

Collective Learning and Knowledge Development in the Evolution of Regional Clusters of High Technology SMEs in Europe

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KEEBLE D. and WILKINSON F. (1999) Collective learning and knowledge development in the evolution of regional clusters of high technology SMEs in Europe, *Reg. Studies* 33, 295–303. This paper outlines the aims and objectives of the TSER Network on Networks, Collective Learning and Research and Technology Development in Regionally Clustered High Technology Small and Medium Sized Enterprises (SMEs), and considers evolutionary trajectories of European regional clusters of such SMEs in the 1990s. It reviews the development of ideas concerning regional clustering, from Marshall's industrial districts, through innovative milieux, to notions of regional untraded interdependencies, networks and collective learning. Particular attention is paid to how firms and regions develop competences and new knowledge as the basis for successful innovation. It concludes by outlining the focus of individual papers.

Collective learning High technology SMEs Marshall's industrial districts Innovative milieux
Untraded interdependencies Innovation

KEEBLE D. et WILKINSON F. (1999) L'apprentissage collectif et le développement des connaissances dans l'évolution des regroupements régionaux des PME de pointe en Europe, *Reg. Studies* 33, 295–303. Cet article cherche à esquisser les buts et les objectifs du Réseau TSER relatif 'aux réseaux, à l'apprentissage collectif, et au développement de la recherche et de la technologie dans les PME de pointe regroupées sur le plan régional', et examine le développement des trajectoires des regroupements régionaux européens des PME de ce genre aux années 1990. On fait la critique du développement des idées qui portent sur le regroupement régional, de la notion de districts industriels selon Marshall, par la notion de milieux innovateurs, aux notions d'interdépendances régionales non-commercialisables, de réseaux et d'apprentissage collectif. On prête une attention particulière à la façon dont les entreprises et les régions développent des compétences et de nouvelles connaissances, ce qui sert de base à l'innovation réussie. Pour conclure, on esquisse le centre d'intérêt de chacun des articles.

Apprentissage collectif PME de pointe
Districts industriels selon Marshall
Milieux innovateurs
Interdépendances non-commercialisables Innovation

KEEBLE D. und WILKINSON F. (1999) Kollektives Lernen und Mehrung des Wissensstandes bei der Entwicklung regionaler Cluster kleiner und mittelgroßer, hoch technisierter Unternehmen in Europa, *Reg. Studies* 33, 295–303. Dieser Aufsatz umreißt die Ziele und Objekte des TSER Netzes für 'Netzwerke, kollektives Lernen und Forschung, und technologische Entwicklung in regional geklusterten, hoch technisierten kleinen und mittelgroßen Unternehmen' (small and medium enterprises = SME), und betrachtet evolutionäre Bahnen europäischer regionaler Cluster solcher SME in den neunziger Jahren dieses Jahrhunderts. Er bespricht die Entwicklung von Ideen, die sich mit regionalen Clustern beschäftigen, von Marshall's Industriegebieten über innovative Milieus bis zu außergeschäftlichen gegenseitigen Abhängigkeiten, Netzwerken und kollektivem Lernen. Besondere Aufmerksamkeit wird der Art und Weise gewidmet, in der Firmen und Regionen Kompetenzen und neue Kenntnisse als Grundlage für erfolgreiche Innovation entwickeln. Der Aufsatz schließt mit einer Übersicht über die Hauptanliegen der einzelnen Beiträge.

