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LINKS BETWEEN HIGHER EDUCATION INSTITUTIONS AND HIGH TECHNOLOGY FIRMS

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ABSTRACT

Universities and other higher education institutions (HEIs) are an important resource network for high technology firms. In order to develop stronger links with industry HEIs have established Science Parks. To ascertain the 'added-value' of a Science Park location in the United Kingdom the formal and informal links developed with local HEIs by independent Science Park firms are compared with the links made by a comparable group of independent high technology firms not located on a Park. Analysis of the combined sample of on and off-Park firms revealed having a link with a local HEI in 1986 encouraged organisation survival over the 1986 to 1992 period. However, on the downside, empirical evidence collected in 1992/93 from firms in a follow-on sample (originally interviewed in 1986) as well as a 'new sample' study (independent firms that had located on a Science Park between 1986 and 1992) both revealed that the vast majority of links developed with local HEIs are generally informal ones. The policy implications of the research findings are discussed.

Keywords: high technology firms; higher education institutions; links; Science Parks; policy implications
INTRODUCTION

High technology firms are a source of structural change altering the mix of products, industries and jobs in an economy (Malecki, 1991, p.26). Their prime contribution, however, is as a source of innovation which:

"...depends on people, their accumulated knowledge and capabilities gained through experience, and the information and contact networks on which they draw...." (Malecki, 1991, p.158).

Universities and other higher education institutions (HEIs) are an important source of new scientific knowledge. Industry can gain access to this knowledge or resource by developing formal and/or informal links with HEIs (OECD, 1981, 1993).

"Although some may question the historical importance of universities in transferring technology to the commercial sector, few can question that universities are increasing their technology transfer activities....Universities see linkages to industry as providing financial and practical support for their larger knowledge creation, dissemination, and retention missions" (Bird et al., 1993, p.60).

The development of HEI-industry links is, therefore, assumed to encourage innovation and production. Hence locales with highly inter-linked HEI and industry are expected to have enhanced levels of wealth creation and job generation (Malecki, 1991, p.117). As a result, the commercialisation of academic research (in the form of Science Parks or incubator centres, HEI companies, independent spin-off enterprises, licensing agreements and collaboration and joint ventures) has been identified:

"...as a panacea for reversing industrial decline and promoting innovation in many Western countries" (Lowe, 1993, p.27).

This paper reviews the evidence for these statements. It begins with a review of the existing research surrounding the relationship between HEIs and high technology firms. It then derives hypotheses for this research which are formally tested later in the paper. The data upon which the analysis is conducted is described. Results are then presented. The final section speculates upon some of the policy implications of the findings.

LINKS BETWEEN HEIs AND HIGH TECHNOLOGY FIRMS

Industry Links with a Local HEI

Porter (1991, p.115) has asserted that,
"The local environment creates potential for competitive success, but firms must sense and respond to it"

In addition, Lorenzoni and Ornati (1988) have suggested that firms located in 'constellations' (or in new industrial spaces such as a Science Park) are more willing to seek information from outside sources such as HEIs, consultants and community entrepreneurs than other types of firms. Further, they assert that a supportive environment with a leading central organisation (for example, a HEI / Science Park) is crucial not only new firm formation but also organisational survival and development.

Segal Quince & Partners (1985) found the University of Cambridge had indirectly been the ultimate origin of all 261 high technology firms in the Cambridge area. A later study in Cambridge found 46% of local high technology firms claimed to have informal as well formal R & D links with the university (Keeble, 1989, p.162). Similarly, Bishop (1988, p.161) in a study of 79 high technology establishments in the three Travel-to-Work-Areas of Bristol, Plymouth and Exeter in south-west England found 39 establishments (49%) had some links with an academic institution. Firms with over 100 workers were significantly more likely to have a link with an academic institution than firms with less than 50 employees (a similar relationship has been identified by Lawton-Smith (1990, p.130) in Oxfordshire). With regard to the types of link:

"...32 of the 39 firms with linkages had industrial research linkages, whilst only just over half had linkages in management training" (Bishop, 1988, p.161).

Rothwell and Beesley (1988, p.26) also explored the types of inter firm linkages recorded by 102 innovative manufacturing firms in the United Kingdom. They found that sponsorship and placement of students in HEIs provided useful means of gaining access to state of the art research and knowledge. For example, 31% of surveyed firms had sponsored students at educational establishments and a further 39% of firms had provided placements for sandwich students. Moreover, they concluded,

"In general, external expertise acts as a complement to, rather than as a substitute for, internal expertise" (Rothwell and Beesley, 1988, p.29).

However, a lower incidence of academic-industry linkage has been reported along the M4 Corridor in southern England (Boddy and Lovering, 1986). Lawton-Smith (1990, 1991) has also presented evidence surrounding the growth of high technology spin-off firms around Oxford University. Interestingly, this spin-off effect is without any direct university-industry connection being present (Lawton-Smith, 1990, p.132). In addition, the importance of informal contacts between industry and HEIs has been questioned by MacDonald (1987). Sceptical views of HEI-industry relationships have in addition been presented by Lowe (1985), Senker (1985), Miller and Cote (1987), Joseph (1989) and Shachar and Felsenstein (1992). Most notably, in 1986, Howells explored the regional economic
development potential of encouraging HEI-industry links and he found no clear connection. This was principally because the most important links developed were often made across long distances and with a small number of prestigious institutions. Moreover, a study of high technology firms located on Science Parks in Belgium and Holland by van Dierdonck et al., (1991, p.122) observed 'rather sparse' HEI-industry linkages. Thirty-four (83%) surveyed firms in Holland and 46 firms (68%) in Belgium reported the existence of contacts with a local university. But only 17 Belgian firms (25%) and 12 Dutch firms (29%) had collaborative R & D arrangements with a local university. These researchers went on to further argue,

"...a science park is not necessarily the most effective way to become involved in industrial science and technology. A multitude of other mechanisms exist" (p.122)\(^1\).

**HEI Links and Organisation Survival**

Low and MacMillan (1988) argue that ventures can shape their own survival by building networks. Founders with dense and varied personal and business networks of contacts can gain access to information to overcome business development problems. Organisations which have gained access to a wide and diverse relevant knowledge base through contacts with professional advisers may be more likely to survive.

HEIs are an important element of local infrastructure and can act as a vehicle for the sponsorship of high-technology firms through the use of grants, contracts and sponsored research (Flynn, 1993, p.146).

"Sponsorship is a deliberate attempt to make available a significantly higher and more stable level of resources to selected firms...[and]...When organizations are sponsored, their environment is enriched, providing legitimacy (Stinchcombe, 1965) to their birth and early survival" (Flynn, 1993, p.129 and p.131).

