Collaboration and Innovation Networks in Esprit

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ABSTRACT *The Esprit Programme is the oldest and largest of the European Commission's research and development programmes. Collaboration among participants is fundamental to all the projects that it supports. This collaboration is justified in terms of benefits for innovation, yet the very formal collaboration of Esprit is far removed from both the network links which are now seen to join organisations, and the informal information channels of individuals, vital in the supply of information required for innovation. This paper considers what their relationship with formal collaboration might be.*

Keywords: collaboration, innovation, Esprit, R&D, information networks.

Introduction

A fundamental assumption in European policy circles is that collaboration is conducive to technological innovation.[1] Policy makers have justified their support for collaboration among firms, universities and government organisations on a number of grounds, such as sharing the costs and risks of expensive research and development (R&D), expanding the knowledge base of participants through complementary talents and capabilities, and improving competitiveness in an increasingly globalised economy. Esprit, the European Strategic Programme for Research in Information Technology, is an excellent example of this sort of collaborative research.[2] Esprit has not only promoted collaborative structures from its origins in the early 1980s, but has also served as the model on which various R&D programmes of the European Union have been designed and implemented since.

Formal collaboration is organised among firms and organisations, often for the accomplishment of a specific project within industry constraints, or the constraints imposed externally by a mechanism such as Esprit. Informal information flow, however, often occurs on an *ad hoc* basis between individuals across institutional and organisational boundaries.[3] The personal networks of key employees, such as technical experts, transcend the boundaries of formal collaboration and stretch out to other organisations and institutions which provide tacit and uncodified information of great value to innovation. This kind of information is perhaps critical to the success of formal collaboration as new non-linear models of innovation suggest,[4] but does formal collaboration also discourage informal information flow, thus undermining the acquisition of the information critical for innovation? For instance, do people and organisations in the external environment of an Esprit collaboration, when they become aware of a formal agreement, withdraw from the exchange of tacit and uncodified information because they are not part of this agreement? This paper will argue that firms, particularly those

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in the north of Europe, may perceive a conflict between informal networks and the formal collaboration necessary for participation in EU programmes such as Esprit. Very generally it is observed that the links which are really valued, and which must be preserved despite collaboration, are with individuals in non-collaborating and often non-European organisations. There is a strong possibility, as yet unexplored, that the ties which really bind European collaboration and make it work are exogenous to the collaboration, are personal and informal, and connect European partners not directly, but via California, Taiwan and Japan.

Collaboration in Esprit

Collaboration has long been a means favoured at both the national and the European level for extending the knowledge base of individual firms, thus encouraging continuous innovation and increasing the competitiveness of collaborators.[5] Hamel *et al.* argue that formal collaborative agreements among firms extend the knowledge base of each by increasing information flow among the partners, thus contributing to their ability to learn and change.[6] When technology remained relatively stable over time, vertical integration and corporate centralisation offered needed economies of scale and market control. In an age of volatile technology and markets, however, the horizontal co-ordination provided by collaboration enables firms to retain the focus and flexibility needed for continuous innovation. Saxenian points out that technological collaboration in IT shares the horrendous costs and risks of cutting-edge R&D, providing access to a greater range of relevant skills and expertise.[7] It also shortens lead times for the introduction of new core products and services, discouraging potential imitators while fostering reciprocal innovation among partners.

European Commission funding for collaborative R&D in IT started in 1983. Since then, Esprit has received funding within the four Framework Programmes (FP) of the European Commission in four successive phases (Esprit I: 1983–87, Esprit II: 1987–90, Esprit III: 1990–94 and Esprit IV: 1994–98). The Programme has evolved a great deal in its 16 years. Aims and objectives have been changed again and again in response to developments in the world's IT industry, and to the interests of a large number of stakeholders from industry, academia and policy circles at national and European levels. According to the Colombo Report, there are at least four overlapping, complementary and sometimes even conflicting targets for Esprit research.[8] The first two influenced Esprit developments in the 1980s, while the last two are more reflective of Esprit thinking in the 1990s.

The first is the view that the Programme should play an industrial policy role. Back in the early 1980s, the 12 largest European electronics firms were inspired by Japanese-style consortia and persuaded EU officials to launch Esprit as an initiative which would advance intra-European industrial co-operation in R&D among the Continent's national IT champions.[9] The underlying notion was that Europe was competing against the US and Japanese IT industries and that only large firms could be expected to compete successfully. Thus national champions became European champions within a Fortress Europe, and thus the single firm support which many of these large firms had received from their national governments was transformed into assistance that was much more politically acceptable.

