is characterized by the rapid enlargement of production processes from both geographical and institutional perspectives. The crucial change is that the production of scientific and technological knowledge is increasingly self-contained. Clearly, the production of scientific knowledge is no longer the exclusive domain of special institutions such as universities and public research agencies, from which knowledge can diffuse as a spillover or spin-off to the benefit of other sectors. The number of places and actors that are actively involved in the generation of knowledge is rapidly multiplying. As a result, a local production and innovation system is made up of a plurality of actors such as large and small firms working in a production sector where network relationships exist or could be economically foreseen, institutes of research and superior training, private R&D laboratories, agencies of technological transfer, consultancies, venture capitalists, chambers of commerce, associations of enterprises, organizations of professional training and specific governmental agencies as well as informal social groups, networks and associations (Patel and Pavitt 1994; Freeman 1995; Cooke 1998). A central fact about the modern process of innovation is that it is based on the division of labour. Division of labour produces efficiency gains from specialization and professionalization, but it also requires a framework to connect the component contributions of different agents. As far as knowledge and skills are concerned, conventional markets cannot coordinate these aspects of connectivity or technology transfer effectively. Therefore, the creation of institutions enhancing the connectivity of technology should be a central concern of policy.

Thus, a deeper understanding of the mechanisms of learning, knowledge accumulation and innovation is especially useful in order to explore the process of restructuring and diversification in regions, where new tacit and codified knowledge has allowed entirely different innovative productions to 'branch' or emerge from the 'old economy' industries, or these latter have evolved toward medium-technology services/manufacturing productions, where no evidence of 'knowledge economy' advances are discernible. It is important to understand how such sectors developed, what were or are the mechanisms responsible, and to what extent market versus policy forces explain such development; also, how systemic institutional interactions are between business, financial investment, human capital and knowledge institutions, and to what degree firms are engaged in both global and local value chains.

The role of institutions and social capital in knowledge creation

Economic growth should be understood as an evolutionary process, and the endogenous approach seems rather satisfactory for understanding the forces behind the 'immediate sources of growth' and the processes that are within the 'black box'. For interpreting and explaining economic growth, the nature and dynamics of the organization of production, the role and change of institutions and technology and technological advancement should be specified. They generate external and internal economies of scale, reduce production and transaction costs and favour economies of scope. Development processes do not take place in a vacuum but rather have profound institutional and cultural roots (North 1990). 'The central issue of economic history and of economic development is to account for the evolution of political and economic institutions that create an economic environment that induces increasing productivity' (North 1991, p. 98).

Economic development, then, is stimulated in those territories with highly evolved, complex and flexible institutional systems. That is why training and research institutions, entrepreneurial associations, unions and local governments can more efficiently use available resources and improve competitiveness when firms are integrated into territories characterized by thick relational networks. Barriers which hinder self-sustained growth processes frequently appear due to deficiencies in and poor performance of the institutional network. New institutional theory argues that the strategic significance of institutions in development processes lies in the economies their functioning provides. The basic interdisciplinary results for individual learning processes stress the importance of institutional arrangements for the generation of knowledge and learning networks, which are not all available in the markets (Lawson and Lorenz 1999):

- to reduce the uncertainty about the experiential knowledge of others (of other companies, research institutes, etc.),
- to increase incentives for medium-(long)-term investments into diffusion channels – e.g. common codes, products, fora – between different participants in a network,
- to develop and adapt research, production, distribution, and after-sales strategies to increase the absorptive capacity of new information by the participants,

- to raise the specificity of development, processing and diffusing knowledge within the network to strengthen incentives for the participants to concentrate their investments in the network and protect new knowledge against competing networks.

Clusters and networks are learning organizations and among the non-market devices by which firms seek to coordinate their activities with other firms and other knowledge-generating institutions. Organizational learning takes place when the organization develops systemic processes to acquire, use and communicate organizational knowledge, as learning is conceived as something that should deliberately be pursued by the organization and its members (Argyris and Schön 1978; Shrivastava 1983; Pedler *et al*. 1991; Nevis *et al*. 1995; Stankiewicz 2001). Thus, organizational learning can be recognized by the existence of learning systems that are independent of the individuals. Clusters and networks as learning organizations can be regarded as a form of '*Coasean*' institution (Coase 1992) that tries to integrate the positive external effects of innovation, technological knowledge and development activities (Coleman 1988; Keeble *et al*. 1999; Lagendijk and Cornford 2000). The emergence of these institutions is closely connected to concepts of trust and social capital. Social capital is a more inclusive concept which, according to one popular definition (Putnam 1993): 'refers to features of social organization, such as trust, norms and networks, that can improve the efficiency of society by facilitating coordinated actions'. Social capital can be seen as a conceptualization of the glue that facilitates transactions, cooperation and learning in an uncertain world.