Kollektives Lernen Hoch technisierte SMEs
Marshall's Industriegebiete Innovative Milieus
Außergeschäftliche gegenseitige Abhängigkeiten
Innovation

INTRODUCTION

This Special Issue of *Regional Studies* contains a series of original research papers contributed by members of the European research network on Networks, Collective Learning and Research and Technology Development (RTD) in Regionally Clustered High Technology Small and Medium Sized Enterprises. This network, whose meetings have been funded by Directorate-General XII for Science, Research and Development of the European Commission under the Targeted Socio-economic Research Initiative of the Fourth Framework Programme, has been studying the role and importance of research and technology linkages in the evolution and competitiveness of selected European regional clusters of innovative high technology SMEs. These linkages, which are both local and global, involve universities and public research institutes, other technology based SMEs and large firms. A major focus of the network's investigation has been to try to assess the extent and importance for successful SME innovation and knowledge development in these regional clusters of 'collective learning processes', operating through regional linkages and networking between firms and other organizations, by flows of highly-skilled workers within the regional scientific, research and professional labour market, and by localized processes such as new firm spin-off. Network members have also attempted to chart the evolutionary trajectory of, and changes in the role of SMEs in, the selected European high technology regional clusters in the 1990s.

The regions studied and the researchers involved are: Cambridge (David Keeble, Clive Lawson, Barry Moore, Frank Wilkinson and Elisabeth Garnsey); Oxford (Helen Lawton Smith); Grenoble (Michel de Bernardy); Sophia-Antipolis (Christian Longhi); Munich (Rolf Sternberg and Christine Tamásy); the Dutch Randstad (Egbert Wever); Pisa, Piacenza and NE Milan (Roberta Capello and Roberto Camagni); Göteborg (Asa Lindholm Dahlstrand); Helsinki (Ilkka Kauranen and Erkkö Autio); and Barcelona (Pere Escorsa, Ramon Maspons and Jaume Valls), with theoretical contributions from Edward Lorenz. The Network has been co-ordinated by David Keeble and Frank Wilkinson of the ESR C Centre for Business Research, University of Cambridge, with Clive Lawson as Network Rapporteur. While not all network members have contributed to this Special Issue, the individual papers which follow are greatly indebted to the collective endeavours and debates of the whole network.

During the course of its work, the network has produced four substantive reports on the development of these European regional clusters of high technology SMEs. These cover the following themes: regional institutional and policy frameworks; university research links and spin-offs; networks, links and large firm impacts; and collective learning processes and know-

ledge development (KEEBLE and LAWSON, 1996, 1997a, 1997b, 1998). A Final Report on the network's findings is due for submission to the European Commission by March 1998.

COLLECTIVE LEARNING, HIGH TECHNOLOGY SMEs, AND EUROPEAN REGIONAL EVOLUTIONARY TRAJECTORIES IN THE 1990s

The specific aim of the set of papers presented in this Special Issue is to assess the extent and significance of 'regional collective learning' processes of different kinds in understanding the innovative activity and recent evolution of high technology SMEs in the European regional clusters involved. In the papers, the terms 'high technology', 'technology-intensive' and 'technology-based' are used interchangeably to refer to firms and industries whose products or services embody new, innovative and advanced technologies developed by the application of scientific and technological expertise. Such firms almost invariably regard such expertise and resultant technological leadership as the firm's major competitive advantage, and are usually defined in practice by high R&D-intensity (high levels of R&D expenditure and/or employment relative to turnover or total workforce) (AYDALOT and KEEBLE, 1988; KEEBLE, 1992). SMEs are usually defined as smaller independent, owner-managed enterprises with a workforce of less than 250 employees.

Defining, conceptualizing and theorizing the notion of 'regional collective learning' is a major task of the first paper in this Special Issue by Lawson and Lorenz, and is also discussed later in this and in subsequent papers. A simple definition at the outset, however, is that regional collective learning involves 'the creation and further development of a base of common or shared knowledge among individuals making up a productive system which allows them to co-ordinate their actions in the resolution of the technological and organisational problems they confront' (LORENZ, 1996). The creation and development of such a localized knowledge base can involve both conscious and unconscious mechanisms, an example of the former being research collaboration between local SMEs or between an SME and a local university, examples of the latter being the movement of 'embodied expertise' and know-how in the form of researchers, managers and skilled workers within the regional labour market and via entrepreneur spin-off from existing local firms or organizations to create new technology-intensive firms.

