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Urban Stud 2005; 42; 1139
DOI: 10.1080/00420980500121230

Urban Studies, Vol. 42, No. 7, 1139–1160, June 2005

Routledge
Taylor & Francis Group

Role of Interaction between Technological Communities and Industrial Clustering in Innovative Activity: The Case of Hsinchu District, Taiwan

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[Paper first received, July 2001; in final form, October 2004]

Summary. Economic development requires knowledge in today's knowledge-based economy. The achievement of economic development in one area depends directly on the efficiency of the attainment, accumulation and application of knowledge and information. These processes rely heavily on the involvement of human resources with technological knowledge and technical skills. Correspondingly, knowledge creation ability and the efficiency of knowledge creation and application determine industrial clustering and economic sustainability. Current surveys of industrial clusters in Taiwan have ascertained that clusters of traditional industries do not necessarily lead to innovation although, empirically, an industrial cluster is a prerequisite for innovative activity. Recent studies have addressed the effects of the spatial proximity among firms and advanced research institutes in the Hsinchu area. According to their results, industrial clustering positively influences innovation by technological companies. Based on available results, this study considers how interaction between technological communities and industrial clustering influence the innovative activities in a sample area. Additionally, this study analyses social networking within the technological community and the relationship to industrial clustering in the Hsinchu area. Results of this study provide a valuable reference for industrial district planning and management.

1. Introduction

Since the emergence of the knowledge-based economy, globalisation and increased international competition in the 1980s, innovation has become increasingly crucial for local economies (Camagni, 1995; Feldman, 1994; Malmberg, 1997; Malmberg and Maskell, 2002; Porter, 1990; Ritsila, 1999; Storper, 1995). Globalisation has also strengthened regional divergences resulting from local innovation capacity and context. Poor nations typically lack well-developed regional clusters. Thus, the regional or national economies of such nations are forced to rely on cheap labour and natural resources to participate in global markets (Porter, 1998). Accordingly, specific industrial clustering is broadly recognised to bear important advantages.

Most research on the arrangement of regional industrial clusters considers relationships and co-operation, and includes work on collective learning, embeddedness, untraded interdependence and even network formation.

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0042-0980 Print/1360-063X Online/05/071139–22
DOI: 10.1080/00420980500121230

However, when competing for market share, companies in the high-tech sector stress new product and technology supply; thus, corporations participate in areas of industrial agglomeration to compete for significant resources and thus become market leaders by promoting new products or technologies. Such resources include knowledge agents, skilled labour, mobile information and co-operative partnerships established to increase market advantage. Similarly, within the pool of skilled human resources formed by industrial clustering, knowledge agents compete to find corporations that improve and specialised personnel strive for more respectable work opportunities. In their search for value, specialised personnel occasionally leave their employment to create new companies, resulting in spin-offs (Lindholm, 1997).

These recently established corporations feature two main origins of high-tech talent—namely, high-level educational institutions and well-established enterprises in relevant industries. Therefore, newly established corporations are inclined to be centred near universities, research organisations and existing corporations. Aside from the central elements, such as seeking to utilise geographical proximity to continue to be competitive, other considerations include technology transfer, spin-offs and R&D hardware, as well as technological infrastructure. Empirically, clustering is an important prerequisite of innovation (Baptista, 1996; Baptista and Swann, 1998; Breschi, 2000; Wu and Chen, 2001). Conversely, although having gathered in spatial proximity, firms in traditional industries have been ineffective in inspiring innovation.

Knowledge is the core driver of economic growth in the knowledge economy age, representing an 'internal growth mechanism'. Direct dependence on knowledge or the collection and utilisation of effective information, stress the injection of technological wherewithal and specialised human resources. The capacity to generate and employ knowledge and the effectiveness of the creation and utilisation of this knowledge have become crucial to support industrial clustering and continuous economic development. In Taiwan, Wu and Chen (2001) observed that firm innovative behaviour and sources of innovation are both clearly and positively related to a firm's nearness to and interaction with academic and research organisations, as well as to the degree of industrial clustering in a specific area. An assessment of firms inside and outside the Hsinchu Science-based Industrial Park (HSIP) ascertains that location-related factors and agglomeration positively and notably influence innovative activity (Yang and Chen, 2001).

However, firms within a cluster are occasionally weakly reliant on that cluster. Although these firms are geographically near to other enterprises, their existent connection or interaction with other industries within the cluster area is limited. Nonetheless, such firms may often interact with firms outside the specific area (Hart, 2000). Firms such as these, within a cluster, take advantage of the superior and developed industrial environment and the extensive, and communicative, skilled human resources. Consequently, some researchers have claimed that localised industrial clustering with close geographical relationships occurs progressively and is influenced by the features of specific industries and the level of firm development (Steinle and Schiele, 2002).

Therefore, this study will ascertain whether industrial clustering—namely, the geographical proximity of firms to academic or research organisations—benefits firm innovation. In addition, this study elucidates at an individual level, based on the clear relationship between geography and innovative activity, the interactive relationships between the formation of a technological community based on knowledge agent spin-offs and high-tech talent mobility (see Figure 1). Accordingly, this investigation considers whether these relationships significantly influence innovation. Markedly, this approach analyses the importance of network connections to the technological community within an industrial cluster and which is another important influence on the

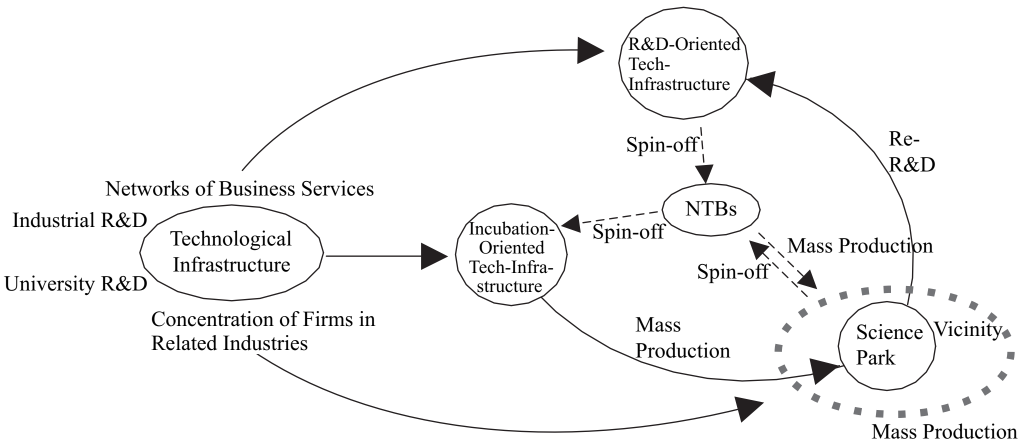

Figure 1. Dynamic structure of the industrial cluster in Hsinchu district, Taiwan.

development and location of the industrial environment.

2. Literature Review

Innovation is undoubtedly crucial, given the present background of globalisation and the growing struggle to gain competitive advantage. Particularly, the localisation of industrial learning is causing high-tech industries to converge or cluster in certain places, and the agglomeration of new knowledge-based industrial activity. Most significantly, high-tech companies are proactively approaching or seeking links with sources of new knowledge production, with the objective of facilitating new knowledge transfer and thus achieving competitive advantage. This situation suggests that, although corporations in traditional industries have tended to gather together, such concentration has failed to inspire innovation.

