Exploring the interaction between incubators and industrial clusters: the case of the ITRI Incubator in Taiwan

Po-Hsuan Hsu, Joseph Z. Shyu, Hsiao-Cheng Yu, Chao-Chen Yuo and Ta-Hsien Lo

Institute of Management of Technology, National Chiao-Tung University, 1001 Ta-Hsueh Road, Hsinchu, Taiwan.
bentham.mt87g@nctu.edu.tw

This article aims to explore the interaction between incubators and industrial clusters, which is an important linkage for local development but has not been analyzed in the literature. A model is proposed to describe this interaction. The Industrial Technology Research Institute (ITRI) Incubator within the Hsinchu industrial cluster, the core of Taiwan's technology industries, is considered to be an empirical case. This case is investigated with the proposed model and methods including data analysis, in-depth interviews, manager surveys and stakeholder analysis. It was found that the clustering effect in the Hsinchu industrial cluster is a main factor in the ITRI Incubator's development. The ITRI Incubator in turn reinforces the cluster in some aspects as feedback. This result confirms the existence and importance of this interaction in local development. It is recommended that government officials and incubator managers take account of this interaction in operating an incubator program and utilize the proposed model to analyze the incubator's contributions to its industrial cluster.

1. Introduction

Incubators are widely considered to be an effective mechanism for connecting research institutes and local industries to inspire technology-based entrepreneurship and innovation. Most preceding studies aimed at describing and evaluating incubators to provide new research methods to assess incubators. The interaction between incubators and industrial clusters, which has only been vaguely discussed in the literature, is a critical subject but lacks of sufficient analysis (e.g., Smilor, 1987; Mian, 1997; Sherman and Chappell, 1998). We were therefore motivated to study how industrial clusters affect incubators and how incubators work as a component of industrial clusters. Based on Porter's (1990, 1998, 2000) models for industrial clusters, we propose a model to analyze this interaction.

Since 1996, the Taiwan government has supported incubator programs at universities and research institutes. The Industrial Technology Research Institute (ITRI) established its incubator, the ITRI Incubator, in July 1996. The ITRI

R&D Management **33**, 1, 2003.

Incubator was the first incubator in Taiwan and has demonstrated rapid growth over the past years. Among over fifty incubator programs in Taiwan now, the ITRI Incubator significantly outperforms other incubators in both scale and tenant number. We chose the ITRI Incubator as the empirical case because it is an appropriate representative for our topic: it is mature and has performed well. We conducted a series of in-depth interviews and found that the main factor influencing the ITRI Incubator's performance is the Hsinchu industrial cluster. We propose a model to elucidate and analyze the interaction between incubators and industrial clusters and apply this model to the ITRI Incubator case in the Hsinchu industrial cluster. The research methods used in this case include data analysis, in-depth interviews, manager surveys and stakeholder analysis. A positive-feedback interrelation was found: the Hsinchu industrial cluster affects the performance of the ITRI Incubator and the ITRI Incubator works as a catalyst to speed up innovation and enterprise. Both of these actions reinforce the local industrial cluster.

The rest of this article is organized as follows: previous relevant studies on incubators and industrial clusters are reviewed in section 2. A model of the interaction between incubators and industrial clusters is proposed in section 3. Some methodologies applicable to the proposed model are also discussed in section 3. An overview of the Industrial Technology Research Institute Incubator Center and the Hsinchu industrial cluster is described in section 4. In section 5, the interaction between the ITRI Incubator and the Hsinchu industrial cluster is analyzed using the proposed model. Discussions from this study are described in section 6.

2. Literature review

Researchers began to discuss the concept of incubators in the 1980s. At first, researchers focused on describing the economic benefits of incubator programs and on discussing the key factors in establishing successful incubators (e.g., Smilor, 1987; Culp, 1990; Mian, 1994). After the incubation conception became widely accepted, studies on incubators in the 1990s diverged in both research goals and methods. Some research proposed new concepts or frameworks (Blakely, 1992; Mian, 1996b); some developed new or integral methodologies (Mian, 1997; Sherman and Chappell, 1998); some analyzed the management practices of incubator operation (Autio and Klofsten, 1998), and still others assessed how incubators impact economic and technological development (Markley and McNamara, 1995; Mian, 1996a). The main research methods in the literature included single or multiple case studies, national or local questionnaire surveys, in-depth interviews with experts and managers, and data analysis. Additionally, some specific methods were also provided, such as perception surveys (Mian, 1996a), stakeholder analysis (Sherman and Chappell, 1998), and cost-benefit analysis (Culp, 1996). Because there is no consensus about the main index for effectiveness or what is a good measure of performance, feasible and tenable research requires multiple measures using both quantitative and qualitative methods (Culp 1996; Mian, 1997).