All but one of the seven European high technology regions which feature in this Special Issue – Cambridge, Grenoble, Sophia-Antipolis, Munich, Göteborg, Pisa/Piacenza/NE Milan, and the Randstad – are classified by a recent OBSERVATOIRE DES SCIENCES ET DES

TECHNIQUES (OST), 1998, p. 47, study in the highest level (type 1 out of eight types) of European science and technology intensive regions based on regional output of patents and scientific publications. The exception (Göteborg, classified in type 2) simply reflects the statistical impact of exceptionally large Swedish regions. All contain a substantial cluster of high technology SMEs, the number of and employment in SMEs in these clusters having generally grown considerably since the 1970s. The origin and nature of these high technology SME clusters vary, the Munich and Italian cases, for example, being dominated by manufacturing firms while Sophia-Antipolis and the Randstad have developed mainly as clusters of service firms. While many are focused on universities or public research institutes, some have been strongly influenced by large local high technology manufacturing companies. In the 1990s, however, vigorous SME resurgence in these clusters following the early 1990s recession appears to have been accompanied by some signs of convergence in growth processes (KEEBLE and LONGHI, 1998). This reflects diversification and technology combination in new dynamic sectors (information and telecommunications technologies, Internet and multimedia applications, biotechnology), continuing SME spin-offs and growth in critical mass, new characteristics of the globalization process of large firms, and new or enhanced characteristics of the organization of production by SMEs. Large global firms appear now to be seeking explicitly to embed their R&D activities within such clusters in order to gain access to highly localized research and technology competences, while specialized SMEs in these growing clusters often exhibit high levels of inter-firm networking and use of local business support and institutional resources, hand-in-hand with active globalization of their markets.

In the light of this introduction, the remainder of this paper seeks to provide a broad conceptual perspective on some of the key themes which recur in subsequent papers, and to highlight the particular contribution of each to understanding the role of collective learning in the recent development of European regional clusters of high technology SMEs.

ORGANIZATION, KNOWLEDGE AND LEARNING: INDUSTRIAL DISTRICTS AND INNOVATIVE MILIEUX

Until relatively recently mainstream economics made little of industrial organization or the relational aspects of inter-firm linkages apart from suspecting them of being in restraint of trade. Coase explained the reason for this: economists think 'of the economic system as being co-ordinated by the price mechanism' (COASE, 1937, p. 387) and 'having regard to the fact that if production is regulated by price movements production would be carried out without any organisation at all, well might we ask, why is there any organisation?'

(*ibid.*, p. 388). From such a perspective, the role of organization is simply to economize on transaction costs.

In Marshall's work, however, organization and knowledge are central to the evolutionary trajectory of capitalism. He argued:

Capital consists in a great part of knowledge and organisation. . . . Knowledge is our most powerful engine of production; it enables us to subdue Nature and force her to satisfy our wants. Organisation aids knowledge; it has many forms, e.g. that of a single business, that of several businesses in the same trade, that of various trades relatively to one another, and that of the state providing security to all and help for many. The distinction between public and private property in knowledge and organisation is of great and growing importance: in some respects of more importance than between public and private property in material things; and partly for that reason it seems best sometimes to reckon Organisation apart as a distinct agent of production' (MARSHALL, 1952, p. 115).

In Marshall the central role of organization is 'the "integration" of the increased subdivision of function, or "differentiation", as it is called, [which] manifests itself with regards to industry in such forms as the division of labour, and the development of specialised skills, knowledge and machinery' (*ibid.*, p. 201).

For Marshall, market success depended on increased specialization and the development of more effective industrial organization. One way in which this came about was from the concentration of production in particular areas in what Marshall (*ibid.*, p. 225) described as 'industrial districts'. The benefits of such localization include an increase in the degree and specialization of skills and their diffusion throughout the community so as to create an abundant supply of appropriately qualified labour, the growth of subsidiary trades and specialized services, and increased use of highly specialized machinery made possible by the combined demand of many firms. The concentration of firms in close geographical proximity allows all to enjoy the benefits of large scale industrial production and of technical and organizational innovations which are beyond the scope of any individual firm.

