Working Paper Number 40

Determinants of Innovation Capability in Small UK Firms: An Empirical Analysis*

Henny Romijn† and Manuel Albaladejo††

The paper is an empirical investigation of key internal and external sources of innovation capability in small and medium firms (SME) in the UK. An experimental measure of innovation capability is designed, which captures not merely the occurrence of innovations but also their scientific complexity and originality. The results obtained with this measure compare favourably to those obtained with more conventional statistics. A range of factors internal to firms are found to be relevant, including owners' technical education and prior working experience in large firms and R&D institutions, technical skills of the workforce, and investments in R&D and training. Significant external factors are: public financial support for R&D, and interaction with nearby R&D and training institutions. Although interaction with customers, suppliers and similar-oriented firms are more frequent than the former, there is no evidence that intensive linkages of this kind would be important for innovative capability. These findings do not support the thrust of current UK policy, which seeks to promote SME innovative performance through the formation of geographical clusters of firms in similar lines of business.

---

* The research on which this paper is based is part of the research programme 'SMEs in Europe and East Asia: Competition, Collaboration and Lessons for Policy Support', co-ordinated by the University of Edinburgh and financed by the TSER programme of the European Union, DG XII. The authors wish to thank Mike Albu for his contributions to the conceptualisation and fieldwork and Sanjaya Lall for his co-ordination of the research.
† Eindhoven University of Technology. E-mail: H.A.Romijn@tm.tue.nl
†† Queen Elizabeth House, University of Oxford. E-mail: Manuel.Albaladejo@qeh.ox.ac.uk

1. Introduction

In the UK, as in other countries, there has been a revival of interest in small manufacturing firms as important agents of industrial growth. Before the 1980s, the small enterprise sector had been on a path of secular decline for decades, and it was essentially seen as an anachronism -- a vestige of 19th century cottage industries with low productivity and incomes and poor working conditions, to be promoted only for purposes of income support for disadvantaged groups (Albu, 1998). However, in the course of the 1980s the contribution of small firms to the national economy began to increase again. The number of manufacturing establishments with a maximum of ten employees rose from a low of 35,000 in the 1960s to over 100,000 by 1985 (Bannock and Peacock, 1989), and their contribution to manufacturing output increased from 19 per cent in the 1960s to 32 per cent by 1990 (Storey, 1994, p.26).

Fundamental shifts in the organisation of manufacturing activity underlie these trends. Vertically integrated forms of mass production have been on the decline. 'Post-Fordist', flexible and lean production techniques and decentralised systems of industrial organisation have emerged in their place, revolving around inter-firm networking and subcontracting. Fast regional economic growth in the 'Third Italy' and Baden-Wuerttemberg in Southern Germany, driven by agglomerations of highly dynamic flexibly-specialised small firms, first documented in Piore and Sabel's (1984) classic *'The Second Industrial Divide'*, has inspired policy makers and researchers around the world.

The recognition that small manufacturing firms could make a key contribution to industrial regeneration has made them a central element in recent UK government policies aimed at increasing national industrial competitiveness.[1] In the 1998 Competitiveness White Paper it is pointed out that if the British SME sector is to enhance industrial competitiveness in the knowledge-driven economy, emphasis should be put on promoting the use of science and technology and stimulating innovation by strengthening links with the national science and engineering base (DTI, 1998). A range of science and technology support schemes for SME have been put in place, especially for high-technology companies. Furthermore, it it believed that SME innovative capabilities and competitiveness will be enhanced by networking and co-operation with other agents in the innovation system, such as suppliers, customers and competitors. The government wants to act as a catalyst to promote regional clusters, especially in those industries where the UK has a strong knowledge base.

Not much systematic research on the effectiveness of these support mechanisms has been carried out to date. A recent literature survey about small firms, R&D, technology and innovation in

[1] Many academic studies about innovativeness in SME also emerged since the mid 1980s. Useful reviews which cover substantial parts of that literature are Hoffman et al (1998) andOakey and Mukhtar (1999). There are now several academic centres with long-standing SME research programmes, e.g., SPRU and CENTRIM at the University of Sussex, and the ESRC Centre for Business Research at the University of Cambridge. Two principal annual conferences on the subject are organised in the country, the Small Business and Enterprise Conference and the National Small Firms Policy and Research Conference.

the UK, commissioned in part by DTI, concluded that academic studies provide little hard empirical evidence about how small firms go about improving their technological performance. Their technological functioning has still largely remained a black box. Even in the largest and most authoritative 1992 Cambridge survey (SBRC, 1992), which collected a varied range 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 contribute to a better understanding of these issues. It hones in on the ongoing debate about the effectiveness of science and technology support policies to strengthen SME technological capabilities, including the usefulness of fostering 'learning regions'. It is based on a small survey of small companies in electronics, software design and garment manufacturing, in which detailed information was collected about their innovative capabilities and about a variety of potentially important internal and external sources of those capabilities. Detailed quantitative data supported by insights based on more qualitative information are used to assess firms' capabilities and to single out those factors that contributed most significantly to their emergence and development.

Relevant theory is summarised in section 2. This sets the scene for the issues explored in the paper. In Section 3 the conceptual framework, sampling, and measurement of the main variables are discussed. Basic introductory information about the sample is given in section 4. Section 5 contains the data analysis and the results. Conclusions and implications for policy and further research are given in Section 6.

2. Theoretical underpinnings

Innovation capability

Central to the subject of this paper is an extensive body of literature that conceptualises firm-level technological advancement in terms of the acquisition of *technological capability*. Technological capability is defined as the knowledge and skills required for firms to choose, install, operate, maintain, adapt, improve and develop technologies. The basic point of departure of this literature is that the existence of such capability cannot be taken for granted. It has to be acquired, necessitating purposive efforts aimed at assimilating, adapting and modifying existing technologies and/or developing new technologies.[2] Firms that are adept at this are called learning organisations. They are '... skilled at creating, acquiring and transferring knowledge, and at modifying their behaviour to reflect ... new knowledge and insights' (Garvin, 1993, p.80).[3] A substantial part of the

[2] See, e.g., Adler and Clark (1991), Malerba (1992) and Cohen and Levinthal (1989). Oerlemans *et al.* (1998) mentions many other studies. Lall (1992) reviews the capability literature relating to less developed countries.
[3] Even when a new technology comes with a full set of blueprints and manuals, instantaneous and complete transfer of all the knowledge and skills required to fully understand the ins and outs of its functioning is not possible because knowledge is

learning may not take the form of well-defined R&D programmes and other formalised 'technological effort'. Informal and incremental problem solving and experimentation take place on the shop-floor and are closely associated with production. This is *a fortiori* the case in small companies that do not have the resources and organisation to mount large R&D and human resource development programmes (Romijn, 1999).

Several kinds of technological capability are distinguished in the literature[4], but for the purpose of this paper the most crucial type is *innovation capability.* It refers to the ability to make major improvements and modifications to existing technologies, and to create new technologies. The notion of innovation capability applies to process technology, product technology as well as the way in which production is organised and managed. Its importance derives from the fact that it is presumed to contribute to *dynamic* competitive advantage of companies since it enhances their capacity to keep up with, respond to, and initiate technological change on an ongoing basis. It is crucial in a competitive economic environment characterised by fast change.

Adequate measurement of innovation capability is difficult. Since skills and knowledge are not directly observable, one has to resort to proxies that capture observable qualities that reflect them.[5] The best measures relate to the outputs that result from the utilization of a firm's capabilities, i.e. its innovations. Input-type proxies such as R&D and training expenditure are also popular, but they are better conceived of as learning inputs (i.e. as *sources* of capability; see below). The disadvantage of output-type proxies is that they are hard to quantify. Most studies tend to stick to proxies such as incidence of patents or major innovations, but these measures are crude, especially when small enterprises are being studied.

