

Towards an “Entrepreneurial University” Model to Support Knowledge-Based Economic Development: The Case of the National University of Singapore

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Summary. — In common with other Newly Industrialized Economies in Asia, Singapore is moving toward a knowledge-based strategy for growth. Increasing prominence has been given to the role of Singapore’s universities in stimulating economic growth through industrially relevant research, technology commercialization, high-tech spin-offs, attracting foreign talent, and inculcating entrepreneurial mindsets. The National University of Singapore (NUS) is examined as a case study of how East Asian universities are responding to the globalization of the knowledge economy. It is argued that a shift toward an “entrepreneurial university” model [Etzkowitz, H., Webster, A., Gebhart, C., & Terra, B. R. C. (2000). The future of the university and the university of the future: Evolution of ivory tower to entrepreneurial paradigm. *Research Policy*, 29(2), 313–330] is critical for NUS to contribute effectively to Singapore’s transition to a knowledge-based economy.
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1. INTRODUCTION

In common with other Newly Industrialized Economies (NIEs) in Asia, Singapore is moving toward a knowledge-based strategy for economic growth (Wong & Singh, 2005). Policy makers have charted a course for Singapore’s transition from an investment-driven economy to an innovation-driven economy, emphasizing the building of intellectual capital and its commercialization to create value and jobs. While the role of Singapore’s universities in nurturing talent has always been recognized, in the current period of economic transformation, increasing prominence has been given to their role in stimulating economic growth through industrially relevant research, technology commercialization, high-tech spin-offs, attraction of foreign talent, and injecting an entrepreneurial mindset among its graduates. This paper examines how the National University of Singapore (NUS), the leading university in Singa-

pore, changes its role in the Singapore economy as a case study of how universities in East Asia are responding to the globalization of the knowledge economy.

Singapore’s case is of particular interest because of its unique status as a relatively small city-state, where the pressure for globalization and the pace for shifting toward a knowledge-based economy to sustain economic survival are particularly intense. As such, the challenges that its university system faces are likely to be symptomatic of those that other small NIEs will likely have to cope with in the near future. In particular, the experience of Singapore is of relevant interest to study how the mission and governance of local universities in late-comer economies may need to be reformed toward an “entrepreneurial university” model to enable

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such economies to achieve a faster “catch-up” in the global innovation race.

2. THEORETICAL FRAMEWORK

As argued by *Etzkowitz, Webster, Gebhart, and Terra (2000)*, universities around the world are increasingly shifting from their traditional primary role as educational providers and scientific knowledge creators to a more complex “entrepreneurial” university model that incorporates the additional role of the commercialization of knowledge and active contribution to the development of private enterprises in the local and regional economy. As a result, universities become an increasingly important component of the national innovation system, and need to operate increasingly within a *Triple-Helix nexus* involving close interaction with government institutions and private industries.

This imperative for universities to shift from their traditional model to the new “entrepreneurial” model is expected to be even more urgent in the context of Asian NIEs, for three reasons. Firstly, the universities in most of these NIEs are relatively younger institutions compared to their counterparts in advanced, mature economies, and invariably are created as public institutions owned and regulated by the government. Academic faculty members are effectively state employees, and university administrators are usually government appointees, tasked to carry out government policies. As such, they tend to have much less autonomy than public universities in Europe, let alone the private universities in the United States. For example, competitive differentiation among local universities is often stifled in favor of bureaucratic directions and coordination by the state. Secondly, as “late-comers,” these economies had traditionally placed a much stronger emphasis on absorbing and diffusing technological knowledge from the advanced countries, rather than on indigenous innovation. Consequently, the universities in these NIEs also tend to have been tasked by their respective governments to focus strongly on their manpower development role through the assimilation of foreign technologies and knowledge, with much less emphasis on new knowledge creation through indigenous research activities.

Thirdly, the shift toward a knowledge-based economy, rather than one based on low-wage and natural resource advantages, requires a sig-

nificant increase in the indigenous capabilities of local enterprises to create and commercialize new knowledge, not just using knowledge imported from advanced countries. However, many of the local private enterprises that had developed in the earlier industrialization phases still tend to be laggards, rather than leaders, in engaging in R&D and innovation activities. Consequently, compared to their more technologically mature counterparts in the advanced economies, local industries in NIEs often have less experience, and lower capability, to commercialize knowledge generated from local universities.