According to Porter (1990, 1998, 2000), an industrial cluster is a geographic cooperative group that includes suppliers, consumers, peripheral industries, governments, and supporting institutions like universities. He proposed a structure to analyze local clusters using the well-known four-dimension diamond metaphor that includes 'factor conditions', 'demand conditions', 'related and supporting industries' and 'firm strategy, structure and rivalry' (Porter, 1990, 1998, 2000). Hill and Brennan (2000) proposed another structure for an industrial cluster grounded on five elements: 'driver industries', 'technology', 'labor', 'consumer industries', and 'supplier industries.' They defined an industrial cluster as a system that made its component firms and institutes generate higher unit earnings and more efficient operations due to innovations stimulated by intense competition and cooperation within clusters (Hill and Brennan, 2000). Moreover, industrial clusters are widely considered to be an important factor for innovation, entrepreneurship and technology industries (e.g., Gover, 1993; Swann and Prevezer, 1996; Bergeron *et al*., 1998). Within industrial clusters, technological innovations and transference among elements are more efficient and more business ventures are generated.

From the literature review, we have made the following findings: the effects of industrial clusters on incubators have been vaguely referred

to (e.g., Smilor, 1987; Mian, 1997), but have never been systematically scrutinized. On the other hand, the same situation has occurred with how incubators impact their industrial clusters (e.g., Sherman and Chappell, 1998). Consequently, analysis of the interrelation between incubators and industrial clusters was insufficient in previous studies and requires more discussion. Moreover, there was no case on Asian developing countries reported in the literature. We therefore have good reasons to propose a model to analyze that interaction and use it on an empirical case in Taiwan.

3. The model and methodologies

Based on Porter's (1990, 1998, 2000) definitions and models, we have structured a model for the interaction between incubators and industrial clusters (Figure 1). Incubators are located in the center of four dimensions 'factor conditions', 'demand conditions', 'related and supporting industries' and 'firm strategy, structure and rivalry'. In this model, each dimension of industrial clusters not only interacts with the other dimensions buts also affects the incubators, and the incubators affect each dimension of the clusters correspondingly. This model is helpful to illustrate and to explain the interaction between incubators and industrial clusters, which has been mentioned only implicitly in former research. With this model, we may observe, describe and evaluate that important interaction.

To measure and describe the interrelationships shown in Figure 1, many methodologies provided by former researchers are applicable. Data analysis of the published and archived data is widely utilized in literature as an objective method for corroborating proposed models and hypotheses (e.g., Markley and McNamara, 1995). Based on data analysis, cost-benefit analysis provides comparable indexes for assessment (Culp, 1996). In-depth interview is a judgment-based method that can help researchers to understand the holistic system and the insider's operations, which are important for identifying critical factors and interactions (e.g., Smilor, 1987; Mian, 1994; Autio and Klofsten, 1998). Questionnaire survey is a multi-purposed method capable of measuring either substantial or intangible indicators (e.g., McKinnon and Hayhow, 1998). Through a questionnaire survey, tenant evaluations and perceptions (Mian, 1996a) and stakeholder analysis (Sherman and Chappell, 1998) are both practicable.

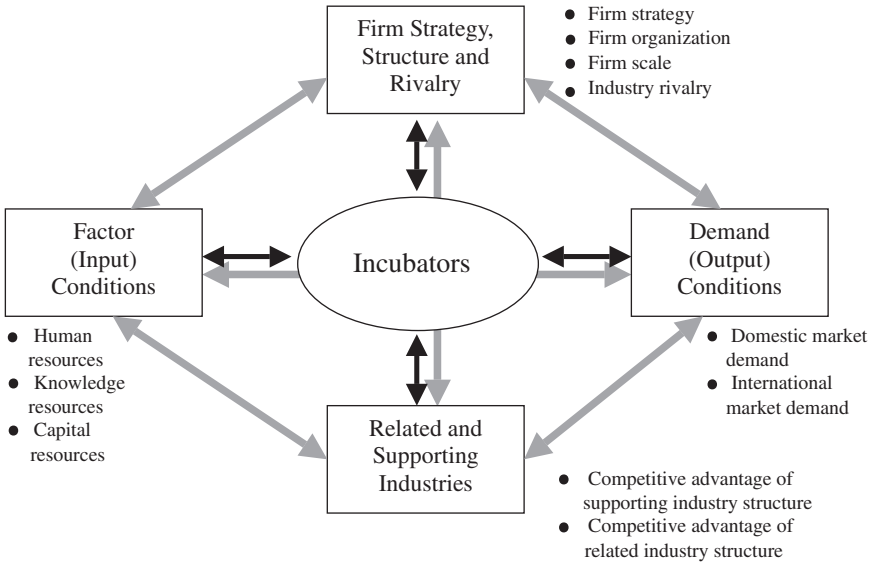

Figure 1. A model of the interaction between incubators and industrial clusters.

4. Overview: the ITRI Incubator and the Hsinchu industrial cluster

4.1. The ITRI Incubator

In July 1996, the ITRI Incubator began its operation with a 53,800 square-foot facility to accommodate its tenants. Its management team consisted of two managers and two assistants. Its mission was to 'help local entrepreneurs start-up their new technology-based businesses and contribute to the growth of innovation and the continuous regeneration of an environment conducive to entrepreneurship'. As the largest incubator program in Taiwan, the ITRI Incubator could accommodate 30–35 tenants in an 89,000 square foot facility by the end of 2001.[1] The ITRI Incubator's target capacity is to substantially incubate 30–35 tenants within a three-year average incubation period. After the incubation period, the ITRI Incubator would help its fledging tenants to apply for settlement admission into the Hsinchu Science-based Industrial Park (HSIP). The HSIP is a favorable industrial district that provides tax incentives and sound infrastructure for technology industries.