Internal sources

A variety of factors internal and external to the firm may contribute to innovation capability (see, e.g., Bell, 1984). As far as internal factors are concerned, the entrepreneur(s) and workforce bring a certain stock of knowledge and skills into the firm, which they obtained through earlier experience. Over time, the capability base of the firm is further enhanced through internal learning, involving investments in formal R&D, informal experimentation, debugging, making minor adaptations to products, processes and organisation, in-house staff training, and so on. Aside from some limited spontaneous 'learning-by-doing', these learning efforts need resources. This makes them to some extent amenable to observation and measurement, although informal, incremental activities tend to be extremely difficult to estimate. Studies generally confine their measurement of intra-firm

partly tacit and can only be gained through first-hand experience. Tacitness plays a central role in the evolutionary theory of technical change (Nelson and Winter, 1982; and Dosi et al, 1988) which is the main theoretical underpinning of the technological capability literature.

[4] Other important types of capability are: production capability, investment capability and linkage capability. For a classification, see Lall (1992).

[5] For a review of innovativeness indicators, see (Hyvärinen, 1990)

learning to the most readily observable inputs, mainly R&D expenditure and number of scientists and engineers or R&D staff employed.

External sources

Interaction with suppliers, customers, public institutions and industry associations may provide missing 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 the like. The mobilisation of external resources for technological learning is called 'learning by interacting' (Lundvall, 1988).

Several authors have suggested that interactive learning would be boosted by regional clustering of the network actors with whom a firm interacts. There appears to be a broad consensus that emerging network structures of economic actors associated with Post-Fordism can somehow foster technological improvement and economic competitiveness through positive externalities, market linkages, and possibilities for collaboration.[6] A variety of explanations have been offered. Storper and Harrison (1991) and Cooke *et al.* (1997) refer to the tacitness of knowledge, which makes its transfer difficult across large distances. Both 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.[7] Dicken *et al.*(1994) and Saxenian (1994) also refer to facilitatation 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. Stewart and Ghani (1991) emphasize the occurrence of positive externalities, especially quick diffusion of innovations and easy inter-firm movement of skilled labour. However, others have debated the importance of proximity effects in present-day globalising economies. Rapidly falling transport and communication costs and rising speed and quality of long-distance interaction could reduce the significance of proximity for technological dynamism and economic competitiveness (Curran and Blackbourn, 1994).[8]

---

[6] Some of that literature makes reference to old theoretical concepts such as Marshall's industrial districts (e.g. Scott and Storper, 1992). Other writers employ new concepts such as innovative milieux (e.g., Camagni, 1991, Maillat *et al*., 1993), collective efficiency (Schmitz, 1994), learning regions (Asheim, 1996) or regional innovation systems (Oerlemans *et al*., 1998).

[7] See Oerlemans *et al.* (1998) for an elaboration of these arguments.

[8] A study exploring the role of proximity for high-technology small firms in the Los Angeles Basin found that the most R&D intensive and high-performing firms were found in non-clustered locations, and that their networks were the most extensive and far-reaching. The authors suggest that locating outside a cluster may have been an advantage for innovative firms in its own right, as it made it easier for them to maintain some independence and secrecy for their R&D activities (Suarez-Villa and Walrod, 1997). Another study found that interregional rather than intraregional linkages predominated in three German regions (Sternberg, 1999). Similarly, a very low incidence of local network links, particularly innovation-related collaborations, was found among innovation-intensive small firms in Hertfordshire (UK) found (Simmie, 1997).

In the UK, the networking & proximity debate gives special importance to two specific types of interaction. Firstly, networking is supposed to be primarily beneficial for SME 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). In line with current policy directives concerning high-technology small firms, counsellors of Business Link (BL) and representatives of Training Enterprise Councils (TECs) — the main vehicles for SME support in the UK at present (see section 4 for more details) — must play the role of network brokers to build local inter-firm networks consisting of firms with similar interests. Secondly, communities of small firms are supposed to be able to benefit from relations with *scientific institutions*. The government has been setting up science parks near universities already for some considerable time. However, the validity of either of these approaches towards small firm promotion remains debated for lack of convincing evidence of their supposed benefits. So far, the success of either policy appears to have been mixed at best.[9] In sum, the debate about the supposed benefits of external interactions of small firms and about their supposed proximity advantages is far from settled, in the UK and elsewhere.

3. Research objectives and analytical framework

The foregoing suggests that a large number of potentially important internal and external factors might contribute to a greater or lesser degree to the innovation capability of small firms. However, more detailed insights are clearly needed, especially for policy design and implementation. In particular: which specific internal and external factors can be considered key sources of SME innovation capability; can geographical proximity to other actors enhance the value of external interactions, and if so, which actors are most important in this respect? The main aim of the paper is to shed light on these questions with data from a small sample of UK SME. The second aim of the paper, which is instrumental to achieving the first objective, is to contribute to improved measurement of the relevant concepts. To this end, the paper develops more comprehensive and detailed proxies of firms' innovation capabilities and the sources that are believed to contribute to their development, than has been the case in SME innovation surveys so far.

The main analytical concepts and the relationships between them that are to be explored are set out in Figure 1. The oval at the top represents the innovation capabilities of firms. These capabilities accumulate as a result of various internal and external inputs.

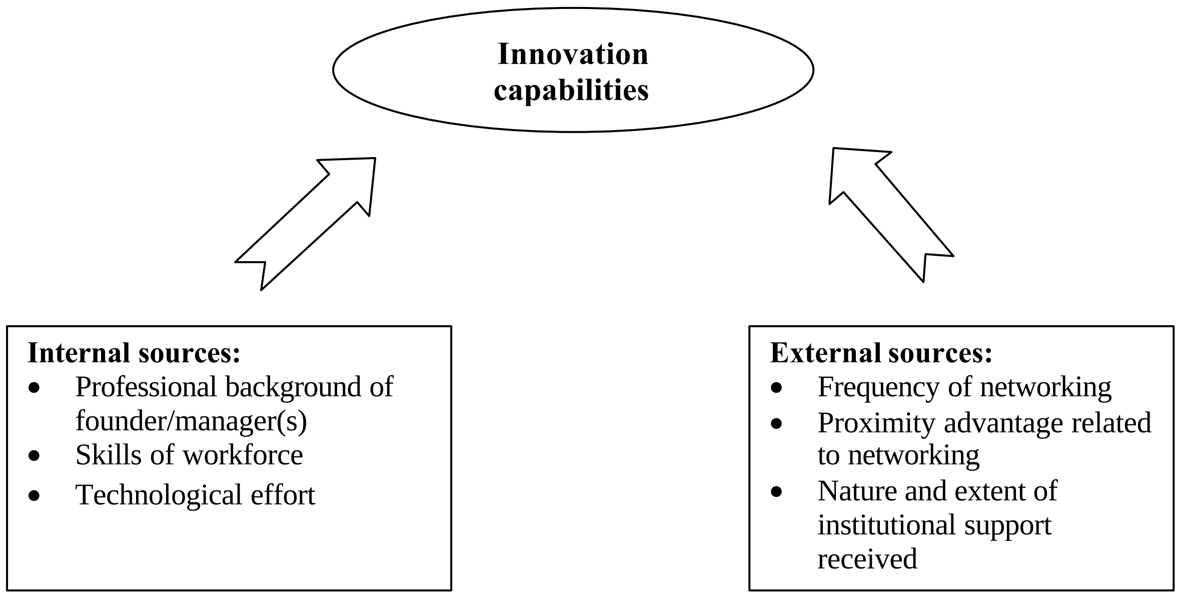
Potentially important sources that are generated inside firms include: (a) the initial educational background and prior working experience of the founder(s)/manager(s); (b) the

[9] There appears to be widespread disappointment with the effectiveness of science parks (Oakey and Mukhtar, 1999). A study about network relations on the Surrey Science Park is illustrative (Vedovello, 1997). Local network relations between firms on the Park and the university were not found to be particularly important, especially in relation to research activities. The network brokering policies are too recent for much systematic evidence to have emerged so far. One recent study examining the effectiveness of 63 TECs as local network brokers reached disappointing conclusions about their impact on inter-firm network formation (Huggins, 1998).

professional qualifications of the workforce; and (c) various kinds of technological effort which induce further accumulation of technological capabilities, such as formal and informal R&D, formal and informal (on-the-job) training, acquisition of technological licences, and so on.