These three factors—a more rigid bureaucratic control by the state, a lower base of research and inventive outputs coming out from the university, and lower demand and ability of private enterprises to commercialize university knowledge—suggest that the pre-conditions for Triple-Helix dynamic interactions is much weaker in the NIEs than in the advanced economies. Thus, arguably, the universities in NIEs have even greater urgency to take on an “entrepreneurial” role than universities in the advanced economies, in order to compensate for these less favorable pre-conditions that they start from. For example, the universities in NIEs may need to be more pro-active in commercializing their inventions through spin-offs, rather than relying on outside private enterprises to license them, because of the weakness of the latter. Similarly, universities in NIEs would need to undergo more drastic reform of their organizational structure and incentive system, in order to change the culture and mindset of their staff toward knowledge commercialization.

In the context of a small NIE like Singapore, we suggest the need for the local university system to take on an additional economic role not mentioned in *Etzkowitz et al. (2000)*’s model: The attraction of foreign talent. Given the small local population, Singapore needs to be able to tap top foreign talent to help staff the top echelons of specialized knowledge workers required in a knowledge economy. Just as the dynamic economic regions like Silicon Valley, London, New York City, and Boston have benefited from the influx of foreign talent, Singapore similarly needs to do likewise to differentiate itself as the leading knowledge-economy hub in Southeast Asia. Moreover, the experience of regions like Silicon Valley, Boston, and London strongly suggests that the competition for global talent not only

works through the increasingly globalized market for qualified technical professional specialists, it actually starts before the talent reach the labor market—through the attraction of top students from overseas. Indeed, top universities like Stanford, UC Berkeley, MIT, Cambridge, and Oxford have for decades served as magnets to attract top students from around the world, many of whom subsequently stayed on to contribute to the growth of key knowledge-economic sectors in these regions—high-tech industries, creative businesses, and knowledge-intensive services. In addition, many of those who returned to their home countries often continue to build economic links with their former alma mater host regions, and indirectly contribute to the vibrancy of the latter. For example, Saxenian (2000, 2002) has documented not only the extraordinarily high level of contribution of immigrant Asian technical professionals—many of whom trained in universities in Silicon Valley itself—to entrepreneurial high-tech formation in Silicon Valley, but also the phenomenon of “brain circulation” between Hsinchu, Taiwan, and Bangalore, India with Silicon Valley, and the beneficial effects this had on Silicon Valley.

In contrast to this foreign talent attraction role of western universities, particularly leading universities in the Anglo-Saxon world, East Asian universities had traditionally been much less globalized, primarily focused on the education of the local elites. Although the use of the local language as the medium of instruction represents an obstacle to attracting foreign students, the more important reason is the lack of a political commitment to foreign talent attraction as a mission for the local university. For large East Asian economies like Japan, China, and Korea, there may appear to be less pressing needs to tap foreign talent through their universities, but for a small economy like Singapore, this economic role is likely to be critical.

This role of attracting foreign talent needs to be distinguished from the related emerging role of many universities in the Anglo-Saxon world to serve as an export industry for their respective countries. Indeed, many universities in UK, Australia, Canada, and the United States have generated significant fee earnings from foreign students, both by attracting foreign students to their home campuses and later through the establishment of foreign branch campuses as well as franchising arrangements. The development of the education industry as a globally

tradable export service is clearly emerging as a potentially important growth sector for some of the more advanced East Asian NIEs like Singapore and Hong Kong. Taking on this economic role further forces on the local universities to become even more globalized in their thinking and operations.

Last, but not least, although Etzkowitz *et al.* (2000) emphasizes the technology commercialization role of the university in their entrepreneurial university model, we believe that the “entrepreneurial” university model, particularly in the context of late-industrializing economies, also implies a significant emphasis on injecting a greater dimension of entrepreneurship to the *contents* of university education itself. Stated differently, not only does the university needs to take on new functions, the nature of its core function of education needs to be re-oriented as well.

The need for the university to play an active role to help foster a more entrepreneurial mindset among students is arguably more imperative in the context of Singapore, where the highly educated population had relatively low entrepreneurial propensity (Wong, Lee, Ho, & Wong, 2005) because consistently high economic growth in the past had generated relatively full employment and bright career prospect in the corporate (mainly MNC subsidiaries) and public sectors. With stable job opportunities and steady corporate career trajectories no longer guaranteed in the increasingly competitive global economy in the new millennium, universities in Singapore need to urgently re-orientate students’ expectation of the job market and prepare them to have a more entrepreneurial mindset.

In summary, we have theoretically expanded the “entrepreneurial” university model to incorporate a number of additional emerging roles that the university needs to play to contribute effectively toward the transition of NIEs toward a knowledge-based economy. Collectively, these new roles require a significant reform and transformation of the structure and incentive system of the traditional university system. Although the emerging literature on the entrepreneurial university model has highlighted various possible new features that universities need to take on, there has as yet been little empirical work done on how pervasive these features in fact are, what regional variations can be expected, and the impact of these changes on university performance. In particular, there has been little empirical examination

of how the “entrepreneurial” university model might operate in the context of East Asia.