However, clustering is a prerequisite for innovation and enables firms or individuals to apply new knowledge to production and successfully to commercialise new knowledge. Such clusters are present in only a few regions around the world (Audretsch, 1998), with examples including Silicon Valley and Boston's Route 128 in the US, Tsukuba and Kansai in Japan, Cambridge and the M4 Corridor in the UK, Sophia-Antipolis in France, Taedok in South Korea and Hsinchu in Taiwan.

This investigation assumes that competitive advantage in innovation-dependent high-tech industries depends not only on participation in local technological infrastructure and the establishment of an environment conducive to innovation, but also on interactions within the technological community that encourage local innovation and knowledge accumulation. This investigation reviews the literature on the formation of local innovative environments to clarify the basis of the interaction between local industrial clustering and the technological community.

2.1 Innovative Activity, Proximity and Knowledge Spillovers

During the past decade, the evolution of computers and telecommunications, and the emergence of new information technologies have altered production locations and revolutionised the use of space, stimulating rapid growth in global demand for knowledge-based industries. Notably, industrialists who can apply new knowledge to production processes and thus commercialise new knowledge, only exist in a few industrial clusters around the world. Each of these clusters has a different development history and thus is unique. A basic hypothesis is that different types of cluster depend on different policies to improve their innovative capacity and competitiveness (Hart, 2000).

In addition to geographical proximity, original sources and knowledge spillover are other mechanisms for stimulating innovation. The important characteristics of this spillover mechanism include the compatibility of new knowledge and firms that invest in R&D developing their own capacity to adapt new technologies and concepts developed by other firms, and thus developing the ability to capture some of the returns associated with external investments in new knowledge (Cohen and Levinthal, 1989). Correspondingly, knowledge spillover mechanisms depend significantly on the movement of skilled human resources and knowledge agent spin-offs. Audretsch (1998) noted that scientists, engineers and other knowledge workers are all agents with new economic knowledge, but that effectively profiting from that knowledge depends mainly on whether the scientist or engineer, in developing knowledge, can make further progress on developing their new knowledge within an organisation that recognises the value of that knowledge. Restated, firms provide the appropriate value of specific new knowledge to compete for knowledge agents, a process that causes knowledge workers to transfer their knowledge to another firm by either changing jobs or creating their own spin-off, resulting in knowledge spillover. Through such spillover, knowledge agents use innovative activity to extract the expected value of their knowledge.

The assertion that knowledge spills over is not really disputed, but the importance of knowledge externalities in the spatial clustering of economic activities is debated. Particularly, knowledge externalities are so important and powerful that no explanation appears to exist for why knowledge spillover should be constrained by geographical or spatial boundaries. Restated, knowledge does not stop spilling over simply because it meets certain geographical boundaries. This fact is illustrated particularly by important breakthroughs and is highly unpredictable because, as Glaeser *et al.* (1992, p. 1126) noted, "intellectual breakthroughs must cross hallways and streets more easily than oceans and continents".

Based on the idea that knowledge, or what is sometimes termed tacit knowledge, is sometimes vague, difficult to codify and generally only accidentally recognised, the cost of transmitting information across physical distances using modern telecommunication methods is constant, but the marginal cost of transmitting knowledge, particularly tacit knowledge, increases with distance. Thus, von Hipple (1994) explained that highly complex, contextual and uncertain knowledge, which he terms sticky knowledge, is best transmitted via face-to-face interaction and through frequent and repeated contact. Furthermore, most of this type of knowledge transmission proceeds by casual personal contact. Another key potential facilitator of such social interaction, besides frequent discussions, is geographical proximity, which stimulates imitation by firms and increases the struggle to attract key talent and thus enhance competitiveness.

Thus, increased relevance of new knowledge and greater innovation capacity of specific industries are more useful for technologically leading firms in achieving further innovations and thus maintaining a competitive advantage (Breschi, 2000). Consequently, strong clustering of related departments facilitates the geographical clustering of innovative activity. Owing to the internal connectivity of a general structure, degree of specialisation and regional industrial foundation, the growing numbers of firms in related industries in a region enjoy increased opportunities to interact with the first users of new technologies. Consequently, the speed at which information on specific technologies circulates increases owing to the mobility of high-tech personnel or spin-offs.

2.2 *Spin-offs and the Spread of Technology*

Firms in a local system have frequently been claimed to share, imitate or derive advantage from structures with similar cultures and mechanisms. Moreover, economic globalisation has also been driven partly by a decrease in the importance of the elements of traditional localised production and a progressive increase in the returns achieved by parts of knowledge-based and learning-type economies (Malmberg, 1997). Furthermore, in response to threats from innovative R&D, firms within a cluster seek active and long-term co-operative partners or organisations to spread risk through division of production labour. This situation is likely to cause technological interdependence and path dependence. Technological interdependence refers to a form of mutually beneficial structural interaction between technologies or obstacles to technological development. The path-dependence model considers situations in which competing technologies already exist and in which decisive technological developments are concentrated within industries (Cowan and Hultén, 1996). Consequently, economic and technological connections exist among various industries. As Dahmén (1989) emphasised, the presence of development obstacles implies that, during development, the solution of problems is not restricted to a single industry, but rather occurs through the establishment of spin-offs through the innovative activities of agents in related industries.

In the present era of the knowledge-based economy, the establishment of local networks, research and technological development, and collective learning are all key elements in future local and regional development and attraction. Regarding the spin-off and acquisition of related technologies, small new high-tech firms have two key sources of scientific and technological human resources: institutions of higher learning and established existing firms (Oakey, 1985). Consequently, new firms are likely to cluster around universities, research institutions and existing firms. This situation generally tends to generate stable, but possibly uneven, growth across regions. Regions with internally undertaken technological development enjoy relatively stable and rapid growth. In contrast, other regions grow more slowly. The presence of universities with innovative research facilities and well-established and large firms is a useful indicator of the potential for creating successful clusters of local technology-centred small and medium-sized enterprises (SMEs) via spin-offs and technology transfers (Feldman and Florida, 1994). Accordingly, large and medium enterprises pursue innovative R&D and long-term growth through technology acquisitions and spin-offs.

Technological change affects economy growth most significantly during technological expansion. Regions that are backward in the development and application of new technologies will suffer industrial decline. However, during technological expansion, the application or use of technologies is not merely a simple function of knowledge, but also involves firm capacity to replace present technologies, and depends on assessment and testing. Secondly, during the application of innovation technology, most required information is transferred through individual, interpersonal contacts, supporting innovation flow. The development of connecting institutions and the use of interpersonal communication networks thus are crucial for expansion. Consequently, the mobility of skilled personnel and the establishment of spin-offs facilitate accelerated technological expansion. The creation of spin-offs is crucial for co-operation and unconscious collective learning in a given area. Notably, spin-offs are more frequent and more important than instances of conscious, formal co-operation.

2.3 Technological Infrastructure and Interaction within a Technological Community

Regional technological infrastructure lies at the core of technological system innovation and analysis. In particular, universities, research institutes and other regional technological infrastructure, and interactions among firms, create a localisation effect. For example, recipients of technological transfers can only really learn new knowledge and technologies by working with researchers or innovators, or by undertaking joint experimental research (Zucker *et al.*, 1994). Thus, although modern highly developed IT and telecommunications technologies can reduce transaction costs, innovation still depends on geographical proximity for face-to-face communication. Furthermore, such physical clustering differs from clustering in traditional economies, where the focus is on reducing transaction costs and price competition. Given such spatial clustering, local competition within the wider environment increases following agglomeration, the acquisition of more information and the development of a mature technological infrastructure. Competition is also facilitated by the need to meet the challenge of the constantly decreasing periods for which companies can maintain their competitiveness.

