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Mobilizing technology transfer from university to industry

The experience of Hong Kong universities

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Abstract

Purpose – The present paper seeks to illuminate the role played by university-based technology transfer offices (TTOs) in driving the transfer of research-based knowledge and technology from institutions of higher education to industry in Hong Kong.

Design/methodology/approach – Following a literature review, the authors use empirical data on technology transfer and innovation, and case studies of existing TTOs at City University of Hong Kong (City U) and Hong Kong University of Technology and Science (HKUST), to analyze and illustrate the changing nature of the role that TTOs have played in Hong Kong, from the late 1980s to the present.

Findings – It is found that, while TTOs originally served primarily to generate additional revenues for their affiliated universities through the creation and commercialization of intellectual property, that role has gradually evolved to support innovative start-up companies through technology transfer.

Research limitations/implications – This study is limited in having included only two case studies. In the future more cases should be examined, not only of other spin-offs and start-ups from City U and HKUST, but also from other Hong Kong universities as well. The study implies that TTOs should continue to learn how to respond to the needs of start-ups through self-evaluation. Universities should better manage TTOs, and the government, through better understanding of the capacity of TTOs to create spin-offs, should develop policy measures that facilitate the process.

Originality/value – This study is among the first to examine the role of TTOs using a case-study approach, especially in addressing the relationship between university-industry linkages and the broader innovation system in Hong Kong.

Keywords Knowledge transfer, Innovation, Universities, Hong Kong

Paper type Research paper

Introduction and purpose

The higher education sector in Hong Kong was transformed significantly in the 1990s as its role changed during the former colony's transition to its current status as a Special Administrative Region of the People's Republic of China, and universities continue to occupy a transitional role in Hong Kong society today. With the development of a new policy framework within which to promote technology and innovation, Hong Kong has witnessed a range of initiatives that promote university-industry linkages (Sharif and Baark, 2005), bringing technology transfer offices (TTOs) in Hong Kong to the frontlines of change. Hong Kong's higher education sector accounted for 80 percent of the total R&D expenditure in 2000, which demonstrates the central importance of universities in Hong Kong's innovation system. Even the 2003 figure of 56 percent is high compared with those of other advanced

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economies, in which the higher education sector performs on average roughly 17 percent of all R&D (OECD, 2006).

TTOs in Hong Kong have evolved gradually; their role in the patenting and licensing of university inventions in Hong Kong has been growing since the late 1980s. As Rosenberg and Nelson (1994) have documented, universities have traditionally transferred knowledge and technology to firms mainly through channels like research publications, consulting, and presentations at professional conferences, and they continue to use such channels today[1]. To understand how the role of the TTO's in Hong Kong has changed in such an environment, we must situate them in Hong Kong's wider innovation system because changes in Hong Kong's general innovation environment over the last decade and a half have driven changes in the functions of Hong Kong's TTOs. In particular, TTOs in Hong Kong's universities are gradually beginning to consider the impact of organizational practices and altering their functions accordingly in order to reach a wider range of clients.

The role played by TTOs can be effectively understood, then, only within the broader framework of academia-industry-and-government relationships. Yet even such a framework needs also to be situated within an understanding of the innovation system in question. In particular, there are specific elements of the innovation system that affect TTOs on which we need to focus more scholarly attention. These include:

- the institutional context of university-industry linkages; and
- the availability of financial support (not only through the banking system and venture capital funding but also through the promotion of start-ups supported by TTOs on the part of local stock markets).

By distinguishing these various "layers" that affect the functioning of TTOs and thereafter mapping their emergence and functioning, we can identify and explain how the role of TTOs has been embedded in a transformative process within Hong Kong's wider innovation system.

In what follows, we first review the applicable literature and then identify the most salient elements of Hong Kong's innovation system affecting university-industry relationships. Subsequently, we present detailed case studies of two of the more successful and active TTOs among Hong Kong's universities – at the Hong Kong University of Science and Technology (HKUST), and City University of Hong Kong (City U). In these case studies, we examine the key activities and functional components of the two TTOs in question. Finally, we provide an analysis and discussion of our research findings. In particular, we show how TTOs in Hong Kong have passed through three distinct transitional phases that have mirrored the transitional phases through which the broader innovation system in Hong Kong has itself passed.

Literature review and conceptual approach

Policymakers increasingly view universities as engines of economic growth, via the commercialization of intellectual property through technology transfer (Siegel and Phan, 2005). Furthermore, many research universities have adopted formal mission statements regarding the role and importance of technology transfer (Markman *et al.*, 2005). The primary commercial mechanisms of university technology transfer are licensing agreements, research joint ventures, and university-based startups.

Although formal management of an intellectual property portfolio is still relatively new to many universities, both academics and policymakers show growing interest in the commercial impact of university intellectual property. This has produced a body of literature primarily derived from research on two forms of university technology transfer: patents/technology licensing (Thursby and Kemp, 2002; Shane, 2002; Carlsson and Fridh, 2002; Chapple *et al.*, 2005) and university spin-offs (Shane and Stuart, 2002; Steffensen *et al.*, 2000; Franklin *et al.*, 2001; Lockett *et al.*, 2003; Lockett and Wright, 2005). These research efforts reflect a substantial increase in the level of involvement by universities in technology commercialization activities, with the major research universities in the USA leading the way.