Potentially important external sources are represented by: (a) the frequency of networking with a variety of other private-sector agents and various institutions; (b) any geographical proximity advantages associated with networking; and (c) the nature and extent of institutional support received. The nature and extent of institutional support is represented as a separate determinant of capability in the model, in addition to frequency of interactions with assistance agencies and proximity advantages associated with these contacts. The latter variables cannot be expected to capture the full effects of external support on firm-level technological efforts and resulting capabilities. One might expect that the size and nature of actual transfers of finance and/or knowledge would also affect the effectiveness of assistance.

Figure 1



4. Sampling and measurement

The sample consisted of 50 small (with fewer than 250 employees) companies in software, electronics and clothing, three important industries in which SMEs are strongly represented.[10] The interviews were carried out during 1998 and 1999. The selection of firms was not random in the sense that an attempt was made to achieve a reasonably good spread across the technological spectrum, including several low- and medium-tech firms with low R&D as well as highly innovative, high-tech

[10] An additional requirement was that the firms had to be substantially independent technologically and financially.

companies.[11] Selecting contrasting cases would facilitate the identification of key determinants of innovativeness. However, the sample is quite small, so the results of the analysis should only be taken as indications of patterns and trends that possibly have wider validity.

The operationalisation of the concepts depicted in Figure 1 was complex, especially in the case of the dependent variable. We use two proxies based on the results of the utilization of a firm's innovative capabilities, i.e., the innovations (new artefacts). The first measure, called Innovation Index 1 (II1), is based on a straightforward recording of the presence or absence of 'major' innovations during the three years preceding the survey. 'Major' in this context is defined as an activity to which the firms' owners/managers attached considerable importance for the firm as a whole. The variable is a simple unweighted average of the absence (0) of presence (1) of major product innovations, process innovations, and organisational innovations (ranging from a overall possible maximum score of 3 to a minimum of 0). Firms would get a score of 1 for each sub-category if they had accomplished at least one major innovation during the reference period. II1 is quite similar to innovation proxies used in other SME surveys, except that an average of three different types of innovation was used, rather than three separate indices. The reason was that the different types of innovation in some of the software companies were difficult to slot into these categories.

The second proxy, Innovation Index 2 (II2) is more complex. In addition to capturing the incidence of major innovations, it embodies an assessment of their originality and technological complexity. Moreover, it includes a rating for the importance of 'incremental' innovations. It is based on extensive qualitative information about the extent and significance of each firm's innovative outputs generated during the three years prior to the survey. This information was used to assign scores to the firm's innovations based on the degree of innovativeness embodied in them, 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 somewhat similar to the scale used by the Cambridge small business research programme, in which there is a distinction between 'new to the world', 'new to the firm's industry' and 'new to the firm only'.[12] However, the breakdown in this paper is more fine-grained and realistic. Innovations rarely fit the Cambridge categories perfectly in practice.

The second dimension was added to take account of the fact that there were 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, whereas others had developed truly science-based innovations.

---

[11] Details of the sampling procedure are in Appendix 1.
[12] See Cosh *et al.* (1996), p.3.

Using this classification, companies could receive a maximum score of 5 when they had recently developed at least one technologically highly complex technology that was fundamentally new to the world, whereas a 'clever gimmick' similar to what other firms in the industry were also working on would get a score of only 2. Each company would receive three scores for major innovations, each ranging between 0 to 5: one for products, one for processes and one for organisation of production. In addition they would receive a score for the extent, complexity and originality of the incremental innovations undertaken by them (minimum 0, maximum 3). The overall innovativeness index (II2) was then calculated for each company as the simple average of these four scores. The design of the classification table and the grading of the firms' innovations was undertaken by the interview team (consisting of an engineer and an economist), based on detailed information supplied by the respondents.

The main advantage of II2 is that it is a great deal more detailed than II1, so it is much more precise. But this inevitably comes at a cost of higher subjectivity. The best assessment is obviously done with a combination of different indicators in order to offset the risk of possible bias arising from their individual weaknesses. The results for the two capability indicators are presented side by side in the data analysis section, in order to facilitate comparison.

Table 1: Scale used for grading firms' innovations

Degree of novelty ↓		← Low *Degree of science intensity* High →	
		'Clever gimmick'	Science-intensive
I. Major innovations (products, processes and organisation)	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 identifyable ways from other companies' innovations	3	4
	d) same or very similar innovations adopted by competitors	2	3
	e) no major innovations at all	0	
II. incremental innovations	Yes	1	3
	No	0	

Three additional capability measures were also experimented with, but they did not perform well in the data analysis and are therefore omitted from this paper. They were: the number of technological licences sold by the firm; the firm's ISO 9000 (and other, such as QS 1000) accreditation status concerning quality of production and design procedures; and the number of patents and trademarks owned. The poor performance of these variables may suggest that such formalised outputs from innovation are rather poor proxies of innovation capability in small firms. Especially, many of their innovations are never patented, especially in industries with rapid technological change, such as software and IT.

The measurement of the sources of capability was relatively more straightforward. A summary with all the source variables and their measurement is in Appendix Table 2.

The education and working experience background of the entrepreneur / founder(s) was represented by measures of different academic degrees obtained (yes/no), and relevance of prior working experience in different professional environments. The latter variables were measured on a Likert scale ranging from 1 (completely irrelevant) to 10 (absolutely essential), according to the opinion of the respondent. The human capital of the workforce was measured by the numbers of technicians, scientists, engineers and designers present in the companies. The internal technological efforts were measured by variables representing R&D investment, training expenditure, the importance of R&D staff relative to total employment and number of technological licenses obtained. In addition to obtaining estimates of formal R&D and training budgets, the interviews also elicited estimates of the value of 'shopfloor'-type experimentation and informal on-the-job training, since a lot of technological effort in small companies may take this form. Thus, the training and R&D variables are more inclusive than in other SME surveys.

The frequency of networking with external agents was again measured on a Likert scale ranging from 0 to 10, according to the importance that the entrepreneurs attached to different networking relationships. A range of different networking relationships with private enterprises and private and public institutions were distinguished, namely with customers, suppliers, competitors and enterprises in related lines of business, financial institutions, training institutions, public R&D institutions (universities and public science laboratories), service providers and industry associations. The overall average score for all networking relations together was also used as a variable in the analysis, since it is a convenient summary statistic for the overall networking intensity of a firm.

The geographical proximity advantages associated with the network interactions were assessed by asking the respondents to indicate, whether or not a proximity advantage was attached to the interaction in each network link, in this case on a scale with just two categories (0, 1). The scores were amalgamated in the same way as the frequency scores discussed above. Strictly speaking the proximity scores are independent of the frequency scores, although very infrequent interactions with a particular agent are unlikely to carry major proximity benefits. One overall average proximity score was also calculated.

Finally, the importance of financial and knowledge transfers through institutional support was measured with a set of three simple proxies. First, there is an indicator ('Institutional support received') which measures whether or not firms had received (mainly non-financial) services from governmental bodies under support schemes which are intended to reduce barriers or obstacles faced in the technological development by SMEs. This support covers areas such as access to capital markets, business advisory services and help with accreditation. One of the most tangible manifestations of public SMEs policy has been the Business Link (BL) programme. A dense network of regional BL offices has been set up, intended to provide single points of easy access for SMEs in an integrated range of business support services. It is estimated that around 35 per cent of firms having between 50 and 200 employees are using BL services in any quarter, although the proportion is much lower for smaller companies (DTI, 1997, quoted in Albu, 1998). Also important are the Training and Enterprise Councils (TECs), which were established sometime before BL, with the aim to provide services for existing or potential entrepreneurs. They were mainly oriented towards training, and they have continued to function alongside BLs. In addition to the above schemes, support for garment companies is also provided by local government bodies, in the form of clothing design and training centres.