Accordingly, from the perspective of technological infrastructure, the emphasis should be on the need for innovative activities to rely on connections between various resources and organisations. The different resources and organisations include the manufacturing capabilities of networks of firms related to local industries with long histories of development and R&D, capabilities of firms and universities, and the extent of agglomeration of specialised and commercialised support service industries (Feldman and Florida, 1994). Restated, these specific areas develop various innovation-related technological capacities. Such a technological infrastructure forms an industrial network for maintaining local clusters of sustainable development by strengthening the connections among various innovating, nurturing-oriented, research and development-oriented and mass production-oriented support spaces and related producer services (Hu *et al.*, 2005).

In local industrial clustering, scientific and technological interactions between academic and research organisations and firms within high-tech industries comprise part of the technological infrastructure. Such technological infrastructure facilitates the production, transfer and application of knowledge, information and technology. Furthermore, the search for evidence of the interaction between academic and research institutes and industry has already generated a very large body of research and related literature, characterised by its review and discussion of interaction mechanisms between industry and academia. Of all useful and feasible mechanisms, academic research has focused especially on the industrial clustering following from spin-offs in science parks. Science parks have more mature and proactive mechanisms for establishing basic infrastructure. Such infrastructure can help to establish and strengthen interactions between academic and research institutes and firms, as well as interactions within high-tech talent communities (Bell, 1993).

Given the success of science parks within industrial clusters, most existing research and literature stresses the importance of academic and research institutes (Monck *et al.*, 1988; Massey *et al.*, 1992; Westhead and Batstone, 1998). Restated, most current and past research, both in Taiwan and elsewhere, has discussed the links established between firms within science parks and neighbouring academic and research institutes from the perspective of physical proximity by comparing firms inside and outside science parks, and clarifying the interaction between firms and academia within an area. Furthermore, these investigations have established a reasonably clear understanding of the establishment of connections between industry and academia, and especially of links formed in industrial clusters in science parks.

Accordingly, science parks are essential to all attempts to improve expected relationships and mechanisms. However, Massey *et al.* (1992) have noted that the extent of these links is unclear. Although geographical proximity among firms and academic institutions is important in maintaining and promoting industrial clustering, both within science parks and in surrounding areas, to promote interaction between industry and academia, whether the close relationships between scientific and high-tech talent and firms encouraged by this close proximity are a significant promoter or strengthener of these links remains uncertain. Spatial proximity between firms and academic institutes (such as that provided by science parks) incrementally influences interaction between firms and academic and research organisations. Such interaction also stimulates knowledge, information and even technology exchanges among co-operating high-tech personnel. However, research on the interactions between technological communities within industrial clusters is scarce. Still, a lack of documentary evidence and research into this and related topics has not prevented policy-makers from extensively promoting the spatial proximity of co-operative partners to provide a basis for assessing the establishment of science-based parks.

In summary, the above literature review demonstrates that, from the perspective of regional economic innovation, science-based parks and the industrial clusters that slowly evolve around them can be used to encourage local economic development. Furthermore, the critical determinants of the effect of clustering are interactions within the community and network links; which in turn rely on the establishment of an initial basic infrastructure and input from a sustainable technological infrastructure. Consequently, this investigation analyses whether interactions within the technological community among spatially close firms in science parks, can consolidate the connections on which innovative activity depend.

3. Research Hypothesis and Data Collection

3.1 Hypothesis

The presence of neighbouring research facilities was traditionally believed to enhance industrial cluster productivity. Some investigations have also hypothesised the existence of a positive correlation between firm innovation activity and physical proximity and interaction with neighbouring research facilities. Relationships also have been identified between innovation activities and the extent of industrial clustering (Baptista, 1996; Baptista and Swann, 1998; Breschi, 2000; Wu and Chen, 2001; Yang and Chen, 2001). However, other works have found that, despite industrial clustering promoting innovation, interactions and links among firms within the same area are relatively weak (Hart and Simmie, 1997; Hart, 2000).

Given this discrepancy, this investigation first attempts to analyse the development of local clustering by addressing innovative activity and interactions within production chains in industrial clusters in the Hsinchu area of Taiwan. Then, at an individual level, this investigation addresses the relationships within technological communities that follow from knowledge agent spin-offs and high-tech talent mobility. The geographical relationships between knowledge agent spin-offs and high-tech talent mobility and the innovative activities of industrial clusters are also clarified. Finally, the two hypotheses are tested statistically. Documentary evidence and responses to a questionnaire survey of firms and high-tech personnel within the HSIP are analysed. It is hoped that the analytical results can verify the two following hypotheses.

(1) No correlation exists between the innovation activities of firms within industrial clusters and interaction among high-tech talent via formal and informal channels;[1]
(2) No clear relationship exists between the innovation activities of firms within industrial clusters and high-tech spin-offs or talent mobility.

3.2 Data Collection and Analysis

To date, the Taiwanese high-tech industry has been heavily concentrated in the Hsinchu area.[2] Government planning and the establishment of a science park and other industrial parks have boosted this trend. Several potential causative factors must be considered (see Figure 2). For example, is this trend related to the abundance of high-tech R&D resources in the surrounding area, the plentiful supply of technologies, the human resources most required by high-tech firms from related research institutes in this area, or the maturity and community of interacting technological specialists? Also, is industrial innovation

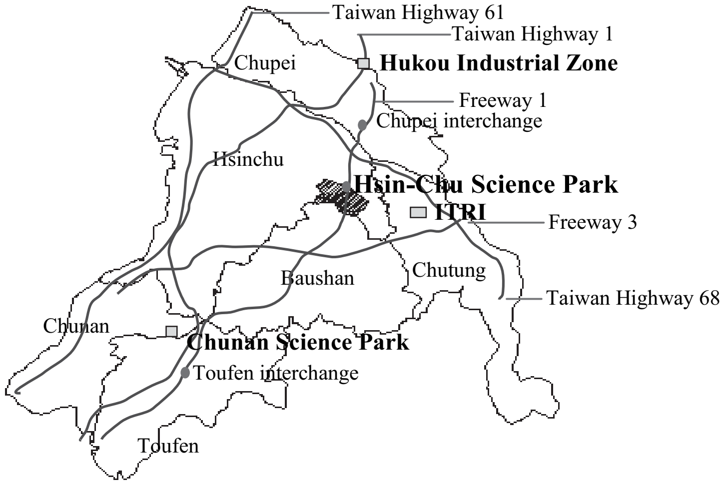

Figure 2. Hsinchu district: location, major infrastructure and urban characteristics.

related to interaction between high-tech personnel and spin-offs?

In answering these questions, this investigation first analysed data on government-sponsored corporate Industrial Technology Development Programmes (ITDP)[3] from the Industrial Technology Research Institute (ITRI), the company prospectuses of corporations within the HSIP[4] and information on patents held by firms in the HSIP to examine production chain innovation and interactions for firms within the Hsinchu industrial cluster (see Appendix).