Marshall's industrial districts effects are long term, cumulative and depend on co-operation in knowledge creation and innovation:

When an industry has thus chosen a locality for itself, it is likely to stay there long; so great are the advantages which people following the same skilled trade get from near neighbourhood to one another. The mysteries of the trade become no mysteries; but are as it were in the air, and children learn many of them unconsciously. Good work is rightly appreciated, inventions and improvements in machinery, in processes and the general organisation of the business have their merits promptly discussed: if one man starts a new idea, it is taken up by others and combined with suggestions of their own; and thus becomes the source of further good ideas (*ibid.*, p. 225).

And: 'the broadest, and in some respects the most efficient forms of constructive co-operation are seen in a great industrial district where numerous specialised branches of the industry have been welded almost automatically into an organic whole' (MARSHALL, 1920, p. 599).

For Marshall, the driving force in industrial districts is freedom of industry and enterprise.¹ Nevertheless, trade associations had a co-operative role to play in co-ordinating production and standardizing products but he also argued that such benefits could accrue automatically by the individual efforts of entrepreneurs within industrial districts. Moreover, although firms could benefit from scientific and other specialized services provided by formal associations, without the profit incentive staff of the associations 'may be found lacking in energetic enterprise' and the proliferation of such institutions 'might dry up many of the sources of truly original inventions' (*ibid.*, chapter XII, book III, pp. 606–7). For similar reasons, public sector intervention had a positive though limited role to play in the development of industrial organization and technical progress (*ibid.*, pp. 666–72).

Individualistic initiative and free enterprise are therefore the central driving force of economic progress in Marshall. Collective action may foster individual success but it risks blunting initiative and inhibiting competition. For Marshall, the importance of the localization of production within industrial districts is that it creates an environment more favourable to individual success. These positive external economies to individual firms stem, fundamentally, from their geographical proximity rather than any institutional structuring. The close proximity of firms within a particular industry provides opportunities for entrepreneurs to specialize and for the district as a whole to secure economies of scale (both static and dynamic) denied to isolated individual firms because of internal restrictions on growth. They can therefore afford to stay small and concentrate their initiative and inventiveness on what they do best. By doing so they create, in turn, an environment which improves the competitive position of the locality.

Marshall's analysis has played a significant role in theorizing the success of local clusters of small manufacturing firms in northern and central Italy and elsewhere – so much so that they have been labelled 'Marshallian industrial districts'. However, contemporary analyses of these industrial districts put much greater stress than did Marshall on the collectivist and institutional basis for successful co-ordination. Emphasis is placed on the influence of community – defined as family and other social relationships, rules of behaviour embedded in those relationships, and more formal institutions such as churches and political parties – in guaranteeing standards of behaviour which engender trust and co-operation and thereby strengthen inter-firm networks. Within industry, trade associations are seen as playing a

central role in providing technical, financial, marketing, training and other services. Trade associations also represent employers in their dealings with local and central government and with organized labour. In turn, government establishes by social, company and other legislation a framework of standards which underpins the equitable and co-operative relationships between firms (SENGENBERGER *et al.*, 1990). An important feature of modern industrial districts is, then, what AMIN and THRIFT, 1994, 1995, p. 102, have described as 'institutional thickness'² (see KEEBLE *et al.*, this issue). The outcome is seen as competitive success based on high rates of process and product innovation, the rapid diffusion of new techniques and good design, high quality and wide variety in products (BRUSCO and SABEL, 1981).

The importance of Marshall's theory of organization, especially when compared with its impoverished version rooted in transaction costs, is the central role given to technical and organizational change, inter- as well as intra-firm relations and the importance of learning in the process of knowledge formation. These have emerged as the central concerns of social scientists studying the process of technical change and particularly the evolution of high technology industries and regions. In this context, European researchers have adopted the term 'innovative milieu' (*milieu innovateur*: see AYDALOT, 1986; AYDALOT and KEEBLE, 1988; CAMAGNI, 1991; RATTI *et al.*, 1997) to describe the local clustering of highly innovative producers of high technology products and services.