Most notable among a growing number of university-specific studies along these lines[2] are those conducted by Mowery *et al.* (2004), which presented the most extensive analysis of university-industry technology transfer in the USA in recent years, and by Mowery and Sampat (2005), which provides a concise comparative analysis of both the USA and international experiences[3].

The Triple Helix conception of university-industry-government relations offers a range of constructive ideas that cast fresh light on how the roles of each of these main actors have been gradually transformed through evolutionary processes (Leydesdorff and Meyer, 2006). The Triple Helix concept also provides a comprehensive framework in which to study the new role of universities in practical terms, noting the tensions that emerge as the core responsibility for training human capital to carry a knowledge-based society forward conflicts with various profit motives and drivers of a Mode 2 approach to research (Nowotny *et al.*, 2001; Etzkowitz and Leydesdorff, 2000).

The body of literature that has emerged in this field of research during the last two decades has provided a set of theoretical and methodological approaches for understanding the role of universities in advanced economies and the influence of policies designed to enhance the commercialization of technology through university-industry linkages. International experience thus suggests that the effectiveness of TTOs depends to a considerable degree on the organizational set-up and responsiveness of such units *vis-à-vis* industry partners (Siegel *et al.*, 2003).

Research on the universities' role in Hong Kong's innovation system is scarce. Parayil and Sreekumar (2004) provided an overview of the development of innovations in Hong Kong based on the Triple Helix concept, but they focus on overall issues and employ very limited empirical evidence pertaining to university-industry linkages. Similarly, a recent study by Mok (2005) summarizes recent policy changes related to entrepreneurship and university spin-off firms in Hong Kong – again utilizing the Triple Helix concept – but similarly without significant empirical research results. On the other hand, articles published by Patchell and Eastham (2001, 2003) have provided more detailed empirical evidence about the various factors influencing linkages between universities and industry in Hong Kong. Their analysis primarily reports the results of a survey of staff at HKUST on incentives and barriers to such linkages. Chan and Lau (2005) provide a study of technology incubators focusing on business development data for six technology start-ups. Most of these start-ups were set up by university research graduates from the Polytechnic University of Hong Kong.

We believe that it is necessary to understand technology transfer from universities to the commercial sector within a broader context, as argued by Carlsson and Fridh (2002) on the basis of their investigation of offices of technology transfer in

12 universities in the USA. Carlsson and Fridh found that the success of a technology transfer process depends not only on the interface between the university and the business community, but also on the receptivity to technology transfer that characterizes the surrounding community as well as the culture, organization and incentive structures in the universities themselves. There is, in other words, a mutual relationship between the broader innovation system and the TTOs within which Hong Kong's TTOs operate. We can therefore conceptualize the TTO as occupying a position between the universities and industry, as shown in Figure 1.

The institutional setting in Hong Kong

Linkages between universities and industry in Hong Kong have traditionally centered on the provision of human resources – particularly engineering talent for R&D and innovation in private industry – and little else. Increasingly, local universities have sought to extend their cooperation with business firms in Hong Kong. These efforts have included establishing specialized units to promote technology transfer or support for entrepreneurial spin-off firms that commercialize university research (Mok, 2005, pp. 544-6). In the early stages these efforts responded primarily to a parent university's interest in generating revenue. Gradually, however, as the broader institutional environment has been transformed with Hong Kong's innovation system, there has been an increased recognition among the TTOs that their roles need to be less short-sighted and money-centred as well as broader in scope and more persistent.

The advent of a new innovation policy since the late 1990s has further reinforced efforts to promote the development of new technology (Baark and Sharif, 2006a, b).

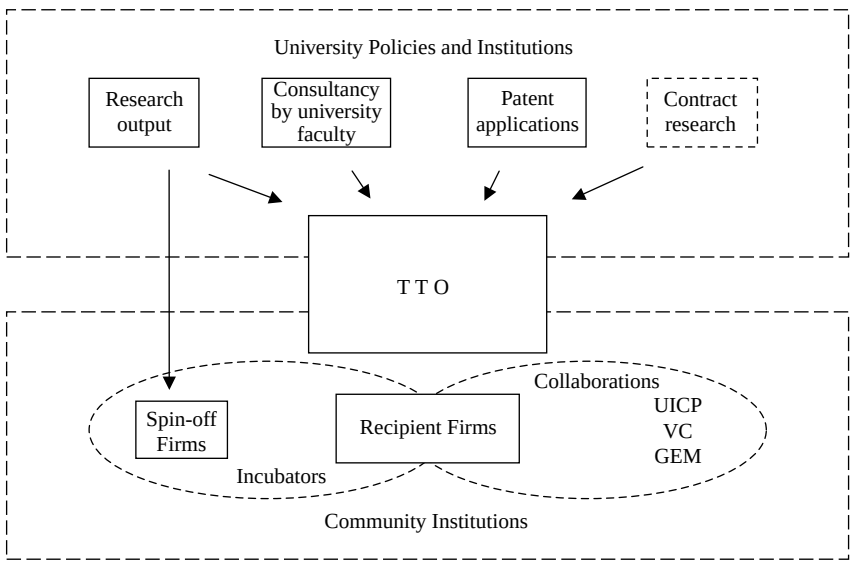


Figure 1.
TTOs as Interface mechanisms: institutional embeddedness

TTO: Technology transfer office
UICP: University-Industry Collaboration Program
VC: Venture capital
GEM: Growth Enterprise Market