Secondly, the social interaction of high-tech personnel at firms within the HSIP was surveyed. The survey questions dealt with three areas—frequency of interaction among high-tech personnel, mobility of high-tech talent and firm innovation performance. The frequency of social interaction among high-tech personnel was divided into four categories: three or more times weekly; once or twice per week; at least once a month; less than once a month. The mobility of high-tech talent was divided into three categories: changing jobs annually; changing jobs every 1–3 years; changing jobs every three years or more. Firm innovation performance was based on the number of ROC patents obtained in the period from 1995 to 2001 and was divided into 3 categories: 10 or fewer patents; 11–50 patents; and over 50 patents. Some 36 companies were surveyed. The firms were in the integrated circuit, computer and peripheral, telecommunications and opto-electronics sectors. Some 600 questionnaires were distributed and 243 usable responses were returned. The results of the survey are analysed below.

4. Innovation and Production Chains in Industrial Clusters

The influx of research organisations, academic institutions and R&D activities in the Hsinchu area has contributed to the marked regional clustering of the high-tech industry. As Baptista (1996) noted, knowledge economy activities or innovative activities generally are concentrated in areas that are rich in scientific knowledge relevant to the specific industry. Restated, given the proximity, knowledge stimulates interaction, which in turn fosters more effective knowledge production and transfer. This process leads to new knowledge-based economic activities becoming concentrated in particular geographical regions (Audretsch, 1998).

During the second decade of rapid development in the HSIP (1990–99), approximately 25 per cent of the 171 new firms established at the HSIP were spin-offs established by

ITRI. These spin-offs constituted the original local technological infrastructure. Of these spin-offs, 10 firms were successfully developed by ITRI's Incubation Centre, which was established in 1996. Moreover, during 1996–2003, approximately 80 per cent of the firms developed by the Incubation Centre chose to locate in the Hsinchu area (including 40 per cent in the HSIP and 38 per cent elsewhere), establishing a local innovation chain that begins with research and development, is followed by incubation and results in the spinning-off of a new company.

Secondly, during the government-sponsored ITDP from 1994 to 2000, almost 90 per cent of partner firms in the IT and electronics industries were in northern Taiwan. Within the Hsinchu area, most technology transfers, in terms of both frequency and value, occurred in the IT and electronics industries. The financial value of technology transfers in the Hsinchu area represented approximately half of the value of all such transactions in northern Taiwan (Table 1). Over 80 per cent of all technological transfers in all industries[5] in the Hsinchu area were in the IT and electronics industries (Figure 3).

In relation to Taiwan as a whole, and even to the northern region in which IT/electronics is concentrated, firms in the Hsinchu area are highly specialised. However, this situation begs the following question: does this specialisation and centralisation create a realistic and close-knit industrial network? Consequently, besides addressing transfers of technology under government-sponsored ITDP and production and co-operation among firms, this work also discusses the area production chain based on the collected company prospectuses, with reference to firm investment in production and the spatial distribution of production.

Technological co-operation among firms in various industries involves five main types. Two forms of contracted technical co-operation, involving licensing or transfer of technology, together comprise most co-operation. These types are followed by achievement transfer, technological co-operation and patent licensing. Table 2 reveals that most co-operating R&D partners in the integrated circuit, computer and peripherals, telecommunications and opto-electronics industries, already mentioned, as well as in other industries, are research or academic institutions in the Hsinchu area, with ITRI at the centre and National Chiao-Tung University and National Tsing-Hua University at the periphery. This arrangement is the same as for ITDP-related technology transfers, mentioned earlier.

Moreover, most contracts governing technological co-operation involve technology transfer. The second-largest number involves technology licensing. In contrast, most technological co-operation contracts between local and other firms are in the integrated circuit industry (over 70 per cent). Furthermore, most contracts for technological

Table 1. Technological transfer of electrical and electronic machinery in Hsinchu district and Northern Taiwan Region, by number of companies and value

	Hsinchu district		Northern Taiwan		The ratio of Hsinchu district/Northern Taiwan	
	Number of companies	US$ (thousand)	Number of companies	US$ (thousand)	By number of companies	By US$
2000	71	4500	224	9720	0.317	0.464
1999	64	1840	207	5670	0.309	0.324
1998	79	3280	231	6380	0.342	0.514
1997	44	1350	168	2980	0.262	0.454
1996	52	4650	165	6040	0.315	0.770
1995	28	1000	103	2650	0.272	0.378
1994	49	1050	198	4660	0.247	0.227

Source: ITRI.

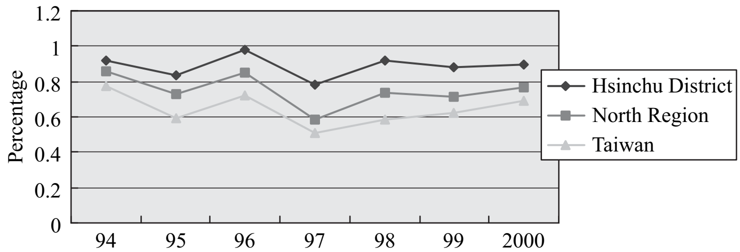

Figure 3. Ratio of technology transfer of electrical and electronic machinery in manufacturing industry by geographical hierarchy.

co-operation involve foreign firms, followed by firms from northern Taiwan. Domestic research institutions represent most firm-contracted technological co-operation partners, with nearby institutions comprising the largest fraction. Furthermore, technological relationships among local firms are weaker than those with domestic research institutions, even among firms in the same area.

Additionally, the production and trade networks of firms within the HSIP (Figure 4) are such that interaction, including critical investment and product sales, with firms in northern Taiwan is quite extensive (exceeding 70 per cent). Meanwhile, the production and trade network involving firms outside the HSIP but within the Hsinchu area is relatively weak. Accordingly, combining the previously mentioned ITDP technology transfers, technological co-operation contract relations and production trade networks yields the initial results of this work, indicating that northern Taiwan is a complete and comprehensive local industrial cluster characterised by clustered trade interaction and weak innovating interactions.[6]

However, the results also indicate that the Hsinchu area is characterised by spatial proximity or interaction with overseas firms in innovative technological interaction. Furthermore, new firms tend to cluster in the Hsinchu area. On maturity, around 40 per cent of these corporations are likely to expand further in northern Taiwan after 3–5 years. Some firms might even, after 5–8 years, go beyond their current cluster to form links with other clusters, especially clusters in mainland China.

Recently, almost 30 per cent of firms in the HSIP had already opened offices in or shifted production to mainland China. Consequently, innovation and production links that have developed in the Hsinchu industrial cluster hide specific interactive factors that have attracted firms to the area to compete for economic agents with endowments of new knowledge, high-tech personnel, knowledge, information and other interaction advantages, while simultaneously becoming magnets

Table 2. Partners and geographical distribution of R&D co-operation within industries (percentages)

	Partner			Geographical distribution		
	R&D institutes	Firm	Hsinchu District	Northern Taiwan	Other	Overseas
Integrated circuits	27.6	72.4	38.8	22.9	3.8	34.5
Computer and peripherals	88.9	11.1	88.9	0	0	11.1
Communications	80	20	60	26.7	0	13.3
Optical electronics	73.9	26.1	65.1	8.6	4.6	21.7

Source: Prospectus of listed Companies, Taiwan Stock Exchange Corporation.

