ELSEVIER

Research Policy 31 (2002) 1053–1067

research policy

www.elsevier.com/locate/econbase

Determinants of innovation capability in small electronics and software firms in southeast England

Henny Romijn [a,*], Manuel Albaladejo [b]

[a] *Department of Technology and Policy, Faculty of Technology Management, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands*

[b] *Queen Elizabeth House, University of Oxford, Oxford, UK*

Received 6 September 2000; received in revised form 22 February 2001; accepted 6 September 2001

Abstract

The paper explores determinants of innovation capability in small UK electronics and software firms. An experimental innovation index is used alongside conventional proxies of innovative performance. These indicators are correlated with variables capturing a range of potentially important internal sources—such as education, prior work experience and R&D effort—as well as measures of intensity of external interactions and proximity in network relations. The findings support the importance of R&D, the key role played by the regional science base in nurturing high-tech spin-offs, and proximity to suppliers. However, no support is found for the current policy fashion of encouraging regional networks revolving around firms in similar business activities and close customer relations. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Innovation measurement; Technological capability; High-tech small firms; Networks; Clusters

1. Introduction

Small high-technology firms have lately received much attention among researchers and policy-makers world-wide. Since the mid 1980s, regional networks of dynamic small firms started to emerge, which began to make inroads into the hegemony of large industrial corporations based on mass production. This led to a new belief in the economic viability of small-scale production, and in its ability to contribute—not just to employment and income creation—but to innovation, productivity and competitiveness (e.g. Porter, 1990; Audretsch, 1998; Best, 1990; Becattini, 1989; Camagni, 1991; Piore and Sabel, 1984; Steiner, 1998; Storper, 1993; Storper and Harrison, 1991). In the UK, small firms operating in the field of newly emerging technologies, especially ICT, biotechnology and high-tech electronics, are expected to hold particularly promising potential as agents of industrial regeneration. This has made them a central element in recent government policies to build a 'knowledge-driven economy' (DTI, 1998).

One would hope that the policies that were set up in the course of the 1990s to nurture the innovative performance of these companies would be informed by insights based on sound empirical research. However, despite several innovation surveys (for instance, those reported in Pavitt et al., 1987; Centre for Business Research, 1996; Thomas and Jones, 1998), there is still little empirical evidence about how companies improve their innovation capacity. The difficulty of quantifying technological performance remains a

* Corresponding author. Tel.: +31-40-2474754; fax: +31-40-2474646.
E-mail address: h.a.romijn@tm.tue.nl (H. Romijn).

PII: S0048-7333(01)00176-7

major hurdle to solid statistical research. Indeed, a recent review of innovation and technology studies in small- and medium-sized UK firms noted that even in the authoritative 1992 Cambridge survey (SBRC, 1992), which collected a variety of data from more than 2000 small companies, '. . . the data collected and presented in the section on technology and innovation is largely qualitative, based on subjective perceptions of the SMEs; and the analysis, though suggestive of some useful broad correlations, does not quantify innovative investment' (Hoffman et al., 1998, p. 42).

The aim of this paper is to make a modest contribution towards filling this gap in the literature. The paper reports on a small pilot survey of 33 small software development and electronics manufacturing companies in southeast England held in 1998. The survey elicited detailed information about the companies' innovative performance as well as a large range of internal and external factors that might have contributed to that performance. The interviews were conducted in the Thames Valley and along the M4 corridor as well as in more rural parts of Berkshire and Oxfordshire, an area with high concentrations of small high-tech software and precision electronics companies.

Different proxies for innovation performance and determinant factors are constructed in the paper, and the links between them are analysed statistically.[1] The performance indices include commonly used innovation measures as well as a more experimental index, which is intended to circumvent some of the problems associated with conventional indicators. Qualitative case-study material from the interviews is used to help interpret and illustrate the statistical patterns.

Obviously, a small pilot survey cannot come up with firm conclusions about the driving forces behind innovation in small high-tech firms in England's southeast as a whole. However, it can throw some new light on policy-relevant issues that are also being discussed in other studies on the subject, thereby generating key pointers that contribute to the ongoing policy debate and help to give direction to further research on the subject. Another contribution of the paper is to provide some input into the ongoing methodological discussion about innovation measurement.

In Section 2, we discuss relevant literature that forms the conceptual basis for the statistical analysis. It is also shown that some of the issues discussed in that literature have a close bearing on current UK policies towards promotion of innovativeness in small high-technology firms. The conceptual model and indicators used in the paper are discussed in Section 3. The data analysis and a discussion of the findings are in Section 4, followed by conclusions in Section 5.

2. Review of relevant literature

The point of departure for this paper is a body of literature in which firm-level technological advancement is conceptualised as a learning process (Garvin, 1993; Malerba, 1992; Dodgson, 1991, 1993; Hitt et al., 2000; UNCTAD, 1996; Lall, 1992; Cohen and Levinthal, 1989). Learning results in technological capability—knowledge and skills needed for firms to choose, install, operate, maintain, adapt, improve and develop technologies.[2] In the sort of competitive environment characterised by fast change in which small high-technology firms would be operating, capability to innovate is likely to be a particularly crucial learning output because it is the key to gaining dynamic competitive advantage. Innovation capability is defined as the skills and knowledge needed to effectively absorb, master, and improve existing technologies, and to create new ones (Lall, 1992).

Existing studies on the subject provide several leads about various factors that can be expected to contribute to the build-up of innovation capability. Factors internal to the firm include first of all, the knowledge and skills brought into the firm by the entrepreneur(s) and workforce, which they obtained through earlier experience. Firms require an adequate stock of technically qualified manpower to absorb new technologies, modify them, create and transfer new technological

[1] An analysis of the relationship between innovation and economic performance remains outside the scope of the paper. The link is highly complex because companies that are technologically capable are not necessarily equally adept at attuning their technological capabilities to market needs. Furthermore, in high-tech companies there are typically very long lead times before innovations become commercially profitable, so we would expect current economic performance to be associated with past innovations rather than innovations reported at the time of interview. For further discussion of this issue, see Oakey and Mukhtar (1999).

[2] Lall (1992) distinguishes between production, innovation, investment and linkage capability.

information, particularly scientists and engineers (Hoffman et al., 1998; Wignaraja, 1998). The inability to recruit high quality technical staff can be a serious constraint on subsequent growth (Hoffman et al., 1998). Firms can further enhance their human capital stock over time through (formal and informal) internal staff training (Bell, 1984). Yet another major internal activity is 'learning-by-doing' through involvement in R&D, both as a formally organised activity (Malerba, 1992; Cohen and Levinthal, 1989; Hitt et al., 2000) and as informal technological efforts closely allied to production, directed at incremental problem solving and experimentation on the shop-floor (Bell, 1984; UNCTAD, 1996; Kim and Nelson, 2000).