Second was the view that the Esprit programme should facilitate long-term, blue sky research. Firms and universities, with limited individual resources and working to very short time frames, it was argued, would not otherwise carry out such research.[10] The notion of pre-competitive research was devised to distinguish research in which

collaboration was appropriate from that in which it was not. Pre-competitive research focused on generic, basic technologies and produced results which could be used by all partners, and ultimately by the whole European IT industry. It provided the research infrastructure for competition on which individual firms would develop their own competitive resources. Pre-competitive research was deemed to be much riskier than this near-market research. Thus was the role of policy kept quite distinct from the role of the market.

The third is the current view that the Esprit Programme should underpin the competitiveness of the whole European economy, and not be limited to the IT industry. The third Framework Programme shifted the emphasis of Esprit from a narrow, technical approach to IT R&D, to applications embracing for the first time examples of best IT practice, and to diffusion and training initiatives across many sectors of the economy. Thus, Esprit was to influence the European IT industry not only through technology-push initiatives backed up by large vendors, but also through demand-pull initiatives driven by users.

Finally, the view of the fourth Framework Programme is that the Esprit Programme should pave the way for Europe's entry into the information society by providing IT infrastructure and services for the first decade of the new millennium. The Carneiro Report explicitly demands that Esprit address the needs of society at large, and not only the needs of business and industry, in order to boost competitiveness and employment across many economic sectors.[11] This view is further enhanced in the forthcoming fifth Framework Programme (1998–2002), when all information and communication technology (ICT) programmes of the EU, including Esprit, will merge in one thematic programme called 'Creating a User-friendly Information Society'.[12]

Esprit research is divided into a number of domains which are revised annually in the light of changes in the IT industry, and broad consultation with various committees and stakeholders in Europe. Each domain has its own budget so competition varies considerably across domains. Overall, there is a high level of competition for Esprit funding and less than 20% of the proposals submitted are funded.[13] Organisations can find collaborators for proposals through a wide range of channels. Some have been collaborating with their Esprit partners for many years,[14] while others find partners casually through friends of friends. Information about potential partners is also provided on the Commission's CORDIS database on the world wide web.[15] The Commission has set up national Esprit contact points and regularly holds Esprit information days in Brussels. Large boards are provided at these on which hundreds of putative partners post notices and cards advertising their availability. In addition, the European Information Technology Conference has long been a contact point where academics, government officials and industry researchers meet annually and communicate results from Esprit research.

In all, 2250 Esprit projects have been completed, or are near completion. Average project cost has consistently fallen from approximately 6 million ECU to 2 million ECU. This reflects the changes behind Esprit thinking, especially since the early 1990s, when a shift from large-scale research took place. The average number of partners per project rose from approximately 5 in Esprit I to 9 in Esprit II. The average fell to 7 and then to 5 for Esprit III and IV, respectively. This trend to some extent reflects the aspirations of the European Commission to support large collaborations in the late 1980s involving as many partners as possible. In the 1990s, smaller budgets cut down the average size of collaboration and a new emphasis was placed on including small- and medium-sized firms in these. Total funding for ESPRIT research has increased over the years with more than 5.5 billion ECU spent so far.

Doubts about Collaboration

Despite changes over the years in the emphasis of Esprit research, the Commission has adhered doggedly to the doctrine that research must be collaborative. There are, of course, political attractions to collaboration which have little to do with its efficiency as a research mechanism. Collaboration is a ready means by which resources and incentives can be distributed to the least advantaged of Europe, whether these be regions or small firms. However, the tide of both industry and academic opinion seems to have turned very much against the sort of formal collaboration the Commission still espouses.