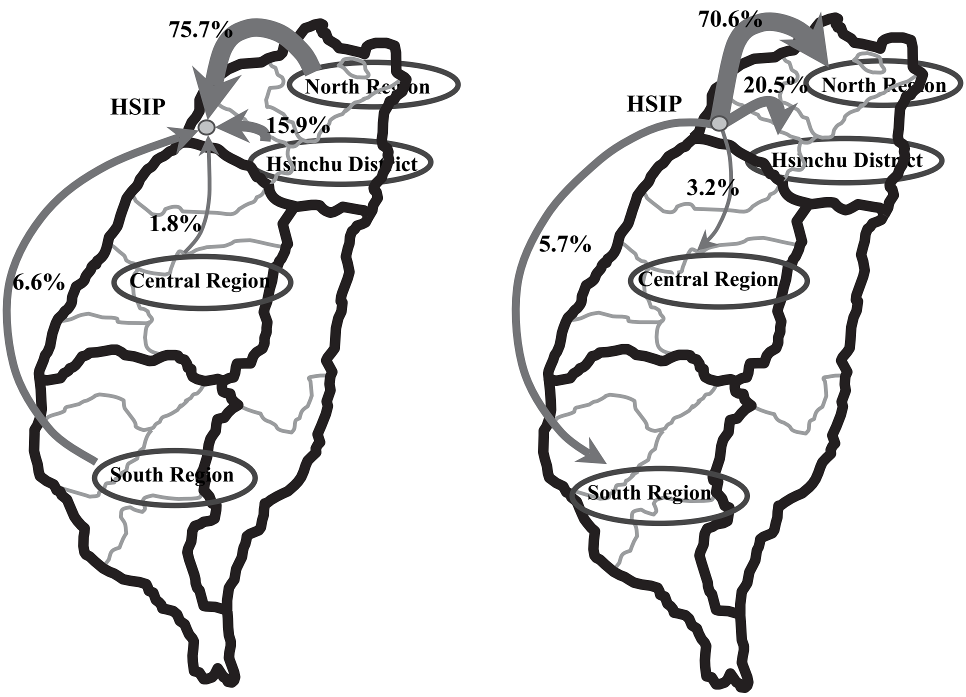

Figure 4. Input network (left) and output network (right) in Hsinchu district.

attracting high-tech talent to the area. Consequently, this investigation analyses how the high-tech talent interactions influence innovative activities.

5. Analysis of Results

This work investigates innovative knowledge-dependent industrial clustering and the relationship between cluster innovation activities and the high-tech community. It attempts to clarify whether spatial proximity, besides positively influencing firm interactions, increases talent mobility and the generation of spin-offs in technological communities, thus promoting community formation and encouraging the accumulation of local innovative activities. Secondly, it attempts to verify the previously stated hypotheses regarding whether a clear relationship exists between firm innovation activities and interaction among high-tech talent, and whether a clear relationship exists between firm innovative activities and spin-off set-up, or the mobility of, high-tech talent.

5.1 Analysis of Basic Data

A total of 243 effective responses were obtained from a questionnaire surveying high-tech personnel. Most of these samples (53 per cent) were taken from personnel in the integrated circuit industry; the remainder, in order, were obtained from the opto-electronics industry (18 per cent), the computer and peripherals industry (17 per cent) and the telecommunications industry (12 per cent). The educational levels of the subjects were as follows: doctorate (PhD), 8 per cent; Master's degree, 40 per cent; Bachelor's degree, 45 per cent; and vocational college certificate, 7 per cent. Periods of employment at the HSIP were as follows: 8 per cent of subjects had worked at the HSIP for over 10 years; 24 per cent had worked there for 5–10 years; 40 per cent had worked there for 2–4 years; and 28 per cent had worked there for less than 2 years. Most of the subjects were between 30 and 39 years old (52 per cent); 26 per cent were under 30 years old and just 3 per cent were over 50 years old.

5.2 Information Mobility in Technological Communities

The close proximity to research/academic institutions and large firms promotes knowledge spillover. Moreover, the mobility of knowledge and information among high-tech personnel within the workplace reinforces this effect. A study of the processes by which knowledge and information are obtained by workers while at work revealed that, first, when high-tech personnel encountered difficulties or problems at work, almost 72 per cent of them followed internal company procedures and obtained the information they required via formal information channels, while the remaining 28 per cent obtained this information via informal channels—for example, through seeking the assistance of, or discussion with, friends in related industries within or outside the HSIP.

Secondly, those who used informal channels to gain knowledge or information tended to switch jobs within the HSIP more frequently than those who obtained information via formal channels (Table 3). Personnel who obtained knowledge or information via formal channels tended to prefer to work at large and prestigious companies within the HSIP. However, most personnel who obtained knowledge or information through informal channels tended to favour small, high-profit firms within the HSIP, with their second choice being new firms, with significant potential for innovative activities (Table 4).

In seeking knowledge or information via informal channels, 50 per cent of subjects confirmed the accuracy or validity of the information obtained through numerous cross-references. Another 32 per cent of users of informal channels determined the accuracy of the information obtained from the information suppliers. Although this situation appears overall to involve collective learning, firms within related industries are really competing with one another; therefore, information from a single source is unreliable. This situation is frequently referred to by papers on industrial theory discussing competition and co-operation among employers and employees, respectively. The extent of competition and co-operation varies significantly, mainly because most information is obtained via informal channels, and not only varies according to the supplier, but also requires verification from other sources. One possible positive result of the abundant and diverse range of sources of information made available by this type of co-operation is that high-tech personnel benefit from more ideas and stimuli.

Critical knowledge is difficult to obtain, even via informal channels, and thus nearly 20 per cent of the R&D and technology personnel interviewed said that they extended their informal channels for obtaining information to classmates and friends abroad, most of whom were located in Silicon Valley.[7] Consequently, nearly 20 per cent of Silicon Valley high-tech personnel who have interacted with the HSIP have, at some time, invested in a newly created high-tech firm in Taiwan. Based on such interaction, many Silicon Valley high-tech personnel have also stated their enthusiasm for working for a new company in Taiwan, should the opportunity arise (Saxenian and Hsu, 2001).

Table 3. Turnover times vs problem-solving technique (percentages)

	Turnover times					
	0	1	2	3	4	Over 4
Informal channels	0.5	1.8	4.5	5.5	2.5	13.2
Formal channels	3.7	21	15	10.8	13.3	8.2

Table 4. Planned frequency of changing jobs in HSIP vs problem-solving technique

	Planned to change jobs in HSIP		
	Well-known companies	High-bonus companies	Start-up companies
Informal channels	3.5	14.5	10
Formal channels	57	8	7

Consequently, the high-tech human resource market, which has been developed by the agglomeration of firms in related industries in the Hsinchu area, is not the only important influence on production, and competition among high-tech personnel to realise increased knowledge value is another determining factor. Moreover, firms can establish new knowledge teams or opportunities from this pool of competing experts. Firms may even be able to establish a network to facilitate the movement of information across various fields and regions, such as the long-standing movement of information between Taiwan and the US, or the more recent information network between Taiwan and mainland China.

5.3 Human Resource Mobility in Technological Communities

The rate of turnover of engineers and skilled employees exceeded that of all other high-tech personnel in firm manufacturing departments. Meanwhile, the second highest rate of turnover was for skilled personnel in sales and R&D departments. Of these, approximately 37 per cent changed jobs every 2–3 years and 25 per cent changed jobs every 1–2 years (Table 5). In contrast, 42 per cent of high-tech personnel expected to remain in their current place of employment for up to 3 years; 28 per cent estimated that they would keep the same job for 3–6 years, and just 6 per cent planned to remain in the same job for over 10 years.