Interaction with suppliers, customers, public assistance agencies, industry associations, foundations and the like, can provide missing external inputs into the learning process which the firm itself cannot (easily) provide. Interaction may take place for the purpose of gathering information about technologies and markets, and also for obtaining various other inputs to complement the internal learning process, such as external staff training, parts and components, consulting services, and R&D grants (UNCTAD, 1996; Rothwell and Dodgson, 1991; Dodgson, 1993; Lundvall, 1988, 1992; Edquist, 1997; Freeman, 1991, 1995; Panda and Ramanathan, 1996). Intensive interaction with customers and suppliers is thought to be particularly beneficial (Von Hippel, 1988; Lundvall, 1988; Håkansson, 1989).

It has further been suggested that the effectiveness of such 'learning-by-interacting' would be boosted by regional clustering between the network actors. Many writers argue that emerging post-Fordist network structures could foster technological improvement and competitiveness through positive externalities, market linkages, and possibilities for collaboration generated by geographical proximity.[3] A variety of explanations have been offered. Storper and Harrison (1991) and Cooke et al. (1997) refer to the tacitness of new knowledge, which makes its transfer difficult across large distances. Lundvall (1992) and Maillat et al. (1993) link the importance of proximity to radical innovation, which is associated with high uncertainty and risk. Close interaction between network partners engenders the building up of personal relations and trust, which reduces these problems. Dicken et al. (1994) and Saxenian (1994) also refer to facilitation of interaction and collaboration through trust. In addition, they argue that proximity lowers communication costs, while face-to-face contact may also enhance the quality of the interaction. Caniëls (2000) emphasises the importance of local knowledge spillovers, including quick diffusion of new information and knowledge through close inter-firm interactions and inter-firm movement of skilled labour. However, others have found evidence contradicting the importance of proximity benefits (Suarez-Villa and Walrod, 1997; Sternberg, 1999; Simmie, 1997; Larsson, 1998). Possibly, rapidly falling transport and communication costs and rising speed and quality of long-distance interaction are reducing the significance of proximity for technological dynamism and economic competitiveness (Curran and Blackburn, 1994).

The notion that regional networks could foster innovativeness of small high-technology firms features prominently in current UK policy. A dense network of regional business link (BL) centres has been set up, which are designed to provide single points of easy access to a range of business support services. Innovation and technology counsellors coordinate the use of local sources of innovation support and act as innovation management consultants. Several BLs have begun to facilitate local information exchange and networking through formation of local business groups, provision of referral services that put like-minded enterprises in touch with each other, and help with establishment of research collaborations (DTI, 1997; Huggins, 1998). Networking is supposed to be primarily beneficial for small companies involved in related lines of business. The apparent motivation is that '... however, good your technology is, geography and community of interest will still make the biggest difference' (Beavis, 1998, p. 19). Communities of small firms are also supposed to benefit from close relations with scientific institutions. Several science parks and incubators have been created to promote such linkages. The science park policy dates back some considerable time before the advent of the regional clustering strategy, but has now become an integral part of it. Linkages with the

[3] Some writers refer to old theoretical concepts such as Marshallian industrial districts (e.g. Scott and Storper, 1992). Others employ new concepts such as 'milieux innovateurs' (e.g. Camagni, 1991; Maillat et al., 1993), collective efficiency (Schmitz, 1995), learning regions (Asheim, 1996) or regional innovation systems (Oerlemans et al., 1998).

science base are also being fostered through financial incentives. The LINK scheme is aimed at supporting collaborative research partnerships between to UK industry (of all sizes) and the research base, which provides 50% financing for pre-competitive research and for further investments required for successful commercialisation of new technologies.

So far, the validity of some of these policy instruments remains debated. Some studies focusing on the Southeast region have found some support for the importance of specific local network relations, but at the same time they point towards the complementary importance of wider national and global networks for key innovation inputs (Keeble et al., 1998, 1999; Simmie, 1997). Evidence about the success of science parks is also mixed (Westhead and Cowling, 1995; House of Lords, 1997; Massey et al., 1992; Oakey and Mukhtar, 1999; Vedovello, 1997).

3. Conceptual model and variables

The main analytical concepts and the relationships between them that are to be explored in the paper are set out schematically in Fig. 1. The oval at the top represents the innovation capability of a firm, which accumulates as a result of the various internal and external inputs discussed above. For the purpose of the data analysis, these inputs have been reorganised under a few main headings. Potentially important internal sources include: (a) the initial educational background and prior working experience of the founder/manager(s); (b) the professional qualifications of the workforce; and (c) ongoing technological efforts which induce further learning over time, such as formal and informal R&D, formal and informal (on-the-job) training, investments in technological licenses, and so on. Potentially important external sources are represented by: (a) the intensity of networking with a variety of agents and institutions; (b) geographical proximity advantages associated with networking; and (c) receipt of institutional support. Institutional support is represented as a separate factor, because actual transfers of finance and/or knowledge may well have an effect independent from networking intensity or proximity to the assistance source.

For the measurement of innovation capability, we limited the focus to *product* innovation because this was clearly the dominant form of innovation in the sample. A similar orientation was found in the studies reviewed in Hoffman et al. (1998).

Three measures of product innovation are used, two of which are similar to proxies used in other major innovation surveys (OECD, 1992; Pavitt, 1985; Patel and Pavitt, 1995; Archibugi and Pianta, 1996; Basberg, 1987; Griliches, 1990). The first of these is a simple binary variable that indicates whether or not a firm had accomplished at least one major product

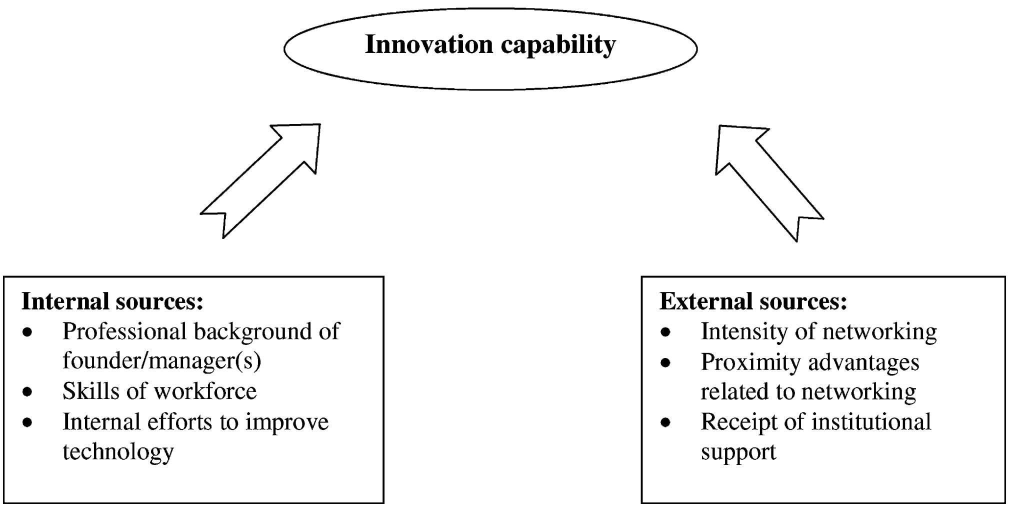

Fig. 1. Conceptual framework.