In particular, a HK$5 billion Innovation and Technology Fund (ITF) was set up on November 1, 1999 in accordance with the planning proposed in the two Commission on Innovation and Technology reports of 1998 and 1999. This initiative – to finance projects that strengthen research capabilities in Hong Kong and increase research spending on R&D projects in the business sector – was the single most important initiative in terms of both financial clout and impact on innovation-related activity in Hong Kong. Implementing the related policy has resulted in the establishment of new science and technology infrastructure, but more importantly in government-sponsored incentives – notably the University-Industry Collaboration Programme (UICP) – for the promotion of university-industry links[4]. Despite such laudable government efforts in the late 1990s, we cannot discount the effect of the broader institutional setting within which both universities and the private sector operate and co-operate. This institutional framework surrounding university-industry linkages is shaped by various channels for raising capital for technological upgrades or new innovative technologies. Below, we provide a brief overview of the government-sponsored incentives, the salient features of university-industry collaboration, and of the broader institutional setting.

Government-sponsored incentives

Funding of new technology development projects by the ITF has sought to enhance linkages among research groups in universities and private industry. One of the four programs under the ITF rubric, the above-mentioned UICP, aims to expand network creation between universities and industries.

As Table I shows, by March 31, 2007 there were 164 UICP projects (out of a total of 947 projects in total under the ITF) with funding amounting to a total of HK$186.3 million (out of a total of HK$2,834.4 million funded by the ITF), and each of these projects was approved on the basis of the participation of an industrial firm in a collaborative arrangement with a university. UICP support is given as a grant, subject to a cash contribution by the company amounting to no less than 50 percent of the project cost. Table I shows that 87 percent of UICP projects involved one industrial partner while 13 percent involved two or more partners.

UICP projects explicitly make cooperation between universities and industry a major objective. These projects aim to leverage the knowledge and resources of universities to stimulate private sector interest in R&D. Projects funded under another component of ITF, the Innovation and Technology Support Programme (ITSP),

Program	Number of approved projects	Funds approved (HK$ million)
Innovation and Technology Support Program	441	2,281.8
General Support Program	84	108.7
University-Industry Collaboration Program	164 (*17.3*)	186.3 (*6.57*)
Small Entrepreneur Research Assistance Program	258	257.6
Total	947	2,834.4

Note: Figures are given in parentheses are percentages
Source: ITF web site (www.itf.gov.hk)

Table I.
ITF approved projects

are intended to promote the development of new technology rather than cooperation as such. Nevertheless, if the technology developed through ITSP projects should succeed in the commercial application of new technology in industry, it would be appropriate to achieve a high level of collaboration for the purpose of ensuring active industry participation and benefits.

As Table II shows, the majority of projects under the UICP program fall into the information technology area (42 projects with a total funding amount of HK$49.1 million), manufacturing technology (34 projects with a total funding amount of HK$20.8 million) and electrical and electronics (34 projects with a total funding amount of HK$31.2 million).

University-industry collaboration in Hong Kong

Information about collaborative projects promoting the development and application of new technology is collected as part of the Census & Statistics Department's (2006) Annual Survey of Innovation Activities in the Business Sector (ASIA). The 2005 survey indicates that approximately half of the firms that engaged in R&D activities cooperated on R&D, mostly with other business firms in Hong Kong (31 percent) or the PRD (25 percent), but also with overseas firms (20 percent). In contrast, cooperation with higher education institutions in Hong Kong and the PRD was reported by only about 6 percent of the sample.

Cooperation on R&D activities has grown in the private sector in Hong Kong. Table III shows data extracted from the ASIA surveys from 2001 to 2004. The figures reported demonstrate that although Hong Kong manufacturing firms have experienced a declining share in cooperative arrangements, the "wholesale and retail," as well as the "finance" sectors have both witnessed a dramatically increasing share of cooperative arrangements from 2001 to 2004. Part of the explanation for this is that the sector designated "wholesale and retail" includes a very substantial number of Hong Kong-based firms engaged in manufacturing in the PRD (designated "Import-Export" firms in the survey). These firms have clearly expanded their level of cooperation related to R&D, including with higher education institutions. A similar,

	UICP		Total for four ITF programs	
Technology area	No.	HK$mn	No.	HK$mn
Information technology	42	49.1	295	866.9
Electrical and electronics	34	31.2	227	716.9
Manufacturing technology	34	20.8	146	510.8
Biotechnology	19	30.5	87	219.2
Chinese medicine	15	26.9	26	70.9
Materials science	11	6.7	38	77.6
Environmental technology	8	19.6	37	67.4
Nanotechnology	1	1.5	19	206.7
Others	–	–	72	98.5
Total (HK$ millions)	164	186.3	947	2,834.4

Source: ITF web site (www.itf.gov.hk)

Table II.
Distribution of approved projects under the UICP program

Industry sector[a]	Type of collaborating organization: Government and quasi-government organization	Higher education institutions	Within group business firms	Other business firms	Others	Overall
2001						
Manufacturing	90	17	10	10	3	107
Wholesale and retail[b]	2	30	27	21	6	67
Finance[c]	8	30	16	25	4	56
2002						
Manufacturing	6	21	9	14	0	34
Wholesale and retail[b]	1	22	17	24	1	54
Finance[c]	13	27	9	34	1	61
2003						
Manufacturing	5	19	7	17	3	38
Wholesale and retail[b]	18	39	275	62	2	345
Finance[c]	26	40	36	62	104	225
2004						
Manufacturing	5	16	8	31	1	50
Wholesale and retail[b]	10	170	685	217	25	1,068
Finance[c]	46	55	237	193	18	421

Notes: [a]Only selected sectors are presented in the above table; [b]wholesale and retail include wholesale, retail and import/export trades, restaurant and hotels; [c]finance includes financing, insurance, real estate and business services

Source: ASIA for 2001 to 2004, conducted by Census and Statistics Department, HKSAR

Table III.
Patterns of R&D-related collaboration by Hong Kong firms, 2001-2004

but less extensive, pattern can be observed in the increasingly innovative finance and business services sector (not indicated in the table).