In this respect, a comparison may be made with the Tainan area in the south of Taiwan. The Tainan Science-based Industrial Park (TSIP) was established in Tainan in 1996. According to the TSIP administration, 50 companies in TSIP had an annual production of US$5000 million and a total of 10 000 employees at the end of 2003. The rate of turnover of engineers and skilled employees exceeded that of all other high-tech personnel in firm manufacturing departments. Of these, over 50 per cent change jobs at least every 3 years. Job mobility is less frequent at TSIP than at HSIP. This difference suggests that TSIP remains in the initial development stage, with around 40 per cent of firms there being branch firms from HSIP, and most R&D departments continue to be concentrated in HSIP. This difference between the two parks in terms of job mobility also emphasises that information access, technological skill and socio-demographic characteristics significantly influence job mobility.

However, a comparison of the expected period in a particular job with the actual period in a particular job demonstrated that the actual time spent with one employer before switching to another job was considerably less than the time that respondents specified that they expected to spend in a job. This finding suggests that specific factors influence mobility. These factors can be divided into four major categories: unattractive salary and bonuses (profit-sharing) at the current place of employment (accounting for 56 per cent of mobility); lack of challenging work at the current place of employment (15 per cent); transition of an entire work team to a new place of work owing to an innovative technology (9 per cent); and, desire of an individual to remain within the HSIP despite their job being moved elsewhere (8 per cent). Moreover, statistical analysis

Table 5. Turnover vs relationship with former colleagues (percentages)

	Frequency of turnover (years)				
	Under 0.5	0.5–1	1–2	2–3	Over 3
Competitive	—	—	—	—	10
Sharing experiences and discussion	—	—	18.5	32	—
Keep connection to get job information	—	20	6.5	5	—
Seldom connection	3	—	—	—	5

demonstrated that the frequency with which personnel who listed 'unattractive salary and bonuses at the current place of employment' and 'transition of the entire work team to a new place of work as a result of innovative technology', as influences on mobility, was generally once every 2–3 years.

The results also demonstrated that most of those surveyed—namely, around 60 per cent—claimed that the most popular destinations within the HSIP were large, prestigious firms, regardless of their innovative ability.[8] Newly created firms explained just 17 per cent of movement between jobs.[9] Since employees work for these newly created firms, they would generally take higher risk and lower salary than the large and prestigious firms. This finding indicates that the career paths followed by most R&D and skilled technical personnel are driven primarily by the desire to secure employment at large, mature firms with a good reputation and that such personnel are most attracted by company profit-sharing schemes and good company prospects. This result in turn indicates that such personnel lack the risk-tolerant mindset required for participating in the initial stages of new knowledge-based firms, as well as the entrepreneurial spirit required to establish their own companies.

Furthermore, when skilled personnel leave their HSIP jobs and seek employment elsewhere, they tend to select positions near the HSIP, within the knowledge-intensive service industry, related to their previous employment and with management consulting companies. Moves to venture capital investment companies are also popular (Table 6). These findings indicate that, owing to proximity to academic and research institutions, most R&D activity based in innovative ideas uses technological infrastructure for transfer or spin-off into new firms. Accordingly, innovative firms tend to cluster in the Hsinchu area. This situation stimulates the development of the productivity-related, knowledge-intensive service industry, reinforcing the formation of local innovation networks.

Table 6. Selected location vs job of personnel that had left HSIP (percentages)

	VC	Consulting firm	R&D institute	Other
Stay around the HSIP	22.2	41.7	16.7	13.8
Other area	—	5.6	—	—

Since most job turnover of skilled personnel employed within the HSIP occurs within 3 years of taking a job, the nature of subject relationships with former colleagues after changing jobs is interesting. This question is especially interesting when the new employer is competing with the previous one. Table 5 illustrates that respondents whose job turnover was between 1 and 3 years tended to maintain good co-operative relationships with their former colleagues and discussed problems and shared experiences. Personnel whose rate of job turnover was 6 months or less tended to maintain contacts to be used in the event of changing jobs again in the future. However, most personnel who changed jobs every 3 years either developed competitive relations with their ex-colleagues or minimised contact. This method of expanding professional networks displayed a similar result (Table 7). Interaction is mainly through informal personal contact or social gatherings. This type of contact is not only helpful in effectively timing job changes, but also in enabling teams working with innovative technologies to make career transitions when their technology matures, or establish new spin-offs.

5.4 *Innovative Chains within Technological Communities*

The analytical results of this investigation indicate that in-house R&D, local academic and research institutes, and foreign companies are the three main sources of technology for firms in the HSIP. R&D co-operation and product design co-operation among firms represent below 30 per cent of all responses. R&D co-operation is mostly on a different hierarchy in related industries. This situation is consistent with firms having different technological co-operation contracts, as displayed

Table 7. Extent of individual professional network vs turnover (percentages)

	Frequency of turnover (years)				
	Under 0.5	0.5–1	1–2	2–3	Over 3
Education and training	—	3.5	4.5	3	3
Attend seminar	—	2	8	3.5	2
Informal interaction or meeting	3	14.5	12.5	30.5	6.5
Attend project	—	—	—	—	3.5

in Table 2. Of the almost 30 per cent of high-tech personnel that engage in R&D co-operation or product design co-operation with other personnel, 26 per cent claimed that they engaged in face-to-face interaction at least 3 times weekly during co-operation, while 28 per cent said that this face-to-face interaction occurred at least once weekly (Table 8).

This high frequency of face-to-face interaction follows mostly from the fact that high-tech products have decreasing lifetimes and thus any problems must be solved quickly and efficiently. Furthermore, problems of design or engineering technology are best solved through face-to-face interaction. Those high-tech personnel who participate in co-operative R&D or co-operative design tend to participate more frequently and in more numerous research projects, training sessions and seminars than others, thus strengthening their innovation abilities and promoting innovation via such interaction (Table 9).

Given the decreasing life of high-tech products and the need to solve design or engineering technology problems immediately through face-to-face interaction, high-tech personnel mostly use formal channels to seek the assistance they require from their company and only as a second choice use informal information links between their company and nearby academic or research institutions or other firms. In contrast, since the accuracy of most information obtained though informal channels not only depends on the supplier of the information, but also requires verification from various sources, the efficiency in terms of time spent for information achieved by using this approach to obtaining information is generally lower than that obtained using other channels.

However, in expanding their own personal professional networks (Table 8), individuals who interacted face-to-face on at least a weekly basis developed their networks mostly through informal personal contact or social gatherings (about 30 per cent). Similarly, most skilled personnel who were not involved in R&D or design co-operation activities tended to expand their personal professional networks informally via personal

Table 8. Frequency of face-to-face interaction vs expanding individual professional network (percentages)

	Frequency of face-to-face			
	At least 3 times weekly	1–2 times weekly	1–3 times monthly	Less than once a month
Attend project	4 (0)	1.8 (0)	4.5 (0)	0 (0.6)
Education and training	3.5 (0)	5 (0)	7.5 (3.6)	3.4 (8.7)
Attend seminar	4.5 (0)	5.2 (0)	8 (4.6)	15 (3.5)
Informal interaction or meeting	14 (2.9)	16 (10.2)	6.5 (29.8)	1.1 (36.1)

Notes: Figures in parentheses denote the frequency of face-to-face without R&D/design co-operation.

Table 9. Personnel with or without R&D/design co-operation vs expanding individual professional network (percentages)

	Attend project	Education and training	Attend seminar	Informal interaction or meeting
With R&D/design co-operation	3.1	5.8	9.8	11.3
Without R&D/design co-operation	0.4	8.6	5.7	55.7

contacts or social gatherings; however, the frequency of their interactions was significantly lower than that of personnel involved in co-operation activities.