The creation of such institutions may be endangered by high transaction costs (Williamson 2000). Yet because of the specific character of technological knowledge, its asymmetric and tacit character these transactions have to be mediated by non-market methods, primarily through networks and other forms of arrangement between organizations and individuals, procedures which build trust and work to limit the damaging consequences of asymmetric information. So we need the support of clusters by policy reducing transaction costs.

In the literature, one often finds the concept of 'locally bounded knowledge spillovers' (Feldman 2000). According to some contributions, knowledge (at least locally) 'is in the air' and everybody benefits (at least in principle) by the existence of such a 'stock of knowledge', as it is embodied for example in universities and research centres, other firms, etc. Others argue that knowledge is transferred mainly through

F2F contacts, formal and informal conversations, etc. While both mechanisms are certainly important, these representations are too extreme and may fail to capture some fundamental processes and channels through which knowledge is exchanged and created. It might be argued, for example, that spillovers are much less automatic than described in the literature and they are organized and mediated by a variety of other institutional devices, including the labour market, markets for technologies, labour mobility, etc.

Thus, 'integrative capabilities' belong to the most important factors for learning networks as prerequisites for regional development. This means that different fragments of knowledge, competencies, etc. have not only to be accessed but also integrated into specific configurations. Again, the available literature has focused mainly on the processes through which knowledge is accessed and acquired, much less on how it is actually integrated. Yet there is considerable suggestive evidence that the ways different agents frame available fragments of knowledge and information constitutes a major source of differentials in competitiveness and leads to strongly differentiated performances. At the same time, the transfer of 'integrated knowledge' appears to be much more difficult than the transfer of specific pieces of knowledge and information, even within the same firms and organizations.

Integration or 'compatibility', however, is intensely linked with the availability of common diffusion channels – i.e. standards of communication, codes of expressing experiences, etc. – which emerge by common and repeated routines and intended investments. To make an example, empirical results about scientific research tend to show numerous top-level research centres are present in Europe in most scientific disciplines, but they tend to remain more strongly specialized and less integrated in different phases of the research process than their American counterparts. Moreover, in the US, institutions sometimes exist that provide precisely this type of integration among differentiated research groups (e.g. the NIH as far as biomedical research is concerned).

In particular, 'institutions building' or 'institutional thickness' to build up learning networks with integrative capabilities is important in the CEE transition countries. In fact, CEE countries are facing two main closely interconnected problems: (a) building up market economy; (b) building up a democratic political system. This results in undertaking huge structural changes in industry and performing reorganization of a country administration. The restructuring processes in the industry need a lot of effort and generate a lot of social tensions.

Reorganization of country administration was performed in CEE countries allowing for future acceptance of EU Structural Funds. Networks as a form of cooperation between group of individuals, firms, scientific institutions, political bodies, etc. are of great importance, especially for CEE countries, as they build up trust and cooperation between partners, promote democracy and active participation in solving local and national problems, e.g. unemployment, contribute to development of innovativeness and cooperation with R&D institutions and promote cooperation on interregional and international level. We will turn later in this chapter to the consequences of this for EU policies. Before that, we will extend the argument that it is not enough to concentrate solely on local learning networks and geographical proximity but to secure openness of these networks.

Openness as a factor of innovation and development

The literature on clusters and local networks often neglects the role of external relations. On the other hand, the actual ‘knowledge society’ is characterized by the rapid enlargement of the production processes both in a geographical and institutional perspective. Thus, we have to discuss the role of multinational enterprises (MNE) in this context.

Economic literature has identified both positive and negative effects of MNE on recipient economies:

- on the positive side particularly additional options for knowledge transfer and growth,
- on the negative side weakening of existing local clusters and decreasing competitiveness of peripheral and lagging regions.