The second support proxy ('Innovation awards') intends to measure whether the firms had received innovation financing from schemes designed to promote science and technology development (SET) in the SME community operated by the UK Department of Trade and Industry schemes. There are basically three schemes: (a) Link, aimed at supporting collaborative research partnerships between UK industry and the research base, which provides 50 per cent financing for pre-competitive research and for further investments required for successful commercialisation of new technologies; (b) Small Firm Merit Awards for Research and Technology (SMART), which provides grants for small firms (max. 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. Grants are awarded in a two-stage annual competition; and (c) the Queen's Award for Innovation, which also provides funding for technologically innovative projects.

Finally, the third support proxy measures whether firms have obtained innovation / R&D-related funding from EU programmes.

5. Introduction to the sample firms

The sample contains 17 software and IT developers (SIC code 30.02), predominantly in Oxfordshire and Berkshire, two counties with thriving clusters of software and IT firms. The three software and IT areas that are especially strongly represented there are mathematical and scientific, publishing and education, and computer games. The presence of the first two categories is related to the existence of the Oxfordshire science base. London is also a major hub for publication-related software developers.

The 16 electronics companies in the sample (SIC codes 30.02, 32.10, 32.20, 33.20 and 33.30) were also concentrated in the Thames Valley and along the M4 corridor, as well as more rural parts of Oxfordshire and Berkshire. These areas are home to hundreds of electronics companies, especially high-tech ones. Thirteen of the companies were located in Oxfordshire, in order to capture any locational effects associated with the Oxford science base. In particular, several high-tech precision instrument makers in this area appeared to be promising cases for a study about SME innovative capability.

Finally, the sample also contains 17 small clothing manufacturers in the West Midlands and Nottinghamshire. The former county hosts the bulk of low-value clothing companies in the UK, whereas design-oriented firms are concentrated in the latter (and London). In order to achieve a good spread, design-oriented firms ('final producers') as well as Cut-Make-Trim (CMT) companies which function as subcontractors to large trading firms were interviewed.

The average size of the sample companies is 31 employees, with an average gross value of plant and equipment of £ 465,230, and an average age of 12.6 years (Table 2). Average net profits amount to 6.5 per cent of total sales and average exports are almost 30 per cent of total sales. The relatively low profitability is partly due to the strong sterling and the minimum wage legislation which has been introduced recently.

Table 2. Basic data about the sample companies

	Mean	St. deviation	N
Number of employees 1997	31.35	32.57	48
Gross value of plant and equipment (£)	465,230	944,210	44
Age of company (years)	12.58	9.12	50
Profit as % of sales (average 95-97)	6.55	6.75	43
Exports as % of sales (average 95-97)	22.95	31.70	44

In spite of this, the sample companies showed a strong propensity to innovate. Sixty-six per cent of the sample reported having achieved at least one major product innovation during 1995-97; 55 per cent reported at least one major process innovation, and 46 per cent reported at least one major innovation in the organisation of production. Incremental innovations had been implemented by 74 per cent of firms. According to the scores on Innovation Index 1 (II1) in Table 3, thirty-eight per cent of the sample companies had achieved major innovations of all types (product, process and organisation) as well as incremental innovations during 1995-97. Only 22 percent acknowledged not to have innovated at all.

Table 3. Innovation capability scores

II1 Scores	No. of firms	Percent	Cumulative Percent	II2 Scores	No. of firms	Percent	Cumulative Percent
0	11	22	22	0	7	14	14
0.33	9	18	40	>0-1	11	22	36
0.50	3	6	46	>1-2	15	30	66
0.66	8	16	62	>2-3	12	24	90
1	19	38	100%	>3	5	10	100%
Total	50	100%		Total	50	100%	

Innovation Index 2 (II2) reveals something more about the degree of originality and science-intensity of the innovations (Table 3). Only 5 out of 50 companies interviewed (10 per cent) achieved a score above 3; that is to say, only a few companies had achieved major innovations that could be considered unique and science-based. Most companies (30 per cent of the sample) obtained an average score between 1 and 3. Thus, although the majority of the firms displayed substantial innovative activity, most of the innovations were neither scientifically complex nor highly original.

The firms' scores on II1 and II2 were linked to the various determinant variables by means of simple Spearman Rank Correlations[13] to determine statistically significant relationships and the strength of the associations. In view of the small sample size, more advanced analysis by means of (logistic) regressions did not yield satisfactory results and is therefore not reported in the paper.[14]

6. Main findings

Internal determinants of innovation capabilities

The contribution of the internal sources of innovation capabilities will be discussed with the help of Table 4, which lists the relevant Spearman correlations. Looking at the table as a whole, it appears that several variables related to previous education and working experience of the owner/manager(s), the education of the workforce employed, as well as the resources devoted to technological improvement and internal learning show a statistically significant relationship with II1 and II2. Moreover, the relationship is in all cases stronger for II2 than for II1. In three cases, the II2-coefficients are significant while those of II1 are not. These findings suggest that II2 is indeed a more detailed and precise measure of innovativeness.

The *education background of founder/manager(s)* was examined with reference to the effect of academic degrees on technological performance. Degrees are common in the sample, with 76 per cent of firms being run by at least one owner/manager with an academic qualification. There is a prevalence of science degrees over other university degrees. As many as 30 managers/founders (60 per cent of the sample) reported to have a degree in either science or engineering whilst only 18 per cent ackowledged to have a degree in either business management or finance.

Table 4 shows that an owner/manager with an academic degree can boost a firm's innovation capability, but not in all circumstances. Whereas the presence of an owner/manager with a degree in science or engineering in a company is associated with statistically significant higher scores on both capability indices (II1 and II2), the presence of someone with a degree in management, finance or another field does not have that effect. The impact of the science or engineering degree is stronger

[13] Non-parametric statistics were used because both II1 and II2 are ordinal variables.

[14] Thus, the data analysis yields basic insights into the question which learning-related factors are most strongly linked to high innovative performance, but it cannot shed light on the relative contributions made by these factors, nor on the question how much of the total observed variation in the firms' innovative performance (as measured by II1 and II2) can be explained by the various determinant variables together.

with respect to II2 (significant at 1 per cent level) than to II1 (significant at 5 per cent level), suggesting that this type of educational background not merely boosts the number of innovations achieved by companies, but also their originality and technological sophistication.

Table 4. Internal determinants of capability: Spearman correlation coefficients

(p-values in parentheses)

Internal Sources of Innovation		II1	II2
Background of founder/ manager	Degree in business management/finance	.176 (.221)	.228 (.111)
	Degree in science or engineering	**.322*** (.023)	**.457**** (.001)
	Degree in other field	.072 (.621)	-.031 (.832)
	Prior work experience in SME (incl. family firm)	-.062 (.670)	**-.300*** (.034)
	Prior work experience in multinational or large domestic firm	**.284*** (.046)	**.350*** (.013)
	Prior work experience in public R&D institutions	.191 (.184)	**.353*** (.012)
Skills of workforce	No. of univ.-trained engineers and designers (fte) as % of total workforce	**.499**** (.000)	**.611**** (.000)
	No. of technicians (fte) as % of total workforce	.106 (.462)	.278 (.051)
Technological effort	Total R&D expenditure per employee	**.339**** (.006)	**.591**** (.000)
	Total R&D expenditure as % of sales	**.366*** (.014)	**.527**** (.000)
	No. of R&D employees (fte) as % of total workforce	**383**** (.007)	**.548**** (.000)
	Total training expenditure per employee	.276 (.063)	**.364*** (.013)
	Total training expenditure as % of sales	.163 (.289)	.224 (.144)
	No. of technology licenses bought	**.357*** (.011)	**.390**** (.005)

** Significance at the .01 level (2-tailed)
* Significance at the .05 level (2-tailed)

Previous work experience obtained by founder/manager(s) can also have a significant impact on companies' innovative capabilities (Table 4). However, just like in the case of academic degrees, the usefulness of the work experience obviously varies, depending on the extent to which it had presented opportunities for technological learning, and on the relevance of the acquired skills and knowledge for the current job. For instance, previous employment in a small or medium-sized company (including family business) did not seem to have provided the skills, training, and knowledge needed to run an innovative business. In fact, the higher the importance attached by the respondents to this type of experience, the *lower* their score on Innovation Index 2, as shown by a negatively significant coefficient in Table 4. This suggests that owner/manager(s) whose prior work experience was predominantly in the small and medium-sized enterprise sector had come up with relatively simpler, less radical innovations than the firms run by entrepreneurs with previous experience in other sectors of the economy.