Table 1
Scale used for product innovation index

Degree of novelty (major product innovations)	Degree of science intensity	
	Low 'clever gimmick'	High science-intensive
(a) Fundamentally new to the world	4	5
(b) Similar innovations adopted in other industries	3	4
(c) Similar innovations adopted in firm's own industry, but its innovations differ in identifiable ways from other companies' innovations	3	4
(d) Same or very similar innovations adopted by competitors	2	3
(e) No major innovations at all	1	1

innovation during the 3 years preceding the survey. 'Major' in this context is defined as an activity to which the firms' owner/manager(s) attached strategic importance for the firm as a whole.[4] Measurement is reasonably straightforward, although some variation in respondents' interpretation of the concept of 'major innovation' cannot be ruled out. The second variable is the number of patents held.

Both indices are crude. The mere incidence of major innovations conveys little idea about the extent of a firm's innovative capabilities because it does not include information about the degree of newness of the innovations. The number of patents is more useful from that point of view, but many innovations that small firms come up with are never patented. The expense and effort needed to apply for patent protection and to deal with patent infringements may be beyond the firm's limited capacity; the pace of technological advance may be so fast that it is not considered worthwhile to pursue patenting; or an innovation is not so fundamentally new as to qualify for patenting, although it can still be considered new from the point of view of the country or region in which a firm operates.

The third measure of innovation capability is a product innovation index that is meant to get around these drawbacks to some extent. It is based on extensive qualitative information about the extent and significance of each firm's innovative outputs generated during the 3 years prior to the survey. This information was used to assign a score to the firm's innovations based on the degree of innovativeness embodied in them on a scale from 5 (most innovative) to 1 (least innovative), using the classification in Table 1.

The classification has two dimensions, namely (a) the degree of novelty embodied in the innovations; and (b) the extent to which the development of these innovations required specialised scientific or advanced technological expertise. The first dimension is rather similar to the scale used by the Cambridge Small Business Research Programme, which initially served as the starting point for our classification (Centre for Business Research, 1996; Cosh et al., 1996). The distinction between 'new to the world', 'new to the firm's industry' and 'new to the firm' used in the Cambridge Research also appears in Table 1 (categories a, b, and d, respectively). There is one additional category 'c' between 'new to the industry' and 'new to the firm'. The need for this category arose during the interviews, as many respondents could not readily fit their innovations into either category 'b' or 'd'. The innovations in this category typically belong to a small group of related, but not identical, new products made by a few competing companies that together constitute the leading players in their market. Each company fills an identifiable small niche in that market with products that can be distinguished from the others in terms of major performance characteristics. Ultimately, these cases were given the same score as 'new to the firm's industry' innovations, because they clearly necessitated a great deal of independent research effort. Firms in this category derive inspiration from competitors, which helps to guide their work into particular new directions, but they do not copy.

The second dimension in the innovation index was added by the interviewing team after the completion

[4] Radical innovative upgrades of existing software packages are included in this definition.

Table 2
Correlations between innovation capability indicators[a]

	Incidence of major product innovations	No. of patents	Product innovation index
Incidence of major product innovations	1		
No. of patents	0.238 (0.091)	1	
Product innovation index	0.760** (0.000)	0.382* (0.014)	1

[a] Spearman correlation coefficients, *P*-values in parentheses.
* Significance at the 0.05 level (2-tailed).
** Significance at the 0.01 level (2-tailed).

of the survey, to take account of the fact that there were some companies in our sample that had come up with highly creative novel products that were nevertheless quite easy to develop from a technical point of view. The most creative of these could even qualify for a patent, but their development had not required much in-depth scientific or engineering expertise. A good example of this type of innovation are advertising gadgets for vending machines, made by a company using electro-luminescent lighting technologies developed in the USA. A less radically new clever gadget consists of innovative graphics display functions incorporated into screen savers and graphics programmes made by another firm. In contrast, other companies had developed innovations that were truly high-tech in the sense that they did require substantial scientific or engineering expertise. Some representative examples are thin-film technology; a cryostat with an extensive range; low-temperature crystallometres with associated components and software; complex mathematical software; and low-cost ozone sensors. To reflect the difference between the two categories, the companies that had come up with the latter received a one-point higher score than others, for each category of newness. In short, a company could receive a maximum score of 5 when it had recently developed at least one technologically highly complex technology that was fundamentally new to the world, whereas a company that had produced a ‘clever gimmick’ similar to what other firms in the industry were also working on would get the lowest score of 1.

The cross-correlations between the three innovation capability measures are presented in Table 2. The statistically insignificant correlation coefficient between the two conventional measures suggests that there is little overlap between them. As expected, the more comprehensive innovation index correlates significantly with both conventional indices, suggesting that it combines to a great extent the information captured by the other two plus some additional information. However, this comprehensiveness comes at a cost of higher subjectivity. The measure inevitably reflects the perceptions of the respondents and interviewers. The results for the three capability indicators will be presented side by side in the data analysis, in order to facilitate comparison of the results.

The measurement of the sources of capability is more straightforward. The education of the entrepreneur/founder(s) is represented by binary measures of management, science and engineering and other academic degrees obtained.[5] Relevance of prior work experience in small business, large corporations, and scientific institutions to current work was measured on a Likert scale ranging from 10 (absolutely essential) to 1 (completely irrelevant), according to the opinion of the respondent. Human capital of the workforce is measured by the numbers of technicians, scientists and engineers in the companies relative to total employment. Internal technological efforts are captured by variables representing R&D investment, training expenditure, the number of R&D staff relative to total employment, and number of technological licenses obtained. The estimates include rough estimates of the value of experimentation on the shop-floor and informal on-the-job training alongside formal R&D and training budgets.

The intensity of networking was captured by the frequency of contacts with external agents on a Likert scale ranging from 10 to 1, according to the importance that the entrepreneurs attached to different network-

[5] In firms with more than one owner-manager, the distinguishing feature was the presence of at least one business partner with the relevant degree.

ing relationships. Relationships with customers, suppliers, enterprises in related lines of business, financial institutions, training institutions, universities and public science laboratories, service providers and industry associations are scored separately. The overall average networking score was also calculated as a convenient summary statistic for overall networking intensity.