On the one hand, MNE may positively affect local productivity by training workers and managers, who may move or spin off from foreign-owned firms and become available to domestic enterprises (Fosfuri *et al.* 2001), by demonstrating the feasibility of new technology, providing technical assistance, transferring patented knowledge and generating opportunities for imitation of technological, organizational and managerial practices (Mansfield and Romeo 1980; Dunning 1993; 2000), by creating demand for local inputs, increasing the specialization and efficiency of upstream and downstream activities and generating positive externalities for local industries (Hirschman 1958; Rodriguez-Clare 1997) and exerting competitive pressures to improve the static and dynamic efficiency of domestic firms (Caves 1974;

Cantwell 1989). The hypothesis that multinational firms can act as export catalysts has also received some support (Rodriguez-Clare 1997; Aitken and Harrison 1999).

The impact of foreign direct investments (FDI) on productivity growth and the development potential of a local economy have been interpreted according to two contrasting hypotheses (Blomström and Kokko 1998). On the one hand, some have put forward the idea that the larger the productivity gap between host country firms and foreign-owned firms, the larger the potential for technology transfer to the former. Thus, the '*catching up hypothesis*' (Findlay 1978) identifies a positive relation between the size of the technology gaps and growth opportunities induced by FDI. This should motivate the entry of MNE that are active at the technological frontier, particularly where domestic manufacturers are relatively weaker, provided that appropriate antitrust and other competition policies are adopted to reduce the risks of monopolization in these markets.

On the other hand, scholars have argued that the lower the technological gap between domestic and foreign firms and the higher the relative absorptive capacity of the former, the higher are the expected benefits in terms of technology transfer to domestic firms. Thus, the '*technology accumulation*' hypothesis (Cantwell 1989) stresses the role of domestic absorptive capacity and the development of internal catching-up capabilities in addition to the coherence of foreign and domestic technology as determinants of virtuous effects of FDI. This is consistent with the view that relatively low technological differentials between domestic and foreign firms would grant higher ability of local economies to capture technological opportunities and respond to the stimuli created by MNE. In contrast, large gaps may signal that foreign technologies are too different from local ones and that local firms have nothing to learn, or are so weak that they are not able to learn. In fact, Cohen and Levinthal (1989) reveal that R&D investments are not only directed towards the production of new information, but are also devoted to the function of assimilation of external knowledge.

The *absorptive capacity* of a firm corresponds to the quantity of external knowledge it is able to utilize and is related to the technological distance (or organizational proximity) between two economic actors. Thus, in order to benefit from interregional/international transfers of knowledge, it is necessary for the firm to own internal capabilities to assimilate or reproduce this imported knowledge. Clearly, the absorption capacity is related to the concepts of social capital and institutional thickness, which have been illustrated above.

Turning to the negative aspects of MNE, it is argued that local and regional clusters are increasingly internationalized or exposed to international threats or opportunities (Szarka 1990; Storey 1994). Particularly important in this framework is to identify whether small and medium sized firms (SME) are able to be present in global markets. Local networks are increasingly integrated in larger networks where flows of intermediate products, specialized services, capital, information, know-how and knowledge circulate. In fact, this internationalization requires the capability by SME to work in different environments, to organize its functions in a more decentralized way and to create flexible alliances with foreign firms. Instead of interpreting the globalization process as an external constraint and risk to their survival, the increasing internationalization of local production systems has to be seen as the spatial extension of the same model of specialization and cooperation with other firms that has long existed within a regional framework. The internationalization process is similar to a gradual process of 'organizational learning' (Cappellin 1998), where the forms adopted by the individual firms vary continuously, trying to adapt pragmatically to the different environment of the various countries on the base of experience.

In a globalized world of freely moving capital and increasingly freely moving people, it is only social capital that remains tied to specific locations. Thus, the 'learning economy' is characterized by the hyper-mobility of information and knowledge and the local character of social capital. What does this mean for the institutional setting of learning networks in an internationalized framework? The relationships between the firms become more complex and risky and need to be redesigned in a long-term perspective. This has compelled firms to devise new organizational forms and contractual arrangements that may be capable of managing these new and more complex relationships. But in particular, peripheral regions are still often rather isolated and less connected or open to economic and social technological relations with other regions and countries.

This rather simplistic view on consequences of the internationalization of learning networks on regional developments becomes more differentiated when two concepts of distance are distinguished (Bellet *et al*. 1993; Gilly and Torre 1998; Rallet and Torre 1998):

(a) 'geographical' and
(b) 'organizational/institutional'.