The main mechanisms for knowledge transmission and learning in innovative milieux include: inter-relationships between suppliers and customers and the makers and users of capital equipment; formal and informal collaborative and other links between firms in particular sectors;³ inter-firm mobility of workers in localized markets for high skill; and the spin-off of new firms from existing firms, universities and public sector research laboratories. Labour mobility and new firm spin-offs transfer knowledge 'once and for all' and/or serve to establish an ongoing link between the firms and with research institutions via the maintenance of personal relationships. More one-off milieu effects include imitation, emulation and reverse engineering but, in this case, proximity is more important than sustained interaction and enduring relationships.

Capello (in this issue) has provided a schema of the emergence of innovative milieux by listing the pre-conditions for the various stages of development. Specialized areas emerge from simple geographical proximity with the growth of stable inter-SME linkages and the establishment of a local labour market for the required skills. These provide continuity over time for local technological and scientific know-how. Industrial districts develop from specialized areas as close social interaction and supportive institutions generate high trust and encourage informal and tacit knowledge

transfers. This leads to industrial atmosphere, external economies and savings in transaction costs. From co-operative relations and the free flow of knowledge, synergies and innovative capacity evolve and the industrial district becomes an innovative milieu. The hallmark of the innovative milieu is that the localized labour markets, inter-firm relationships and firm spin-outs enrich the local knowledge base and enable exploitation of localized collective learning capabilities to develop profitable new products and processes.

It should be noted that progression from each stage depends on achieving the appropriate pre-conditions. Moreover, although the achievement of the innovative milieu stage reinforces the stability of the labour market and inter-SME links and increases the opportunity for spin-out activity, these positive feedbacks are not guaranteed in the long run. The continuous accumulation of knowledge could lock firms into obsolete and increasingly non-competitive technological trajectories. In these circumstances, collective learning processes which function as 'barriers to entry' to outsiders may be transformed into 'barriers to exit' for insiders (BIANCHI, 1989). Learning from knowledge sourced externally is therefore an essential ingredient for the continued success of an innovative milieu (CAMAGNI, 1991; KEEBLE *et al.*, this issue).

COMPETENCES, KNOWLEDGE AND LEARNING

Competences determine what are the technical, marketing, managerial and other capabilities of organizations and therefore their competitive performance. The dynamic capabilities of organizations are their ability to modify their competences so as to improve business performance. The basis of competences is the knowledge organizations hold that is embodied in their routines and procedures. Shared knowledge of the technical, marketing, organizational and other aspects of the productive system enables organizational members to effectively communicate with one another and co-ordinate their joint activities. In turn, learning serves to incorporate new information into the knowledge base by which the competences of organizations are improved and new ones developed. As the knowledge base of competences is necessarily shared by the members of the organization, and is enhanced by their participation in the organization's activities, learning is essentially a collective activity.

Knowledge is either codifiable (and therefore readily transferred) or tacit (and therefore not readily transferable beyond the context in which it is embedded). Tacit knowledge, importantly, is specific to organizational and geographic locations and this increases its internal circulation but impedes its external accessibility. Learning processes which absorb information and generate and diffuse knowledge (of both sorts) are collective activities which form part of the background

and experience of each organization. Their effectiveness depends on the quality of social interaction and lines of communication. These are enhanced by a shared social and cultural environment from which develop common routines, norms and standards which depend upon trust and the willingness to co-operate. The ability to form and maintain effective social relations is therefore a key competence.

Learning depends on combining diverse knowledge which becomes incorporated into organizations' routines in an incremental manner. The development of the competences of organizations is therefore path dependent. Organizations learn by consolidating new information into their knowledge base which is further enhanced by the practical experience of implementing the modified operating systems. However, established competences may prove obstacles to the adoption of radical innovations so that organizational progress may require dis-learning. In a similar way, whilst close inter- and intra-firm linkages are important for initiating and diffusing incremental change, they may also form obstacles to the spread of radical new ideas which requires openness to the outside.