Geographical proximity advantages associated with the above network interactions were measured as simple binary variables, by asking the respondents to indicate, whether or not a proximity advantage was attached to each of the interactions. Strictly speaking the proximity scores are independent of the frequency scores, although few interactions with a particular agent are unlikely to carry major proximity benefits. An overall average proximity score was also calculated.

The importance of financial and knowledge transfers through institutional support was measured with a set of three simple binary proxies. The indicator 'institutional support received' measures whether or not firms had received (mainly non-financial) services from governmental bodies such as BL, which are intended to address technological barriers or obstacles, at any time during the past 3 years. This support covers areas such as access to capital markets, business advisory services and help with ISO 9000 accreditation. Another indicator, 'innovation awards', intends to measure whether the firms had received innovation grants from national sources during the same period. Aside from LINK (see Section 2), there is a Small Firm Merit Awards for Research and Technology (SMART) scheme, which provides grants for small firms (up to 50 employees) to undertake feasibility studies for innovative pre-competitive research projects and for development up to pre-production prototype stage of new products and processes involving a significant technological advance. The Queen's Award for Innovation also provides funding for technologically innovative projects. A separate variable measures whether firms had obtained R&D funding from EU programmes in recent years.

4. Main findings

The average size of the companies in our sample is 34 employees. The large majority are small (fewer than 50 people) rather than medium in size.[6] The largest company employed around 166 people, the smallest one just 5. Average gross value of plant and equipment is £ 633,000. None of the firms were majority-owned by another non-small or medium-sized entity. They had been operating for an average of 14 years and had a profit-to-sale ratio of about 8% between 1995 and 1997.

Out of 33 companies, 25 reported having developed major innovations in products or product range, but only 3 companies held any patents (with one very highly innovative company holding 10 patents). Evidently, producing a major innovation is one thing, but patenting it is quite another. Our sample covers the whole spectrum on our product innovation index (Fig. 2). There are eight manufacturers with no major innovations at all, but there are an equal number of highly advanced companies that had developed science-intensive innovations which were new to the world.

4.1. Internal determinants of innovation capability

The firms' innovation scores were linked to the determinant variables by means of simple Spearman rank correlations to identify statistically significant relationships.[7] The results for the internal sources of innovation capability are highlighted in Table 3. Some patterns stand out. The presence of an owner/manager with an academic degree is not associated with high innovation capability in the sample companies, not even a degree in science or engineering. However, prior work experience in a scientific environment does matter, as shown by the highly significant correlations with the patent variable and the product innovation index. This type of background is apparently conducive to the production of innovations that have a high degree of newness, and that require in-depth scientific or engineering expertise. There is no evidence, though, that it would also contribute to a higher incidence of major innovations as such. Since prior working experience

[6] All firms are well below the upper limit of 249 workers used by Storey (1994) to delineate the small- and medium-enterprise sector.

[7] Non-parametric statistics had to be used because most of the variables are ordinal. Logistic regressions were also run, but did not yield satisfactory results.

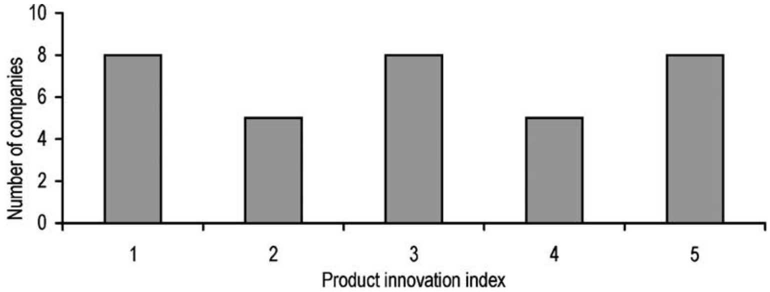

Fig. 2. Scores on the product innovation index obtained by sample firms: 1, least innovative; 5, most innovative.

in a university or a science laboratory is only possible after gaining a relevant degree, the figures suggest that science and engineering education is important after all, but only as a necessary first step. Apparently, experience in a scientific research environment after gaining the degree is what makes the difference.

This pattern is typical for the science-based companies in the sample that had spun-off from a university or former public laboratory (mainly the laboratories of the Atomic Energy Authority at Harwell and Culham, and the Rutherford Appleton Laboratory of the University of Oxford). They include a company producing CAD software for electromagnetic design in engineering and scientific fields, whose three founders worked in a science laboratory in Oxford on electromagnetic design; a firm designing mathematics software

Table 3
Internal sources of innovation capability[a]

Internal sources of innovation		Incidence of product innovation	No. of patents held	Product innovation index
Background of founder/manager(s)	Degree in business management/finance	0.029 (0.437)	0.109 (0.273)	−0.066 (0.358)
	Degree in science or engineering	−0.121 (0.252)	−0.156 (0.193)	−0.028 (0.439)
	Degree in other field	−0.067 (0.355)	−0.133 (0.230)	−0.277 (0.059)
	Prior work experience in other small business (inclusive family firm)	−0.036 (0.422)	−0.064 (0.361)	−0.240 (0.089)
	Prior work experience in multinational or large domestic firm	−0.098 (0.295)	−0.174 (0.167)	−0.097 (0.296)
	Prior work experience in public R&D institutions (universities and science labs)	0.280 (0.057)	0.445** (0.005)	0.545** (0.001)
Skills of workforce	No. of university-trained engineers (fte) as percent of total workforce	0.323* (0.033)	0.082 (0.325)	0.298* (0.046)
	No. of technicians (fte) as percent of total workforce	−0.322* (0.034)	0.008 (0.482)	−0.197 (0.136)
Technological effort	Total R&D expenditure per employee	0.346* (0.024)	0.435** (0.006)	0.566** (0.000)
	Total R&D expenditure as percent of sales	0.194 (0.148)	0.321* (0.039)	0.389* (0.015)
	No. of R&D employees (fte) as percent of total workforce	0.287 (0.053)	0.296 (0.047)	0.385* (0.013)
	Total training expenditure per employee	−0.063 (0.363)	0.000 (0.500)	−0.148 (0.205)
	Total training expenditure as percent of sales	−0.103 (0.290)	0.028 (0.440)	−0.151 (0.209)
	No. of technology licenses bought	0.238 (0.091)	−0.140 (0.218)	0.213 (0.117)

[a] Spearman correlation coefficients, *P*-values in parentheses.
* Significance at the 0.05 level (1-tailed).
** Significance at the 0.01 level (1-tailed).

(FORTRAN and other products), whose founder (who holds a Ph.D. in Maths) had worked in a university computing centre; and five firms designing high-precision electronic instruments for big corporations and/or for science and university laboratories. Their products included blue laser technology, cryogenic equipment, high-sensitivity gas sensors and nuclear magnetic resonance devices.