The IT industry has never been the sort of industry in which innovation is associated with large firms and economies of scale. From the very inception of the microelectronics industry, innovation was associated with small firms, often new entrants to the industry. In the US, though not in Europe, not only did the incumbents in the old electrical industry not thrive in this environment of rapid innovation, they often left the business altogether.[16] For new firms in a new industry, the environment of Silicon Valley, an environment created largely by the firms themselves, proved conducive to the innovation fundamental to their competitiveness. Silicon Valley was never the product of policy, but it has certainly contributed to policy in the sense that it provided a powerful model for policy makers to emulate.[17] The most extreme version of this emulation was the science park movement and the high technology policy of the early 1980s, which assumed that the advantages of Silicon Valley could be re-created wherever policy determined. Fundamental to this assumption was the co-existence of high technology firms in such locations, agglomerations conveniently interpreted as a form of the collaboration with which government science policy was very familiar. Moreover, the Japanese model for policy intervention in the industry—alliances of players from industry, government and universities orchestrated by MITI—seemed a clear collaborative response to Silicon Valley. Even in the United States, government had encouraged the establishment of Sematech, a collaborative research venture of microelectronics firms. By then, of course, the industry was changing with some parts becoming decidedly mature and some firms entering into the sort of formal alliances familiar to Brussels. Yet, the heart of the industry is still dependent not on formal collaboration at all, but on informal co-operation within competition. This sort of co-operation is extremely hard even to identify, let alone accommodate within traditional science policy, though some of its elements are coming to be appreciated in academic and managerial thinking.

While the notion that research could be pre-competitive satisfied the policy requirement to separate government intervention from market forces, the distinction seemed artificial to many academics. At what point did pre-competitive research become competitive research? A more fundamental objection arose from the linearity implied in the idea of pre-competitiveness. The linear model of resources injected into R&D at one end of a system to emerge as innovation at the other has long been rejected in favour of much more complex models involving inputs to innovation from throughout the organisation and beyond, entailing interaction, re-iteration and networking rather than a uni-directional process. Moreover, strategy now demands that innovation be market-led rather than technology-driven, a notion which fits well with 'Creating a User-friendly Information Society', but which conflicts with Esprit's traditional aim of encouraging pre-competitive research in collaboration.

Academic thinking never showed much support for Fortress Europe either. It seemed absurd that any amount of policy could make Europe self-sufficient in microelectronics. Growing interest in internationalisation stressed the interdependence of economic activity.[18] It put into doubt even the nationality of firms and consequently undermined

further the notion of national champions. Firms would operate wherever their resources gave them competitive advantage. Certainly this often meant combining resources with other firms, in joint ventures for example, but academic interest was in how very difficult such ventures were to manage. In particular, it was pointed out that static agreements in a dynamic world led to an almost inevitable increase in the imbalance of the partners. Why, it was asked, did some firms seem to learn so much more from a partnership than others? The problems of collaboration attracted much more attention than the benefits. Trust was essential and trust took time to build, but time brought the problems of dynamic change in the relationship. Interest in transaction costs stressed the advantages of the unitary organisation and the problems of sharing resources with other organisations.[19] In the real world, appreciation of these transaction costs has been evident in an orgy of mergers and acquisitions as firms seek to place resources within a single boundary and under a single control. Strategic alliances are less favoured, posing, as they do, so many of the problems inherent in collaboration.

Certainly there has been massive and increasing interest in new structural forms for the firm, most evident in the consideration of the network firm and even the virtual firm. These go some way towards recognition that the firm's primary resource is information. What they also begin to do is appreciate that the organisation, information organism that it is, is not always impressive in its handling of information.[20] It is superb at dealing with information within its own boundaries, information which it owns, familiar information flowing along customary channels and with established uses. Owning all this information, the organisation can concentrate on establishing systems for its internal transfer to those parts of the organisation where it is needed. This is not the case with external information; this the organisation does not own, this it must somehow find and acquire without the aid of organisational systems. Nor can it rely on the market, which notoriously fails in the buying and selling of information. Organisational and market failure in securing external information is important for this is the very information required for the organisation's innovation. The information contained within the firm's boundaries supports very well what the organisation already does, but innovation usually requires an injection of new information and this must generally come from outside the firm's boundaries. Consequently, information transactions are required rather than the simple information transfer to which the firm is much more accustomed.