ORGANIZATION, NETWORKING AND UNTRADED INTERDEPENDENCIES

To understand the organization of production and business operations it is necessary to put them in their historical, socio-cultural, institutional and spatial context. In this respect, increasing attention has been paid to business networks. In an authoritative recent review, YEUNG, 1994, p. 476, defines a 'business network' as 'an integrated and co-ordinated set of ongoing economic and non-economic relations embedded within, among and outside business firms', a definition broad enough to include geographical groupings of SMEs, transnational corporations and the linkages between them. Localized clusters of high technology SMEs may exhibit a considerable degree of intraregional networking in which collective learning is a club good from which outsiders are excluded (CAPELLO, this issue). More generally, these territorial clusters are characterized by what STORPER, 1995, has termed 'untraded interdependencies' which extend beyond traditional customer/supplier and servicing relationships to embrace formal and informal collaborative and information networks, interactions through local labour markets, and shared conventions and rules for developing communications and interpreting knowledge.

However, internal networks are not the only consideration for high technology districts. The markets for their products are often world-wide (KEEBLE *et al.*, 1998) so that questions arise as to how such locally concentrated firms develop external links. A related issue is how large transnational firms relate to local clusters in which they, or their branch establishments,

may be located. This is of particular relevance as transnational firms are increasingly decentralizing their learning processes and the development of their core competences so as to benefit from linkages with, and embeddedness within, a particular local innovative milieu, as noted earlier. Increasingly, networks internal to innovative large firms and with localized firms are becoming complementary, mutually reinforcing mechanisms designed to develop synergies with a particular milieu so as to increase the innovative capacity of the large firm. However, to the extent that this requires the corporation to become engaged in collective learning processes within regional clusters, benefits can be expected to spill over to small firms with significant milieu effects (see STERNBERG and TAMÁSY, this issue). It is therefore important to recognize that knowledge transmission and collective learning may be fostered by cultural, institutional and geographical proximities often in combination. It also follows that networks and dependencies may be within, between and outside firms and although they may not be traded (or even tradable) they may have significant effects on the competitive performance of organizations.

INNOVATION PROCESSES

Innovation requires the development of new vocabularies and concepts to enable the creation of new knowledge and these changes are the greater the more radical the innovation. As Lawson and Lorenz argue (in this issue), innovation should be understood as a cycle involving interaction between tacit and articulated knowledge. A pre-condition for this process is the building of shared values, norms and technical understanding so that often diverse knowledge can be shared. The second stage is when individuals with diverse and complementary knowledge come together and collectively seek to explain their ideas about a new product or technology. This requires the members of the group to articulate early ideas about new developments by clarifying their notions and developing new concepts which are mutually comprehensible within the group. Modified in this way, new knowledge becomes easier to combine with that of known technologies and methods in the process of building testable prototypes. At the fourth stage the new product or process goes into production and, with this, the knowledge underlying the new competences, which was articulated in the initiation and development phases, becomes increasingly tacit and forms the basis for new knowledge creation by learning by doing and incremental technical change.

To an important extent the second stage is crucial because it is at this stage that the cross-fertilization between science, engineering, production, marketing and other specialisms is achieved. In this collective effort, it is essential that the contribution of each is sufficiently understandable to the others. This is facilit-