The owners of these companies had built up in-depth expertise about a particular product or process over a number of years in their capacity as employees of these laboratories, using the internal facilities and resources. They subsequently set themselves up in business to turn a potentially fruitful idea into a profitable innovation. One path-breaking innovation can be the sole driving force in such companies during the first years of their existence. Contact with their former employers is usually maintained for some years in the form of collaborative research, use of public lab and library facilities, participation in academic workshops and conferences, or even (part-time) employment of one of the business partners. These relations had been crucial in many cases, as commercialisation of truly complex, science-based innovations involves long lead times and success cannot be guaranteed for several years. In this way, the public science base had contributed significantly to the subsequent success of highly innovative new ventures in the sample.

Table 3 also indicates that the education profile of a firm's workforce can contribute to its innovative capabilities, particularly the presence of university-trained engineers. The share of university-trained engineers in total employment correlates positively with both the incidence of major product innovations and the product innovation index, although not with the number of patents. The negative correlation between the proportion of technicians in the workforce and the incidence of major innovations can be explained by the fact that only a few less innovative firms in the sample tended to hire a substantial number of such staff. These were producers of electronics components such as cable assemblies and PCBs, who employed some middle-level technical staff in their manufacturing operations. In contrast, the truly high-tech firms in the sample were more oriented towards contract-design and development than manufacturing. This is not only the case for the software developers but also for the electronics firms. In several instances, only prototype testing and perhaps some component assembly took place in-house, while the actual production of components was subcontracted to specialised suppliers. Highly qualified scientists, engineers and mathematicians rather than technicians were needed in these companies.

In keeping with other literature on the subject (see Section 2), the level of the companies' innovation capability is also positively associated with ongoing in-house technological efforts. Total R&D expenditure per employee correlates significantly with the incidence of major innovations, and highly significantly with the number of patents and the innovation index in Table 2. R&D as a percentage of sales correlates with the latter two variables as well. Moreover, the number of R&D staff as a proportion of the total workforce correlates with the innovation index. Of the three innovation indicators, the innovation index clearly performs best as it appears to be capturing not just the incidence of product innovation but also its scientific content.

Resources devoted to training do not appear to have a similar effect. Perhaps, training does not always translate in higher innovative capability, as its purpose could also be to improve managerial or secretarial functions. Acquisition of licences is not significantly related to higher innovation performance in the sample either.

4.2. External determinants of innovation capability

The results of the analysis concerning the interaction with external agents are given in Table 4. The table shows no support for the contention that the overall intensity of external interaction would matter for innovative performance. Neither are there strong indications pointing towards the importance of geographical proximity to other parties in general (although the overall proximity coefficients are not far from being significant). Thus, our study does not support the belief, expressed in some of the studies reviewed in Section 2, that strong overall locally-based interaction would be conducive to innovativeness. A few specific network links do appear to be relevant, however.

One pattern that clearly emerges is the apparent importance of strong interactions between the sample companies with the science base. Moreover, proximity in these contacts appears to matter too. The pattern is quite similar for the three innovation capability

Table 4
External interaction and innovation capability[a]

	Incidence of product innovation	No. of patents	Product innovation index
Frequency of interaction			
Customers	−0.264 (0.069)	−0.002 (0.495)	−0.237 (0.090)
Suppliers	−0.275 (0.061)	0.164 (0.180)	0.016 (0.464)
Competitors	−0.023 (0.450)	−0.055 (0.381)	0.009 (0.480)
Financial institutions	−0.187 (0.149)	−0.031 (0.432)	−0.070 (0.349)
Training institutions	−0.101 (0.287)	0.227 (0.102)	−0.011 (0.476)
R&D institutions	0.406** (0.009)	0.389* (0.013)	0.621** (0.000)
Service providers	−0.045 (0.401)	0.319* (0.035)	0.137 (0.223)
Industry associations	−0.011 (0.475)	0.074 (0.342)	−0.122 (0.249)
All agents (overall score)	−0.052 (0.387)	0.219 (0.110)	0.129 (0.238)
Proximity advantage related to interaction			
Customers	−0.123 (0.248)	−0.183 (0.154)	−0.306* (0.041)
Suppliers	0.343* (0.026)	0.145 (0.211)	0.412**(0.009)
Competitors	−0.067 (0.355)	−0.133 (0.230)	−0.277 (0.059)
Financial institutions	0.141 (0.216)	0.047 (0.398)	0.138 (0.221)
Training institutions	0.173 (0.168)	0.247 (0.083)	0.172 (0.169)
R&D institutions	0.393* (0.012)	0.305* (0.042)	0.292* (0.050)
Service providers	0.087 (0.316)	0.031 (0.432)	0.128 (0.238)
Industry associations	0.267 (0.067)	−0.198 (0.134)	0.076 (0.310)
All agents (overall score)	0.230 (0.098)	0.277 (0.060)	0.276 (0.060)

[a] Spearman correlation coefficients, *P*-values in parentheses.
* Significance at the 0.05 level (1-tailed).
** Significance at the 0.01 level (1-tailed).

measures. On the basis of the statistics alone one cannot rule out the possibility of some reverse causality. It is possible that highly innovative firms would be more likely to form links with scientific institutions because they already constitute attractive collaboration partners. However, the impressions gained from the interviews do not provide much support for that idea. Almost all the links with universities and science laboratories had historical origins, emanating from previous employment of owner/managers in these institutions. This is also consistent with the earlier finding on the importance of previous working experience in public R&D labs on a firm's current innovation capacity. Thus, the results should be interpreted as further support for the notion that the regional science base had played an important role in the sample by acting as a breeding ground for high-tech spin-offs. They should not be viewed as support for any assumed benefits of getting companies to locate on science parks. Very few companies in the sample were in fact located on a park, and the few that did had no close relations with science institutions close by.

Another noteworthy result are the benefits that are apparently associated with proximity to suppliers, as shown by the statistically significant correlations for the incidence of major product innovation and the product innovation index. Yet, there is no evidence to support the idea that high frequency in those contacts would matter as well. Apparently, it is not the *frequency* of contact with suppliers as such that confers an advantage for major product innovation, but rather the possibility of 'face-to-face' contact *as and when interaction is required*. This provides some support for the idea noted by other writers (Section 2), that problems related to tacitness associated with major innovations could play an important role here. Being located in an area where crucial suppliers are within a 1 h travelling distance is apparently a key facilitating factor.