The experience required to achieve truly original and complex innovations seems to be built up in multinational and large domestic companies and the public science base. Experience in the corporate sector promotes higher innovativeness in terms of high numbers of innovations (II1) as well as technological excellence and high originality of those innovations (II2). There were several electronics and software firms in the sample that had been established by experienced former technical staff of large firms, who had come up with a promising idea which their employers were not interested in commercialising because it did not constitute a core activity for the business. Help from former employers in the initial years had often proved crucial for the success of these new ventures, especially in the form of access to an established customer network, or direct demand for the new product by the former employer itself.

Although work experience in research laboratories and universities is not associated with a greater number of major innovations as such, the statistical significance of the II2-coefficient indicates that the innovations that do take place score highly in terms of technological complexity and originality. This pattern is typical for the science-based companies in the sample that had spun off from a university or public sector laboratory (mainly laboratories of the Atomic Energy Authority). The owners 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 available. 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, either in the form of collaborative research and use of public lab facilities or (part-time) employment of one of the business partners. In this way, the public science base has contributed significantly to the subsequent success of such new ventures. It is hard to underestmate this role, because commercialisation of truly complex, science-based innovations involves long lead times and success cannot be guaranteed. Current government policy concentrates on stimulating private venture capitalists and business angels to finance such start-ups rather than providing public seed money. However, in view of the long pay-back periods and high risks involved, securing adequate private funds may not be feasibly in all circumstances. Several respondents also indicated that they preferred to avoid such financing because they did not want to loose their independence in strategic decision-making.

There is also evidence from the sample that *education of a firm's workforce* can contribute to its innovative capabilities, particularly university-trained engineers and/or designers who constitute as much as 29.0 per cent of the firms' total workforce on average. The share of university-trained engineers or designers in total employment is highly correlated (at 1 per cent significance level) to companies' innovation capabilities for both indices (Table 4). It is evident that the more companies invest in a workforce with high technical qualifications, the more companies are likely to achieve a greater number of innovations with a high degree of originality and technological complexity. On the other hand, the proportion of technicians in the firms' workforce does not seem to be relevant for innovation capability. With an average proportion of 7.3 per cent technicians in the total workforce, technicians do not appear to play as big a role as engineers and designers in any case. Software development simply does not require technicians. The majority of the electronics firms, too, did not employ them in large numbers. Several of these firms concentrated on the design of prototypes, while subcontracting the actual manufacturing operations to others. In the garment companies some technicians were employed, but they were often engaged in non-innovation-related tasks. Although the findings about workforce education may be affected by the sectoral composition of the sample, it is also plausible that they point up the increasing importance of knowledge-based (rather than skill-based) work for high technological performance in small enterprises in the UK more generally.

In addition to education and working experience that are brought into a firm by its managers and workforce, a company's innovation capabilities would depend on the extent to which *internal technological efforts* are devoted to pursue innovation and ongoing learning in the firm itself. Expenditure on R&D efforts and the number of technological licenses acquired are indeed strongly correlated with innovative performance in the sample (Table 4). Total R&D expenditure per employee and as a percentage of sales, as well as R&D employment as a percentage of the total workforce are all strongly positively correlated with both innovation indices. In addition, the number of licenses bought correlates positively and significantly with both indices. The fact that the II2-coefficients are higher than the II1 ones suggests that R&D efforts and licences not only boost companies' innovativeness in a quantitive sense but that they also promote the achievement of qualitatively more significant innovations. The sample companies spent an average of 8.1 per cent of sales on formal R&D and 'informal technological effort' during 1995-7, which is quite substantial considering the limited resources that can usually be devoted to such activities in small businesses.

Resources devoted to formal and informal on-the-job training together amounted to 1.6 per cent of total sales in the sample on average. This is more modest than R&D expenditure, and the effects of training on innovation capabilities does not seem to be as strong as that of R&D either. The correlation coefficient between training expenditure (per employee and as percentage of sales) and the number of major inovations (II1) is not statistically significant. However, higher training expenditure per employee appears to be associated with higher technological complexity and originality of the innovations achieved (II2) at the 5 per cent significance level. Some of the training may be aimed at improving enterprise efficiency in general, as would be the case for secretarial courses, for example. In contrast, investment in R&D and acquisition of licenses would be directly aimed at boosting a company's technological performance.

External determinants of innovation capabilities

Inputs supplied by various external private and public agents complement the internal sources of capability discussed above. The scores on the questions about *frequency of interaction with external agents* (Table 5, left column) show that high interaction frequencies were recorded for only a few external agents: customers (average score 8.3), suppliers (6.3), followed at some distance by service providers (4.2). In other words, backward and forward interactions in the value chain and to a lesser extent with suppliers of services constitute the most common external interaction practices in the sample companies.

These same types of relationships appear to carry some *proximity advantages* (Table 5, right column). Thirty percent of the sample firms reported that they benefited from geographical proximity of customers, 40 per cent from closeness of suppliers, and 54 per cent from propinquity of service providers. The proximity scores with respect to the other types of agents mentioned in Table 5 are quite low.

Table 5. External interaction: frequency and proximity advantage

	Frequency of networking (avg. score)	% of firms indicating proximity advantage related to networking
With customers	8.3	30
With suppliers	6.3	40
With competitors	2.9	12
With financial institutions	2.2	16
With training institutions	2.2	22
With public R&D institutions	2.0	15
With service providers	4.2	54
With industry associations	3.5	24

However, strong networking with clients, suppliers and service providers does *not* go together with high scores on either of the two innovation capability indices (Table 6). Neither is there a statistically significant relationship between firms' benefits from proximity of these agents and their innovation capability scores (Table 6). This seems to suggest that much of the interactions with clients, suppliers and service providers are not innovation-related. As far as customer links are concerned, a substantial number of respondents indeed affirmed that the main benefits of the relationships with their clients are increased sales and enhanced reputation through word of mouth. A lot of the interaction with customers is focused on the maintenance of quality standards and the formulation of product specifications, while only a minority benefit from actual technical support, technical performance feedback and inter-firm collaboration on product design and development. The same holds for contacts with suppliers. Intensive and close networking with service providers is not linked with high innovation capabilities either, for similar reasons. Agents providing private services include printers, equipment maintenance companies, cleaners, management and tax consultants, and so on, which would not be expected to have a major direct effect on firms' technological learning processes. The same appears to be true for public services. Interviews with staff from key small business support agencies such as Business Link and local municipal bodies appear to confirm that a lot of the interaction with companies is aimed more broadly at improving managerial business practices, providing information, and setting up quality systems (especially ISO 9000). Business Link does provide technology management-related counselling services, but only a few companies in the sample had made use of this facility.

Quite different patterns emerge for networking with training and R&D institutions. In contrast to links with suppliers, customers and service providers, the average frequency of interaction with these agents is reported to be quite low (Table 5). This is caused by the fact that there is only a minority of sample firms that interact regularly with these types of organisations. However, those few companies did achieve a greater number of major innovations (II1), and also a higher degree of originality and technological sophistication in their innovations (II2) than the others, other things being equal (Table 6). Moreover, geographical proximity to these institutions is apparently important, as shown by statistically significant coefficients in Table 6. However, causality may not strictly be unidirectional. It would also be plausible that firms with strong innovative capabilities would be more likely to form links with such institutions because they constitute attractive collaboration partners.

Frequency of networking with, and geographical proximity of, companies in similar lines of business (including competitors), industry associations and financial institutions does not appear to be significant in any way. The average frequency and proximity scores are quite low (Table 5), and the interactions that do occur are unrelated to innovative performance (Table 6).