Broader features of Hong Kong's institutional setting

The broader elements of the institutional setting in Hong Kong within which TTOs function and are strongly embedded include, first, the reluctance of the banking industry to provide support for innovation and technology ventures. Technology and innovation-related start-ups rely heavily on personal savings in lieu of readily available business loans. In practice, large firms are typically better able to demonstrate creditworthiness and are therefore favored in terms of loan disbursement.

In the absence of bank financing, one would expect the venture capital industry to come to the rescue of university-industry collaborative projects. Despite its status as the largest venture capital center in Asia, Hong Kong is most distinctively an administrative hub serving the region: So in 2000, 91 percent of all funds under management by venture capital firms originated outside Hong Kong, and the bulk of these funds financed companies in the broader region, principally in Mainland China. Given the comparative lack of development of the mainland's capital market, most venture funds pursue their exit strategies outside China, mainly through Hong Kong's main board and the Growth Enterprise Market (GEM), as well as the US's Nasdaq exchange. Hong Kong serves therefore more as a regional centre than as an actual, primary investment target for venture capitalists.

The aforementioned GEM offers a channel through which innovative and high-growth companies with short histories and little or no proven record of profitability can seek equity funding to capitalize on new opportunities by raising expansion capital under a well-established market and regulatory infrastructure.

Hong Kong also features formal legislation that protects already existing innovations. For example, the Intellectual Property Department fosters local awareness of intellectual property rights and encourages respect for the rights of others. The government's support of patent applications is administered and assisted by the Innovation and Technology Commission, while the enforcement of intellectual property rights falls to the Customs and Excise Department. Legal provisions for protection of intellectual property rights are clear and transparent enough as written.

Empirical case study findings: two technology transfer offices at Hong Kong universities

We have, as noted in the introduction, focused on TTOs established in two universities: HKUST and City U. We chose to focus on these two particular TTOs because of a combination of three factors:

(1) *History*. City U's TTO has the longest history in Hong Kong, while HKUST's TTO is the youngest among those of the three research-heavy universities.

(2) *Success*. City U's TTO has a leading spin-off company that serves as an exemplar for other TTOs, whereas HKUST has recently begun to engage in new, entrepreneurial modes of engagement with its incubates.

(3) *Links to local industry*. Whereas the two other major universities – the University of Hong Kong and the Chinese University of Hong Kong (CUHK) – have strong links with industry, those links are broader in scope.

This is not a shortcoming of the two universities, but by offering a wider range of academic programs and specialties, they are unable to achieve the same degree of depth or sharpness in focus as either City U or HKUST. The latter therefore are better able to achieve excellence in engineering research and, accordingly, in new innovative and technological spin-offs (under the broad spectrum of engineering sciences).

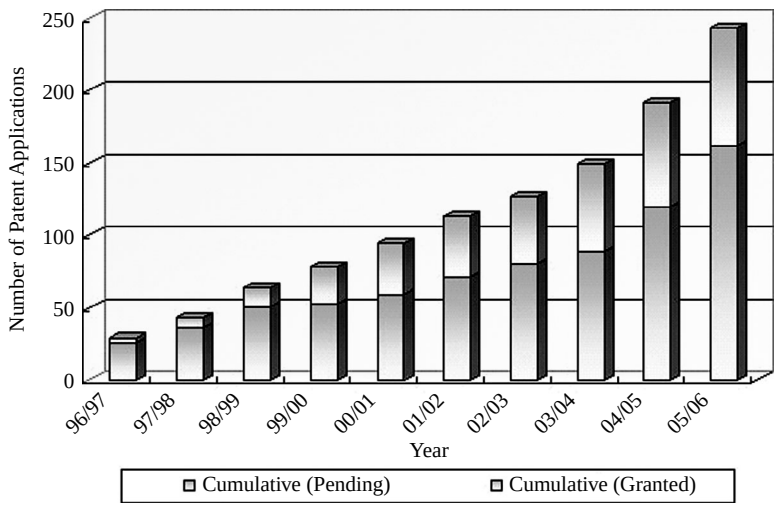
In each of the two cases, we interviewed key personnel at the TTO and also those at the partner companies with experience in utilizing the TTOs' services. We believe such a "symmetrical" or "rounded" approach allows us to attain a better understanding of the efficacy – or lack thereof – of the TTOs in question.

Hong Kong University of Science and Technology (HKUST) Technology Transfer Center (TTC)

HKUST's Technology Transfer Center (TTC) and the HKUST Research and Development Corporation Ltd (RDC) engage in university-industry collaboration, R&D partnerships, and the protection and licensing of intellectual property. HKUST's TTC has prioritized three major functions (each investigated in detail below).