This paper aims to fill this knowledge gap by examining empirically the changing roles of the leading university in one of the East Asian NIEs, Singapore. The paper examines how the NUS has sought to reform its organizational structure and incentive system since the late 1990s, and the consequent impact that such changes have had on the university’s changing role in the knowledge-based economic development in the island state.

3. OVERVIEW OF SINGAPORE’S TRANSITION TOWARD A KNOWLEDGE ECONOMY

As highlighted by Wong (2004), Singapore has achieved the highest economic growth performance among newly industrializing economies, with an average GDP growth of over 8% per annum in the four decades during 1960–2000. While the manufacturing sector has been a key engine for Singapore’s economic growth, consistently accounting for over one-quarter of total GDP, the rapid growth of Singapore has also been sustained by the development of the city-state economy into a major regional and international hub in East Asia for trade, finance, transport, communications, and an increasing range of knowledge-intensive business services (KIBS) (Wong & He, 2005).

Figure 1 summarizes the four distinct phases of post-independence economic development in Singapore, and the accompanied changes in the focus of Singapore’s national innovation system (Wong & Singh, 2005).

As highlighted in Figure 1, a distinctly new phase of economic development appears to be emerging in the new millennium, as the strategic focus for economic growth increasingly shifts to making a transition toward a knowledge-based economy that incorporates three major sectors: (1) high-tech manufacturing, comprising a balanced high-tech enterprise ecosystem of large global MNCs as well as young dynamic entrepreneurial start-ups and growth companies, similar in spirit and style to the Silicon Valley model (Wong, 2004) and incorporating the newly emerging life science sector (Wong, Ho, & Singh, 2005); (2) Knowledge-intensive business services (KIBS) that support Singapore’s role as a value-adding regional business hub (Wong & He, 2005); and (3) creative contents production and distribution, that generate new sources of growth from the “new media” industries as well as add to the cultural vibrancy of Singapore as a living environment for creative talent (Wong *et al.*, 2005).

The primary focus of Singapore’s national innovation system in this emerging knowledge-economy development phase is increasingly focusing on the creation and commercialization of knowledge protected by intellectual property (patented high-tech innovations and trademarked designs, proprietary specialized knowledge assets and processes, and copyrighted creative contents). A key part of this shift is the development of entrepreneurial mindsets and capabilities toward knowledge commercialization. In particular, this calls for a fundamental re-examination of the traditional manpower development role of the university system in Singapore.

	1960s-1970s	1970s-1980s	1980s-late1990s	From Late-1990s
Economic Development	Beginning of DFI-Driven, Export led Industrialization	Transition to NIE	Transition from NIE to Developed Economy	Transition to Knowledge-based Economy
National Innovation System	Primary focus on developing Operative Capability to man Production	Primary focus on developing Adaptive Capability to support Process Technological Deepening	Primary focus on developing Innovative Capability to support applied R&D	Primary focus on developing Intellectual Capital Creation and Commercialization/Entrepreneurial Capability to support Knowledge-based economic growth

Figure 1. Stylized stages of Singapore’s economic development and national innovation system changes.

4. OVERVIEW OF NUS AND THE SHIFT TOWARD AN "ENTREPRENEURIAL" UNIVERSITY MODEL

(a) Overview of NUS

Established in 1905, NUS is the oldest and largest public university in Singapore, with a total student enrolment of over 28,000, three-quarters of which are undergraduates. Although there are two other public universities in Singapore, namely Nanyang Technological University (NTU) and Singapore Management University (SMU), both are newer¹ and not as comprehensive in scope as NUS.² Historically, the government's educational policy has emphasized public education, resulting in no large private university in Singapore, although many diploma-level private colleges and distant-learning degree programs had been allowed to operate in Singapore. However, since the late 1990s, the government had actively encouraged leading overseas universi-

ties to establish branch campuses and other forms of operational presence in Singapore.

Table 1(b) provides a summary profile of NUS as of the financial year 2005–06. With an annual R&D budget of about S\$186 million, NUS alone constitutes about 4% of total R&D spending in Singapore. With 162 US patents as of 2004, NUS is also the third largest patent holder in Singapore, after Chartered Semiconductor (a local firm) and HP (a foreign MNC subsidiary).

In terms of research and technology commercialization performance, NUS enjoys a substantial lead over NTU, the second largest university in Singapore. While NUS is only 30% larger than NTU in terms of academic and teaching faculty (2,679 in NUS versus 2,013 in NTU in 2004), the gap between the two universities is much wider in terms of cumulative patents granted (162 US patents for NUS versus 22 for NTU) and number of spin-offs formed (30 spin-offs in NUS as at March 2003, versus 12 spin-offs in NTU).