The third pattern in Table 4 concerns the positive link between frequency of contact with service providers and number of patents. The category 'service providers' includes a number of items, mainly business consultants, advertising agencies, printing facilities, equipment servicing and repair services, and public assistance. The fact that the patents variable is the only one of three innovation indicators showing a significant association probably suggests that the processes of patenting an innovation and dealing with infringements on patented innovations requires contacts with specific agents who provide assistance for those particular purposes. Thus, the association cannot be taken as support for the idea that intensive interaction with consultants, maintenance and repair providers and so on, have helped to make the sample firms more innovative.

Frequency of interaction with firms in similar lines of business, banks, training institutions or industry associations does not correlate significantly with innovation performance. Neither is there any sign of significant proximity benefits that might be associated with these interactions. Furthermore, there is a significantly *negative* correlation between customer proximity and performance as measured by the product innovation index. This result is remarkable because it runs counter to received literature in which close face-to-face user–producer contacts are seen to promote innovativeness (Section 2).

Some additional statistics from the survey help to throw more light on this finding (Table 5). The firms' scores on all three innovation capability indicators correlates highly significantly with their degree of export-orientation. Again, the production innovation index performs better than the other two indices of innovation capability. Orientation towards the local or even national market is not associated with higher innovation performance at all; in fact, two of the correlations related to sales on national markets are significantly negative. Thus, the most innovative companies in the sample are clearly those that are operating in leading global markets (especially in the USA and Japan and to a lesser extent in Europe), and competing on the world's technological frontier. This finding is supported by subjective impressions from the interviews. For instance, one company had developed an instrument for Sony Japan, which could produce the atomic N ingredient needed to grow thin film required for blue laser, used in the production of CDs. Another company had developed marine instrumentation capable of tracking pipes and cables on deep ocean seabeds for the world's big oil companies. It had developed expertise in picking up the latest available technologies embodied in components developed by big world players (e.g. micro gyroscopes in the automotive industry) and create new high-tech applications with these technologies in its own area. Although the respondents of these (and several other) highly innovative companies did indicate that ongoing interaction with these customers was essential to keep abreast of their needs and new developments in their domain, neither high frequency nor physical proximity appeared to be particularly advantageous for successful innovation. As suggested in Section 2, major recent advances in ICT and associated cost reductions of long-distance communication may play an important role here.

The links between institutional support and innovative performance are presented in Table 6. Some of the institutional support (first row) represents direct innovation-related assistance in the form of counselling by innovation and technology counsellors from business link, but more often it involved financial support and advice related to introduction of ISO 9000, or information provision about potential export markets, potential overseas business partners, machinery suppliers, and so on. The UK innovation awards include LINK, SMART and the Queen's Award for Innovation. The EU schemes are grants from the ESPRIT, BRITE and COPERNICUS programmes.

Table 5
Market orientation and innovation capability[a]

Proportion of products sold on	Incidence of major product innovations	No. of patents	Product innovation index
Local markets	−0.106 (0.592)	−0.290 (0.134)	−0.191 (0.230)
National markets	−0.210 (0.284)	−0.412* (0.030)	−0.545* (0.016)
International markets	0.483** (0.010)	0.526** (0.004)	0.777** (0.001)

[a] Spearman correlation coefficients, *P*-values in parentheses.
* Significance at the 0.05 level (2-tailed).
** Significance at the 0.01 level (2-tailed).

Table 6
Institutional support and innovation capability[a]

	Incidence of major product innovations	No. of patents	Product innovation index
Institutional support received (yes/no)	0.126 (0.242)	0.134 (0.228)	0.356* (0.021)
UK innovation awards obtained (yes/no)	0.083 (0.322)	0.026 (0.442)	0.392* (0.012)
EU innovation grants obtained (yes/no)	0.239 (0.090)	0.299* (0.046)	0.363* (0.019)

[a] Spearman correlation coefficients, *P*-values in parentheses.
* Significance at the 0.05 level (1-tailed).

The product innovation index again performs notably better than the other two indicators of innovation capability. Possibly, the greater amount of detail encapsulated in the innovation index pays-off here. All three types of support are significantly correlated with it, although the direction of causality cannot be expected to be one-way. The interviews suggested that the problem is likely to be most severe in respect of the EU grants. Firms with an established track record of successful innovations, and which are run by people who were familiar with the art of writing research proposals through previous employment as research staff of public institutions or big firms, were definitely more successful in tapping into EU sources than others. This pattern would also largely explain the significantly positive correlation between EU support and the number of patents in the table.

The evidence in respect of the other two sources of support is more mixed. A proven innovation track record is not required to qualify for assistance from business link. Innovation and technology counsellors in the region certainly do not limit their visits to highly innovative firms. However, some of the respondents indicated that the support that BL can offer appears to be more relevant to the needs of well-established medium-sized companies with some innovation experience than to very small start-ups. The innovation financing schemes run by the UK Department of Trade and Industry suffer from the same problem. Firms are able to qualify for them only when they already have proven innovation potential. Even so, the respondents from the firms that had received such grants maintained that the money from these sources had been beneficial in boosting their innovative performance, because they rarely had sufficient money of their own to finance substantial pre-competitive R&D. The projects financed by these schemes could not have been undertaken in the absence of external funding.

5. Conclusions

A range of internal and external factors were found to be statistically significantly related to the innovative performance of the electronics and software development firms that were analysed in this paper. Among the internal factors, the importance of prior experience in a scientific environment stands out. A prevalence of staff with science and engineering degrees in the enterprise was also found to have a positive effect.

These results point towards the importance of specialised knowledge and experience in science and engineering, rather than practical, intermediate-level technical skills or general managerial capabilities, as a precondition for subsequent technological learning and achievement of innovative excellence in small high-technology firms. They also concur with findings from earlier research in that they point towards the key role played by the UK science base in fostering entrepreneurs capable of running and developing the type of knowledge-based, innovation-driven firms that the UK government seeks to bolster. Several businesses in the sample would not have succeeded without initial support and encouragement from the science laboratory or university department from which they had spun-off. Access to laboratory and library facilities and scientific contacts, or subsidising of staff costs through continued part-time employment of one of the business partners during the first years after start-up were found to have been particularly effective support mechanisms. Perhaps even more crucial was the fact that a large share of the initial development costs of the initial innovation was borne by these institutions, since substantial pre-competitive research had already been completed before the decision to branch out on one's own was actually taken.

The analysis further supports findings from earlier research concerning the importance of R&D investment as a means of boosting innovativeness. Adequate medium-term R&D funding is crucial for sustained innovation and learning and, ultimately, for achievement of technological excellence in a specialised niche that can lead to competitiveness in leading international markets. Although problems with causality should be noted, it is clear that R&D funds from the UK Department of Trade and Industry and the European Union had contributed to the innovative performance in some of the sample firms. Few companies had been able to earmark sufficient internal funds for R&D on an ongoing basis, especially during the first 5–6 years after their establishment.