Promotion of intellectual property rights. HKUST's TTC seeks to promote technology transfer via licensing of the university's intellectual property. The key instrument for this process is patenting. The cumulative stock of patent applications rose from about 25 in 1996/1997 to around 250 in 2004/2005, as shown in Figure 2.

For the academic year 2005-2006, the TTC was involved in the evaluation of 48 invention disclosures from HKUST researchers. During the same period, the Center arranged for the filing of 77 patent applications, including full and provisional applications with the US Patent Office, continuation-in part (CIP) patents, and international filings. In order to raise awareness among HKUST researchers about the possibilities and requirements of patenting, the TTC also arranged several seminars with US patent attorneys specializing in patent and other forms of intellectual property protection in the USA and abroad. During the current academic year, HKUST also



Source: HKUST Technology Transfer Center website (http://www.ttc.ust.hk/)

Figure 2.
Patent applications at HKUST, 1996-2005

received notification of the granting of 9 patents. Marketing of HKUST intellectual property remains at the core of TTC objectives, and this activity has been expanding steadily over the years.

Research contracts. Marketing the university's expertise to local and international industrial partners, for instance, via a web-based database of research capabilities and projects, is aimed at securing additional funding for highly productive research groups at HKUST, but it also ensures that the results of research projects are implemented in the market. In this area, the TTC cooperates with the HKUST RDC, which was established in 1993 as the business arm of HKUST, dealing with activities relating to the exploitation and commercialization of research conducted at HKUST.

The number of research contracts with industrial clients and the total income from these contracts has grown steadily over the years. In 2003-2004, for example, the RDC signed 98 contracts worth a total of HK$19 million; in 2004-2005, the figures were 105 contracts at a total value of HK$31.9 million; while in 2005-2006 the RDC signed 118 R&D contracts with industrial clients, worth more than HK$35 million.

During the most recent academic year for which figures are available, 2005-2006, the RDC licensed 24 patents that were assigned to HKUST. This included, for example, catalytic nanotechnologies for the removal of biologically active indoor air contaminants that have been patented and licensed to Chiaphua Industries Ltd for use in appliances that are now in the marketplace. These nanotechnologies have also been licensed to Artenano Ltd, an HKUST spin-off company, for the production of nanostructed catalysts, again for indoor air-quality applications.

Entrepreneurship program. The HKUST Entrepreneurship Program was introduced in 1999 to assist faculty, staff and students in the establishment of technology-based start-up companies. It is HKUST's policy to promote such activities for the benefit of Hong Kong's economy and society. Start-up companies are incubated in the privately-funded Annex Building at HKUST, where they are provided with serviced and furnished space at modest cost, with access to university facilities and resources and to an Advisory Committee that provides assistance with business development. The Entrepreneurship Center currently comprises 1,200 square meter. During 2007, HKUST will be opening its new Enterprise Center, constructed with a donation from the Hong Kong Jockey Club, which will serve as the primary interface between the academic and research community at HKUST and the business and industrial environment of Hong Kong and the region. The university takes as a base a 3 percent equity stake in companies accepted into the Entrepreneurship Program. The transfer of intellectual property to the company usually increases equity. Such equity is held by the RDC on behalf of HKUST. The RDC also manages a modestly sized (HK$10 million) Venture Capital Fund. Start-up companies may seek funding to advance their business development. While the process for entry to the Entrepreneurship Program is designed to give companies the opportunity to prove their potential, an application to the Venture Capital Fund is subject to a more rigorous review process, as this involves a business decision to invest the assets of RDC.

Evaluation. Concentrated focus on activities related to intellectual property development has led some to criticize HKUST's TTC for neglecting other forms of assistance to start-up companies. In particular, start-ups struggle to find industrial partners – otherwise known as "tie-ins" with manufacturers – with the desired level of expertise to match the firm's technical competencies. This was the view of an HKUST

start-up formed in July 2001 (and currently in operation) which develops microdisplays. The chief executive of the microdisplay company contends that the focus of HKUST's TTC on building a patent portfolio may cause it to overlook smaller companies such as theirs which specialize in extracting the benefits of single (or a small number of) patent(s). Having drawn on the TTC's services in the past, the microdisplay manufacturer now prefers to go it alone, engaging with the TTC at only a superficial level to gain access to HKUST resources such as laboratories and equipment, and for proper documentation of practices and procedures.

A second characteristic of HKUST's TTC that our microdisplay manufacturer-respondent sees as a drawback is its excessive focus on protecting the university's interests first and foremost. While clearly acknowledging that the TTC is a HKUST-owned and -funded centre, and is therefore bound by its charter and mission goals to uphold the university's interests, our respondent feels that, during the initial stages of setting up a high-tech start-up, the newly formed company is akin to a little baby needing concentrated attention, assistance, and resource inputs. The TTC's emphasis on upholding HKUST's requirements and regulations results in its not sufficiently addressing how its requirements or goals conflict with, align with, complement, or affect the start-up's goals. It was this feature that led to our respondent's disengaging from the TTC after a brief engagement.

This failure to fully analyze its relationship to start-ups naturally reduces the TTC's responsiveness to the start-ups' needs. In our respondent's case, for example, an engineer from a related industry had approached the HKUST start-up to develop an integrated circuit display in cooperation with the HKUST microdisplay manufacturer. In this case, training and knowledge transfer – but no intellectual property – was involved. Three months passed before HKUST's TTC approved of this arrangement for cooperation, an excessively long delay that ultimately caused the industry partner to withdraw from the arrangement. Such an experience indicates that the TTC is better-suited to projects in the early stages of research within a longer time frame, particularly projects involving intellectual property generation. The TTC is not, then, as well suited to shorter-term product development projects in which intellectual property has no part to play but rather where the circumstances require a nimble and timely response to an industry's needs.