Table 1. Profile of NUS (FY2004–05 and AY1996–97)

Indicator	(a)	(b)
	AY1996–97	FY2005–06
Teaching staff of which % foreign	1,14 39.0%	1,765 ^a 51.9%
Research staff of which % foreign	843 70.1%	1,087 ^a 78.6%
Undergraduate students enrolled	17,960	22,510
Graduate students enrolled	4,478	8,231
Graduate students as % of total student enrolment	20.0%	26.8%
Percentage of foreign students studying at NUS	13% ^b	33.3% ^c
Total research funding	\$101.7mil ^d	\$185.9 mil
of which % industrial sponsored research ^e	na	6.7%
Total no. of research projects funded	1,408 ^d	1,759
Research publications	4,949 ^f	7,382 ^g
of which % articles in refereed journals	34.7%	53.1%
Patents filed	13	150
Patents granted	4	40
Cumulative patents granted by USPTO	20 ^h	187 ⁱ
Cumulative patents granted by USPTO and IPOS	30 ^h	345 ⁱ

Source: NUS Annual Research Report (various years); NUS Annual Report; US patents & Trademark Office (USPTO); Intellectual Property of Singapore (IPOS).

^a As at end June 2005.

^b Percentage of total student intake for 1997–98.

^c Figure for AY2005.

^d Figure for FY1997.

^e Includes foundations and individuals.

^f CY1997.

^g CY2005.

^h CY1990–97.

ⁱ CY1990–2005.

Table 2. *NUS' share of national R&D expenditure, FY1997–FY2003*

Year	R&D expenditure (S\$ million)			NUS R&D expenditure as % of higher education expenditure
	Total national R&D expenditure	Higher education R&D expenditure	R&D expenditure in NUS	
1997	2104.5	277.7	101.7	36.6
1998	2492.3	305.8	106.17	34.7
1999	2656.4	310.0	94.8	30.6
2000	3009.5	338.3	122.8	36.3
2001	3232.7	367.0	210.7	57.4
2002	3404.7	430.0	205.5	47.8
2003	3424.5	457.5	165.2	36.1
2004	4061.9	424.7	157.6	37.1
2005	4582.2	478.0	185.9	38.9

Sources: Agency for Science, Technology and Research (various years); National Survey of R&D in Singapore (various years); NUS Research Annual (various years); NUS Office of Research (2004).

Note: Figures for NUS exclude NUS-hosted PRICs. The decrease in funding in FY2003 is partly because reduced calls by government research councils.

NUS has historically played a large role in Singapore's knowledge creation. Until 1991, public R&D was concentrated in the Higher education sector (particularly in NUS) and in a small number of government agencies (Wong & Singh, 2005). Since then, a large number of public research institutions and centers (PRICs) have been established, and the relative share of R&D spending by these PRICs now equals that of the Higher education sector. Nevertheless, R&D funding in NUS has grown quite rapidly, doubling in the five years during 1997–2002 (Table 2). Over the years, R&D expenditure in NUS has typically accounted for over one-third of R&D spending in the Higher education sector, including the four polytechnics.

As further evidence of NUS' position as Singapore's premier university in the areas of Science and Technology, Table 3 shows that NUS also makes a significant contribution to Singa-

pore's R&D manpower. Following the formation of the National Science and Technology Board (NSTB) and the launch of the country's first National Technology Plan in 1991, the number of research staff employed by NUS increased dramatically from 274 in 1991 to 1002 in 1996, an average growth rate of 29.6% per year. The number of research staff was subsequently reduced over the next few years as a few of the research institutes previously under university management were hived off into autonomous units reporting directly to NSTB. Nevertheless, by 2004, NUS' research staff strength of 1,109 still accounted for almost 30% of the RSEs in Singapore's Higher education sector and close to 6% of total national RSE manpower (Table 3). When the teaching faculty in the Science, Engineering and Medical faculties are included, NUS accounts for half of the Research Scientists and Engineers (RSEs)

Table 3. *NUS' share of RSEs in Singapore, 1991–2004*

Year	Total RSEs in Singapore	Higher education RSEs	NUS research staff ^a	NUS research staff share of total higher education RSEs (%)	NUS Faculty in Science, Engineering and Medicine	NUS research staff + Sci., Eng. and Med. Faculty share of total higher education RSEs (%)
1991	5,218	1,851	274	14.8	670	51.0
1995	8,340	2,558	735	28.7	740	57.7
2000	14,483	3,087	758	24.6	792	50.2
2004	18,935	3,746	1,109	29.6	773	50.2

Source: Agency for Science, Technology and Research (various years); National Survey of R&D in Singapore (various years); NUS Annual Report (various years).

^a Figure is for all NUS research staff, including those in non-technical areas.