Since beginning in 1996, the ITRI Incubator has experienced rapid growth. The total number of tenants and graduated firms was 5 in 1996, 14 in 1997, 30 in 1998, 43 in 1999, 54 in 2000, and 64 in 2001. The average number of new tenants per year has been 14.75 from 1997 to 2001. From July 1996 to January 2002, the ITRI Incubator has created 1,760 job opportunities and attracted 177.38 million dollars in investment capital in several technology industries (see Table 1).[2] Some of those firms work in burgeoning technology industries such as opto-electronics and telecommunications, and others upgrade current industries such as semiconductors and precision machinery. In 1998, the average number of employees was 15.7 per tenant, which is much greater than the average 5.5 employees in other incubators in Taiwan (Su, 1998) and approximates the average 8.4 employees in the study by the University of Michigan, NBIA, Southern Technology Council and Ohio University (1997). Additionally, it is noted that employees of ITRI Incubator tenants are more highly educated in comparison to the employees of firms in HSIP and Taiwan's top 1000 companies (Common Wealth Magazine, 2000). In 1999, 6.5% of the ITRI Incubator tenant employees held a doctorate degree, while HSIP averaged 1.3% and Taiwan's top companies averaged only 0.4%. Of the ITRI Incubator tenants, an average of 28.5% of the employees held a graduate degree, 16.3% in HSIP and only 7.9% in Taiwan's top companies in 1999. The current 30 tenants in the ITRI Incubator (May 2000) have an average capital of $1.86 million dollars and an average R&D budget amounting to $1.49 million dollars.

Table 1. Overview of the ITRI Incubator tenants (by industry).

	Cumulative			Current		
Industry	Number of firms	Capital (million)	Jobs	Number of firms	Capital (million)	Jobs
Telecommunication	18	48.46	640	5	12.13	89
Integrated circuits	16	41.71	459	8	13.61	149
Precision machinery	6	17.64	182	2	4.37	29
Opto-electronics	5	11.99	103	1	0.67	20
Biotech and pharmaceutics	5	5.72	84	4	4.22	44
Chemistry and material	8	46.28	157	1	1	14
Software	5	5.56	134	4	3.56	57
Others	1	0.03	1	1	0.03	1
Total	64	177.38	1,760	26	39.58	403

Source: ITRI Incubator, January 2002.
Note: 'Cumulative' means the total number, including the people and capital of the tenants and graduated firms of the ITRI Incubator since July 1996. These data do not include additional employment of graduated firms after they left. 'Current' means the number of people and capital of the tenants in the ITRI Incubator in January 2002. The amount is in US dollars at the exchange rate of 30 NT dollars to 1 US dollar.

It is estimated that the R&D budget was $96,750 dollars per employee among the ITRI Incubator tenants, compared to $14,610 dollars per employee in HSIP in 1998. These indexes show the high investment and intensive R&D activities of the ITRI Incubator tenants.

There were 37 graduated tenants and one failed firm from the ITRI Incubator in 2001, making a 97.4% survival rate (still-in-business rate), a slightly higher rate than the 90% for technology incubators in the NBIA survey (University of Michigan, National Business Incubation Association, Southern Technology Council and Ohio University, 1997, p. 17). The three-year survival rate for small and medium enterprises (SMEs) in Taiwan is 72.3% (SMEA, 1998).[3]

To assess the quality of facilities and services provided by the ITRI Incubator and other incubators in Taiwan, we conducted a satisfaction survey on their tenants (details are described in Appendix A). The ITRI Incubator received a satisfactory ratio from over 80% of its tenants in nine questionnaire items (six items were related to the facilities and general business service; the other three items were 'legal consultation', 'venture capital channels', and 'training programs'). All other incubators received an 80% or greater satisfactory ratio in only two items. Moreover, the ITRI Incubator performed superior to the other incubators on nine items (more than a 30% difference in satisfactory ratio). Six items were related to the facilities and general business service, and the other three items were 'legal consultation', 'intellectual property rights protection' and 'venture capital channels'. These results verify the ITRI Incubator's advantages in facilities and some important business services, such as legal consultation and venture capital sources.