Recent developments. Notwithstanding the success of activities related to intellectual property development and licensing, contract research, and the promotion of entrepreneurship, the Director of HKUST's TTC, Professor Matthew Yuen, has tried to intensify the university's efforts to develop sustainable routes for the commercialization of technology developed at the university. This strategy aligns with changes in the broader environment for innovation and technology development in Hong Kong and also serves as a response to some of the TTC's current shortcomings. As the government and other innovation actors have gradually focused more intently on university-industry collaboration and a general climate that recognizes – and to a degree respects a little more – the importance of innovation and technology, and the broader innovation system has begun supporting and rewarding industry's efforts to collaborate with universities (and vice versa), HKUST's TTC has been reorienting.

Taking a more proactive approach, the TTC has sought to develop a new framework around the take-up of technology by industry that moves beyond the simple spin-off model. This approach emphasizes the mobilization of a social network

of business managers who are keen to aid the commercialization process and are willing to cooperate closely with the university's faculty members and post-graduate students to bring the technology to a stage at which it can be launched on the market. The managers attract investment that is the augmented by a substantial matching investment made by the RDC (which then claims a larger equity share in the resulting enterprise). These new forms of joint venture provide a much more professional environment within which to commercialize technologies.

City University of Hong Kong (City U) Technology Transfer Office

The City Polytechnic of Hong Kong – the former embodiment of the City U – was in fact the first Hong Kong organization of higher education to recognize the importance of technology transfer in the late 1980s[5]. By setting up a wholly owned company called City U Enterprises Limited in 1991, City U was the first Hong Kong tertiary institution to recognize the importance of commercializing newly found knowledge or technologies and applying them to the industrial sphere by establishing a dedicated TTO for the purposes of technology transfer.

As is the case with other universities funded by the University Grants Council (UGC) in Hong Kong, City U's primary goal is the provision of tertiary education. City U established its TTO very much with the intention of avoiding conflicts as a result of its involvement with business/industrial partners. City U began by investing its own money in City U Enterprises with the mission of commercializing its faculty's research and technology development through business ventures. In 1992, City U set up what it called the Industrial Business and Development Office (IBDO). The main aim of the IBDO is to help start-ups. In 1992, the IBDO helped set up four companies. Eight years after its establishment (by 2000), the IBDO had helped set up more than 30 companies. These companies have worked closely with City U in the transfer of knowledge and resources. The new technology developed by researchers at City U form the foundation for these companies.

The primary goal of City U's TTO is to promote the transfer of advanced technologies and know-how developed in City University to enhance the competitiveness and development of local industries[6]. In particular, City U's TTO has prioritized three sets of functions (each examined below).

Funding for applied research. As City U was formerly a technical college that provided training in engineering subjects to post-secondary students, it has carried over the tradition of cooperation with local manufacturing and service sectors in applied research as well as in programme design and delivery, particularly in the electronics industry. In this connection, the TTO functions as an administrator of funding for applied research projects.

Promotion of intellectual property rights. Similarly to HKUST's TTC, City U's TTO seeks to promote technology transfer via licensing of the university's intellectual property. The key instrument in this process is patenting. As of June 30, 2005, the University has received 46 patents with protection in the USA, China, Europe, and Hong Kong, while another 66 patents are pending.

Technology licensing. Although technology licensing is relatively new to Hong Kong, City U emphasizes technology transfer with a view to sharing the technologies and know-how developed on campus with industry and public/private sector organizations. City U has granted licenses to local and overseas companies.

For example, a technology for a Chinese lexical database, with lexical entries from six Chinese speech communities, has been licensed to a US company that provides software solutions for multilingual text mining and information retrieval applications.

A particularly successful case of technology developed at City U and commercialized in a spin-off company is TeleEye. Founded in 1994 by the City University of Hong Kong and a group of engineering researchers, the TeleEye Group is principally engaged in the development, sales and marketing of innovative network CCTV and DVR devices that make use of advanced signal-processing technologies. The TeleEye Group has become a world-class supplier of remote visual management systems with extensive application in several industries. TeleEye Holdings Limited was listed in the Stock Exchange of Hong Kong Limited in 2001. Signal Communications Limited, a wholly owned subsidiary of TeleEye Holdings Limited, is the main operation arm of the TeleEye Group. The Group is the first publicly traded spin-off from an academic institution in Hong Kong. The listing further enhanced TeleEye's brand awareness, marking a historical moment as TeleEye was the first hi-tech company nurtured by a local government-sponsored university in Hong Kong.

Evaluation. The smaller-scale approaches of City U's TTO, combined with a deep level of engagement, has helped it yield positive results and acquire a strong, well-deserved reputation. Our interview with TeleEye typified the high esteem in which many hold City U's TTO. In particular, the TTO was most influential in aiding TeleEye by providing business advice to TeleEye rather than technical advice. There is an obvious distinction between the two domains, but they constitute two sides of the same coin: in commercializing university research: neither domain of knowledge can be put into practice effectively without the other.