ated by shared tacit knowledge which enables the individuals involved to effectively formulate and resolve technical problems. The analysis of innovation from this perspective forces recognition of influences which do not stop at the research, science and technology base of firms or regions at given points in time, and necessitates recognition of the dynamic and evolving interplay between information, codifiable and tacit knowledge and competence (AMIN and WILKINSON, 1999). The specificity of tacit knowledge and competences means that externally derived information requires converting if it is to be readable within internal knowledge and learning systems. The absorption of radically new codifiable knowledge requires the development of new, or the modification of, existing tacit knowledge if competences are to evolve effectively. The problems of the absorption of change may be eased if the relevant tacit knowledge is shared by the creators and users of new knowledge so that effective interpretative mechanisms can develop. For any organization, then, the successful generation, diffusion and utilization of new ideas can be expected to involve interactions between internally and externally generated codifiable and tacit knowledge extending to the range of suppliers, customers and research institutions to which it relates. What is notable in this important respect is the increasing externalization of research and development from large corporations and the growth of business service firms specializing in the production of technological competence and knowledge. These operate as intermediaries between firms and the scientific community serving as providers of 'quasi-generic' knowledge extracted by means of repeated interactions with their customers and the scientific community in which computer communication systems play a pivotal role. The outcome is an increasing institutionalization of markets for knowledge in which such firms provide a bridge for incorporating scientific knowledge into tacit knowledge, learning processes and competences of firms (ANTONELLI, 1999).

The ability to share and utilize diverse knowledge is an important pre-condition for the success of high technology regions. In some cases this emerges from a rich history of local interaction between users and producers of the technology (DE BERNARDY, this issue) or from the activities of technology consultants (LAWSON and LORENZ, this issue). In other cases the critical factor may be the way the multidisciplinary culture of a local university, combined with a history of spin-offs, serve to diffuse it widely amongst local producers (LINDHOLM DAHLSTRAND, this issue). Links between large and small firms are important in München and Grenoble as is the role of technical universities. In Sophia-Antipolis no such pre-conditions existed, but have begun at last to emerge because of new developments in the 1990s, again resulting in the successful combining of different technologies within new innovative firms (LONGHI, this issue).

INDIVIDUAL PAPERS AND THEIR FOCUS

The paper by Lawson and Lorenz identifies the key ideas in the capabilities literature and shows how they can be usefully extended to develop a conception of collective learning among regionally clustered firms. In elaborating this framework, the paper explores the relationship between codifiable and tacit knowledge in the innovation process. The claim that tacit knowledge, because it is difficult to transfer in the absence of labour mobility, may constitute a basis for sustained regional competitive advantage is also investigated. The closing section uses case study material based on Minneapolis and Cambridge to illustrate the importance for innovation of a regional capability for combining and integrating diverse knowledge, and of the sources of such capabilities as pre-conditions for successful high technology regions.

The Keeble *et al.*, paper then applies the concept of regional collective learning to understanding the recent growth of high technology SMEs in the Cambridge region, and demonstrates empirically from an original interview survey of local firms the extent and role of three different learning processes, namely: spin-offs; local networking and linkages; and labour market recruitment. Two important features of this paper are its stress on the parallel importance of wider national and global networks for the innovative activity of R&D intensive SMEs in Cambridge, and its discussion of the extent and nature of recent collective initiatives which seek to enhance the region's 'institutional thickness' (AMIN and THRIFT, 1995) and innovative capacity.

Sophia-Antipolis, the government-funded science park inland from the Côte d'Azur in southern France, represents an historically totally different type of high technology region. In reviewing its evolution from a collective learning perspective, Longhi's paper shows how the insertion of branch units of large international firms and public research institutes into a relatively empty space meant that, if anything, the new development internalized high technology capabilities within large organizations. Attempts to stimulate local technological transfer from this knowledge base failed due to the insufficient numbers of highly qualified workers to support the formation of a local labour market. In the 1990s, however, the capabilities of Sophia-Antipolis to generate a milieu effect have significantly improved with the relocation of departments of the University of Nice to the science park, increased encouragement of spin-offs by public research institutes and large firm downsizing resulting in significantly increased small firm formation and strengthening of links between large and small firms as the former externalized an increasing proportion of their R&D activities. The result is a striking 'endogenization' of a previously externally controlled 'satellite platform'.

The development of collective learning capacities in

Grenoble is reviewed by De Bernardy, who stresses how the region's rich mix of public research institutes, universities, large firms and technology-based SMEs has created over time a critical mass of scientific and managerial competences, a density of informal and formal inter-firm and organization networks, and a professional milieu, which has enabled the region's economy to restructure itself through the development of new innovative products and firms, in the face of external technological and market challenges. A particular feature of De Bernardy's compelling story of this 'dynamic innovation system' is his identification of different types of technology based SMEs, each with different interaction networks and patterns of dependence on regional collective learning capacities and other local firms and organizations.