Associated with this trend has been a rapid growth in the number of Science Parks in the United Kingdom the function of which is to encourage the formation, survival and growth of high-technology firms. The United Kingdom Science Park Association (UKSPA) has asserted that Park firms

"...would not have survived if they had located off-park" and the support for new businesses on Science Parks has been the "...salvation of the academic entrepreneur..." (Grayson, 1993, p.120).
HEIs as Growth Poles for High Technology Firms

For several reasons HEIs are important as facilitators for growth:

* First, HEIs concentrate a large critical mass of scientifically sophisticated individuals who can generate new technologies (Florax, 1992). Innovative ideas (and technological knowledge) generated in a HEI can be channelled and diffused by new commercial ventures. Supporting this view Jaffe's (1989, p.968) empirical study of patent activity in the United States revealed, "...university research causes industry R & D and not vice versa. Thus, a state that improves its university research system will increase local innovation both by attracting industrial R & D and augmenting its productivity" (p.968)^2.

* Second, the technical expertise available in HEIs can be used by existing local businesses to solve production process problems (Link and Rees, 1990, p.28) and to supplement their commercial advantage (Lawton-Smith, 1990, p.128). As a result, local firms can become more technologically sophisticated thus enhancing their competitive performance.

* Third, HEIs have computing, testing and analysis and library facilities which are an incentive for engaging in a HEI-industry based relationship (Link and Rees, 1990, p.28).

* Fourth, HEIs are increasingly seen as a crucial source of skilled graduates whom local businesses can employ after graduation (Link and Rees, 1990, p.28; Laranja, 1994, pp.171-172).

* Fifth, the development of a centre of academic excellence in a certain field can create or enhance a favourable public image and reputation. As a result, additional jobs can be created not only in the HEI, but also in the wider community surrounding the HEI, because of its enhanced economic and social status (Malecki, 1991, p.305).

In addition, other groups have an interest in fostering cooperation between HEIs and industry (McMullan and Melnyk, 1988, pp.6-9; van Dierdonck and Debackere, 1988, p.343; Bower, 1992; Bell, 1993, pp.308-310; Bonaccorsi and Piccaluga, 1994; López-Martinez et al., 1994, p.18)^3. First, since 1979, United Kingdom Government has encouraged the higher education sector to become more flexible and business-minded, through reduced dependency on public funding (Palfreyman, 1989, p.207). A number of HEIs have turned directly to industry for additional external funding and have established mechanisms to commercially exploit research conducted within the HEI. Further, HEIs have encouraged HEI-industry links because they believe the exposure of academics to industrial environments will improve the quality of teaching within a HEI. As a result,
"HEIs are less 'ivory towered' in attitude than they might have been in the past; academics are more willing to negotiate for industrial sponsorship for their research and/or move into industry and other sectors of the economy in order to further their careers. Academics and the HEIs that employ them want to exploit their assets more effectively to generate revenue..." (Bell, 1993, p.308).

Second, industry facing stiff competition, has appreciated the need to increase its knowledge base. Technology-driven competition is technically difficult and expensive to counter. Links with HEIs enable industry to gain early access to scientific or technological knowledge, access to unique research skills and cost reductions, through delegation of selected activity.

Third, local and national Governments view the high technology sector as a source of direct and indirect employment opportunities and HEIs are seen as crucial to facilitating the growth of the local high technology sector.

Development of Science Parks in the United Kingdom
The phenomenal growth in the number of high technology firms (and resultant new employment) around, for example, Stanford University in Palo Alto and Massachusetts Institute of Technology (MIT) in Boston in the United States was a role model. It encouraged many British universities to seek to upgrade the technological capability of firms in their local communities by establishing or expanding regional innovation centres adjacent to the HEI.

Property developments, linked with a local HEI, were planned to become 'growth poles' in which clusters of high technology firms would interact with each other and with the 'host' HEI (van Dierdonck et al., 1991, p.111), enabling both applied research and businesses to achieve their full potential. As a result, in recent years Science Parks have been established around more British HEIs to formalise these linkages between academics and industry. Science Parks are property-based initiatives which (Monck et al., 1986, p.64; Massey et al., 1992, p.28)4:

* have formal and operational links with a university, other HEI or research centre and thus improve the take-up of ideas to new products or processes;

* were designed to encourage the formation and growth of knowledge-based businesses and other attendant organisations normally resident on site;

* have a management function which actively encourages the transfer of technology and business skills between the organisations on site and the local HEI; and

5
they can create employment opportunities and they can promise a 'sunrise' future which replaces a 'sunset' in a potentially depressed local economy.

Science Parks reflect an assumption that technological innovation stems from scientific research and that Parks can provide the catalytic incubator environment for the transformation of 'pure' research into production. Adherents of this so-called 'linear model' assume there is a chain of successive interrelated activities. These begin with basic scientific research, pass through applied and more developmental research activities, the development of new product and process ideas, the evolution and testing of proto-types, to commercial production and finally to diffusion (Massey et al., 1992, p.56). Further, adherents of the Science Park model see information channels as central to the transfer of knowledge from person to person from HEI to firm and from firm to firm. As a result, a Science Park can encourage local synergistic linkages between a HEI and high technology firms (Keeble, 1994, p.212).

As early as 1985, however, the Science Park movement in the United Kingdom was criticised by Oakey (1985, p.59) who questioned the presumed 'role models' of American university developments being transferred to a British university setting. He warned:

"...without the generation of production to create the critical mass of technical production skills, the new science parks are unlikely to reach a stage where the full critical mass of research and development and production economies allow the self-sustained growth of the development. A degree of 'ivory towerism' is inherent in the superficial social responsibility apparent in the setting up of science parks" (p.64).

He went on further to argue:

"The current eagerness of university bodies to establish science parks is less based on a thorough understanding of how they might best create and nurture high technology industrial production, and more on a pragmatic attempt to come to terms with the current political climate" (p.66).

Later, Massey et al., (1992, pp.76-85) argued that the linear model of innovation assumed by the Science Park movement in the United Kingdom was too simplistic. They identified alternative theories of innovation and suggest there is no single model of the way innovation takes place. They also claim that the conceptualisation of Science Parks intrinsically entails social inequality.

Nevertheless, Science Parks can provide a range of key benefits to tenant firms. Most notably,

* close proximity to an HEI,
* the opportunity for HEI academics to exploit their business ideas,
* high quality accommodation,
* management facilities,
* the opportunity for links between firms, and
* the opportunity for inter-trading between firms.

Through these benefits, firms on Science Parks might be expected, in some sense, to out-perform otherwise comparable businesses not located on a Park. Some evidence for this is provided by Hauschildt and Steinkühler (1994, p.190). They found new technology-based firms (NTBFs) located on Science and Technology Parks in Germany had on average a greater ability to survive and grow than high technology firms forced to develop in the open market5.