From 1996 to 1999, ITRI supplied a total of $624,700 to facilities and operation expenses at the ITRI Incubator. In addition, we estimated the costs of the space provided by ITRI as implicit costs in $0.4 per square-feet of space per month. Therefore, the cost of job creation has been $665 per job in the ITRI Incubator. By comparison, the cost is $1,109 per job at the members of National Business Incubation Association (NBIA) from a 1997 survey by the University of Michigan, NBIA, Southern Technology Council and Ohio University (1997). In 1999, only 41.8% of the ITRI Incubator budget was granted from ITRI, while an average of 66.5% of the budget for other incubators in Taiwan was supplied by Small and Medium Enterprise Administration (SMEA) (Su, 1998). This difference indicates that the ITRI Incubator is in a more efficient and effective operating situation. Finally, it is noteworthy that ITRI has received good rewards from operating the ITRI Incubator. In March 2000, 20 tenants and graduated firms signed research contracts with ITRI, which amounted to $3.26 million. Therefore, ITRI produces a $5.23 return from each investment dollar in the ITRI Incubator.

4.2. The Hsinchu industrial cluster

The Hsinchu industrial cluster is the pivot of Taiwan's economy and technology. The Hsinchu industrial cluster is defined to include the HSIP, Hsinchu City and Hsinchu County. There are four cornerstones in the Hsinchu industrial cluster foundation: ITRI, National Chiao Tung University (NCTU), National Tsing Hua University (NTHU) and the HSIP. ITRI is the leading industry-oriented research institute in Taiwan. The ITRI staff comprises the main R&D force and high technology entrepreneurial group in industry.[4] From 1986 to 1997, about 7,500 ITRI employees left ITRI. About 31.9% of these employees left for companies at the HSIP. Furthermore, 15.18% of these former ITRI employees hold positions as CEOs or board members (Hung, 1998). NCTU and NTHU are the two leading science and engineering universities in Taiwan. These universities have accommodated the technology industries in Hsinchu with well-educated human resources and R&D support over the past two decades.[5] Moreover, HSIP provides a favorable industrial environment for technology firms with many attractive incentives.[6] From the Hsinchu industrial clustering effect, the average personal income in Hsinchu City is $10.6 thousand per year, which is 20% higher than the average for Taiwan in 1999. The unemployment rates were 1.46% in Hsinchu City, 2.35% in Hsinchu County, and 2.82% in Taiwan. The average R&D investment of manufacturing firms was $3.63 million in Hsinchu City and $1.97 million in Hsinchu County, but only $0.52 million overall in Taiwan in 1999 (Ministry of Economic Affairs, 2000).

5. Exploring the interrelation between ITRI Incubator and Hsinchu industrial cluster

5.1. How the Hsinchu industrial cluster affects the ITRI Incubator

After observing the development and performance of the ITRI Incubator, we are motivated to study: 'which factor contributes to the ITRI Incubator's performance?' To answer this question, in-depth interviews were conducted with several experts, incubator managers and tenants (list of interviewees is in Appendix B). We found consensus in their opinions and judgments: the clustering effect of the Hsinchu industrial cluster is a main factor in the ITRI Incubator's performance.[7] To ascertain this finding from the in-depth interviews, we conducted advanced data analysis. From the data provided by the ITRI Incubator, the significant overlap in the backgrounds of the start-up teams in the ITRI Incubator confirms the effect of the industrial cluster. In the start-up teams of 30 tenants and graduated firms from the ITRI Incubator in 1998, eight entrepreneurs held degrees or faculty positions from NCTU or NTHU; 12 left from companies in HSIP, and 11 left from ITRI. In May 2000, more than 37.5% of the employees of the ITRI Incubator tenants were from ITRI.

Besides in-depth interviews and data analysis, a manager survey on incubator managers in Taiwan was carried out. We mailed questionnaires to all incubator managers in Taiwan to investigate the industrial clustering effects. The proposed model of the interaction between incubators and industrial clusters was utilized in the questionnaire design. The manager survey evaluated the incubator managers' perceptions on 11 items in the four dimensions of the proposed model (details are described in Appendix C). Incubator managers described their perceptions of each item on a 5-level scale (1 = strong negative effect, 2 = negative effect, 3 = no effect, 4 = positive effect, 5 = strong positive effect). We divided the samples into two groups by location, incubators within the Hsinchu industrial cluster or outside it, to compare the perceptions on the effects of the industrial clusters in their environments. It was found that three incubators within the Hsinchu industrial cluster (ITRI Incubator, NTHU Incubator, and NCTU Incubator) were far higher on average than others in every dimension: 4.8 versus 4.1 in 'factor conditions', 4.8 versus 4.2 in 'demand conditions', 4.9 versus 3.7 in 'related and supporting industries', and 4.8 versus 3.3 in 'firm strategy, structure and rivalry'. Using ANOVA, the means for the two groups were significantly different in all four dimensions under 10% significance levels. Therefore, the in-depth interview findings that the Hsinchu industrial cluster is a main factor in the ITRI Incubator's development was supported by data analysis and the manager survey in this study.

5.2. How the ITRI Incubator reinforces the Hsinchu industrial cluster

To examine how the ITRI Incubator reinforces the Hsinchu industrial cluster, we utilized data analysis and stakeholder analysis. In the data analysis, some indicators like R&D expenses, tenant survival rate and technical employment opportunity creation were presented in section 4.1. Moreover, 14 out of the 20 graduated firms in 2000 remained in the Hsinchu industrial cluster. This percentage, 70%, is lower than the 84% for incubators in North America (McKinnon and Hayhow, 1998). Those graduated tenants form the main pioneers of Taiwan's technology industries and they are expected to create more economic value and technological innovations for the Hsinchu industrial cluster.