Capello's paper argues that ambiguities exist in the definitions of learning and collective learning. She suggests that 'club externality' is a distinguishing feature of collective learning which has 'continuity' and 'dynamic synergies' in common with learning. Her empirical analysis based on three Italian high technology manufacturing milieux reveals that the largest group of firms combines external learning with more traditional benefits of industrial district membership (cultural proximity and industrial atmosphere), with a small group which is more autonomous with mainly internal learning processes, and an even smaller group characterized by socialized mechanisms of spatial transfer of knowledge (collective learning). A positive relationship between labour turnover and innovation supports the idea that collective learning is an important feature of radical product innovation while both radical and incremental product innovation is associated with the cultural proximity of the workforce.

The paper by Sternberg and Tamásy uses an array of indicators of R&D intensity to identify Munich as Germany's leading high technology region with a broad industrial base. It identifies two dominant reasons for Munich's emergence as a leading European high technology cluster, namely the presence of large firms such as Siemens, and the regional impact of federal R&D and military expenditure channelled to the region in part by influential regional political advocacy. At the same time, the region is characterized by numerous technology-based SMEs, and 'an innovative environment' characterized by 'intensive intraregional co-operative networking'. Special attention is paid to the role of Siemens and especially its connections to R&D intensive SMEs. Rather than dominating them and threatening their independence, Siemens enjoys diverse and often informal co-operative links in innovation with local SMEs.

The focus of Lindholm Dahlstrand's contribution is specifically on the role of technology intensive spin-offs as a key process in the development of collective learning in the Göteborg region which, despite major restructuring of old manufacturing industries, has

witnessed substantial growth of new high technology SMEs since the 1980s. Most such spin-offs have emerged either from Chalmers University of Technology or from the region's larger firms, while there is a surprisingly high incidence of local labour market recruitment and mobility of technical staff. Both these processes result in the diffusion and combination of embodied technological expertise, and hence the development and strengthening of a regional collective learning capacity. Interaction with spin-off 'parents' does however diminish over time, with a corresponding increase in the importance of wider national networks, as in the Cambridge case.

Finally, and as an important qualification of the emphasis in this Special Issue on the benefits of spatial proximity in SME innovative activity, Wever and Stam's paper shows that in the case of the Netherlands, regional clusters of small high technology firms scarcely exist. While most such firms are concentrated in the Randstad, this spatial pattern, in a small and homogeneous country, applies to firms generally. Moreover, the innovative linkages of technology intensive SMEs in the Utrecht area are national, not regional. Most such firms are engaged in the provision of technology intensive services, and supply national markets. A significant minority are spin-offs from large foreign-owned computer firms. The paper thus highlights the limits of a regionally bounded approach to high technology SME growth when dealing with the particular case of a small, culturally homogeneous economy with open borders situated at the heart of an integrating Europe.

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NOTES

1. A term Marshall preferred to 'competition' because of the need for a term 'that does not imply any moral quality, whether good or evil, but which indicates the undisputed facts that modern business and industry are characterised by more self reliant habits, more forethought, more deliberate and free choice' (MARSHALL, 1952, p. 25).
2. A term that no doubt Marshall would have appreciated although he would probably have preferred 'organizational thickness'.
3. Recent unpublished research by HUGHES, 1998, based on a large 1997 survey of R&D intensive British SMEs, reveals that such firms report engaging in collaborative or partnership arrangements with other firms significantly more frequently than less R&D intensive firms, and that high technology service firms most frequently collaborate with 'firms in the same line of business' (73% of collaborating firms) with customers (52%) being the second most frequent partner; for high technology manufacturing firms, this pattern is reversed (48% and 71%, respectively). Suppliers came third and universities/higher education institutions fourth in both cases.

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