**DERIVATION OF HYPOTHESES**

Based on the above literature review the following hypotheses have been identified and will be tested:

\[ H_{1a} \quad \text{Independent Science Park firms are more likely to use the resources of a local HEI than independent off-Park firms.} \]

\[ H_{1b} \quad \text{Independent Science Park firms will have more links with a local HEI than independent off-Park firms.} \]

\[ H_{2a} \quad \text{Independent firms which have a link with a local HEI are more likely to survive.} \]

\[ H_{2b} \quad \text{Surviving independent firms will have more links with a local HEI than non-survivors.} \]

\[ H_{3} \quad \text{Young independent firms which have a link with a local HEI are more likely to survive.} \]

\[ H_{4} \quad \text{Small employment sized independent firms which have a link with a local HEI are more likely to survive.} \]

\[ H_{5a} \quad \text{Over time independent Science Park firms will be more likely to have a link with a local HEI.} \]

\[ H_{5b} \quad \text{Over time independent Science Park firms will be more likely to have more links with a local HEI.} \]
\[ H_{6a} \quad \text{Over time independent off-Park firms will be more likely to have a link with a local HEI.} \]

\[ H_{6b} \quad \text{Over time independent off-Park firms will be more likely to have more links with a local HEI.} \]

\[ H_{7a} \quad \text{Over time surviving independent Science Park firms will be more likely to have a HEI link than independent off-Park firms.} \]

\[ H_{7b} \quad \text{Over time surviving independent Science Park firms will have more HEI links than independent off-Park firms.} \]

\[ H_{8a} \quad \text{Recently established independent Science Park firms are more likely to have a link with a local HEI than independent Science Park firms interviewed in the past.} \]

\[ H_{8b} \quad \text{Recently established independent Science Park firms will have more links with a local HEI than independent Science Park firms interviewed in the past.} \]

\[ H_{9a} \quad \text{Recently established independent off-Park firms are more likely to have a link with a local HEI than independent off-Park firms interviewed in the past.} \]

\[ H_{9b} \quad \text{Recently established off-Park firms will have more links with a local HEI than independent off-Park firms interviewed in the past.} \]

\[ H_{10a} \quad \text{Recently established independent Science Park firms are more likely to use the resources of the local HEI than recently established independent off-Park firms.} \]

\[ H_{10b} \quad \text{Recently established independent Science Park firms will have more links with a local HEI than recently established independent off-Park firms.} \]

**DATA COLLECTED**

Data Collected in 1986

To facilitate testing of these hypotheses data are derived from a longitudinal study which explored the characteristics and performance of firms located on and off Science Parks in Great Britain (Westhead and Storey, 1994). Data was originally collected through a face-to-face questionnaire survey of organisations located in 1986 on Science Parks and with comparable off-Park firms (Monck et al., 1988).

In total, 284 direct face-to-face interviews were conducted in 1986 (most frequently with the owner-managers of independent and subsidiary organisations) (row 1 in Table 1), of which 183 were
on a Science Park and 101 were not on a Park. This constituted 53% of all tenants on United Kingdom Science Parks at that time, with Heriot Watt the only significant location omitted. Monck et al., (1988, pp.110-111) argued,

"...that the firms in this survey do provide an adequate sample of Britain's new high technology industries, providing adequate geographical, technological, sectoral and ownership coverage".

The Science Park firms were thus 'matched' with 101 firms which were not on a Park but which were in similar sectors, of similar age, of similar ownership pattern and in comparable areas of the United Kingdom. The matching was successful with regard to three out of the four categories, the exception being that the off-Park firms tended to be somewhat older than the Science Park firms. This paper will chart the formation of links over the 1986 to 1992 period between HEIs and the 135 independent Science Park organisations as well as the 101 independent off-Park organisations first interviewed by Monck et al., (1988) in 1986 (row in Table 1).

Data Collected in 1992 - Follow-On Sample

In 1990 a follow-on pilot study of thirty-five Science Park organisations (rows 2 and 3 in Table 1) was conducted by Storey and Strange (1992). The pilot longitudinal study did not attempt any contact with the off Park 'control' group sample of high-technology organisations. During 1992/93 empirical evidence from a second, and much more extensive, longitudinal follow-on survey of independent and subsidiary organisations located on and off Science Parks in 1986 was collected (Westhead and Storey, 1994). It was decided not to re-survey those organisations contacted in 1990.

The survival of organisations surveyed in 1986 was ascertained by contacting Science Park managers and by searches through the Companies House register of limited liability companies in the United Kingdom, telephone listings, telephone books and local trade directories. The following definition of independent organisation closure was used:

"An independent business is regarded as a closure if, in 1992 it is no longer identifiable as a trading business. An independent business which moves locations but continues as a trading business is not regarded as a closure. If the business is a subsidiary or a branch plant then it is regarded as having ceased if it no longer trades at its previous location" (p.25)°.

A similar definition has been utilised elsewhere (Cooper and Bruno, 1977, p.17; Kalleberg and Leicht, 1991, p.144; Garnsey and Cannon-Brookes, 1993, pp.185-186).

Table 1 also shows that out of the 135 independent organisations interviewed in 1986 which located on a Science Park, 92 (68%) remained in business in 1992 (rows 2, 4 and 5). Over the same period 62 off-Park independent organisations (67%) remained in business (rows 4 and 5).
Rows 3 and 6 in Table 1 indicate 31 independent Science Park organisations were closures. For untraced organisations additional evidence from direct fieldwork was gathered from individuals adjacent to the original location of the organisation surrounding its current status and location (a similar method was used by Reid, 1991, p.547). Twelve independent Science Park organisations could not be traced and did not appear in any identifiable form (row 7). This latter group of organisations were also regarded as closures. Hence the total number of independent Science Park closures was 43 (row 8). With regard to the off-Park sample, 19 were closures (row 6) and a further 11 could not be traced (row 7). Hence 43 (32%) independent Science Park organisations closed over this six year period compared with only 30 (33%) independent off-Park organisations (row 8).

Row 9 in Table 1 shows 75 independent surviving Science Park organisations in the valid 1992/93 follow-on sample (excluding the 17 surviving independent organisations re-interviewed in 1990 and 43 independent organisation closures) and a further 62 independent off-Park organisations (excluding the 32 independent organisation closures). Questionnaire responses surrounding current links with a local HEI were collected from surviving independent organisations (in 1986) during late 1992 and early 1993. Row 4 in Table 1 indicates 49 follow-on interviews were conducted with independent Science Park organisations (65% valid response rate - row 10) and a further 44 interviews were conducted with independent off-Park organisations (71% valid response rate - row 10).

Data Collected in 1992 - 'New Sample'
HEI-industry links were also examined by Westhead and Storey (1994). All 448 organisations located on Science Parks in the United Kingdom between 1986 and 1992 were identified. From this list 110 organisations were randomly selected covering Science Parks in the Government designated 'assisted' and 'non-assisted' areas. Seventy-one interviews were conducted with these independent and subsidiary firms (65% response rate).