A great deal of interest has been shown over the past decade or so in just how the organisation copes with these transactions.[21] The general conclusion is that the very nature of organisation circumscribes what it can do as an organisation, and that individuals within the organisation cope very much better. The individual, operating on his own account, can undertake information transactions which the organisation cannot. Basically, the individual trades in information, exchanging internal information for external, most effectively in information networks. While these dealings are appropriate to the nature of information with its peculiar characteristics as an economic good, they are less appropriate to the nature of organisation.[22] Most firms do not welcome their information, often their most valuable information, being given away by their own employees for their own personal gain, often to the employees of competitors. At best, the process means loss of a degree of control which keeps the organisation together and functioning: at worst, it seems like the loss of a key resource. Yet, this information trading, and the employee mobility which tends to accompany it, are efficient means of effecting the information transactions essential for innovation. They are particularly important where innovation is rapid and dependent on tacit and embodied information. These are the conditions in which high technology operates and the conditions in which

high technology industries prosper are generally those which allow these transactions to take place.

Basically, the formal structure of the organisation limits its ability to deal with information for innovation and it relies on much more effective informal mechanisms. Such concepts as the network firm go some way towards recognising this deficiency in their appreciation that no organisation can contain within its own boundaries all the resources required for competitiveness in general, and for innovation in particular. This bears some resemblance to the principal argument for collaboration, but the distinction is important. The notion of the network firm challenges the importance of organisational boundaries: collaboration, with its fundamental concern for who will put what resources into the partnership and who will get what resources out of it, reinforces organisational boundaries. Such collaboration, which is necessarily formal, is also far removed from the informal information trading which compensates for the deficiencies of the organisation in high technology. Collaboration requires formal agreements on responsibilities, on who will do what, and consequently, as research is a particularly information-intensive activity, on what will and will not be revealed. At its most formal, research collaboration is information flow arranged by accountants and is the very antithesis of information exchange through personal networks. Indeed, it is possible that such formal collaboration may be inimical to informal know-how trading. If this is the case, given that such trading is fundamental to high technology innovation, it may be that formal collaboration of the Esprit variety actually discourages the innovation it seeks to promote.

IT and related industries place a high premium on speed and focus in the innovation process. Rising costs of product development, shorter product cycles and accelerating technological change have rendered obsolete the vertically integrated model of technological production which dominated the post-war period. Before the early 1980s, firms such as IBM and DEC manufactured most of their technically sophisticated components and subsystems internally. Successful companies, such as SUN and Hewlett Packard in Silicon Valley, have demonstrated over the past decade that informal information exchange, inter-firm mobility and networking, even between intense competitors, are the characteristics of a successful innovation strategy.[23] Low risk, low value-added, arms-length relations characterised by low loyalty are increasingly being replaced by high risk, high value-added, loyalty and trust based relations which create mutually beneficial interdependencies and cross-cutting structures and cultures. Such institutional arrangements not only lower fixed costs and respond to increasing demands for shorter product cycles, but demonstrate how the whole economy is embedded in social relations which enable information exchange and thus mutual learning and adaptation to continuous change.[24]

Organisational theorists, such as Badaracco, have highlighted this transformation of companies from medieval citadels to renaissance city states through knowledge links.[25] These knowledge links mean that even large firms, such as IBM and General Motors, no longer have clear boundaries. Some knowledge is explicit and can migrate very fast and easily. Such migratory knowledge is often encapsulated in pieces of machinery, or codified in formulae, designs, manuals, computer software and the like, but some knowledge is deeply embedded knowledge and moves slowly.[26] The reason is that embedded knowledge usually resides in people and in complex patterns of social relations. A team of engineers, a department, or an organisation, regardless of whether it is a small firm or a whole technological community, 'knows' things through social interaction which none of its individual members know.[27] Some of this knowledge cannot be fully articulated because it is tacit and uncodified.[28] Tacit knowledge includes ideals, values and beliefs which are expressed in highly subjective and qualitative insights,

intuitions and hunches. Tacit knowledge is sticky and moves slowly and awkwardly among organisations. For one firm to acquire tacit knowledge embedded in the routines of another, it must form a complex, intimate pattern of multi-stranded relations with it. Such embedded knowledge cannot simply be codified and put in a piece of hardware, a formula, or a manual and then exchanged for money. Similarly, if two companies want to create new capabilities by combining their knowledge and talents in a unique way, they must create not only contractual and economic links of the Esprit sort, but also knowledge and social links to enable personnel from both firms to work closely together. Physical proximity and face-to-face interaction are key facilitating factors which enable people to build trusting working relations in an era of increasing electronic communication.[29]