Table 4. *Ranking of NUS in the World University Rankings by the Times Higher Education Supplement, 2004–05*

	2004 Ranking	2005 Ranking
Overall	18	22
Biomedicine	25	15
Science	35	34
Technology	9	9
Social sciences	10	13
Arts and humanities	17	56

Source: The Times Higher Education Supplement (various years).

in the Higher Education sector in 2004, and 10% of total RSE manpower in Singapore.

The university's rapidly growing research output also positions it as an important research university; earning the status of a “Doctoral/Research University—Extensive” under the Carnegie Classification of Institutes of Higher Learning since the late 1980s. Despite being a relatively late comer, NUS research capabilities and educational standards have also begun to attract international recognition. This is reflected in the university's commendable placing in a number of international rankings. In 2000, NUS was ranked 5th in Asiaweek's list of Asia's Best Universities. More recently, NUS achieved a surprisingly high ranking in the 2004 Times Higher Education Supplement's ranking of top 200 universities in the world (Table 4), both overall as well as for individual faculties. While slipping a few spots in the 2005 rankings, NUS continued to rank highly overall and made significant improvement in the area of biomedical science. As the 22nd ranked university globally, NUS further achieved the distinction of being the fourth-highest placed Asia-Pacific university in the list.

(b) *Recent shift toward an entrepreneurial university model*

Like most other public universities developed under the British Commonwealth tradition, NUS has in the past been following the traditional model of having teaching as its primary mission, with research as a secondary function. While the 1980s and 1990s saw increasing emphasis on research, it was not until the mid-1990s that NUS began to establish a technology licensing office.

The major impetus for change came only in the late 1990s, when a new vice-chancellor was appointed who enjoyed the strong support of a number of senior ministers in the government. Harvard-trained and having prior background in US industry (General Electric) as

well as research administration experience at an Ivy-League university in the United States, the new vice chancellor not only significantly accelerated the pace of change of several initiatives that were already in motion earlier, but more importantly, he initiated a shift toward what *Etzkowitz et al.* (2000) has described as the “entrepreneurial university” model. Emphasizing the need to make the university more entrepreneurial, he created a new division in the university that has come to be known as NUS Enterprise, and hand-picked a professor from the engineering school who had been among the earliest to have started a venture to commercialize his inventions to serve as the CEO of the new organization. Under the broad mission to inject a more entrepreneurial dimension to NUS education and research, the CEO was given great latitude to define and implement new initiatives to make the university “more enterprising.”

After some early experimentation, NUS Enterprise began to take shape and introduced a number of major initiatives to reform university policies with respect to governance of technology commercialization, and to inject a stronger entrepreneurial element in university education. Annex Figure A shows the new organizational structure of NUS after the introduction of the new “Enterprise” cluster. As can be seen, the new Enterprise cluster basically took over most of the functions previously under the administrative (corporate) cluster that deal with knowledge commercialization, including technology licensing and industrial sponsored research (integrated within an Industry and Technology Relations Office (INTRO)), consulting, continuing education, and publishing. NUS Enterprise also took over a unit that previously reported to the Academic Cluster and expanded it to become a university-wide Entrepreneurship Center that has educational, research as well as other promotional functions related to entrepreneurship. Last, but not least, it also introduced two new

units: (i) a Venture Support unit to provide focused assistance to faculty, students, and alumni engaging in new venture activities; and (ii) an Overseas College Program (NOC) to launch new experimental programs in international entrepreneurship education.

Among the key initiatives introduced by NUS Enterprise is the re-organization of the technology licensing office to make it more “inventor friendly,” with less emphasis on maximizing licensing revenue, and greater focus on getting greater deployment of NUS technology to the marketplace, whether through licensing to existing firms or spinning off new firms. Through the new Venture Support (NVS) unit, a number of new programs were launched to provide assistance to NUS professors and students to commercialize their inventions and knowledge. These include the provision of Incubator facilities on campus and in the Silicon Valley, and the establishment of a seed fund that provides very early stage seed funding to NUS spin-off companies. A separate student start-up fund was also established to provide smaller seed funding to new ventures started by students.

In terms of education programs, the new Entrepreneurship Center established within NUS Enterprise was tasked with the mission to significantly expand the teaching of entrepreneurship courses to all students on campus, particularly students in engineering, computing and science. A technopreneurship minor program was introduced that can be taken by any undergraduate student. At the graduate level, elective courses in new venture creation were introduced, targeted at Masters and Ph.D. students interested in commercializing their inventions. The center was also given the task of raising awareness and interest in entrepreneurship among students and faculty, which it performed through outreach activities such as organizing annual national and international business plan competitions, facilitating the development of a student entrepreneurship society on campus, and conducting regular “techno-venture forums” that bring prominent entrepreneurs and venture professionals to campus to speak. The center also began building a network of entrepreneurs, venture capitalists, and angel investors to provide NUS spin-offs with mentoring by practitioners and access to external venture funding.