To ascertain the 'added value' of a Science Park location high technology firms not located on a Park were also interviewed. Science Park firms were 'matched' with off-Park firms by industry, ownership type of the organisation, age of the organisation and location of the business. Seventy-one off-Park firms were identified (for a full discussion see Westhead and Storey (1994)). Face-to-face interviews were conducted both with Science Park tenants and with 'comparable' firms not located on a Park7. This paper will explore whether the 47 surveyed independent Science Park firms and the 48 independent off-Park firms in the 'new sample' had utilised their local HEI resource networks.

RESULTS
Links with a Local HEI by Independent Science Park and Off-Park Firms in 1986
As hypothesised (H₁₂), the top section of Table 2 shows, in 1986, independent Science Park firms were significantly more likely than independent off-Park firms to have a link with a local HEI (87.9% and
77.0% of Science Park and off-Park firms, respectively). The second section of the table shows that for those firms having a link there was no statistically significant difference between the two samples with regard to the number of links with a local HEI in 1986 (means of 4.7 and 3.7 links for Science Park and off-Park firms, respectively)\(^8\). As a result, hypothesis H\(_{1b}\) can not be supported.

The third section of Table 2 shows that a total of eighteen different links are identified. The most frequently specified link for firms in both samples was informal contact with academics (70.7% and 62.7% of Science Park and off-Park firms, respectively)\(^9\). The table shows Science Park firms were significantly more likely to have developed other formal links (25.0% compared with 9.0%) have used HEI computer facilities (57.8% compared with 25.4%), as well as library (35.3% compared with 7.5%), conference (29.3% compared with 6.0%) and dining facilities (12.1% compared with 3.0%). This suggests that for links, in general, there was little difference between on and off-Park firms. The Science Park firms were, not surprisingly, much more likely to use HEI facilities than the off-Park firms.

**Survival of Independent Science Park and Off-Park Firms, 1986-1992**

Hypothesis H\(_{2a}\) suggests that independent firms (in a combined sample of Science Park and Off Park firms) with links in 1986 would be more likely to survive until 1992 than those without. The top half of Table 3 shows this is the case. The bottom half of the table shows that it is whether or not the firm had a link, not the number of links influences firm survival. Hence, hypothesis H\(_{2b}\) is rejected. Also, no statistically significant differences were recorded between both groups of firms with regard to the types of links made in 1986.

Table 4 suggests having an HEI link overcomes some of the 'liability of newness' (Stinchcombe, 1965; Aldrich and Auster, 1986) for independent high technology firms. As hypothesised, young firms (less than 3 years of age in 1986) with an HEI link (in 1986) were more likely to survive over this six year period, although not in a statistically significant direction (58.3% of 'non-surviving' firms had a link compared with 71.4% of 'surviving' firms). Only weak support for hypothesis H\(_3\), however, is provided.

Table 5 tentatively suggests some of the 'liability of small employment size' (Aldrich and Auster, 1986) can be offset by having a link with a local HEI. This table shows 'surviving' firms in the 1 to 2 employment size category (in 1986) were more likely to have established an HEI link than 'non-surviving' firms (75.0% of 'non-surviving' firms had a link compared with 90.9% of 'surviving' firms). Therefore, only weak support for hypothesis H\(_4\) is provided.

**Development of HEI Links by Independent Science Park and Off-Park Firms, 1986-1992**

Table 6 shows in 1992 all 46 surviving surveyed Science Park firms had at least one link with a local HEI, four more firms than in 1986. Hypothesis H\(_{5a}\) is, therefore, confirmed. The second part of the
table shows that surviving Science Park firms had more links with their local HEI in 1992 than they had in 1986 (means of 5.0 and 5.8 links for surviving surveyed Science Park firms in 1986 and 1992, respectively), although not in a statistically significant direction. This confirms hypothesis $H_{5b}$. Further, over this six year period the prime growth in links was in the greater use of HEI library (38.1% compared with 71.7%) and recreation facilities (16.7% compared with 37.0%). In addition, Science Park firms had increasingly commercialised their activities by selling their own skills and services to HEIs (21.4% compared with 41.3%). Interestingly, due to the rapid growth in the use of personal microcomputers Science Park firms reported a marked reduction in their use of HEI computer facilities (down from 59.5% to 26.1% of firms).

Table 7 shows all 29 surviving off-Park firms reported in 1992 they had at least one link with a local HEI. For 4 firms this link was new since 1986. As a result, hypothesis $H_{6a}$ is supported. Contrary to expectation ($H_{6b}$), off-Park firms with at least one link in 1992 suggested they had fewer links with the HEI in 1992 than they had in 1986 (means of 4.4 and 3.4 links for surviving surveyed off-Park firms in 1986 and 1992, respectively). Although not shown in detail, it was found that there were falls (but not in a statistically significant direction) in the proportion of firms reporting informal contact with academics or the use of HEI computer facilities.

The links in 1992 developed by the 46 surviving Park and the 29 off-Park firms are compared in Table 8. At that time, all firms had developed at least one link with a local HEI. Hypothesis $H_{7a}$ is, therefore, not confirmed. However, as found with the total sample of surveyed firms in 1986 (Table 2) Table 8 indicates surviving Science Park firms had significantly more HEI links in 1992 than their off-Park counterparts (means of 5.8 and 3.4 links for surviving Science Park and off-Park firms in 1992). As a result, hypothesis $H_{7b}$ is supported.

Examining the individual links four statistically significant differences emerged between the two groups of firms. As found in 1986, Science Park firms continue to be significantly more likely to use the computer (26.1% compared 3.4%), library (71.7% compared with 34.5%) and dining facilities of a local HEI (26.1% compared with 3.4%). In addition, by 1992, Science Park firms were significantly more likely to utilise the recreation facilities of a local HEI (37.0% compared with 3.4%).

Development of HEI Links by Independent Science Park and Off-Park Firms in the 'New Sample'

Table 9 shows that over 86% of independent Science Park firms in both the Monck et al., sample and the Westhead and Storey 'new sample' had contacted a local HEI. Hypothesis $H_{8a}$ is, therefore, not supported. However, as hypothesised ($H_{8b}$), independent Science Park firms in the 'new sample' had more links in 1992 than independent Science Park firms interviewed by Monck et al., in 1986 (means of 4.7 and 5.7 links for Monck et al., Science Park firms and Westhead and Storey's 'new sample' Science Park firms, respectively).

Examining the individual links it appears that Science Park firms in the 'new sample' were significantly more likely to indicate their businesses had assisted the HEI in a teaching programme.
(7.8% compared with 26.8%). Moreover, significantly more 'new sample' firms had used HEI library (35.3% compared with 78.0%), recreation (16.4% compared with 43.9%) and dining facilities (12.1% compared with 36.6%). In marked contrast, 'new sample' firms were significantly less likely to have contacted a HEI to use its computer facilities (57.8% compared with 9.8%).