Geographical distance is related to transport and communication technologies determining the availability of F2F contacts and direct communication, whereas institutional proximity refers to common technological paradigms or countries that have traditions, norms and institutions in common. As we have seen, the enhancement of the process of networking requires some 'enabling structures', both material (transport, ICT) and immaterial (intermediate institutions, service centres, agencies, technological transfer centres). Geographical proximity certainly enhances the organizational and institutional proximity between the various local actors. When spatial distances are important, access to knowledge and learning networks depends on the existence of specific skills, of social relationships and of organizations and 'soft' infrastructures, which may enable access to tacit knowledge and involvement in the processing of new experiences. However, physical distance may represent a sufficient but not necessary condition for the creation of knowledge and innovation networks between firms and organization. In fact, the accumulation of tacit knowledge, the building of new skills and the knowledge spill-over are enhanced by geographical proximity, but they especially require a common culture, organizational framework, social capital and institutions. Thus, knowledge transfers are not territorially bounded when culture, organizational framework, social capital and institutions are common or harmonized. As indicated by Perroux's definition of the 'polarized space', (Perroux 1955) space may be considered as the result of various economic relations. Otherwise, as indicated by the theories of local development, the territory is a social construct.

The two concepts of distance imply a different structure of networks, in particular production, technological and financial networks. In fact, a lower geographical distance allows the development of tighter relations of production integration, such as in just-in-time (JIT) systems or outsourcing of different parts of the production process. In contrast, a lower institutional/organizational distance allows tighter forms of financial and technological integration, as often occurs in MNE operating in high-technology sectors. The learning process both within and between firms is occurring within an organizational and institutional framework. The un-traded interdependencies between the firms become less informal as they were originally in local industrial clusters, and the modern economic relationships require *ad hoc* institutions and organizations which perform the role of specialized intermediaries. But once having managed this and achieved a low organizational/institutional distance, this facilitates FDI in joint ventures together with local firms as well as the acquisition of or financial participation in local firms. This process encourages the creation of technological spin-offs and the specialization of local firms in innovative production, which may be integrated with that done by other firms of the same group at international level. These forms of international technological, production and marketing collaboration do not require a strong geographical proximity as the information and financial flows could be managed at large distance when a strong organizational and institutional proximity exists.

This is the case demonstrated by various dynamic areas in Europe, such as Ireland as well as the Italian regions of the Centre-North, which have been very successful in attracting non-European investments. At the international level, this case may be represented by some Far East countries, which are distant from European and US markets but are tightly embedded in the networks of international alliances between firms and clearly characterized by a strong openness to international linkages. Looking at this ambiguous result of the influence of geographical proximity, the question arises to what extent the technology can be incorporated as an independent factor of production in the theoretical analysis of integration processes and – particularly against the background of EU enlargement – the creation of the learning regions integrated into a 'European Single Market of Knowledge'. Further integration and cohesion within an enlarged EU offers the opportunity to link together different national (regional) innovation systems into one unique multi-disciplinary and multi-sectoral network of innovation, where different strengths are multiplied and weaknesses are compensated. In the following, we will investigate how far EU policies have contributed to such integration.

The framework of European R&D and regional policies

At the Lisbon European Council in March 2000, Europe's Heads of State and Governments set an ambitious objective: over the next ten years, Europe should become the most competitive and dynamic knowledge society in the world, capable of sustainable economic development, accompanied by a quantitative and qualitative improvement in the level of employment, and greater social cohesion. In its Communication *Towards a European Research Area* of January 2000 (European Commission 2000a), the Commission outlined the objectives and scope of a new strategy, aiming at a fully developed, functioning and interconnected research space.

However, as indicated by the Second Report on Economic and Social Cohesion adopted by the Commission in January 2001, significant differences remain at the national and regional levels in terms of technological development and innovation, as well as in terms of human resources. Data and analyses indicate that the technology gap between the less-favoured regions and those in the EU member-states where research and innovation related expenditure is highest (Germany, France, Sweden and Finland) has widened rather than narrowed (with the notable exception of Ireland). This technology gap is reflected at the level of the regions. In fact, one of the most important gaps between Objective 1 regions and those located in the rest of the EU member-states remains business expenditure for R&D and innovation. These differences are also illustrated by the latest available statistics on Science, Technology and Innovation produced by the Commission (European Commission 2000b and c, 2001a and b). Thus, as indicated by the Communication from the Commission (European Commission 2001c):

> These overall disparities may impede the process of transition of the Union to a knowledge-based economy. Serious efforts have to be targeted on enhancing knowledge diffusion, upgrading human resources and promoting organizational changes that will drive science, technology and innovation efforts further.