Besides pushing for greater enterprise through the NUS Enterprise Division, the new university vice-chancellor also seeks to “globalize” the university, arguing that, with

growing global competition for faculty, students and resources, NUS needs to adopt globally competitive governance and practices to stay competitive. Indeed, he adopted a “Global Knowledge Enterprise” as the vision for NUS. Under this globalization drive, he began to shift the emphasis away from local manpower development to incorporate a twin objective of making the university a global educational hub, attracting top foreign students and faculty in increasing competition with other leading universities in the world. In line with this globalization drive, NUS began revising its faculty compensation and policy, making it more flexible to allow the university to pay more to attract top talent, as well as to reduce pay for under-performing staff. Tenure and promotion policy was made much more stringent and performance-based in line with the benchmarks of leading universities in the United States. Intake of foreign students also increased, while a larger share of local students are encouraged to go on exchange program abroad for at least a semester.

The NUS Overseas College (NOC) program was introduced via NUS Enterprise in 2001 as a new initiative that integrated both dimensions of globalism and entrepreneurship. Under the NOC program, NUS began a program to send its brightest undergraduate students to five entrepreneurial hubs in the world to work as interns in high-tech start-up companies for one year, during which they would also take courses related to entrepreneurship at partner universities in each of the region. In essence, the NOC program represents an experiment in learning entrepreneurship by “immersion,” i.e., by immersing the student as an “apprentice” in a high-tech start-up or growth enterprise in a foreign location to expose them to the tacit aspects of entrepreneurial practice and foreign business culture. The program does not expect the students to be able to start their own ventures right after graduation, but rather, to infuse in them an entrepreneurial mindset that will orient their future research toward commercializable innovation, as well as influence their future career choices toward more entrepreneurial and innovative settings. In addition, the program also aims to help them establish valuable life-long social networks with the entrepreneurial communities in leading high-tech hotspots overseas, so that they will be more inclined toward, and better equipped for, working in or starting new high-tech start-ups that will have global aspiration.

The first such NOC program was launched in Silicon Valley in 2002, followed by Philadelphia in 2003, Shanghai in 2004, Stockholm in 2005, and Bangalore in 2006. In steady state, the program aims to send 50 students per year per location. The NUS Entrepreneurship Center worked closely with NOC to provide educational support to these overseas internship programs by helping to develop the academic collaborations with the selected partner universities in the respective locations (e.g., Stanford in Silicon Valley, Fudan in Shanghai, and KTH in Stockholm), and by conducting additional entrepreneurship courses not available at those overseas locations from the partner universities as well as providing academic supervision of internship-based student projects.

Complementing the “outward-bound” NOC program that seeks to expose NUS students to diverse international entrepreneurial high-tech environments by sending them abroad, NUS Entrepreneurship Center also began an “inward-bound” program to attract foreign students to come to Singapore for high-tech start-up internships and to take entrepreneurship courses at NUS. Starting with a program that brings about 50 graduate students a year from Norway to Singapore, the center had also organized an intensive technology commercialization summer school for member universities of the U21 Consortium, which links 16 universities in Asia, Australia-NZ, Europe, and North America to collaborate in educational initiatives. In addition, the program has launched a technology commercialization program for professors from major Thai universities.

In summary, through the Enterprise cluster initiative, NUS can certainly be described as having embarked on a shift toward an entrepreneurial university model, but with distinctive characteristics that go beyond the broad features suggested by *Etzkowitz et al. (2000)*. In particular, as suggested in Section 2 earlier, NUS appears to have embraced the need to inject a more entrepreneurial and global dimension to its educational mission.

5. IMPACT OF NUS’ SHIFT TOWARD THE “ENTREPRENEURIAL UNIVERSITY” MODEL

(a) *Overview of impacts*

As the shift toward the “entrepreneurial university” model is still in its early stage, it may

be pre-mature to assess the impact this may have on the university’s performance in terms of the broader set of objectives that the new model implies. It is also not clear that what mix of performance benchmarks may be appropriate for conducting such an assessment. Finally, any change in performance in recent years may have been caused by other factors than those we have associated with the shift toward the entrepreneurial university model.

Notwithstanding, the above caveat, *Table 1* provides a summary overview of the key changes that NUS has undergone during 1996/97–2004/05. In essence, *Table 1* shows that although there was only a moderate expansion of the university in terms of the conventional performance dimension of education output and research output, a more dramatic change can be observed in the new dimensions of foreign talent attraction, entrepreneurship promotion, and technology commercialization. These are further elaborated below.