Table 10 shows that in both the Monck et al., sample and the Westhead and Storey 'new sample' over 74% of independent off-Park firms had contacted a local HEI. Firms with links in both samples also mentioned, developing a similar number of links with their local HEI (means of 3.7 and 3.6 links for Monck et al., off-Park firms and Westhead and Storey's 'new sample' off-Park firms, respectively). As a result, neither hypothesis H9a nor H9b can be confirmed.

Finally, Table 11 shows that independent Science Park 'new sample' firms interviewed in 1992 were not significantly more likely to have contacted a local HEI than 'new sample' off-Park firms. However, Science Park firms were likely to have significantly more links than off-Park firms (means of 5.7 and 3.6 links for Westhead and Storey's 'new sample' Science Park and off-Park firms, respectively). Hypotheses H10a is, therefore, rejected but hypothesis H10b is accepted. In addition, with regard to only three types of links were statistically significant differences recorded between firms in the two groups. Science Park firms had a significantly greater propensity, in 1992, to have used HEI library (78.0% compared with 27.8%), recreation (43.9% compared with 0.0%) and dining facilities (36.6% compared with 0.0%).

CONCLUSIONS AND IMPLICATIONS

This research has examined the impact or 'added-value' of the decision made by a high technology business to locate on a United Kingdom Science Park. One of the key findings in the 1986 survey was that, although closeness to a HEI was seen to be an important factor influencing firms to locate on Science Parks, the extent to which these HEI-industry links existed was less than anticipated (Monck et al., 1988). To some extent this was rationalised at that time on the grounds that most of the firms, and many of the Science Parks, were relatively new. It was felt the building up of links would take place only over a lengthy period of time.

In 1986, firms located on a Science Park were significantly more likely to have a link with a local HEI and have more links than off-Park firms. However, the key result of this paper is that independent high technology organisations in the combined sample (irrespective of location) with a link (irrespective of the number and/or type of link(s)) with a local HEI in 1986 (and access to the HEI resource network) were significantly more likely to survive to the end of 1992. Also, the liabilities of newness and small employment size can be alleviated if organisations 'tap-into' local HEI resource networks. This research has, therefore, shown that the survival of new and small independent high technology organisations can be enhanced if organisation decision-makers, network gatekeepers (such as Science Park managers and HEI industrial liaison officers) as well as academics in HEIs appreciate
the potential benefits of HEI-industry co-operation. Most notably, they should appreciate an appropriately structured 'hands-on' support to new NTBFs,

"...can have a positive effect in enabling viability and survival, if not growth, of such enterprises" (Keeble, 1994, p.215).

Both Science Park and off-Park firms were more likely to use the resources of a local HEI in 1992 than in 1986. However, off-Park firms with at least one link with a local HEI in 1992 reported they had fewer links in 1992 than they had in 1986. This is an area for additional research.

By 1992, surviving surveyed Science Park as well as off-Park firms had appreciated the advantages of a HEI link. Science Park firms had generally increased their links with the local HEI, whereas the off-Park firms had reduced the number of links with a local HEI. Nevertheless, it would be unwise to assume off-Park firms had little contact with a local HEI in 1992; for example, 59% of off-Park firms claimed to have informal contact with academics and 48% claimed to have employed recent graduates.

It is also interesting that firms in the 1992 'new sample' were not significantly more likely to have an HEI link than those firms surveyed in 1986. In part, this is because more than 86% of Science Park firms in both samples had a link with a local HEI in 1986 as well as 1992. Similarly, over 74% of off-Park firms in both 1986 and 1992 had established at least one HEI link.

Even so, contact with a local HEI is vital. Science Park managers and HEI industrial liaison officers have an important role here not only establishing links but also encouraging the development of more formal links over time. In part, the higher incidence of HEI-industry linkage in the Science Park 'new sample' than in the off-Park 'new sample' may be due to the activities of Science Park managers and HEI industrial liaison officers actively attempting to link Park firms with their local HEI.

Interestingly, additional empirical analysis (summarised in Westhead and Storey (1994, pp.118-123)) revealed a 'latent demand' for contact and liaison with HEIs, both amongst Science Park and off-Park firms. Firms irrespective of location claimed the HEI should make greater efforts to ensure its services and facilities are made more accessible to businesses. It is, however, disconcerting to note, that Science Park firms were no more likely to have received a visit from a representative of an HEI to discuss its facilities available than off-Park firms. It may be that HEI personnel felt responsibility for initiating this contact lay with the Science Park manager but the assumption that Science Park firms are well informed about research in the HEI does not seem valid. In addition, technology-based firms in general felt links with HEIs could be improved and that, perhaps by implication, the first move had to be made by the HEIs to set the process in motion. Respondents also suggested that there is a lot of information within HEIs which would be useful to a business if only it were able to access it appropriately. From the businesses' perspective, however, they found the 'searching out' of information extremely time-consuming and they believe it is the responsibility of the
HEI to foster better links with the business community. In reality, both parties have a responsibility of ensuring a successful academic/industry network.

The empirical evidence presented here lends additional support to the view that the role of industrial liaison officers within HEIs need to be strengthened. Science Park managers and HEI industrial liaison officers must appreciate,

"Environmental conditions can influence network formation but they do not make relationships happen" (Cromie and Birley, 1994, p.312).

Consequently, Science Park managers and industrial liaison officers need to be become even more proactive and establish systems which actively link individuals in specific firms with individuals in appropriate HEI departments (and other high technology firms located on and off the Science Park).

We also believe HEIs should appreciate, in order to maximise the contribution which a Science Park makes, it is necessary to have an effective (but not extravagant) managerial structure designed to 'add value' to the tenant firms. There is a 'happy medium' between, on the one hand, a solely property-based initiative which happens to be located adjacent to a HEI and, on the other, what is perceived by tenant firms as an overstuffed bureaucracy which they are funding from their rental payments. The happy medium is a lean central unit which both manages property aspects efficiently and is an effective conduit to the HEI and other sources of business information and resources. This role can be exercised with regular contact between Science Park management and tenant firms.

In 1988, Monck et al., pointed to the need for HEIs to enter into flexible relationships with members of their staff wishing to commercialise their research ideas. The evidence from this survey is that these (generally informal) arrangements have only developed very modestly and, given the need to increase the number of high technology businesses, this is an area were HEIs should look at more closely. Finally, we agree with Tsipouri (1991), policy should encourage the development of links between academe and industry,

"...through institutional improvement, financial incentives and especially a consensus that this link will benefit all parties concerned" (p.147).

ACKNOWLEDGEMENTS
We would like to thank the Department of Trade and Industry, National Westminster Bank, KPMG Peat Marwick and the United Kingdom Science Park Association (UKSPA) for their financial sponsorship. All opinions (and errors) expressed in this paper are the authors alone.
NOTES

1. "Indeed Science Parks only represent one particular mechanism to stimulate technology transfers between academia and industry; multiple other mechanisms exist, e.g. research consortia, joint ventures, contract research, etc" (van Dierdonck et al., 1991, p.111).