Summing up, there is some support for the contention that the *overall* intensity of external interaction appears to matter for innovative performance. There is also some evidence of a positive *overall* link between geographical proximity of the external agents and innovative performance. The two relevant II2-coefficients are significant at the 5 per cent level in Table 6 (although the II1-coefficients are not significant). However, the results of the more disaggregated analysis reported above suggests, that these effects are primarily caused by interaction with R&D and training institutions alone. Interactions with, and proximity to, other types of actors do not appear to be associated with high innovative performance at all. These findings, therefore, do not lend support to the current thrust of UK government policy, which seeks to boost SME technological performance by means of intensive interactions among clustered small firms in similar lines of business. Although it is conceivable that such close interactions would give rise to more 'conventional' beneficial economic effects through the generation of economies of scale, scope and agglomeration in a region, such static collective efficiency 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, which is what the government would like to see.

On the face of it, there appears to be more support for the validity of UK government's emphasis on the promotion of science parks on which small firms can interact more easily with academic institutions. However, the linkages with, and closeness to, the public science base among the sample firms were mainly historical, resulting from their having started as spin-offs from these institutions. There were only a few instances in which onging firms had forced new linkages with scientific institutions. A policy of merely (re)locating small firms on science parks close to universities may not automatically lead to the establishment of extensive linkages with the science base.

Table 6: External interaction and innovation capability: Spearman correlation coefficients

(p-values in parentheses)

		II1	II2
Frequency of interaction	with customers	.039 (.790)	.103 (.478)
	with suppliers	-.143 (.706)	-.055 (.706)
	with competitors	.043 (.768)	.082 (.569)
	with financial institutions	-.037 (.799)	.042 (.772)
	with training institutions	.278 (.050)	**.424****(.002)
	with public R&D institutions	**.408****(.003)	**.606****(.000)
	with service providers	.095 (.513)	.104 (.473)
	with industry associations	.063 (.664)	.068 (.640)
	with all external agents (overall score)	.142 (.326)	**.285*** (.045)
Proximity advantage related to interaction	with customers	.175 (.223)	.170 (.237)
	with suppliers	.151 (.295)	.201 (.162)
	with competitors	-.023 (.875)	-.188 (.190)
	with financial institutions	.107 (.461)	.176 (.222)
	with training institutions	**.319*** (.024)	**.413****(.001)
	with public R&D institutions	**.407****(.003)	**.468****(.001)
	with service providers	.226 (.115)	.255 (.073)
	with industry associations	-.013 (.926)	-.096 (.507)
	with all external agents (overall score)	.257 (.072)	**.296*** (.037)

** Significance at the .01 level (2-tailed)
* Significance at the .05 level (2-tailed)

Finally, details about the *nature and the extent of institutional support* are given in Table 7. Forty per cent of the sample companies reported to have received assistance from UK small business support organisations either now or sometime in the past. Some of this support had been innovation-related (in the form of counselling by Business Link Technology Counsellors, support with product design work by local Clothing Centres, etc.) but more often it involved some financial support or advice for introducing ISO 9000, or provision of information about potential export markets, new business partners overseas, machinery suppliers and so on. In addition, 12 per cent of the sample companies had obtained financial support in the form of innovation awards from the UK Department of Trade and Industry, and 10 per cent had obtained EU innovation grants, mainly from the ESPRIT, BRITE and COPERNICUS programmes.

Table 7: Institutional support

	No. of firms	% of total sample
Support received from public UK institutions	20	40
UK innovation awards obtained	6	12
EU innovation grants obtained	5	10

The assistance from the UK small business agencies was not found to be related to the level of innovation capability of the sample companies (Table 8). This is not so surprising in view of the fact that, as noted earlier, much of the support by Business Link and local sector-specific agencies does not aim specifically at boosting firms' innovation performance as such, but rather at improving their economic performance more broadly. In contrast, the UK and EU grant schemes, which are specifically meant to finance R&D, are highly correlated to the II2 scores in Table 8. Participation in an EU R&D scheme is significantly correlated with II1 as well (although less strongly). Tentatively, this suggests that that the innovation financing schemes had been effective in raising the innovative performance of the sample firms. Indeed, the respondents of the firms that had received such grants did confirm that the money had been useful for financing pre-competitive R&D which the firms would not have been able to undertake otherwise.However, the causality of the relationship is likely to run in two directions. It emerged from the interviews that firms 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 definintely more successful in tapping into these sources of funds. This was especially the case for EU grant schemes, less so for the schemes run by the UK Department of Trade and Industry (because their application procedures are less complex). However, the causality problem manifests itself with respect to the DTI grants too: firms could qualify for them only when they had proven innovation potential.

Table 8: Institutional support and innovation capability: Spearman correlation coefficients

(p-values in parentheses)

	II1	**II2**
Whether institutional support received	.172 (.232)	.206 (.152)
Whether UK innovation awards obtained	.197 (.169)	**.383****(.006)
Whether EU innovation grants obtained	**.307***(.030)	**.401****(.004)

7. Conclusions

It is increasingly recognized that small and medium-sized enterprises with strong innovation capabilities can make a valuable contribution to a country's competitiveness. Strengthening these capabilities involves a costly and time-consuming learning process. In view of the serious resource constraints typically faced by SMEs, a range of bottlenecks may prevent them from realising their full potential. A good understanding of the nature of the learning process and of the factors that contribute most crucially to its success is needed, so that public support can be targeted effectively towards the alleviation of the most pressing constraints. The analysis in this paper contributes to this, by means of an empirical assessment of the factors that have contributed to the accumulation of innovative capability among a group of small and medium-sized firms in the UK. In view of the small sample, the results of the analysis cannot be considered to be representative for UK SMEs at large, but they do point in certain directions which could be indicative of broader patterns and trends. The main conclusions are as follows:

A range of factors internal as well as external to the firms were found to be statistically significantly related to the two innovativeness variables measuring the level of the firms' innovative capabilities. Among the internal factors, the importance of an academic education in science or engineering and relevant working experience by the founder/manager(s) in large firms or scientific institutions stands out. A prevalence of staff with science- or engineering degrees or higher education in design in the enterprise was also found to have a positive effect. Firstly, 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 SME. Secondly, it suggests that large corporations and the national science base might be the main breeding grounds for the type of entrepreneurs capable of running and developing the type of knowledge-based, innovation-driven firms that the UK government seeks to bolster. While it may be true, as often suggested in the small business literature, that the small enterprise sector itself is an important source of entrepreneurial talent by exposing prospective self-employed people to the art of running a small business through practical experience in this kind of environment, this type of background is evidently insufficient for acquiring the skills, knowledge, experience and contacts needed to establish a successful technology-based venture. Several businesses in the sample would not have succeeded without initial support and encouragement from the institute or corporation from which they had spun off. Access to established markets or laboratory facilities, or subsidising of staff costs through continued (part-time) employment of one of the business partners in the first years were found to be 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.

Aside from education and experience, which are acquired elsewhere and brought into a firm by its staff, a firm's technological capabilities accumulate further in the course of time as a result of efforts devoted to technological improvement and associated 'on-the-job' learning. The importance of these efforts in the sample companies is evident from the statistical significance of variables measuring investment in R&D, purchases of technological licenses and investment in training (especially the first two). Further evidence of the importance of R&D expenditure is provided by the significant correlations between the innovation capability variables and the use of financial support schemes of the UK Department of Trade and Industry and the European Union. Although a certain degree of reverse causality cannot be ruled out, personal statements by the respondents make it clear that adequate and secure financial resources for R&D during several years is crucial for sustained innovation and learning and, ultimately, for achievement of technological excellence in a specialised 'niche' market that can lead to international competitiveness in leading markets in the USA, continental Europe and Japan. Very few small companies in the sample were able to earmark sufficient internal funds for this purpose on an ongoing basis, especially during the first 5-6 years after their establishment.

No clear evidence of effectiveness of other types of public support was found, at least as far as impact on innovation capability is concerned. The small size of the sample prevented a thorough assessment of the technology counselling services provided by Business Link. Aside from this limitation, it is clear that most of the support provided by Business Link, TECs and local municipal bodies seems to have had a much broader focus than innovation. Much of the support had been geared towards meeting managerial or general operational bottlenecks that constrain a company's daily operations or future growth. In contrast, the innovation grant schemes of the UK government and the EU were specifically meant for funding promising R&D proposals.