Most firms in related industries are in competition with one another. The primary reasons for these firms concentrating in the Hsinchu area are ease of obtaining information, availability of industrial support, presence of economic agents and other reasons related to better understanding of their competitors. Firm co-operation usually takes the form of international alliances with foreign companies, but co-operation with other firms around the HSIP also occurs in the form of horizontal collaboration across related industries or vertical integration, such that relations between firms are simultaneously competitive and co-operative, creating a strong competitive advantage for the HSIP and surrounding area (Hu *et al.*, 2002). Thus, interactive networks between local firms make a crucial contribution to the development of specific innovative activities.

Secondly, although firms within the HSIP and in surrounding areas contribute to the production chain, their contribution is limited to short-term, non-systematic production networking and thus their involvement in the local economy is weak. Restated, double-edged relationships between co-operation and competition prevent firms with such relationships from establishing deep roots in the local economy. This situation differs significantly from that described by most relevant studies, which see innovation and production networks as rooted in the high-tech region. However, it can be confirmed that innovation production networks motivate innovative industries to cluster in a certain area.

5.5 Hypothesis Testing and Verification

This investigation proposed two hypotheses: first, that no correlation exists between the innovative activities of firms and interaction among high-tech talent; and secondly, that no clear relationship exists between the innovative activities of firms and spin-off set-up or the mobility of high-tech talent. These hypotheses are based on an individual-level understanding of relationships within the technological community, supported by knowledge agents and spin-offs and high-tech talent mobility, as well as by the geographical connectivity associated with industrial clustering. The two hypotheses were tested using the chi-squared independence test, based on documentary evidence. The responses to the questionnaire survey of high-tech personnel within the HSIP were analysed to determine their validity.

Regarding the innovation performance of firms, various ROC patents, registered by firms between 1995 and 2001, were used to measure individual firm innovativeness. Firms were classified into three categories: those with 10 patents or fewer; those with 11–50 patents; and those with over 50 patents. Moreover, the responses of high-tech

Table 10. Testing Hypothesis (1)

Frequency of professionals face-to-face interaction	Performance on innovation		
	Low	Middle	High
At least 3 times weekly	0	1.6	8.2
1–2 times weekly	0.6	10.3	4.7
1–3 times monthly	18.8	14.5	1.3
Less than once a month	23.9	16.1	0

$\chi^2 = 84.24$; $p = 0.00$.

Table 11. Testing Hypothesis (2)

Interval of professionals' turnover (years)	Performance on innovation		
	Low	Middle	High
Under 1	9.2	10	3.8
1–3	29.2	28.3	4.5
Over 3	4.9	4.2	5.9

$\chi^2 = 12.11$; $p = 0.196$.

personnel were classified into four categories, depending on the frequency of interaction with other high-tech personnel: those who interacted with others socially at least three times per week; those who interacted once or twice a week; those who only interacted once a month or more, and those who interacted less than once a month. High-tech personnel were also grouped into three categories based on mobility, which was measured in terms of job-changing frequency: those who changed jobs every year; those who changed jobs every 1–3 years; and those who changed jobs only every 3 years or more.

The chi-squared independence test (Tables 10 and 11) demonstrates a significant correlation between firm innovation and the degree of interaction among high-tech personnel. ($\chi^2 = 84.24$ and $p = 0$). Accordingly, hypothesis (1) is false. Specifically, the correlation was strongest with the frequency of face-to-face interaction and the frequency and types of approaches used to develop professional networks. This finding shows that face-to-face interaction and the expansion of professional networks promote rapid knowledge flow and application. Thus, existing or newly created firms continue to attract other firms to agglomerate in the same area, despite possibly having no relationship with the local production network. Furthermore, statistical testing demonstrated no clear relationship between firm innovation and the spin-offs or mobility of high-tech talent ($\chi^2 = 12.11$ and $p = 0.196$). Therefore, hypothesis (2) is supported. However, this analytical result implies that, although high-tech personnel mobility or spin-offs support the establishment of industrial production networks and stimulate competition, they did not directly and significantly enhance innovation performance.

Additionally, this investigation also analyses the correlation between R&D investment and innovation performance (namely, patent numbers) to clarify the influence of interactions on innovation performance. Correlation analysis of R&D investment and innovation performance for samples used in this work reveals a positive correlation. However, this work also finds that the correlation coefficient differs markedly between including (0.805) and excluding (0.485) larger firms.[10] This analytical result demonstrates that the correlation between R&D investment and innovation performance in small and medium high-tech firms is less significant than in larger firms. Moreover, Table 12 illustrates that no clear relationship exists between firm R&D investment and the degree of interaction among high-tech talent. This analytical result implies that R&D investment is useful for innovation performance, but interactions among high-tech talent are significant in promoting innovation

Table 12. Frequency of face-to-face interaction vs R&D investment (percentages)

R&D investment (US$ millions)	Frequency of face-to-face			
	At least 3 times weekly	1–2 times weekly	1–3 times monthly	Less than once a month
Over 100	6.9	0	13.9	6.9
50–100	0	2.8	2.8	8.3
10–50	10.8	5.5	12.5	4.2
Under 10	5.5	6.8	4.2	8.9

activities. That is, it underlines the finding that, given increased R&D investment and more frequent interaction among high-tech talent, innovation activities strengthen small and medium high-tech firms in particular.

6. Conclusion

In knowledge-based economies, economic growth necessitates the acquisition, accumulation and application of valuable knowledge and information. Through the effective application of innovative knowledge in high-tech industries, technological knowledge and specialised human resources became the driving-forces of industrial cluster growth and continued economic development. Regarding industrial clusters, numerous studies have addressed the effect of knowledge spillover and diverse other factors in terms of geographical proximity. Related investigations have generally agreed that significant positive correlations exist between the innovative activities of firms and factors such as spatial proximity to academic and research institutions, and the level of industrial clustering. Namely, those firms in the industrial cluster can take advantage of the healthy and productive industrial environment with an abundance of specialised human resources. Closely examining and verifying the survey results in this study reveal that the close spatial clustering of technology firms favour repeated knowledge agent spin-offs and high-tech personnel mobility that then clearly influence the innovative activity of technology-based firms.

Survey results in this study demonstrate that the spatial proximity of firms clustering within the HSIP strengthens the interaction among high-tech personnel and the expansion of their professional networks; as a result, innovative R&D activities are effectively promoted. The geographical proximity of firms also facilitates rapid mobility of high-tech human resources within the industrial cluster and encourages the spinning-off of work teams. The study found that this process has directly and significantly improved innovative activity in the cluster and the establishment of industrial production networks.

Moreover, interaction among high-tech talent is particularly significant in encouraging innovative activities in small and medium high-tech firms. In Taiwan, more than 90 per cent of firms are SMEs; they can not compete with large firms in R&D investment. Thus, most SMEs, especially new high-tech entrepreneurs, tend to cluster in the Hsinchu area to benefit from knowledge-based advantages from various technology interactions. In order to generalise the findings of this study, further investigations on other clusters such as HSIP and TSIP should be conducted in the future.

Considering factors such as the intentions of R&D investment and activity, technology transfers, human resource spin-offs, production and trading interactions and so on, this study also determined that northern Taiwan consists of a complete industrial cluster. Firms in northern Taiwan tend to locate around ITRI and HSIP during the early stages of new products and the spin-off of young firms. When these firms have developed mature and extensive relationship networks, as demonstrated by an analysis of their production and trade interactions, they tend either to remain in an appropriate location within the northern Taiwan industrial cluster or alternatively establish connections with other clusters in order to integrate cross-boundary resources.