The significance of embedded and tacit knowledge in continuous innovation is emphasised by Nonaka and Takeuchi, who argue that Western managers need to pay more attention to the less formal and systematic side of knowledge and start focusing on highly subjective values and beliefs, insights, intuitions and hunches that are gained through the use of qualitative, unquantified experiences and mental models.[30] Their cyclical theory of organisational knowledge creation totally rejects the linear view of innovation (implicit in the notion of pre-competitive research) as the creation of a sequential series of discrete stages starting from government funded basic research, leading through applied R&D to the commercialisation of new products and services. Instead of partitioning roles and portraying scientists, engineers, commercialisers and customers as unconnected actors, Nonaka and Takeuchi propound a spiral process upon which knowledge is continuously created at the organisational level. Socialisation as a fusion of participants' tacit knowledge in a shared mental model plays a key role in the transfer of information within and across organisational boundaries.[31] Innovation is viewed as an interactive, relational and emergent process in which the personal networks of individuals informally communicate not simply information, but also associated values, beliefs, intuitions, and subjective insights.[32]

The value of informal information networks in technological innovation is also explored in depth in a complementary body of literature on collaboration which focuses on information, rather than knowledge. Knowledge is unlike information because it is partly about subjective values, beliefs and commitments which stem from a particular perspective, or action. Knowledge, however, like information, is about meaning because it is context specific and relational. This relational view of information is taken by Rogers and Kincaid in their convergence model of communication.[33] According to this model, communication is again a spiral process in which participants create and share information with one another to generate mutual understanding. This cyclical process involves giving meaning to information that is exchanged between two or more individuals as they move towards convergence (or divergence). Communication networks highlight the form of such information exchange at the team, organisational and community level. Fundamental to communication networks is that collaboration within and across organisations is mediated by people who exchange and share information.

Two Case Studies

Esprit has evolved over the past 16 years into an enormously complex structure which involves thousands of projects and partners throughout Europe. Collaboration networks in Esprit include large, medium and small firms, university and research laboratories, and IT users from government agencies, based in more than 15 European countries and hundreds of European regions. Consequently, it is too complex a task to draw general

conclusions applicable to the whole Programme. However, two cases from Esprit literature (one a 'success' and the other a 'failure') help to illustrate the range of firm response to collaboration.

Case Study 1: ARM Ltd

Advanced RISC Machines (ARM) is a world leader in microprocessor cores and peripherals for computing, communications and consumer electronics applications.[34] ARM's products are used in ISDN telecommunications equipment, video games, palmtop organisers and networked computers. From a start-up company with a 12-person research team in 1991, the company has grown rapidly to employ 160 people in 1996 with sites in Cambridge, Munich, Los Gatos in California, and Tokyo. From 1991 to 1995, the company increased revenues at a compound annual rate of 78%, resulting in sales of $US 28 million, and profit before tax of $US 6.5 million in 1996. The company has been involved in about 10 Esprit projects, of which seven are on-going in Esprit IV. ARM has been the main contractor and co-ordinator in about half of these. Typically, ARM is involved in an Esprit collaboration as technology provider, together with a software house, an equipment manufacturer and an end-user to exert the necessary 'market pull'. Esprit has helped ARM to develop links with original equipment manufacturers, end-users and universities. With the Department of Computing Science at Manchester University, ARM has created the world's first asynchronous computer chip—AMULET.[35] It has also acquired the AMULET patents and intends exploiting them in future products.

Case Study 2: Black Sun Interactive

Black Sun Interactive is a highly dynamic software start-up with two offices, in Munich and in San Francisco.[36] Founded in August 1995, the company envisions a world in which people meet, work and play in cyberspace as normally as they do in the real world. It has developed a three-dimensional multi-server Internet browser and aims to provide even more sophisticated support for interaction on the world wide web. Given the risk aversion of the banking community in Germany, Black Sun sought venture capital in the US, where investors are more familiar with the close association of high risk and high technology. Black Sun's activities are driven by the extraordinary speed of innovation in Internet services. At this pace, strategy demands speed to market, coupled with acceptable functionality, to establish market dominance. Rapid upgrades are essential as new generations succeed old. After a brief examination, Black Sun turned down the opportunity to participate in Esprit. The Programme's time scales are far out of line with those of its market. The pace of change in the IT market means that companies like Black Sun cannot contemplate pre-ordained work programmes revised every 12 months, and standard procedures for the protection of intellectual property, mandatory in Esprit programmes. Esprit collaboration would inevitably have slowed Black Sun's rapid development.