2. On the downside, Jaffe (1989, p.968) also found, "There is only weak evidence that spillovers are facilitated by geographic coincidence of universities and research labs within the state". This latter assertion has recently been questioned. Acs et al., (1992, p.306) in their study of innovations (rather than the number of patented inventions) recorded in the United States in 1982 interestingly found corporate innovation activity responded positively to commercial spillovers from university research.

3. A variety of factors influence the development of HEI-industry links, most notably, culture, individual motivations, institutional stimuli and structural conditions (van Dierdonck and Debackere, 1988, p.344; López-Martínez et al., 1994, pp.18-20). In addition, operational characteristics may act as barrier. Recently, Bell (1993, p.317-318) has identified a number of perceived problems and obstacles surrounding academic-industrial collaborative arrangements. For example, the HEI research agenda could be set by industrial rather than academic interests; academics will have less freedom to publish and discuss their findings; in order to minimise risk and uncertainty the innovatory research process in HEIs could be replaced by hierarchical and bureaucratic managerial procedures; industry can change its research needs and, hence, there is the danger that industry can take a cynical attitude towards the value of research and regard it as a vehicle for training and motivating their scientific and technical labour forces; industry can change the research agenda faster than is conducive to academic progress; there are dangers in socialising students only for industry; common technology transfer practices may disadvantage small firms who can not pay a local HEI the same level of remuneration as a large firm; there are also significant ownership issues and patent right obligations, particularly when new technology has been developed and supported by a multiplicity of sources (both from the public and private sectors); businesses complain about the high initial option and licence fees and royalty rates demanded by HEIs for embryonic technology; and finally, valuation disputes are not uncommon with HEIs reportedly tending to overvalue their technology, either because they overlook the development issues or because they are unfamiliar with the production process or market environment into which their technology is to be inserted.

4. Few HEIs in the United Kingdom have developed Science Parks on their own (a detailed summary of the rapid growth in the number of Science Parks in the United Kingdom has been detailed by Monck et al., (1988, pp.70-78) and Grayson (1993)). In the main, Science Parks have been established by a variety of external partners, generally a regional development agency, a local authority (particularly those located in declining urban areas) or a private
sector group (usually including a financial institution). These various parties all anticipate numerous wealth creation and job generation benefits associated with the development of a cluster of high technology firms in their locale. Also, in the United Kingdom it has been appreciated that, "...there is no single model to be followed" (Monck et al., 1988, p.67). Nevertheless, the United Kingdom Science Park model is much closer to American Innovation Centres than to the United States style Science Parks (Monck et al., 1988, p.70).

5. Hauschildt and Steinkühler (1994, p.190) also found, "...the strong companies have a much better opportunity to develop, and the weak firms are given better chances of survival".

6. The key justification for this definition relates to the purpose of the study conducted by Westhead and Storey (1994). "Our objective is to be able to track and compare over a six-year period the on-Park firms interviewed in 1986 with the off-Park firms. A definition of closure needs to be chosen which enables a valid and direct comparison to be made between the two groups of firms. It also needs to recognise that the quality of information about the off-Park firms is weaker than that for Science Park firms. A definition therefore has to be employed which the researchers can be confident ensures that both groups of firms are treated comparably" (Westhead and Storey, 1994, p.25).

7. The Science Park and the off-Park samples were perfectly matched with regard to sectoral composition. In addition, no statistically significant difference was recorded between the two 'new samples' with regard to ownership characteristics and the age of surveyed firms. However, the 'matching' of surveyed Science Park and off-Park firms was not successful according to location. Relatively more Science Park firms were located in Scotland and the West Midlands of England whilst markedly more off-Park firms were conducted with firms in South East England.

8. Those with 1 or more link with a HEI in 1986.

9. Percentages relate to valid responding cases (or independent firms that had established 1 or more link with a HEI).
REFERENCES


<table>
<thead>
<tr>
<th></th>
<th>Science Park sample (b)</th>
<th>Off-Park sample</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Ind</td>
<td>Sub</td>
</tr>
<tr>
<td>1. Number of surveyed organisations in 1986</td>
<td>183</td>
<td>135</td>
<td>48</td>
</tr>
<tr>
<td>2. Survived - either original or new address by the end of 1992</td>
<td>24</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>3. Confirmed closure by the end of 1992</td>
<td>11</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>4. Survived - interview completed during 1992/93</td>
<td>59</td>
<td>49</td>
<td>10</td>
</tr>
<tr>
<td>5. Survived - either original or new address, 1992</td>
<td>31</td>
<td>26</td>
<td>5</td>
</tr>
<tr>
<td>7. Organisation has no telephone listing / not recorded in telephone book or trade directory by the end of 1992</td>
<td>12</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>8. Total sample closure rate (including no telephone listings) over the 1986 to 1992 period</td>
<td>43 (32%)</td>
<td>30 (33%)</td>
<td></td>
</tr>
<tr>
<td>9. Number of organisations in the valid 1992/93 follow on sample (excluding those 23 independent Science Park organisations re-interviewed in 1990 and the organisations that had closed over the 1986 to 1992 period)</td>
<td>75</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>10. Valid response rate to interview survey, 1992/93</td>
<td>65%</td>
<td>71%</td>
<td></td>
</tr>
</tbody>
</table>

Notes: (a) The 'tracking' of Science Park organisations was more successfully achieved because information was more extensive from Science Park managers surrounding organisation name changes and / or organisation relocations.
(b) Nine surveyed firms located on a Science Park in 1986 have subsequently survived and moved to an off-Park location.
(Ind) Independent organisation in 1986.
(Sub) Subsidiary organisation in 1986.
Table 2  Links with the Local University, Polytechnic or Institute of Higher Education (HEI) in 1986 by Independent Science Park and Off Park Firms

<table>
<thead>
<tr>
<th>Link with HEI</th>
<th>Science Park firms, 1986</th>
<th>Off Park firms, 1986</th>
<th>Total</th>
<th>( \chi^2 ) statistic significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>1. No</td>
<td>16</td>
<td>12.1</td>
<td>20</td>
<td>23.0</td>
</tr>
<tr>
<td>2. Yes</td>
<td>116</td>
<td>87.9</td>
<td>67</td>
<td>77.0</td>
</tr>
</tbody>
</table>

\( \geq 1 \) link with HEI

Science Park firms - 1986 \( \bar{x} = 4.66 \quad \sigma = 2.79 \quad n = 116 \quad \text{median} = 4 \)
Off Park firms - 1986 \( \bar{x} = 3.73 \quad \sigma = 2.97 \quad n = 67 \quad \text{median} = 3 \)