The current approach to government support of small firms is predominantly a 'market-led' one, intended to facilitate access to crucial inputs from private sources (Bessant, 1999). However, the survey results suggest that some public R&D support remains vital, especially to facilitate new start-ups and to boost pre-competitive research in recently established ventures. It is unlikely that private financial agents such as venture capitalists, business angels and finance trusts will be able and willing to fully meet all the financial needs of new small technology-based firms. Market failure is likely to remain especially high for science-based companies, which typically experience very long lead times from the first conception of an idea to the commercialisation of a marketable product. Sustained R&D financing for several years prior to commercialisation is required for such companies to be ultimately successful. It is precisely these types of ventures, in fields like particle physics, software algorithm development, biotechnology or precision instrument making that can contribute significantly to the establishment of the new knowledge-driven economy by achieving competitiveness in leading markets abroad.

The analysis did not provide much support for the contention that overall intensity of external networking would be conducive to innovativeness, nor that proximity to network partners in a general sense would contribute to this. Even so, a few specific types of local interactions clearly did appear to matter, notably those with R&D institutions and suppliers. A further noteworthy finding is the positive association between an orientation towards leading international markets and innovative performance. Firms with local or even national customer networks appear to be performing comparatively less well.

These findings concur with other recent research that points to the importance of a local–global interface, in which specific local network linkages contribute to success of small technology-based UK companies in global markets (Keeble et al., 1998, 1999; Simmie, 1997). On the other hand, they provide only partial support to the current thrust of UK government policy which seeks to boost the technological performance of small high-technology firms by means of intensive customer–producer interactions and 'horizontal' networking among clustered small firms in similar lines of business. Neither do the findings support the promotion of science-based clusters of firms around leading universities. The linkages with the science base in the sample had predominantly emanated from previous employment, not from co-location on parks. Although such policies could conceivably give rise to more 'conventional' static agglomeration economies in regional clusters, this should not be confused with the creation of durable competitive advantage driven by capabilities to develop and commercialise new knowledge in the form of profitable innovations.

A final note about measurement of firm-level innovative performance is in place. The experimental product innovation index performed consistently well in the analysis. The combination of the two conventional, more or less objective measures with this more subjective experimental proxy yielded more insights than the two conventional measures would have yielded on their own (especially about the role played by customers and institutional support). It clearly is important to continue to search for better, finer grained measures of innovation performance than those that are widely used at present, and to attempt to find ways to reduce their subjectivity.

Acknowledgements

This paper is an output from the research programme 'SMEs in Europe and East Asia: Competition, Collaboration and Lessons for Policy Support', coordinated by Edinburgh University and financed by the TSER programme of the European Union. The authors wish to thank Mike Albu for his contributions to conceptualisation and fieldwork, Sanjaya Lall for coordinating the research, and three anonymous reviewers for comments on an earlier draft.

References

Archibugi, D., Pianta, M., 1996. Measuring technological change through patents and innovation surveys. Technovation 16 (9), 451–468.

Asheim, B.T., 1996. Industrial districts as learning regions: a condition for prosperity. European Planning Studies 4, 379–400.

Audretsch, D.B., 1998. Agglomeration and the location of innovative activity. Oxford Review of Economic Policy 12 (2), 18–29.

Basberg, B., 1987. Patents and the measurement of technological change: a survey of the literature. Research Policy 16, 131–141.

Beavis, S., 1998. When proximity powers profits. Financial Times, 18 November, p. 19.

Becattini, G., 1989. Sectors and/or districts: some remarks on the conceptual foundations of industrial economics. In: Goodman, E., Bamford, J., Saynor, P. (Eds.), Small Firms and Industrial Districts in Italy. Routledge, London.

Bell, M., 1984. Learning and the accumulation of industrial technological capability in developing countries. In: Fransman, M., King, K. (Eds.), Technological Capability in the Third World. Macmillan, London, pp. 187–209.

Bessant, J., 1999. The rise and fall of Supernet: a case study of technology transfer policy for smaller firms. Research Policy 28 (6), 601–614.

Best, M.H., 1990. The New Competition. Institutions of Industrial Restructuring. Polity Press, Cambridge.

Camagni, R. (Ed.), 1991. Innovation Networks: Spatial Perspectives. Belhaven Press, London.

Caniëls, M.C.J., 2000. Knowledge Spillovers and Economic Growth. Edward Elgar, Cheltenham.

Centre for Business Research, 1996. The Changing State of British Enterprise. ESRC Centre for Business Research, University of Cambridge, Cambridge.

Cohen, W.M., Levinthal, D.A., 1989. Innovation and learning: the two faces of R&D. The Economic Journal 99, 569–596.

Cooke, P., Gomez Uranga, M., Extebarria, G., 1997. Regional innovation systems: institutional and organisations dimensions. Research Policy 26, 475–491.

Cosh, A., Hughes, A., Wood, E., 1996. Innovation in UK SMEs: causes and the consequences for firm failure and acquisition. Working Paper 48, ESRC Centre for Business Research, University of Cambridge, Cambridge.

Curran, J., Blackburn, R.A. (Eds.), 1994. Small Firms and Local Economic Networks: The Death of the Local Economy. Routledge, London.

Dicken, P., Forsgren, M., Malmberg, A., 1994. The local embeddedness of transnational corporations. In: Amin, A., Thrift, N. (Eds.), Globalization, Institutions and Regional Development in Europe. Oxford University Press, Oxford, pp. 23–45.

Dodgson, M., 1991. Technology learning, technology strategy and competitive pressures. British Journal of Management 2/3, 132–149.

Dodgson, M., 1993. Organisational learning: a review of some literatures. Organisation Studies 14 (3), 375–394.

DTI, 1997. Competitiveness UK: A Benchmark for Business. UK Government, Department of Trade and Industry, November; http://www.dti.gov.uk/comp/bench.htm.

DTI, 1998. Building the Knowledge-Driven Economy. UK Government, Department of Trade and Industry, December; http://www.dti.gov.uk/comp/competitive/wh_int1.htm.

Edquist, C., 1997. Systems of Innovation: Technologies, Institutions, and Organizations. Pinter, London.

Freeman, C., 1991. Networks of innovators: a synthesis of research issues. Research Policy 20, 499–514.

Freeman, C., 1995. The national system of innovation in historical perspective. Cambridge Journal of Economics 19 (1), 5–24.

Garvin, D.A., 1993. Building a learning organization. Harvard Business Review, July–August, pp. 78–91.

Griliches, Z., 1990. Patent statistics as economic indicators: a survey. Journal of Economic Literature 28, 1661–1707.

Håkansson, H., 1989. Corporate Technological Behaviour: Co-operation and Networks. Routledge, London.