Conclusion

The case studies serve to illustrate a basic issue which is often overlooked in discussion of the costs and benefits of collaboration. This is simply that firms are not homogeneous and the circumstances in which they operate can be very different. Collaboration seems to have suited ARM nicely, while it would have been quite inappropriate for Black Sun.

Similarly, it is possible that Esprit collaboration may suit the IT firms of Southern Europe in that it provides links to the IT industry of Northern Europe and the world beyond which they would otherwise lack. It may be that Esprit collaboration simply brings the firms of Northern Europe less benefit, but this conclusion assumes that collaborative links of Esprit can simply be added on to other collaborative links. Perhaps they can, but there is a vast difference between the formal links of collaboration and the informal networks which supply so much information for innovation in high technology industries. What happens to these? It may be that formal collaboration damages such informal networks and thereby actually discourages the innovation it seeks to encourage. More likely though, and really more intriguing, is the possibility that formal collaboration in Esprit may be held together by informal networks. In other words, the linkages which bind European partners so formally operate through the informal inclusion of unacknowledged partners world wide. If this is the case, new light is cast on an old debate which suggests that the time may have come to amend if not the practice of European collaborative R&D, then at least the justification.

Notes and References

1. See L. Soete and A. Arundel (eds), *An Integrated Approach to European Innovation and Technology Diffusion Policy: A Maastricht Memorandum*, Commission of the European Communities, Brussels, 1993; D. V. Gibson and E. M. Rogers, *R&D Collaboration on Trial: The Microelectronics and Computer Technology Corporation*, Harvard Business School Press, Cambridge, MA, 1994.
2. See L. K. Mytelka, 'States, strategic alliances and international oligopolies: the European ESPRIT programme', in L. K. Mytelka (ed.), *Strategic Partnerships: States, Firms and International Competition*, Pinter, London, 1991, pp. 182–210; J. Hagedoorn and J. Schakenraad, 'A comparison of private and subsidized R&D partnerships in the European information technology industry', *Journal of Common Market Studies*, 31, 1993, pp. 373–90; V. Koutrakou, *Technological Collaboration for Europe's Survival: The Information Technology Research Programmes of the 1980s*, Avebury, Aldershot, 1995.
3. See, for example, E. M. Rogers, 'Information exchange and technological innovation', in D. Sahal (ed.), *The Transfer and Utilization of Technical Knowledge*, Lexington Books, Lexington MA, 1982, pp. 105–23; S. Macdonald, 'Informal information flow and strategy in the international firm', *International Journal of Technology Management*, 11, 1996, pp. 219–32.
4. M. Boisot, *Information Space: A Framework for Learning in Organizations, Institutions and Culture*, Routledge, London, 1995; I. Nonaka and H. Takeuchi, *The Knowledge Creating Company: How Japanese Companies Create the Dynamics of Innovation*, Oxford University Press, Oxford, 1995.
5. See, for example, B. R. Guile and H. Brooks (eds), *Technology and Global Industry: Companies and Nations in the World Economy*, National Academy Press, Washington, DC, 1987; B. A. Lundvall and C. Freeman (eds), *Small Countries Facing the Technological Revolution*, Pinter, London, 1988; L. Georghiou *et al.*, *The Impact of European Community Policies for Research and Technological Development upon Science and Technology in the UK*, HMSO, London, 1993; A. C. Inkpen, 'Creating knowledge through collaboration', *California Management Review*, 39, 1996, pp. 123–40; R. Burgelman and S. Rosenbloom (eds), *Research on Technological Innovation, Management and Policy*, Vol. 6, JAI Press, Greenwich, CT, 1997.
6. G. Hamel *et al.*, 'Collaborate with your competitors and win', *Harvard Business Review*, 1, 1989, pp. 133–9.
7. A. Saxenian, *Regional Advantage*, Harvard University Press, Cambridge, MA, 1994.
8. European Commission, *ESPRIT Review Board 1996 Review: Making Progress Happen Through Development, Application and Diffusion of Information Technologies (Colombo Report)*, Brussels, 1997, pp. 10–12.
9. L. K. Mytelka, *op. cit.*, p. 184. See also E. Sharp and C. Shearman, *European Technological Collaboration*, Routledge and Kegan Paul, London, 1987; E. Sharp and P. Holmes, 'Conclusions. Farewell to the national champion', in E. Sharp and P. Holmes (eds), *Strategies for New Technologies. Case Studies from Britain and France*, Philip Allan, London, 1989, pp. 212–33.
10. P. Quintas and K. Guy, 'Collaborative, pre-competitive R&D and the firm', *Research Policy*, 24, 1995, p. 326.