'\( t = 2.09, \) d.f. = 181, Reject \( H_0 \) at the 0.05 level of significance (one-tailed test).

| Type of HEI link for those firms with \( \geq 1 \) link |
|---------------------------------|-------------|-------------|---------|--------------------------|
| 1. Informal contact             | 82          | 70.7        | 42      | 62.7         | 124          | 67.8        | n.s.            |
|                                 | with academics |           |         |              |              |             |                 |
| 2. Employment of academics      | 43          | 37.1        | 24      | 35.8        | 67           | 36.6        | n.s.            |
| on a part-time basis/           |             |             |         |              |              |             |                 |
| consultancy basis               |             |             |         |              |              |             |                 |
| 3. Sponsor research trials      | 19          | 16.4        | 14      | 20.9        | 33           | 18.0        | n.s.            |
| or projects                     |             |             |         |              |              |             |                 |
| 4. Access to specialist         | 52          | 44.8        | 25      | 37.3        | 77           | 42.1        | n.s.            |
| equipment                       |             |             |         |              |              |             |                 |
| 5. Test / analysis in HEI       | 17          | 14.7        | 12      | 17.9        | 29           | 15.8        | n.s.            |
| 6. Student projects             | 33          | 28.4        | 23      | 34.3        | 56           | 30.6        | n.s.            |
| 7. Employment of recent         | 39          | 33.6        | 25      | 37.3        | 64           | 35.0        | n.s.            |
| graduates                       |             |             |         |              |              |             |                 |
| 8. Training by HEI              | 7           | 6.0         | 6       | 9.0         | 13           | 7.1         | n.a.            |
| 9. Assistance by business       | 9           | 7.8         | 10      | 14.9        | 19           | 10.4        | n.s.            |
| in HEI teaching programme       |             |             |         |              |              |             |                 |
| 10. Other formal links          | 29          | 25.0        | 6       | 9.0         | 35           | 19.1        | 0.05            |

Use of facilities:

<table>
<thead>
<tr>
<th>Use of facilities</th>
<th>( \text{No.} )</th>
<th>( % )</th>
<th>( \text{No.} )</th>
<th>( % )</th>
<th>( \text{No.} )</th>
<th>( % )</th>
<th>( \chi^2 ) statistic significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Computer</td>
<td>67</td>
<td>57.8</td>
<td>17</td>
<td>25.4</td>
<td>84</td>
<td>45.9</td>
<td>0.001</td>
</tr>
<tr>
<td>12. Library</td>
<td>41</td>
<td>35.3</td>
<td>5</td>
<td>7.5</td>
<td>46</td>
<td>25.1</td>
<td>0.001</td>
</tr>
<tr>
<td>13. Recreation</td>
<td>19</td>
<td>16.4</td>
<td>9</td>
<td>13.4</td>
<td>28</td>
<td>15.3</td>
<td>n.s.</td>
</tr>
<tr>
<td>14. Conferences</td>
<td>34</td>
<td>29.3</td>
<td>4</td>
<td>6.0</td>
<td>38</td>
<td>20.8</td>
<td>0.001</td>
</tr>
<tr>
<td>15. Dining</td>
<td>14</td>
<td>12.1</td>
<td>2</td>
<td>3.0</td>
<td>16</td>
<td>8.7</td>
<td>0.1</td>
</tr>
<tr>
<td>16. Audio-visual</td>
<td>3</td>
<td>2.6</td>
<td>5</td>
<td>7.5</td>
<td>8</td>
<td>4.4</td>
<td>n.a.</td>
</tr>
<tr>
<td>17. University as a customer</td>
<td>22</td>
<td>19.0</td>
<td>16</td>
<td>23.9</td>
<td>38</td>
<td>20.8</td>
<td>n.s.</td>
</tr>
<tr>
<td>18. Other</td>
<td>12</td>
<td>10.3</td>
<td>6</td>
<td>9.0</td>
<td>18</td>
<td>9.8</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

Valid cases: 116, 67, 183

Notes:  n.s.  Chi-square statistic not statistically significant at the 0.05 level of significance.
       n.a.  Due to the assumptions of the chi-square test it was not possible to calculate a coefficient.
Table 3  Links with the Local University, Polytechnic or Institute of Higher Education (HEI) in 1986 by Independent Business Survival over the 1986 to 1992 Period

<table>
<thead>
<tr>
<th>Link with HEI</th>
<th>Independent business non-survival</th>
<th>Independent business survival</th>
<th>$\chi^2$ statistic significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>19</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>24.6</td>
<td>12.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>75.4</td>
<td>87.3</td>
<td></td>
</tr>
<tr>
<td>1. No</td>
<td>17</td>
<td>19</td>
<td>0.05</td>
</tr>
<tr>
<td>2. Yes</td>
<td>52</td>
<td>131</td>
<td></td>
</tr>
</tbody>
</table>

$\geq 1$ link with HEI

Independent business non-survival  $\bar{x} = 4.10 \quad \sigma = 2.83 \quad n = 52 \quad \text{median} = 3$

Independent business survival  $\bar{x} = 4.41 \quad \sigma = 2.91 \quad n = 131 \quad \text{median} = 3$

$t' = -0.68$, d.f. = 181, Accept $H_0$ at the 0.05 level of significance (one-tailed test).
Table 4  Independent Business Survival over the 1986 to 1992 Period by Age of the Firm in 1986 and a Link with a HEI in 1986

<table>
<thead>
<tr>
<th>Age in 1986</th>
<th>Non-Survival</th>
<th>Survival</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Link No.</td>
<td>%</td>
<td>No link No.</td>
</tr>
<tr>
<td>1-2</td>
<td>7</td>
<td>58.3</td>
<td>5</td>
</tr>
<tr>
<td>3-5</td>
<td>26</td>
<td>81.3</td>
<td>6</td>
</tr>
<tr>
<td>6-10</td>
<td>6</td>
<td>75.0</td>
<td>2</td>
</tr>
<tr>
<td>≥ 11</td>
<td>2</td>
<td>66.7</td>
<td>1</td>
</tr>
<tr>
<td>Employment size of the firm in 1986</td>
<td>Non-Survival</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Link No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>1-2</td>
<td>6</td>
<td>75.0</td>
<td>2</td>
</tr>
<tr>
<td>3-25</td>
<td>29</td>
<td>76.3</td>
<td>9</td>
</tr>
<tr>
<td>26-50</td>
<td>1</td>
<td>50.0</td>
<td>1</td>
</tr>
<tr>
<td>≥51</td>
<td>1</td>
<td>100.0</td>
<td>0</td>
</tr>
<tr>
<td>Link with HEI</td>
<td>Science Park firms, 1986</td>
<td>Science Park firms, 1992</td>
<td>$X^2$ statistic significance level</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------------------</td>
<td>-------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>1. No</td>
<td>4</td>
<td>8.7</td>
<td>0</td>
</tr>
<tr>
<td>2. Yes</td>
<td>42</td>
<td>91.3</td>
<td>46</td>
</tr>
</tbody>
</table>

≥ 1 link with HEI

Science Park firms - 1986

$$x = 4.98 \quad \sigma = 3.02 \quad n = 42 \quad \text{median} = 5$$

Science Park firms - 1992

$$x = 5.80 \quad \sigma = 4.13 \quad n = 46 \quad \text{median} = 5$$

$t' = -1.07$, d.f. = 86, Accept $H_0$ at the 0.05 level of significance (one-tailed test).