Hitt, M.A., Ireland, R.D., Lee, H., 2000. Technological learning, knowledge management, firm growth and performance: an introductory essay. Journal of Engineering and Technology Management 17 (3/4), 231–246.

Hoffman, K., Parejo, M., Bessant, J., Perren, L., 1998. Small firms, R&D, technology and innovation in the UK: a literature review. Technovation 18 (1), 39–55.

House of Lords Select Committee on Science and Technology, 1997. The Innovation Exploitation Barrier. HL Paper 62. HMSO, London.

Huggins, R., 1998. Local business co-operation and training and enterprise councils: the development of inter-firm networks. Regional Studies 32 (9), 813–826.

Keeble, D., Lawson, C., Lawton Smith, H., Moore, B., Wilkinson, F., 1998. Internationalisation processes, networking and local embeddedness in technology-intensive small firms. Small Business Economics 11 (4), 327–342.

Keeble, D., Lawson, C., Moore, B., Wilkinson, F., 1999. Collective learning processes, networking and institutional thickness in the Cambridge region. Regional Studies 33 (4), 319–332.

Kim, L., Nelson, R. (Eds.), 2000. Technology, Learning and Innovation: Experiences of Newly Industrializing Economies. Cambridge University Press, Cambridge.

Lall, S., 1992. Technological capabilities and industrialisation. World Development 20 (2), 165–186.

Larsson, S., 1998. Lokal förankring och global räckvidd. En studie av teknikutveckling i Svensk maskinindustri, Geografiska Regionstudier 35. Kulturgeografiska Institutionen, Uppsala Universitet, Uppsala.

Lundvall, B.-Å., 1988. Innovation as an interactive process: from user–producer interaction to the national system of innovation. In: Dosi, G., Freeman, C., Nelson, R., Silverberg, G., Soete, L. (Eds.), Technical Change and Economic Theory. Pinter, London, pp. 349–369.

Lundvall, B.-Å., 1992. User–producer relationships, national systems of innovation and internationalisation. In: Lundvall, B.-Å. (Ed.), National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning. Pinter, London, pp. 45–67.

Maillat, D., Quévit, M., Senn, L., 1993. Réseaux d'Innovation et Milieux Innovateurs: Un Pari pour le Développement Régional. EDES, Neuchâtel.

Malerba, F., 1992. Learning by firms and incremental technical change. The Economic Journal 102, 845–859.

Massey, D., Quintas, P., Wield, D., 1992. High Tech Fantasies: Science Parks in Society, Science and Space. Routledge, London.

Oakey, R.P., Mukhtar, S.-M., 1999. United Kingdom high-technology small firms in theory and practice: a review of recent trends. International Small Business Journal 17 (2), 48–64.

OECD, 1992. Proposed Guidelines for Collecting and Interpreting Technological Innovation Data. Oslo Manual, Paris.

Oerlemans, L.A.G., Meeus, M.T.H., Boekema, F.W.M., 1998. Learning, innovation and proximity. Working Paper 98/3, Eindhoven Centre for Innovation Studies, Eindhoven University of Technology, Eindhoven.

Panda, H., Ramanathan, K., 1996. Technological capability assessment of a firm in the electricity sector. Technovation 16 (10), 561–588.

Patel, P., Pavitt, K., 1995. Patterns of technological activity: their measurement and interpretation. In: Stoneman, P. (Ed.), Handbook of the Economics of Innovation and Technological Change. Blackwell, Oxford, pp. 14–51.

Pavitt, K., 1985. Patent statistics as indicators of innovation activities. Scientometrics 7, 77–99.

Pavitt, K., Robson, M., Townsend, J., 1987. The size distribution of innovating firms in the UK 1945–1983. Journal of Industrial Economics 35, 279–315.

Piore, M., Sabel, C., 1984. The Second Industrial Divide: Possibilities for Prosperity. Macmillan, New York.

Porter, M.E., 1990. The Competitive Advantage of Nations. The Free Press, New York.

Rothwell, R., Dodgson, M., 1991. External linkages and innovation in small and medium-sized enterprises. R&D Management 21, 125–137.

Saxenian, A., 1994. Regional Advantage: Culture and Competition in Silicon Valley and Route 128. Harvard University Press, Cambridge MA.

SBRC, 1992. The State of British Enterprise: Growth, Innovation and Competitive Advantage in Small and Medium Sized Firm. Small Business Research Centre, University of Cambridge, Cambridge.

Schmitz, H., 1995. Collective efficiency: growth path for small-scale industry. Journal of Development Studies 31 (4), 529–566.

Scott, A., Storper, M., 1992. Regional development reconsidered. In: Ernste, H., Meier, V. (Eds.), Regional Development and Contemporary Industrial Response: Extending Flexible Specialization. Belhaven Press, London, pp. 3–26.

Simmie, J., 1997. The origins and characteristics of innovation in highly innovative areas: the case of Hertfordshire. In: Simmie, J. (Ed.), Innovation, Networks and Learning Regions? Jessica Kingsley Publishers, London.

Steiner, M. (Ed.), 1998. Clusters and Regional Specialisation. Pion, London.

Sternberg, R., 1999. Innovative linkages and proximity: empirical results from recent surveys of small and medium sized firms in German regions. Regional Studies 33 (6), 529–540.

Storey, D.J., 1994. Understanding the Small Business Sector. International Thomson Business Press, London.

Storper, M., 1993. Regional Worlds of production: learning and innovation in the technology districts of France, Italy and the USA. Regional Studies 27, 433–455.

Storper, M., Harrison, B., 1991. Flexibility, hierarchy and regional development: the changing structure of industrial production systems and their forms of governance in the 1990s. Research Policy 20, 407–422.

Suarez-Villa, L., Walrod, W., 1997. Operational strategy, R&D and intra-metropolitan clustering in a polycentric structure: the advanced electronics industries of the Los Angeles basin. Urban Studies 34 (9), 1343–1380.

Thomas, M., Jones, P., 1998. UK Results from the 2nd Community Innovation Survey. UK Government, Department of Trade and Industry; http://www.dti.gov.uk/tese/ecrep03.html.

UNCTAD, 1996. Fostering technological dynamism: evolution of thought on technological development processes and competitiveness. A Review of the Literature. United Nations, Geneva.

Vedovello, C., 1997. Science parks and university–industry interaction: geographical proximity between the agents as a driving force. Technovation 17 (9), 491–502.

Von Hippel, E., 1988. The Sources of Innovation. Oxford University Press, New York.

Westhead, P., Cowling, M., 1995. Employment change in independent owner-managed high-technology firms in Great Britain. Small Business Economics 7 (2), 111–140.

Wignaraja, G., 1998. Trade Policy, Technology and Exports: Sri Lanka's Liberalisation Experience. Macmillan, London.