Although the data analysis was objective, using it to gauge the incubator effects on industrial clusters is insufficient. The 'stakeholder analysis', developed by Sherman and Chappell (1998), is applicable to measure judgments or perceptions using a questionnaire for the incubator stakeholders, especially for some intangible and non-measurable effects. The 'stakeholders' in this study were defined as specialists who are acquainted with the incubator programs. We utilized the stakeholder analysis to describe and assess the impact of the ITRI Incubator on the Hsinchu industrial cluster using the four dimensions in our model (details are described in Appendix D). Like the manager survey, stakeholders were asked to describe their perceptions of the ITRI Incubator impact on 11 item from the four dimensions using a 5-level scale (1 = strong negative effect, 2 = negative effect, 3 = no effect, 4 = positive effect, 5 = strong positive

effect). Using Tukey multiple comparison, the degree of impact of the ITRI Incubator was ranked as 'factor conditions', 'related and supporting industries', 'demand conditions' and 'firm strategy, structure and rivalry'. Using the non-parametric Chi-square test, the ITRI Incubator exhibited as significant impact in the 'factor conditions' and 'related and supporting industries' dimensions. The results show that the ITRI Incubator has reinforcing effects on the Hsinchu industrial cluster and is significantly effective in developing key upstream and support industries.

6. Discussions

This study proposed an analytic model for the interaction between incubators and industrial clusters and utilized this model to analyze the empirical case of the ITRI Incubator within the Hinchu industrial cluster. Several applicable methods in utilizing this model were also presented in this empirical study. By our experiment, this model was validated as an effective framework. With this model, researchers and government officials can systematically analyze how an industrial cluster affects an incubator and how the incubator reinforces the industrial cluster. Incubator managers can utilize this model to identify their comparative operating advantages and promote their incubators to local governments and communities.

In the empirical case, the clustering effect was identified as a main effect in the ITRI Incubator's development and helped the ITRI Incubator to outperform other incubators in Taiwan. The ITRI Incubator's operation was found to activate local technology enterprises and enhance ITRI's R&D competence and finance. In the Hsinchu industrial cluster, the ITRI Incubator exhibited significant effects in 'factor conditions' and 'related and supporting industries' dimensions. These results corroborate the location effect on an incubator's performance and the incubator's impacts on its environment as mentioned in the literature. The confirmed interaction between the ITRI Incubator and the Hinchu industrial cluster provides a new approach to research in both incubators and local development. Moreover, this case study contributes to the literature on incubators by providing a successful case in Asian developing countries that were neglected in the previous research.

Based on the findings of this study, it is recommended that governments initiate technology incubators in the right place for the advantages of local clustering and technology diffusion. Officials of institutes and universities in developing countries are suggested to establish and operate incubator programs because, in the long-term, operating an incubator could create profits, promote local R&D activities and enhance local development.

Acknowledgements

The authors gratefully acknowledge the valuable suggestions and comments from the two referees and the editor. We deeply appreciate C.J. Chang and Walter Wu, the managers of ITRI Incubator, for providing the data and helpful opinions. Moreover, the authors owe much to all of the interviewees we visited for their valuable opinions. Finally, the authors appreciate the support received from Joseph C.Y. Hung, Benjamin Yuan and Shawn Kuo in the Institute of Management of Technology at National Chiao Tung University.

References

Autio, E. and Klofsten, M. (1998) A comparative study of two European business incubators. *Journal of Small Business Management*, **36**, 1, 30–43.

Bergeron, S., Lallich, S. and Bas, C.L. (1998) Location of innovating activities, industrial structure and techno-industrial clusters in the French economy, 1985–1990: evidence from US patenting. *Research Policy*, **26**, 733–751.

Blakely, E.J. (1992) Incubating high-technology firms: state economic development strategies for biotechnology. *Economic Development Quarterly*, **6**, 3, 241–254.

Common Wealth Magazine. (2000) *Taiwan's Top 1000 Firms Survey 2000*. Taipei, Taiwan: Common Wealth Publication.

Culp, R.P. (1990) Guidelines for incubator development. *Economic Development Review*, **8**, 4, 19–23.

Culp, R.P. (1996). A test of business growth through analysis of a technology incubator program. Unpublished doctorate dissertation, Georgia Institute of Technology.

Fan, J.L. (1992). *How ITRI researchers perform in private department*. Research report, Industrial Economic Research Center, Industrial Technology Research Institute (ITRI), Hsinchu, Taiwan (in Chinese).

Gover, J.E. (1993) Strengthening the competitiveness of U.S. microelectronics. *IEEE Transactions on Engineering Management*, **EM-40**, 1, 3–13.

Hill, E.W. and Brennan, J.F. (2000) A methodology for identifying the drivers of industrial clusters: the foundation of regional competitive advantage. *Economic Development Quarterly*, **14**, 1, 65–96.