Note: n.a. Due to the assumptions of the chi-square test it was not possible to calculate a coefficient.
<table>
<thead>
<tr>
<th>Link with HEI</th>
<th>Off Park firms, 1986</th>
<th>Off Park firms, 1992</th>
<th>$X^2$ statistic significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>4 13.8</td>
<td>0 0.0</td>
<td>n.a.</td>
</tr>
<tr>
<td>Yes</td>
<td>25 86.2</td>
<td>29 100.0</td>
<td></td>
</tr>
</tbody>
</table>

$\geq 1$ link with HEI

Off Park firms - 1986  
$\bar{x} = 4.40 \; \sigma = 3.29 \; n = 25 \; \text{median} = 3$

Off Park firms - 1992  
$\bar{x} = 3.38 \; \sigma = 2.26 \; n = 29 \; \text{median} = 3$

$t' = 1.31, \; \text{d.f.} = 52, \; \text{Accept } H_0 \text{ at the 0.05 level of significance (one-tailed test).}$

Note:  
Due to the assumptions of the chi-square test it was not possible to calculate a coefficient.
Table 8  Links with the Local University, Polytechnic or Institute of Higher Education (HEI) in 1992 by Surviving Surveyed Independent Science Park and Off Park Firms

| Link with HEI | Science Park firms, 1992 |  | Off Park firms, 1992 |  | Total |  |  | \( \chi^2 \) statistic significance level |
|---------------|--------------------------|------------------|----------------------|------------------|-------|------------------|------------------|
|               | No. | % | No. | % | No. | % | n.a. |
| 1. No         | 0   | 0.0 | 0   | 0.0 | 0   | 0.0 |       |
| 2. Yes        | 46  | 100.0 | 29  | 100.0 | 75  | 100.0 |       |

\( \geq 1 \) link with HEI
Science Park firms - 1992  \( \bar{X} = 5.80 \quad \sigma = 4.13 \quad n = 46 \quad \text{median} = 5 \)
Off park firms - 1992  \( \bar{X} = 3.38 \quad \sigma = 2.26 \quad n = 29 \quad \text{median} = 3 \)

'\( t' = 3.28, \ d.f. = 73, \) Reject \( H_0 \) at the 0.005 level of significance (one-tailed test).

Note: n.a. Due to the assumptions of the chi-square test it was not possible to calculate a coefficient.
Table 9  Links with the Local University, Polytechnic or Institute of Higher Education (HEI) by Independent Science Park Firms Surveyed by Monck et al., in 1986 and Science Park Firms in the 'New Sample' Surveyed by Westhead and Storey in 1992

<table>
<thead>
<tr>
<th>Link with HEI</th>
<th>Monck et al., Science Park sample, 1986</th>
<th>Westhead and Storey Science Park 'new sample', 1992</th>
<th>( \chi^2 ) statistic significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>1. No</td>
<td>16</td>
<td>12.1</td>
<td>6</td>
</tr>
<tr>
<td>2. Yes</td>
<td>116</td>
<td>87.9</td>
<td>41</td>
</tr>
</tbody>
</table>

\( \bar{x} = 4.66 \quad \sigma = 2.79 \quad n = 116 \quad \text{median} = 4 \)

\( \bar{x} = 5.73 \quad \sigma = 3.80 \quad n = 41 \quad \text{median} = 5 \)

'\( t' = -1.65, \quad \text{d.f.} = 155, \quad \text{Reject } H_0 \text{ at the 0.05 level of significance (one-tailed test).}'

Note: n.s. Chi-square statistic not statistically significant at the 0.05 level of significance.
Table 10  Links with the Local University, Polytechnic or Institute of Higher Education (HEI) by Independent Off Park Firms Surveyed by Monck et al., in 1986 and Off Park Firms in the 'New Sample' Surveyed by Westhead and Storey in 1992

<table>
<thead>
<tr>
<th>Link with HEI</th>
<th>Monck et al., Off Park sample, 1986</th>
<th>Westhead and Storey Off Park 'New Sample', 1992</th>
<th>X² statistic significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.  %</td>
<td>No.  %</td>
<td></td>
</tr>
<tr>
<td>1. No</td>
<td>20  23.0</td>
<td>12  25.0</td>
<td>n.s.</td>
</tr>
<tr>
<td>2. Yes</td>
<td>67  77.0</td>
<td>36  75.0</td>
<td></td>
</tr>
</tbody>
</table>

≥ 1 link with HEI

Monck et al., Off Park sample - 1986  \[ \bar{x} = 3.73 \quad \sigma = 2.97 \quad n = 67 \quad \text{median} = 3 \]

Westhead and Storey Off Park 'new sample' - 1992  \[ \bar{x} = 3.56 \quad \sigma = 2.51 \quad n = 36 \quad \text{median} = 3 \]

't' = 0.31, d.f. = 101, Accept H₀ at the 0.05 level of significance (one-tailed test).

Note: n.s. Chi-square statistic not statistically significant at the 0.05 level of significance.
Table 11 Links with the Local University, Polytechnic or Institute of Higher Education (HEI) by Independent 'New Sample' Science Park and Off Park Firms Surveyed by Westhead and Storey in 1992

<table>
<thead>
<tr>
<th>Link with HEI</th>
<th>Westhead and Storey Science Park, 'New Sample', 1992</th>
<th>Westhead and Storey Off Park 'New Sample', 1992</th>
<th>(X^2) statistic</th>
<th>significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No</td>
<td>6 12.8</td>
<td>12 25.0</td>
<td>18</td>
<td>18.9 n.s.</td>
</tr>
<tr>
<td>2. Yes</td>
<td>41 87.2</td>
<td>36 75.0</td>
<td>77</td>
<td>81.1</td>
</tr>
</tbody>
</table>

\[\bar{x} = 5.73 \quad \sigma = 3.80 \quad n = 41 \quad \text{median} = 5\]

\[\bar{x} = 3.56 \quad \sigma = 2.51 \quad n = 36 \quad \text{median} = 3\]

\(t' = 3.00, \ d.f. = 75, \) Reject \(H_0\) at the 0.005 level of significance (one-tailed test).

Note: n.s. Chi-square statistic not statistically significant at the 0.05 level of significance.