Additionally, the analysis in this study demonstrates the emergence of the synergies achieved through the linking with ITRI (the first R&D park) and HSIP (the first production and R&D park) in Taiwan. The interaction has also promoted the formation of an innovation cluster in the Hsinchu district and expanded the production cluster over the northern region of Taiwan. Furthermore, the technological infrastructure reinforced the innovation cluster.

Moreover, following the emergence of the new 'Golden Triangle' of the US, Taiwan and China during the mid 1990s, the establishment of cross-border interactions among-clusters has attracted considerable interest from high-tech firms and researchers. Cross-border interactions among clusters have significantly changed the conventional perspective of cluster dimensions and geographical connections. However, firms still rely on spatial proximity, establishing their R&D centres in Hsinchu or northern Taiwan, to fulfil the practical requirements for face-to-face interaction and reduce the risks associated with uncertainty and technological infrastructure costs. Local industrial clusters with close spatial relations and deep interactions within the technological community enjoy advantages in knowledge competitiveness.

Notes

1. Informal channels include personal contacts with researchers and personnel in related industries or academic/research institutes, the sharing of equipment and facilities, seeking information from related professional literature, private social activities such as book clubs or participation in academic seminars and other discussion activities. Formal channels include firms' joint investments and participation in R&D projects, co-operative research projects involving firms and academic or research institutes, and working with professional consultants.
2. Since 1997, almost 40 per cent of all R&D investment in manufacturing in Taiwan has been focused in the Hsinchu area and over 80 per cent of this investment has originated from companies in the HSIP. Moreover, 20 per cent of human resources for R&D (including researchers, technology personnel and support personnel) from all enterprises in Taiwan work in the HSIP and 23 per cent of all researchers in Taiwan work in the HSIP (National Statistical Centre, 2001).
3. ITDP include corporate ITDP, industry ITDP and university ITDP. Of these, corporate ITDP represent over 80 per cent. Most of these are associated with ITRI's science and technology projects (Source: 2001 ITRI's Technology Service Centre).
4. Prospectuses from firms within the HSIP were obtained from 37 integrated circuit firms, 9 computer and peripheral firms, 7 telecommunications firms and 12 opto-electronics firms, representing 33.3 per cent, 19.1 per cent, 13.7 per cent and 27.9 per cent of all firms in the corresponding industries in the HSIP. Most company prospectuses covered the period 1998–2001.
5. All types of industry include agriculture, forestry, fishery, animal husbandry and mining, manufacturing, water, electricity, fuel and natural gas, metal and mechanics, IT and electronics, chemical engineering, household trades, service and others (Source: ITRI's Technology Service Centre).
6. Technological co-operation contracts and trade networks that originate at the HSIP show that the degree of industrial clustering in the Hsinchu area is highest in the integrated circuit and opto-electronics industries, while the computer and peripherals, and telecommunications industries, tend to cluster throughout the entire northern region. Kung (1999) addressed the agglomeration of spin-offs in these four industries by analysing the family trees of enterprises in the area.
7. Saxenian and Hsu (2001) found that almost 10 per cent of Taiwanese high-tech personnel who had worked in Silicon Valley regularly exchanged work-related information with friends and classmates working in Taiwan. Those who said they only sometimes maintained contact with friends and classmates in Taiwan accounted for 62 per cent of this group. As many as 24 per cent of the high-tech personnel who worked in Silicon Valley and originally came from Taiwan said that they had at one time consulted for a Taiwanese company.
8. It implies that a few larger and/or prestigious firms currently maintain good returns, but do not actively promote R&D investment. Such firms are likely to gradually move to China in 5–8 years after set up (Hu *et al.*, 2003, p. 78).
9. Generally, newly created firms have large capacity for innovation and most of them are spin-offs—for example, from ITRI, Chiao-Tung University and Silicon Valley.
10. The larger firms with over 3000 employees include United Microelectronics Corp., Taiwan Semiconductor Mfg. Co. Ltd, Winbond Electronics Corp., Macronix International Co. Ltd and Macronix International Co. Ltd.

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Appendix

Table A1. Data summary

Corporation	Industries	Number of patents granted (1995–2001)	R&D expenditure (US$000s) (1996–2000)	Number of employees	Usable responses
United Microelectronics Corp.	Integrated circuits	3 292	641 750	8 578	16
Taiwan Semiconductor Mfg. Co. Ltd	Integrated circuits	2 449	638 250	13 777	18
Winbond Electronics Corp.	Integrated circuits	659	629 750	4 500	9
Macronix International Co. Ltd	Integrated circuits	280	481 400	3 800	10
Umax Data System Inc.	Computers and peripherals	268	62 150	233	5
Silicon Integrated Systems Corp.	Integrated circuits	117	142 030	1 650	9

(*Table continued*)

Table A1. *Continued*

Corporation	Industries	Number of patents granted (1995–2001)	R&D expenditure (US$000s) (1996–2000)	Number of employees	Usable responses
Micortek International Inc.	Computers and peripherals	113	89 250	280	5
AU Optronics Corp.	Electro-optical	82	75 250	6 400	9
Accton Technology Corp.	Computers and peripherals	81	101 150	1 500	6
D-Link Corp.	Telecommunication	65	81 200	1 584	8
Powerchip Semiconductor Corp.	Integrated circuits	64	223 100	1 700	7
Sunplus Technology Co. Ltd	Integrated circuits	43	66 560	447	4
Opto Tech Corp.	Electro-optical	34	23 700	920	5
CTX Opto-electronics Corp.	Electro-optical	28	37 500	1 600	9
Etron Technology Inc.	Integrated circuits	21	32 200	250	6
Faraday Technology Corp.	Integrated circuits	20	22 650	280	5
U-CONN Technology Inc.	Electro-optical	19	750	350	5
United Epitaxy Company Ltd	Electro-optical	19	7 950	600	6
Cyntec Co. Ltd	Electro-optical	19	4 850	430	4
Mediatek Inc.	Integrated circuits	17	—	282	6
Realtek Semiconductor Corp.	Integrated circuits	16	70 800	420	4
Weltrend Semiconductor Inc.	Integrated circuits	14	23 600	137	3
Airwave Technology Inc.	Telecommunication	12	—	60	3
Abocom Systems Inc.	Computers and peripherals	8	9 900	400	6
Microelectronics Technology Inc.	Telecommunication	8	57 050	1 200	9
Ultratera Corp.	Integrated circuits	8	—	790	5
Ambit Microsystems Corp.	Telecommunication	7	—	1 430	8
Syntek Semiconductor Co. Ltd	Integrated circuits	3	25 650	110	3
Analog Integration Corp.	Integrated circuits	3	1 600	145	4
Princo Corp.	Electro-optical	2	—	400	6
Taisil Electronic Materials Corp.	Integrated circuits	2	—	650	7
Vate Technology Co. Ltd	Integrated circuits	2	3 100	477	8
Sercomm Corp.	Computers and peripherals	1	7 200	187	5
Taiwan Mask Corp.	Integrated circuits	0	9 200	258	6
Cnet Technology Inc.	Computers and peripherals	0	9 550	250	6
Trace Storage Technology Corp.	Computers and peripherals	0	—	800	8

Sources: HSIP Business Directory (2002); Intellectual Property Office, Ministry of Economics Affairs, Taiwan (1995–October 2001); Taiwan Economic Journal Co. Ltd (1996–2000).