Hung, J.C. (1998) How to cultivate human resource for high technology industry. Research report, Institute of Management of Technology, National Chiao Tung University, Hsinchu, Taiwan (in Chinese).

Lin, W.C. (1994). A study on the model of incubator in Taiwan. Unpublished master thesis, Institute of Management of Technology, National Chiao Tung University, Hsinchu, Taiwan. (In Chinese).

Markley, D.M. and McNamara, K.T. (1995) Economic and fiscal impacts of a business incubator. *Economic Development Quarterly*, **9**, 3, 273–278.

McKinnon, S. and Hayhow, S. (1998) *1998 State of the Business Incubation Industry*. Ohio: National Business Incubator Association (NBIA) Publications.

Mian, S.A. (1994) US university-sponsored technology incubators: an overview of management, policies and performance. *Technovation*, **14**, 8, 515–528.

Mian, S.A. (1996a) Assessing value-added contributions of university technology business incubators to tenant firms. *Research Policy*, **25**, 325–335.

Mian, S.A. (1996b) The university business incubator: a strategy for developing new research/technology-based firms. *Journal of High Technology Management Research*, **7**, 2, 191–208.

Mian, S.A. (1997) Assessing and managing the university technology business incubator: an integrative framework. *Journal of Business Venturing*, **12**, 251–285.

Ministry of Economic Affairs (MOEA). (2000) *The Census on Manufacturers in Taiwan, 1999*. Taipei, Taiwan: Ministry of Economic Affairs, (In Chinese).

Porter, M.E. (1990) *The Competitive Advantage of Nations*. New York: Free Press.

Porter, M.E. (1998) Clusters and competition. In Porter M.E. (eds), *On Competition*. Boston, MA: Harvard Business School Press.

Porter, M.E. (2000) Location, competition, and economic development: local clusters in a global economy. *Economic Development Quarterly*, **14**, 1, 15–34.

Sherman, H. and Chappell, D.S. (1998) Methodological challenges in evaluating business incubator outcomes. *Economic Development Quarterly*, **12**, 4, 313–321.

Small and Medium Enterprise Administration (SMEA). (1998) *White Paper on Small and Medium Enterprise in Taiwan 1998*. Taipei, Taiwan: (Small and Medium Enterprise Administration SMEA).

Smilor, R.W. (1987) Managing the incubators system: critical successful factor to accelerate new company development. *IEEE Transactions on Engineering Management*, **EM-34**, 3, 146–155.

Su, S.Y. (1998) *A Study on the incubation policy of small and medium enterprise: the circumstance of small and medium enterprise incubators in Taiwan*. Research report, Chung-Hua Institution for Economic Research, Taipei, Taiwan (in Chinese).

Swann, P. and Prevezer, M. (1996) A comparison of the dynamics of industrial clustering in computing and biotechnology. *Research Policy*, **25**, 1139–1157.

University of Michigan, National Business Incubation Association (NBIA), Southern Technology Council and Ohio University. (1997) *Business Incubation Works*. Ohio: National Business Incubation Association (NBIA) Publications.

Westhead, P. and Storey, D.J. (1995) Links between higher education institutions and high technology firms. *Omega*, **23**, 4, 345–360.

Notes

1. In McKinnon and Hayhow's (1998) study, the average number of tenants in incubators in North America was 20, and the median was 12 (p. 12). The average space for incubators was 36,657 square-feet (p. 10).
2. In this study, all monetary amounts are in US dollars based on the 1:30 exchange rate.
3. Because most incubators in Taiwan are younger than three years, it is not yet appropriate to evaluate their performance. Therefore, the tenant survival rate, tenant sales and capital growth of other incubators were not evaluated in this study.
4. Industrial Technology and Research Institute (ITRI), one of Taiwan's industry-oriented research institutes, was established in Hsinchu in 1973. ITRI is located adjacent to the Hsinchu Science-based Industrial Park (HSIP). ITRI is a semi-government-founded research institute with over 6,000 employees and a $500-million budget per year. The central government sponsors half of its budget and ITRI gains the other half from contract researches for private companies. It is also well known for spearheading the development of Taiwan's technology industries. For example, two large semiconductor foundry manufacturers, Taiwan Semiconductor Manufacturing Company (TSMC) and United

Microelectronics Corporation (UMC group), are ITRI spin-off firms. Additionally, employees who formerly worked at ITRI have become driving forces in the development of numerous technology industries. 75% of the staff leaving ITRI head into industry (Fan, 1992).

5. This case matches the research of Westhead and Storey (1995) that indicated out the importance of higher education institutions (HEI) for technology firms within a Science-based Industrial Park (SIP).
6. The HSIP was established with the aim of creating a center for the development of technology industries in Taiwan and to provide a high quality environment for new technology firms. It is situated between Hsinchu City and Hsinchu County, five kilometers East of ITRI, and covers an area of about 580 hectares as of 1999. Only high-tech and innovative firms are admitted into HSIP. Currently, there are six categories of firms in HSIP: Integrated Circuits (Semiconductors), Computers and Peripherals, Telecommunications, Opto-electronics, Precision Machinery, and Biotechnology. By the end of 1999, HSIP had a total of 292 companies with total annual revenue of about $21.7 billion, which is about 7.5% of the total GNP of Taiwan. Additionally, these firms have contributed $11.8 billion in exports, which is about 9.8% of the total exports of Taiwan. In line with the growth of technology industries, HSIP has become the most crucial industrial district in Taiwan and is the main production base for the technology industries.
7. Besides the clustering effect, there are some other reasons for ITRI Incubator's performance by interviewees: first, the commitment and full support of ITRI; second, the experienced manager team of ITRI Incubator.