(b) *Manpower development*

NUS played a significant role in the manpower development of Singapore in the 1980s, producing at least one-third of the city’s total tertiary manpower output during the period when the development of the Singapore economy demanded increasingly skilled manpower. NUS’ contribution to national tertiary-educated manpower output peaked in 1980s, with over 40% of Singapore graduates coming from NUS. The number of graduates from NUS grew at an average rate of 14.5% per year during 1980–85, faster than that of the total number of graduates (10.4%) (*Ministry of Manpower, various years*). As the number of tertiary institutions in Singapore has increased since the early 1990s, NUS’ contribution to total national tertiary manpower output has understandably declined, falling to below 30%. However, NUS’ share of tertiary graduates remains significant at about 25–28% of total tertiary manpower output from the mid-1990s to the present.

While the number of graduates coming out of NUS appears to have stabilized around 9,000+ in 2000s, NUS has shifted the emphasis of its contribution to manpower development in Singapore toward the training of graduate research students, in line with its increasing emphasis on knowledge creation. NUS has seen a steady annual increase in research graduate student enrollment since the mid-1990s, as

Table 5. *NUS research publications, 1996–2003*

	Journal publications covered by SSCI, AHI and SCI-extended (a)	Research publications includes conference papers and book chapters (b)	(a/b)
1996	1,446	4,313	33.5
1997	1,716	4,949	34.7
1998	1,886	5,274	35.8
1999	2,230	5,571	40.0
2000	2,294	6,099	37.6
2001	2,555	6,275	40.7
2002	2,619	6,470	40.5
2003	3,160	na	na

Source: NUS Research Annual, various years; ISI Thomson Web of Science.

the number of research graduate students enrolled doubled from 2,763 in 1997 to 5,407 in 2003.

(c) *Knowledge creation*

The output of NUS research publications, including journal articles, conference papers and book chapters, has grown fairly steadily over the years, from 4,313 in 1996 to 6,470 in 2002, an average growth rate of 7% per year (Table 5). The growth of internationally refereed journal publications had been faster, resulting in its share of total publications rising from about one-third in 1996 to 41% in 2002. In part, this reflects the successful recruitment of top tier faculty and research students.

(d) *Knowledge commercialization*

Whereas the rate of new knowledge creation increased moderately during 1997–2003, the pace of knowledge *commercialization* changed more significantly. Annex Figure B shows the pattern of flows of knowledge created by

NUS toward commercialization in recent years, moving from research to invention disclosure, patenting, technology licensing, and new venture spin-offs. We analyzed in greater details the changes in each of the mechanisms identified in Annex Figure B.

(i) *Invention disclosures*

Data on invention disclosures were only available from 1998, when INTRO formally introduced this reporting procedure as part of the streamlining of the university technology commercialization process. The number of invention disclosures as reported by NUS faculty and researchers from 1998 to 2004 appears to be somewhat erratic, fluctuating between 59 and 123 per year (Table 6(a)). As has been found in other universities, this may be due to the fact that not all faculty members in fact disclose their inventions to the university.

(ii) *Patenting*

Reflecting the late entry of Singapore into innovation activities compared to the advanced OECD countries, the absolute cumulative num-

Table 6. *Number of invention disclosures, patents filed by and granted to NUS, FY1997–2004*

Financial year	(a) No. of invention disclosures	(b) Patent applications	(c) Patents granted
1997	NA	52	9
1998	76	75	18
1999	65	103	12
2000	68	130	21
2001	83	83	17
2002	59	91	34
2003	78	119	28
2004	123	124	51

Source: NUS Research Report 2003–04; NUS Annual Report 2005.

Note: Figures include patents filed in multiple countries.

ber of Singapore-based inventions receiving patent grants is still relatively low as of 2004. Nevertheless, Singapore's patenting performance has improved dramatically over the last 10 years. The average number of USPTO-granted patents to Singapore-based inventors and organizations jumped from 50 per year in the early 1990s, to 154 in the late 1990s and again to 497 during 2000–04. The number of US patents granted in the four years 2000–04, 2486, is higher than the total number of patents granted in all prior years. In terms of patenting intensity per 10,000 population, Singapore has already exceeded several OECD countries by the early 2000s (see Wong & Ho (2003) for more detail).

NUS has played a significant role in Singapore's increased patenting activity. Since the early 1990s, NUS has implemented an intellectual property (IP) policy whereby all IP created by NUS staff are assigned to NUS, with IN-TRO tasked to license the IP and distribute any return from commercialization equally among the inventor, his department, and NUS central administration. The total number of NUS patent applications grew steadily over 1997–99, averaging below 80 per year for the period. The pace of increase has continued after 1999, and despite some erratic fluctuations, the period 2000–04 registered a higher average of over 100 applications a year (Table 6(b)). The number of patents granted also registered a distinct increase in the period 2000–04, averaging 30 per year *versus* 13 per year in the period 1997–99 (Table 6(c)).