11. European Commission, *Five Year Assessments of the Specific Programme: Information Technologies (Carneiro Report)*, EUR 17601, Brussels, 1997, p. 5.
12. European Commission, *Towards the Fifth Framework Programme: Scientific and Technological Objectives*, Brussels, 1997, pp. 21–5.
13. European Commission, *Carneiro Report*, *op. cit.*, p. 13.
14. Hagedoorn and Schakenraad, *op. cit.*
15. http://apollo.cordis.lu/cordis/EN_PART_search.html.
16. E. Braun and S. Macdonald, *Revolution in Miniature. The History and Impact of Semiconductor Electronics*, Cambridge University Press, Cambridge, 1982.
17. S. Macdonald, 'Towards higher high technology policy', in J. Brotchie, P. Hall and P. Newton (eds), *The Spatial Impact of Technological Change*, Croom Helm, London, 1987, pp. 357–74.
18. M. Forsgren, 'Managing the international multi-centre firm: case studies from Sweden', *European Management Journal*, 8, 2, 1990, pp. 261–7.
19. O. Williamson, *The Economic Institutions of Capitalism*, Free Press, New York, 1985.
20. 'Why networks may fail', *Economist*, 10 October 1992, p. 93; R. Miles and C. Snow, 'Causes of failure in network organizations', *California Management Review*, 34, 4, 1992, pp. 53–72.
21. A. Freeman, 'Networks of innovators: a synthesis of research issues', *Research Policy*, 20, 1991, pp. 499–514.
22. S. Macdonald, *Information for Innovation. Managing Change from an Information Perspective*, Oxford University Press, Oxford, 1998.
23. Saxenian, *op. cit.*, p. 13.
24. M. Granovetter, 'Economic action and social structure: The problem of embeddedness', *American Journal of Sociology*, 91, 1985, pp. 481–510; S. Macdonald, 'Learning to change: an information perspective on learning in the organization', *Organization Science*, 6, 1995, pp. 1–12.
25. J. Badaracco, *The Knowledge Link: How Firms Compete Through Strategic Alliances*, Harvard Business School Press, Cambridge, MA, 1991.
26. E. von Hippel, '"Sticky information" and the locus of problem solving: Implications for innovation', *Management Science*, 40, 1994, pp. 429–39.
27. A. Assimakopoulos, 'Social networks and geographic information systems (GIS) diffusion in Greece: Disciplinary heterogeneity and constructed advantage within the Greek GIS community', in C. Capineri and P. Rietveld (eds), *Networks in Transport and Communications: A Policy Approach*, Ashgate, Aldershot, 1997, pp. 153–74.
28. J. Senker and W. Faulkner, 'Networks, tacit knowledge and innovation', in R. Coombs *et al.* (eds), *Technological Collaboration: The Dynamics of Cooperation in Industrial Innovation*, Edward Elgar, Cheltenham, 1996, pp. 76–97.
29. See, for example, N. Nohria and R. Eccles, 'Face to face: making network organizations work', in N. Nohria and R. Eccles (eds), *Networks and Organizations: Structure, Form and Action*, Harvard Business School Press, Cambridge, MA, 1992, pp. 288–308.
30. Nonaka and Takeuchi, *op. cit.*, p. 11.
31. *Ibid.*, p. 92.
32. See H. Itami, *Mobilizing Invisible Assets*, Harvard University Press, Cambridge, MA, 1987.
33. E. M. Rogers and D. L. Kincaid, *Communication Networks: Toward a New Paradigm for Research*, Free Press, New York, 1981, pp. 43–78.
34. European Commission, *Solutions for Business: Case Studies from ESPRIT*, Brussels, 1996, pp. 372–5. See also European Commission, *Carneiro Report*, *op. cit.*, p. 42.
35. http://www.cs.man.ac.uk/amulet/index.html.
36. European Commission, *Colombo Report*, *op. cit.*, p. 27.