A lot of the external inputs that firms need for internal learning and innovation does not come in the form of public assistance, but rather through interaction with various agents in the form of information, physical inputs, services and new skills. The impact of these types of interactions was assessed by means of frequency of interactions with these agents, and any geographical proximity advantages associated with the interactions. It emerged that interaction frequency had a significant link with innovative performance only in the case of two specific agents, namely training organisations and public R&D institutions. Moreover, proximity appeared to enhance the effectiveness of interaction in the case of these same institutions. While linkages with customers, suppliers and service providers are actually more common among the sample firm than those with the national science base and training agencies, they do not seem to have contributed much to the innovation capabilities of the sample companies. Neither was there any evidence to suggest that geographical proximity associated with these network links contributed to higher innovativeness.

Thus, there was no evidence from this research to support the idea that the intensity with which firms network with other business parties in, and related to, their own supply chain, and with firms engaged in similar activities, would promote regional technological dynamism. Only a few specific types of network links, unrelated to the firms' immediate business environment, appear to contribute significantly to their innovative capability. These are the links that provide the most direct inputs relevant to the firms' innovation and learning processes. Training instititions are useful for skill inputs, and public R&D bodies provide access to knowledge, information, laboratory facilities, and so on. Proximity appears to matter as well in the transfer of these inputs.

These findings raise some important policy issues. Given that current UK support aims at creating an economic environment that will promote technological excellence among SME, so that they can succeed in the so-called knowledge-driven economy, the findings from this research suggest that there are some things that can be done better than they are being done at present. However, more research involving larger numbers of SME would be required before definite recommendations can be given. The suggestions given here are based on a small pilot survey and therefore there are obviously tentative. However, they do suggest certain broad directions in which improvements in the support infrastructure could concentrate:

- In spite of the government's preference for 'market-led', indirect support, public financial assistance for R&D remains vital, especially to facilitate new start-ups and and to boost pre-competitive research in recently established SME. It is unlikely that private financial agents — mainly venture capitalists and business angels — will be able and willing to meet the financial needs of new technology-based small firms fully. '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 financing for R&D during several years prior to commercialisation is required for such companies to be ultimately successful. Yet, 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-based economy by achieving competitiveness in leading markets abroad. Thus, schemes such as SMART and the Queen's Award meet a need and should be enlarged, if possible. In addition, there is a need for schemes that can meet needs for longer-term R&D financing, and there should be more financing possibilities for new companies which submit a good idea, but which do not yet have a track record of successful innovation.
- Since network links with training institutions and the research establishment appear to be the main carriers of inputs relevant to learning and innovation, it would make sense to concentrate support more on the fostering of these particular linkages, rather than on the establishment of clusters of like-minded firms in particular areas. Settling SME in science parks close to universities may not be the most effective way of achieving communication with the national research base, however. Better ways could be, to put more emphasis on co-funding of collaborative R&D projects involving SME and universities or research laboratories (as already done in the LINK programme). The assistance already provided by some Business Link officers to help SME to form consortia and write research proposals, with which they can bid for EU funding, would seem to go in the right direction. Anther way to promote linkages with the science base is to encourage establishment of spin-offs by experienced engineers and scientists working in research institutes and universities. These institutions should be encouraged to evolve support mechanisms and draw up legal procedures (especially in respect of property rights issues) for that purpose, in collaboration with Business Link. More public finance for start-ups, already detailed above, will also help, especially in view of the fact that the opportunities for scientific instiututions to permit scientists to conduct research that is not strictly related to their core mandate has been decreasing steadily since the early 1980s. Finally, selected training subsidies and subsidised internships by students in local SME could help foster linkages with training institutions and attune the institutions better to the skill needs in the private sector, especially in areas where skill shortages are severe (especially software engineering).

Many issues raised here need further research. First, it would be useful to probe the validity of the outcomes from this research with a larger sample of SME, drawn from larger number of sectors. In addition, it would also be fruitful to explore some issues in more depth. In particular, further research about how interaction with external agents contributes to enhanced innovative capacity in SME could usefully dig more deeply into the reasons for the patterns observed in this study, exploring in more detail the nature and content of the exchanges that appear to promote innovativeness, and the precise reasons why geographical proximity confers an advantage in those interactions.

Further work is als necessary to improve the measurement of innovation capability in SMEs. The new measure introduced in this paper is only a first step in that direction. This measure, Innovation Index 2, takes into consideration not just whether companies have achieved major innovations, but also the degree of originality and science-intensity of such innovations, as well as the occurrence of significant incremental innovations. The empirical analysis showed that Innovation index 2 produces consistently better results than the more 'conventional' Innovation Index 1 which is based on the prevalence of major innovations alone. It would therefore appear that it is useful to aim for a more precise measurement of firm-level innovativeness by incorporating information related to the degree of originality and the technological sophistication of innovations. However, there is room for further improvement and refinement. Especially, subjectivity needs to be reduced through further development of the measurement methodology.

References

Adler, P.S. and K.B. Clark (1991) 'Behind the Learning Curve: A Sketch of the Learning Process', *Management Science*, 37, pp. 267-281.

Albu, M. (1998) 'Public Policy toward Small and Medium-sized Manufacturing Enterprises, in the UK and EU', Background paper for the EU-TSER project "SMEs in Europen and East Asia: Competition, Collaboration and Lessons Policy Support", Queen Elizabeth House, Oxford, Mimeo.

Alchian, A. and H. Demsetz (1972) 'Production, Information Costs, and Economic Organization', *American Economic Review*, 62 (5), pp. 777-795.

Ashheim, B.T. (1996) 'Industrial Districts as Learning Regions: A Condition for Prosperity', *European Planning Studies,* 4, pp. 379-400.

Bannock, G and A. Peacock (1989) *Governments and Small Business.* London: Paul Chapman.

Beavis, S. (1998) 'When Proximity Powers Profits', *Financial Times* 18 Nov., p.19.

Bell, R.M. (1984) '"Learning" and the Accumulation of Industrial Technological Capability in Developing Countries', in: M. Fransman and K. King (eds) *Technological Capability in the Third World*. Basingstoke: Macmillan, pp. 187-209.

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

Cohen, W.M. and D.A. Levinthal (1989) 'Innovation and Learning: The Two Faces of R&D', *The Economic Journal*, 99, Sept, pp. 569-596.

Cooke P., M. Gomez Uranga and G. Etxebarria (1997), 'Regional Innovation Systems: Institutional and Organisations Dimensions', *Research Policy,* 26, 475-491.

Cosh, A., A. Hughes and E. Wood (1996) 'Innovation in UK SMEs: Causes and the Consequences for Firm Failure and Acquisition', ESRC Centre for Business Research, Working Paper 48, University of Cambridge.

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

Dicken, P., M. Forsgren and A. Malmberg (1994) 'The Local Embeddedness of Transnational Corporations', in: A. Amin and N. Thrift (Eds) *Globalization, Institutions and Regional Development in Europe*. Oxford: Oxford University Press, pp. 23-45.

Dosi, G., C. Freeman, R. Nelson, G. Silverberg, and L. Soete (eds) (1988) *Technical Change and Economic Theory.* London: Frances Pinter.

DTI (1997) DTI (1997c) *Competitiveness UK: A Benchmark for Business,* Dept. of Trade & Industry, UK Government, November 1997. http://www.dti.gov.uk/comp/bench.htm

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

Garvin, D.A. (1993) 'Building a Learning Organization', *Harvard Business Review* , July-August, pp. 78-91.

Håkansson, H. (1993) 'Networks as a Mechanism to Develop Resources', in: P. Beije, J. Groenewegen and O. Nuys (eds) *Networking in Dutch Industries*. Leuven: Garant, pp. 207-223.

Hoffman, K, M. Parejo, J. Bessant and L. Perren (1998) 'Small Firms, R&D, Technology and Innovation in the UK: A Literature Review', *Technovation*, 18 (1), pp. 39-55.