This issue was one that Dr Cliff Chan, CEO of TeleEye, recognized from the outset. As an engineer himself, Dr Chan and his research colleagues had ample knowledge of the technologies they (and their students) were working with and trying to develop. In fact, start-ups are so consumed with a passion for and interest in developing technologies that they rarely have the right type of people to see beyond the technological aspects of their work. This is where the TTO comes in. In the case of TeleEye, for example, the engineers developing the technology were intimately familiar with the technical aspects of their products, but they were less familiar with the business dimension involved in establishing a company. They needed someone to help them write a persuasive business plan, present a business model, handle marketing and sales, and handle issues of management, conflict, negotiation, and publicity. City U's TTO assisted with the business side by arranging opportunities for TeleEye that the founders with their engineering background would have been unable to create on their own.

One microcosmic example that illustrates the value of City U's TTO to TeleEye was the TTO's assistance in helping them to achieve credibility. City U's accounts were audited by the accounting firm KPMG. When TeleEye was first established in 1994, it had only three full-time staff members. Normally, such a small company would have passed under the radar of major accountants such as KPMG. As a result of the assistance it received from the TTO, however, TeleEye's accounts were audited by KPMG from the very first day. The credibility gained from having one of the most reputable accounting firms audit TeleEye's accounts carried over to its listing on the Hong Kong Stock Exchange, by which time investors had a much higher degree of

confidence in TeleEye's books (and not only their technologies), resulting in a swifter and more successful initial public offering.

On the other hand, City U's TTO's assistance to TeleEye was not continuous and persistent. Rather, there were "spurts" of intense assistance. One such period occurred in 1994 (lasting two years) when the four TeleEye founders submitted their original business proposal to City U. The TTO director and staff worked to convince the university's administrators to approve the plan. After the plan was accepted and TeleEye established, the amount of assistance offered by the TTO decreased. Thereafter, when TeleEye went public in May 2001, there was, once again, intensive assistance from the TTO when they arranged for investors, sponsors, financial institutes, lawyers, and accountants.

Recent developments. City U's TTO has undoubtedly benefited from the success of TeleEye, particularly its listing on the Hong Kong Stock Exchange, an event that earned the TTO much positive publicity. Despite this success, the director of City U's TTO, Mr Wong Hon-yee, does not see the TTO resting on its laurels. In particular, Mr Wong recognizes the importance of being even more proactive in nurturing the research interests of faculty so as to encourage more start-ups and spin-offs. He points to recent changes in Hong Kong's innovation system (notably in the government's attitude and the role of universities in society) as an indication that universities will have to do much more to "justify" their role as one of the main expenditure sources in society.

No longer can the contribution of universities in Hong Kong be assessed solely on the basis of the quantity and quality of academic publications (and secondarily, teaching performance). Rather, other forms of benefit to society have to be identified and publicized. This in turn means that universities must devise methods for assessing their performance based on their role in generating new knowledge/technology that benefits society. Ultimately, a model of university structure that encourages entrepreneurship is required, one that more openly and robustly provides financial incentives to professors for generating and transferring new technologies.

Analysis and discussion

TTOs are relatively new phenomena in Hong Kong. However, their growing importance is not to be underestimated. As the Hong Kong Government actively attempts to strengthen its innovation system (particularly in the post-1998 period), coupled with the increasing expectation that universities are to rely more on non-government sources of funding, TTOs are gradually increasing the scope of their role as well as their importance, partly as a result of learning from prior errors.

University researchers in Hong Kong are, generally speaking, relatively unaware of the needs of local industries. Although there has been a tradition of rewarding academic excellence in Hong Kong on the basis of research publications, an emphasis on the transformation of new knowledge into applications that meet the needs of local industries is a relatively new phenomenon. Until quite recently, few of Hong Kong's academics possessed the requisite skills and technical and business wherewithal to successfully interact, cooperate and profit from partnerships with industrial partners. This only increases the need for TTOs to play a more active role, especially if universities are to become more active in developing industrial links.

TTOs in Hong Kong have been in the process of transition for the last decade and a half. This transitionary format has been mirrored in the wider innovation system, which also has been undergoing change in the post-1998 period (Sharif, 2006). The exploratory, empirical case studies presented in this paper make it possible for us to discern a development trajectory for Hong Kong's TTOs, which we can divide and describe in detail in three phases.

In the first phase (in the early 1990s), the establishment and running of the TTOs was marked generally by a short-term perspective. Such a perspective was characterized by an emphasis on financial gains that the TTO could generate: in other words, generating revenue was the TTOs' chief priority. This reflected an inadequate emphasis on innovation and technology in general, and university-industry collaboration projects in particular. Therefore, while maintaining their function as a bridge between university and industry, Hong Kong's TTOs concentrated on revenue and profit generation, at first assisting only those projects they believed would bolster the bottom line. There was little consideration of the alternative roles the TTO could perform, and little appreciation that the TTO could also be proactive rather than reactive in achieving its mission.

In the second phase of the developmental trajectory (the mid-to-late-1990s), TTOs began slowly to realize that they needed to think more strategically and broadly about their role. In particular, the TTOs recognized that it was in their direct interests to ensure that the firms they helped as start-ups in fact survived and maintained financial stability over a number of years. Such a realization was in part a natural result of the first phase, in which large numbers of firms and projects were undertaken by the TTOs without their necessarily valuing long-term viability. As the TTOs' projects began to mature and rapidly wither with increasing regularity, the TTOs realized that it served neither their own interests nor those of the companies if these projects and companies were so short-lived.