Helping economically lagging regions to take part effectively in collaborative research projects at national or European level, develop their human science and technology resources, take more advantage of the opportunities offered by venture capital provision and thus integrate faster in the European research community, remain primary targets of Community policy. Also in a previous key European document on the guidelines of the European regional policies (ESDP 1999), it is indicated that: 'Policy must ensure that all regions, even islands and peripheral regions, have adequate access to infrastructure, in order to promote social and economic and, therefore, spatial cohesion in the Community.'

Thus, knowledge and innovation networks have long been recognized as a key factor in promoting European integration. The ESDP document states:

> Knowledge, education and training are becoming an ever more important foundation stone for economic participation and success. Regions with limited or unsatisfactory access to information and knowledge, because of a lack of further education, research and

> training facilities, are likely to have problems in maintaining population and, in particular, getting people with higher education and more advanced skills attached to the region. This could reinforce population movements to areas that are already well endowed with infrastructure, increasing pressures on these areas while reducing the prospects for better living standards in economically weaker regions. (ESDP 1999)

Reflecting this approach, initially, EU Structural Funds activities in less favoured regions were concentrated on physical infrastructure. This was essential to build up capacity in terms of laboratories and equipment. Today, despite the fact that critical infrastructures are still important for enabling the transition to a knowledge-based society and economy (for example the availability of modern telecommunications and data networks), the growing importance of intangible investments in education, training, research and innovation priorities is widely acknowledged. In particular, the programming exercise for EU Structural Funds activity 2000–2006 revealed the strong weight given to R&D and the Information Society as a central axis in development plans for Objective 1 regions.

With enlargement, the adoption of the principle of European cohesion will be extended from the Objective 1 regions of the present 15 member-states to regions in the CEE candidate countries. Thus, also the majority of the concepts developed in the context of the ‘European Research Area’ will be applied to the candidate countries. Consequently, research is one of the areas contributing substantially to the accession strategy.

As well as regional policies, Community R&D policies have supported knowledge and innovation networks at an international level. To date, the prevalent policy stance in the Commission has been to support applied transnational research projects in order to progressively achieve a stronger integration of research teams from weaker countries with those of the stronger. These policies have had some success in this respect, but their record is much less clear as far as the integration of the different stages of the research process and different disciplinary bases are concerned. Despite the success of EU policies, the European research systems remain strongly nationally based. In order to achieve a better integration, for instance, it has been suggested that a European Science Foundation, partly modelled after the US National Science Foundation, might be useful in this context.

As indicated by the Communication from the Commission, ‘The Regional Dimension of the European Research Area’, it is necessary to promote synergies between less developed and advanced regions through the introduction of coordination and networking activities. It is not only necessary to establish a local research and innovation strategy mobilizing all available resources and actors within the individual regions, but also to embark on interregional cooperation schemes, forming networks of various types. In this perspective, it is important to extend innovative experiments by some particularly successful regions which have engaged in cross-border R&D cooperation. These initiatives will have a real Community added value, by virtue of their contribution to economic and social cohesion.

The creation of necessary conditions for the integration of research capabilities existing in less favoured regions in the European research fabric requires stimulating the setting-up of real networks of scientific and technological competence, thus facilitating knowledge transfer and creating transnational organizations that associate regions together. However, the integration of less developed regions in the European Research Area cannot be restricted to the enhancement of international collaboration between R&D institutions. It should consider a wider perspective where R&D institutions are only one of the components of various regional economic and social systems, and innovation is related to interactive learning processes, which involve many firms, specialized services, institutions of vocational and higher-level education, professional associations, etc. Increasing the knowledge base of an economy does not just mean the investing in R&D by one single researcher, company or institute: it is also necessary to improve and intensify linkages both of codified and tacit knowledge between single actors of different kinds. Thus, the study of the national integration of local clusters and their process of increasing international openness sheds some light on a still open issue: How may learning processes and knowledge and innovation networks be extended to the less developed regions of the EU and CEE countries?

Agenda for future research and policy considerations

A number of open questions (already hinted at and described in more detail in previous sections) and agenda for future research and policy issues arise from these considerations.