Huggins, R. (1998) 'Local Business Co-operation and Training and Enterprise Councils: The Development of Inter-firm Networks', *Regional Studies*, 32 (9), pp.813-826.

Hyvärinen, L. (1990) 'Innovativeness and Its Indicators in Small- and Medium-sized Industrial Enterprises', *International Small Business Journal*, 9 (1), pp. 64-79.

Lundvall, B.-Å (1988) 'Innovation as an Interactive Process: From User-producer Interaction to the National System of Innovation', in G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete (Eds) *Technical Change and Economic Theory*. London: Pinter Publishers, pp. 349-369.

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

Malerba, F. (1992) 'Learning by Firms and Incremental Technical Change', *The Economic Journal*, 102, July, pp. 845-859.

Nelson, R.R. and S.G.Winter (1982) *An Evolutionary Theory of Economic Change*. Cambridge, MA.: The Belknap Press of Harvard University Press.

Oakey, R.P. and 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), pp. 48-64.

Oerlemans, L.A.G., M.T.H. Meeus and F.W.M. Boekema (1998) 'Learning, Innovation and Proximity', Eindhoven Centre for Innovation Studies Working Paper 98/3, Faculty of Technology Management, Eindhoven University of Technology, Eindhoven.

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

Romijn, H. (1999) *Acquisition of Technological Capability in Small Firms in Developing Countries.* London: Macmillan.

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

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

Schmitz (1994) 'Collective Efficiency: Growth Path for Small-scale Industry', *Journal of Development Studies*, 31 (4).

Scott, A. and Storper, M. (1992) 'Regional Development Reconsidered', in: H. Ernste and V. Meier (Eds) *Regional Development and Contemporary Industrial Response: Extending Flexible Specialization.* London: Belhaven Press, pp. 3-26.

Simmie, J. (1997) 'The Origins and Characteristics of Innovation in Highly Innovative Areas. The Case of Hertfordshire' , in: J. Simmie (Ed) *Innovation, Networks and Learning Regions?* Jessica Kingsley Publishers, London.

Solo,R. (1966) 'The Capacity to Assimilate an Advanced Technology', *American Economic Review Papers and Proceedings*, 56 (2), pp. 91-97.

Sternberg (1999) 'Innovative Linkages and Proximity: Empirical Results from Recent Surveys of Small and Medium Sized Firms in German Regions', *Regional Studies*, 33 (6), pp. 529-540.

Stewart and Ghani (1991) 'How Significant Are Externalities for Development?', *World Development*, 19 (6).

Storey, D. J. (1994) *Understanding the Small Business Sector*. London: International Thomson Business Press.

Storper, M. and 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, pp. 407-422.

Suarez-Villa, L. and Walrod, W. (1997) 'Operational Strategy, R&D and Intra-metropolitan Clustering in a Polycentric Structure: The Advanced Electronics Industries of the Los Angeles Basis', *Urban Studies*, 34 (9), pp. 1343-1380.

Vedovello, C. (1997) 'Science Parks and University-Industry Interaction: Geographical Proximity Between the Agents as a Driving Force', *Technovation* 17 (9), pp. 491-502.

APPENDIX 1: Sampling methodology

a) Software development

The survey area included the Thames Valley and M4 corridor, as well as more rural parts of the Oxfordshire and Berkshire counties. Since better information was obtained about firms in Oxfordshire than surrounding counties, most interviews were secured in this area. The British standard industrial classification (1992 SIC) was used as a starting point to delineate the population. For software, however, its usefulness was limited since at 4-digit level it does not recognise any distinction between software package developers (our target) and software service consultants and distibutors. SIC Code 72.20 includes every kind of company from the one-person consultant who installs Windows on domestic users' PCs, to the software houses developing cutting-edge mathematical algorithms for the financial sector. Company selection was therefore somewhat arbitrary, based on the brief and sometimes absent descriptions offered in the following databases: FAME Database, Oxfordshire County Council Company Information Database, YELL (Electronic Yellow Pages) and Software and IT Forum list. A total of 220 companies were contacted by mail and/or by telephone, of which 32 agreed to a personal interview (14%). However, since several of those did not meet our criteria, only 17 firms (8%) were interviewed. Geographical breakdown: Oxfordshire – 9 companies; Berkshire – 7 companies; Other areas – 2 companies.

b) Electronics

The same geographical area was chosen as for the software developing companies. The 4-digit British standard industrial classification (1992 SIC) codes were used as as a primary filter in selecting firms. The following groups were chosen: 30.02 (Manufacturers of computers and processing equipment; 32.10 (Manufacturers of electronic valves, tubes and other electronic components); 32.20 (Manufacturers of television & radio transmitters and apparatus for line telephony and line telegraphy); 33.20 (Manufacturers of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment); and 33.30 (Manufacturers of industrial process control equipment). There are some limitations to the use of SIC codes. The categories are evidently outdated and therefore ambiguous. Also, some activities in these categories do not involve electronics at all: 33.20 and 33.30 both include sub-categories for electronic (e.g. 33.20/1) and non-electronic equipment (e.g. 33.20/2). Two data bases were used: the FAME Database and the Oxfordshire County Council Company Information Database. Altogether 120 firms were contacted by mail, and 25 (21%) responded by completing factsheet. Since a few did not meet our criteria, ultimately 17 companies were interviewed. In practice, the better information we obtained about firms in Oxfordshire particularly enabled us to secure most firm interviews in this county. The breakdown is: Oxfordshire – 13 companies; Berkshire – 3 companies. The sample includes three firms making computers and processing equipment; four manufacturers of electronic components; eight anufacturers of instruments and appliances and one manufacturer of industrial process control equipment.

c) Clothing

The West Midlands and Nottinghamshire were selected as interview areas since they are the main counties hosting Cut-Make-Trim (CMT) businesses and design-oriented companies, respectively. Local Clothing Centres and Manufacturers' Associations in these areas were approached for data about members. We managed to get a list with the main SMEs operating in the Midlands. The electronic yellow pages furnished additional addresses of clothing companies. Altogether 319 garment firms were contacted by mail and/ or phone, ultimately resulting in 17 interviews (5.3 per cent).
The geographical breakdown is: West Midlands Coventry and Birmingham – 11 companies, and Nottinghamshire – 6 companies.

APPENDIX 2: List of Variables Measuring Sources of Innovation Capability

Concept	Variable(s)	Measurement
Background of founder/manager(s)	Degree in: • Science or engineering • Management or finance-related field • Other field	3 dummies (yes/no). (Value is 1 if at least one owner/manager in a firm has the relevant degree.)
	Prior working experience in: • Other SME (incl. family business) • Large domestic corporation or multinational firm • University or science laboratory	3 scales from 1 (irrelevant) to 10 (absolutely essential). (If there is more than one owner/manager per firm with experience in a particular field, the highest score among them is used.)
Skills of workforce	• Nr. of technicians • Nr. of engineers, scientists or university-trained designers	Proportions of total workforce.
Technological effort	• R&D investment (3 vars) • Training expenditure (2 vars) • Acquired licenses	% of R&D expenditure of sales; R&D exp. per employee; prop. of R&D employees in total workforce; % of training exp. of sales; training exp. per employee; no. of technological licenses bought.
Interaction with other agents	Frequency of interaction with: • customers • suppliers • competitors • financial institutions • training institutions • R&D institutions • service providers • industry associations • all agents (average)	8 scales from 1 (irrelevant) to 10 (absolutely essential). The score for all agents is an unweighted average of the individual scores.
Proximity advantage related to interaction with other agents	Proximity advantage related to interaction with: • customers • suppliers • competitors • financial institutions • training institutions • R&D institutions • service providers • industry associations • all agents (average)	8 dummies (yes = 1; no = 0). The score for all agents is an unweighted average of the individual scores.
Institutional support	• Support received from UK institutions (at present or in the past) • UK innovation awards obtained (idem) • EU innovation grants obtained (idem)	3 dummies (yes = 1; no = 0)