During this phase, then, deeper consideration was given to:

- vetting projects for their long-term feasibility;
- drawing up and implementing measures to support the longer-term development and growth of supported projects; and
- regularly appraising projects years after their initiation (three years and beyond) to evaluate their performance.

Concomitantly, during this phase, public attention to the importance of technology, especially the transfer of technology from university to industry as well as the promotion of innovation broadly speaking, began to take hold more firmly locally.

We observe that, during the third and final phase of the TTOs' development trajectory (the late 1990s and early 2000s), the wider social and institutional setup in Hong Kong changed, whereby TTOs assumed greater importance as a result of multiple and simultaneous changes taking place in Hong Kong's innovation system. These changes came into effect in the late 1990s and early 2000s as a result of government measures intended to strengthen the local innovation system through:

- a larger number of innovation and technology policy initiatives; and
- greater financial investments in innovation and technology measures (for example, the ITF).

The changing environment led to greater government support for the basic university-industry linkages promoted by local TTOs, which in turn encouraged them to become more entrepreneurial in nature. Nowhere has this transformation been captured better than at HKUST.

As the experience of HKUST – Hong Kong's youngest research-oriented university – shows, there is considerable scope for TTOs to proactively bridge the gap between university and industry. While City U's TTO largely performs the traditional or "early-stage" roles of TTOs (that is, making academic research accessible to local industry), HKUST's Entrepreneurship Program demonstrates a viable alternative means of operation whereby university research can be made practically useful. Furthermore, and importantly, the TTO can be the leader in this process by acquiring an equity stake in a partner company (as well as increasing the equity stake with the transfer of intellectual property), as did City U's TTO with respect to TeleEye. The HKUST TTO's establishment of its modest venture capital fund is another example of this form of creative collaboration. Both examples reinforce the conclusion that there is much room for TTOs to expand their roles.

The development trajectory of TTOs, while to some degree arcing independently, is simultaneously strongly influenced by the social and institutional environment in Hong Kong. Therefore, in order to understand the role of TTOs in the academia-industry nexus, we need to understand the wider innovation system within which these TTOs function – only then will it be possible to map the TTOs' development trajectory accurately.

In summary, while we have drawn tentative conclusions from our exploratory study, it is also apparent that Hong Kong's TTOs are vastly understudied and that they should command greater attention not least because of the strength of the university sector in Hong Kong's broader innovation system. While this paper builds on the works of Parayil and Sreekumar (2004), Mok (2005), and Patchell and Eastham (2001, 2003), further studies, including case studies like the ones we have presented, are in order to address the changing and more central roles TTOs have assumed within Hong Kong's innovation system. Finally, if the Hong Kong Government's desire to improve its innovation system is to materialize, one can expect the bridge between universities and industry to be a major focal area, one which the two TTOs examined in this paper are primed to exploit.

Notes

1. Within the literature examining the role of universities in society, there has been extensive debate over the "Third Mission" or "Third Stream" activities in universities, designating the transfer of knowledge to society. Henry Etzkowitz has discussed this issue in relation to the Triple Helix (Etzkowitz *et al.*, 2000). See also, Molas-Gallart *et al.* (2002).
2. Wallmark (1997) documented the case of Sweden's Chalmers University of Technology, reviewing the rate of inventing, the characteristics of inventors, and the economic value of patents generated. Rogers *et al.* (1999) and Steffensen *et al.* (2000) investigated technology transfers in university-based research centers at the University of New Mexico. Harmon *et al.* (1997) mapped the technology transfer processes at the University of Minnesota to determine if the characteristics of these processes vary according to the size of the firms involved and according to whether new firms are created. Mowery *et al.* (1999) focused on three universities – Columbia, Stanford and the University of California – in their analysis of the effect of the Bayh-Dole Act on universities and the national innovation system.

3. Mowery *et al.* (2004) and Mowery and Sampat (2005) concluded that, although there was no doubt that the Bayh-Dole Act had created a new context for university-industry linkages, the actual implementation of university initiatives was shaped by the previous trajectory of university-industry relations at each university. In this sense, the act appeared to have reinforced rather than revolutionized existing trends in such relationships.
4. New innovation and technology-related infrastructure includes Cyberport and the Hong Kong Science and Technology Park Corporation (HKSTPC). Cyberport promotes entrepreneurship in information technology and media industries in a location close to the University of Hong Kong (Baark and So, 2006), while the HKSTPC has established science park facilities near another major research university, the CUHK. Moreover, the first public applied research unit in Hong Kong – the Applied Science and Technology Research Institute (ASTRI) – has made collaboration with both universities and private industry one of its key priorities.
5. The City Polytechnic of Hong Kong was founded in 1984. City University of Hong Kong was granted university status on January 1, 1995.
6. The TTO is the technology marketing arm of City University of Hong Kong. It serves as a bridge between the university and the industrial and business communities. It identifies collaborative opportunities with industrial and business enterprises in Hong Kong, in the region and in the global arena. The primary goal is to promote the transfer of advanced technologies and know-how that contribute to Hong Kong's economic development. The formal objectives of City U's TTO are:
   - to strengthen links with the industrial and business sectors, helping to project the university's image and showcase its faculty members' accomplishments in applied research;
   - to build fruitful partnerships with industrial and business enterprises through contract research and technology licensing;
   - to attract industrial funding and sponsorship to support the research endeavors of the university; and
   - to provide assistance to faculty members in commercializing their research results.

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