Appendix A

In this satisfaction survey, there were 16 valid responses from 32 tenants and graduated firms from the ITRI Incubator (50% valid return rate), and 34 valid replies from tenants in other incubators in March 1999 (tenant list is from SMEA data of 1998) (16% valid return rate. This questionnaire has 43 items on four dimensions (facilities, general business service, professional

Table A.1. Average satisfactory ratio: tenants of ITRI Incubator and other incubators in Taiwan.

Average satisfactory ratio	Tenants of ITRI Incubator (%)	Tenants of other incubators (%)
A. Facilities		
Plant space	44	39
Common lab	44	50
Conference room	94	83
Dining hall	100	33
Reference room	75	33
Research instruments and equipment	69	67
Audio-video equipment	56	33
Telephone equipment	75	78
Computer and network equipment	81	78
Transportation equipment	56	6
Repair and maintenance	69	17
Parking lot	100	78
Unloading area	81	22
B. General business service		
Copy machine	94	83
Fax machine	50	72
Security service	56	44
Word processing service	38	50
Equipment leasing	13	33
Postal and express	63	33
Inventory management	6	6
Filing service	25	17
Receiving and delivery	50	39
Answering service	38	50
Receptionist	13	22
Insurance	6	11

Table A.1. (Continued).

Average satisfactory ratio	Tenants of ITRI Incubator (%)	Tenants of other incubators (%)
C. Professional service		
Legal consultation	100	50
Intellectual property right protection	75	44
Financial evaluation	19	29
Accounting	31	28
Market survey and information	63	44
Technical information network	69	67
Venture capital channels	88	44
Contract management and assistance	50	44
Loan and financing assistance	25	44
D. Management support		
Business plan	25	33
Advertising and marketing	31	44
R&D direction	56	56
Leasing channels	31	33
Expert contact system	63	61
Training programs	81	67
Business operation education	63	61
Personnel recruitment	25	14
Post-graduate arrangement	13	17

business service, and management support) follows Lin's (1994) design. Receivers of this questionnaire were asked to answer 'satisfied' or 'not satisfied' alternatively in 43 items. The results from two groups (the ITRI Incubator tenants versus other incubators' tenants) were compared. The full results are summarized as following table.

Appendix B

The interviewees include: Chintay Shih, the ITRI president; S.C. Chiou, the director of Technology Transfer and Services Center in ITRI; C.J. Chung and Walter Wu, the managers of ITRI Incubator; Benjamin Yuan, the director of NCTU Incubator; M.K. Tsai and T.P. Chiu, the managers of NCTU Incubator; Y.C. Lee, the manager of NTHU Incubator; C.C. Tseng, the manager of the Tjing Ling Incubator at National Taiwan University; ten tenants of ITRI Incubator, NCTU Incubator and NTHU Incubator. The date of these interviews spanned two periods: The first period was February to June 1999; the second period was December 2000 to January 2001. We are indebted to these individuals for all their help.

Appendix C

This questionnaire was sent to managers of all 50 incubators in Taiwan. In this questionnaire survey, there were 11 items in four dimensions as shown in Figure 1. In each item, managers were asked to measure the effects of industrial clusters on their incubators using a 5-level scale. This survey was started in December 2000 and ended in January 2001. Twenty-five valid replies were received by the end of January 2001, with a 50% response rate. Six replies were from incubators in the Hsinchu industrial cluster (two from ITRI Incubator, two from NCTU Incubator, and two from NTHU Incubator). A summary of this survey is contained in the following table.

Appendix D

Different from incubators in the USA, most incubators in Taiwan are not supported by local government or local banks, but by universities and SMEA. The 'stakeholders' were therefore defined as the experts and officials at the universities, or other relevant institutes and related bureaucracies. In April 1999, The questionnaire was mailed to the members of the

Table C.1. Effects of industrial clusters in manager survey.