(a) New issues in the analysis of learning and innovation processes

In fact, the challenge of globalization and international competition justifies an effort aiming to remove the problems and obstacles hindering a tighter economic and technological integration between the countries/regions of Europe. In a theoretical perspective, the problem to be tackled by the research is that of finding ways to enlarge the geographical span of those interactive learning processes or knowledge spillovers, which according to the literature are common when industrial and service activities are geographically concentrated in specific clusters or linked in local networks. Thus, we still have to investigate the key theoretical question of how important spatial proximity is for the sustainability of learning and innovation networks, and how the need for spatial proximity can be made compatible with the need for connectivity, in order to intensify European integration and cohesion and to bridge the gap between highly and low skilled in European economies.

(b) Confrontation between the experience in the most developed and in the less developed regions

We still have to verify the hypothesis that a firm located in a peripheral area not only needs technological help or transfer, but also needs to develop its own absorptive capacity, in order to be able to absorb knowledge coming from outside. This means that by removing organizational/institutional obstacles and creating appropriate enabling infrastructures, interactive learning and innovation processes in a European interregional/international framework may be enhanced. In particular, coming research will have to compare the experience in the most developed regions with that in the less developed regions, both in the Objective 1 regions of the EU and the regions of the CEE countries, and examine the obstacles to be removed and the local potential to be enhanced for the less developed regions to take full advantage of the increasing integration at the European and international level.

In addition, we should aim to show how the success of clusters in the most developed regions can be replicated elsewhere, especially in the case of the less developed regions in Southern Europe as well as in CEE countries. This raises the well-known problem of whether clusters can be artificially created. However, a more general objective of coming research is to extend the lessons derived from the in-depth analysis of knowledge and innovation networks in local clusters, in order to identify how interactive learning can occur at greater distance and promote a greater international/interregional integration between different national/local production and technology systems from the perspective of the model of the knowledge society.

(c) New perspectives for Community innovation policies

From a policy perspective we have to assess the present state of technological and innovation policies with regard to these issues and develop strategies for an intensification of interactive learning processes and cooperation. We have to indicate a set of policy recommendations for the creation of new hard and soft infrastructures or institutions, both at local and European levels, which can enhance the way in which knowledge and innovation networks existing in the most developed countries of the EU may extend to the economic lagging regions (particularly Objective 1) in Southern Europe and the CEE candidate countries.

Moreover, the European economy is enriched by a wide diversity of social models and cultural and historical backgrounds. Thus, the same policy framework may have different effects in different regions. In particular, the differences between the less-developed regions in Southern Europe and the CEE regions/countries have to be identified and studied. Clearly, European regions are still characterized by a wide institutional distance causing barriers to international knowledge and innovation networks, since the national independence of the various countries leads to higher institutional differences than would exist within the same country, as is the case of the US. A further difference to the US case is the existence of a long and strong tradition of regional policy, i.e. of a policy aiming to promote economic and social cohesion, which has objectives and instruments distinct from those of other public economic and social policies, in Europe and all the individual countries.

Finally, even the concepts of the 'knowledge society' and 'learning economy' are different from related approaches more widely used in other world areas, such as 'new economy' and 'e-economy', with a focus on a restricted set of high-tech sectors, such as ICT. Clearly, the concept of knowledge and innovation networks includes new technologically advanced productions and traditional but complex production, as well as private and public sector activities. Thus, it is important to foster partnerships between the public and the private sector in order to contribute to the European knowledge-based economy and stimulate knowledge creation and diffusion.

(d) New approaches for an appropriate institutional framework

According to a network approach, policy has to look for variety and diversity, not optimality, as evolutionary policy-makers shift away from efficiency toward creativity, and patterns of adaptation move to market stimuli and technological opportunity. The canonical policy problem is defined in terms of the dynamics of innovation, in a world characterized by immense micro-complexity. A new approach in policy-making, based on the concept of international innovation and knowledge networks, encourages study and identification of new measures and mechanisms of integration, which are described in more detail and discussed from a demand-driven perspective in Chapter 10 by Cappellin.

An appropriate institutional framework at the European level may have a key role in determining the rate and direction of technological learning. Thus, it is important to promote an environment conducive to research and innovation, through the introduction of accompanying legal, financial and fiscal conditions. Supranational institutions may become an important actor in setting policies which do not merely support particular innovative activities but create a framework by which knowledge dynamic processes are harnessed. Trans-regional infrastructures could allow greater share of information through more frequent F2F contacts, common culture and greater opportunities for collaboration. These policy indications may contribute to the European R&D policy and to the European regional policy in economic lagging regions.

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