	Incubators in the Hsinchu industrial cluster	Incubators outside the Hsinchu industrial cluster	Significance levels of ANOVA
A. Factor conditions	4.83	4.05	
	(0.183)	(0.558)	0.059
A.1. Human resources	5.00	4.05	
	(0.000)	(0.705)	
A.2. Knowledge resources	5.00	4.16	
	(0.000)	(0.688)	
A.3. Capital resources	4.50	3.95	
	(0.500)	(0.780)	
B. Demand conditions	4.83	4.21	
	(0.258)	(0.749)	0.081
B.1. Domestic market demand	5.00	4.00	
	(0.000)	(0.745)	
B.2. International market demand	4.67	3.63	
	(0.471)	(0.955)	
C. Related and supporting industries	4.92	3.74	
	(0.204)	(0.510)	0.031
C.1. Competitive advantage of supporting industry structure	5.00	3.74	
	(0.000)	(0.452)	
C.2. Competitive advantage of related industry structure	4.83	3.74	
	(0.373)	(0.653)	
D. Firm strategy, structure and rivalry	4.79	3.29	
	(0.246)	(0.366)	0.024
D.1. Firm strategy	4.83	3.32	
	(0.373)	(0.478)	
D.2. Firm organization	4.67	3.26	
	(0.471)	(0.452)	
D.3. Firm scale	4.67	3.26	
	(0.471)	(0.452)	
D.4. Industry rivalry	5.00	3.32	
	(0.000)	(0.478)	

Note: in each reply, the grades of the items in one dimension are averaged into the dimensional grade. ANOVA are conducted based on the dimensional grades. The number in the bracket is the standard deviation.

Chinese Society for the Management of Technology and other experts and officials in relevant institutes and bureaucracies. After the questionnaire collection was completed in June 1999, both parametric method (Tukey multiple comparisons) and nonparametric method (Chi-square test) were utilized to make statistical inferences. Of 450 questionnaires sent out, 97 valid returns were collected after following calls, as a 21.56% valid return rate. In the 450 questionnaires, 100 were sent to scholars, 62 were sent to government officials, 88 were sent to researcher of R&D institute, and 200 were sent to industry people. Within 97 valid replies, 23 were from scholars, 21 were from government officials, 24 were from researcher of R&D institute, and 29 were from industry people. The descriptive statistics are shown in Table D.1. In each reply, an average of all items in each dimension was completed as the dimensional grade. We used the Tukey multiple comparisons test to produce ranking to indicate the priority of ITRI incubator effects on the four dimensions (results are in Table D.2). In the nonparametric method, the collected data on the 5-level ratio scale was transformed into ordinal scale grades for each dimensional variable (if the dimensional grade is 5 and 4, it denotes that the stakeholder 'agrees' with the effective impacts of ITRI Incubator on that dimension. Less than 4 means 'not agree'). The Chi-square test was used to test the effective impacts of ITRI Incubator on each dimension. That is, on each dimension, if the one-tailed Chi-square test result rejected the null hypothesis (the probability of

'agree' being equal to or below that of 'not agree'), it meant that the stakeholder 'agrees' with the effective impacts of ITRI Incubator on that dimension. The results of Chi-square test are shown in Table D.3. The significance levels were set at 5%.

Table D.1. Summary of replies.

	All replies	Scholars	Government officials	Researcher of R&D institute	Industry people
Factor conditions	4.30 (0.503)	4.48 (0.665)	4.19 (0.402)	4.25 (0.442)	4.28 (0.455)
Demand conditions	3.75 (0.726)	3.96 (1.033)	3.36 (0.839)	3.83 (0.525)	3.79 (0.284)
Related and supporting industries	4.04 (0.578)	4.20 (0.780)	3.83 (0.599)	4.08 (0.584)	4.02 (0.283)
Firm strategy, structure and rivalry	3.79 (0.661)	4.10 (0.868)	3.69 (0.402)	3.73 (0.423)	3.68 (0.738)

Note: the number in the bracket is the standard deviations.

Table D.2. Tukey test for priority ranking.

i-variable	j-variable	Mean difference (i-j)	Standard error	Significance level
Factor conditions	Demand conditions	0.5515	0.089	0.000
	Related and supporting industries	0.2629	0.089	0.017
	Firm strategy, structure and rivalry	0.5052	0.089	0.000
Demand conditions	Factor conditions	−0.5515	0.089	0.000
	Related and supporting industries	−0.2887	0.089	0.007
	Firm strategy, structure and rivalry	−0.0464	0.089	0.955
Related and supporting industries	Factor conditions	−0.2629	0.089	0.017
	Demand conditions	0.2887	0.089	0.007
	Firm strategy, structure and rivalry	0.2423	0.089	0.034
Firm strategy, structure and rivalry	Factor conditions	−0.5052	0.089	0.000
	Demand conditions	0.0464	0.089	0.955
	Related and supporting industries	−0.2423	0.089	0.034

Note: using Tukey multiple comparisons, the degree of impacts of the ITRI Incubator could be ranked as 'factor conditions', 'related and supporting industries', 'demand conditions' and 'firm strategy, structure and rivalry' ('demand conditions' and 'firm strategy, structure and rivalry' are not significantly different).

Table D.3. Chi-square test for effectiveness.

Dimensional grades	Agree/not agree (total 97 samples)	Chi-square value	*P*-value
Factor conditions	66/31	12.629	0.000
Demand conditions	54/43	1.247	0.132
Related and supporting industries	76/21	31.186	0.000
Firm strategy, structure and rivalry	37/60	5.454	0.990

Note: by Chi-square test, the ITRI Incubator has significant impacts on 'factor conditions' and 'related and supporting industries'.