With 162 US-granted patents, NUS had by 2004 become the third-largest holder of Singapore-based inventions granted US patents, up from 7th ranking in 1995, when NUS had only 13 patents to its name (Table 7). By 2004, NUS had overtaken large corporations such as Motorola and Texas Instruments in terms of the size of its local patent portfolio. Overall, NUS' share of total US patents granted to Singapore-based inventors has increased over time, from 3.0% in 1990–94 to 4.6% in 1995–99 and 5.1% in 2000–04.

The patenting data also reveal that since 2000 there has been an increase in collaborative innovation activities between NUS and private sector organizations in Singapore. Up to 1999, only one patent had been jointly invented with a private sector organization. Subsequently, however, the proportion of NUS patents jointly owned with private sector companies increased substantially, with over 40% of patents granted in 2000–01 and over 10% of patents granted in 2002–03 being jointly owned and jointly invented with private sector companies.³

(iii) Licensing

A clear increase in the intensity of technology commercialization from 2000 is evident from Table 8. As of the end of FY2004, NUS had made 239 technology licensing agreements. Of these, only one-quarter was issued before 2000; the remaining three-quarters were signed in the last five years 2000–04. The majority of NUS licenses up to 2003 were signed with

Table 7. Top 10 organizations with Singapore patents, 1976–2004^a

Company	No. of patents 1976–95	No. of patents 1976–2004	Rank 1976–95	Rank 1976–2004
Chartered semiconductor manufacturing	14	678	6	1
Hewlett-Packard Company	24	178	2	2
National University of Singapore	13	162	7	3
Seagate Technology	–	155	–	4
Motorola Inc.	26	93	3	5
Texas Instruments	20	92	4	6
Institute of Microelectronics	–	78	–	7
Micron Technology Inc.	–	65	–	8
ST Assembly Test Services	–	60	–	9
<i>Tri-tech Microelectronics</i> ^b	–	56	–	10

Source: Database of the US Patent and Trademark Office (USPTO) (various years).

^a Patents where at least one inventor is a Singaporean. Includes patents which are jointly assigned.

^b A company called Tri-tech Microelectronics was granted a total of 56 patents before filing for bankruptcy and entering liquidation in 1999.

Table 8. *NUS licensing agreements and royalties 1987–2004*

Year of license	No.	Royalties (\$\$)
1987–90	7	na
1991–94	12	na
1995	2	na
1996	8	\$120,000
1997	8	\$76,000
1998	8	\$25,065
1999	15	\$113,959
2000	50	\$590,000
2001	40	\$116,600
2002	34	\$160,000
2003	21	\$290,000 ^a
2004	34	\$100,200 ^a
Total	239	

Source: NUS Industry and Technology Relations Office (INTRO).

^a Data is for financial year.

commercial companies (44.8%) or NUS start-ups (29.5%), with the remaining quarter being signed with government bodies or public research institutions/centers.

In spite of the tangible increase in technology licensing, in terms of actual income generated from licensing royalties, only a slight average increase appears to have occurred after 2000. Moreover, the amount appears to be somewhat erratic from year to year, which is not uncommon among university technology licensing. Although gestation period between licensing and royalty generation may be a contributing factor, it is also likely that the deliberate policy of encouraging more technology commercialization instead of maximizing royalties may partly account for the lower licensing income

growth compared to the growth in the number of licenses.

(e) *Entrepreneurial spin-offs*

The results of NUS' change in policy to encouraging technology commercialization through spin-off and start-up formation after 2000 are evident from Table 9. Of the 82 spin-offs and start-ups formed during 1980–2004, two-thirds were established from 2000 onwards. Focusing only on spin-offs, which are companies formed to commercialize NUS' patented invention (as opposed to other faculty start-ups that do not involve NUS-owned IP), NUS' average spin-off formation rate of four to five per year in recent years is creditable,

Table 9. *Number of NUS spin-offs and start-ups, 1980–2004*

Year	Spin-offs	Start-ups	Total
1980–96	6	7	13
1997	4	1	5
1998	0	1	1
1999	4	4	8
2000	5	2	7
2001	4	3	7
2002	6	5	11
2003	3	13	16
2004	6	8	14
Total	38	44	82

Source: NUS INTRO and NUS Venture Support.

Note: Spin-offs refer to new companies formed by NUS faculty members/researchers to commercialize NUS intellectual property. Start-ups refer to companies formed by NUS faculty/researchers that do not involve IP owned by NUS.

Table 10. *NUS faculty members and research staff by nationality as at end June 1997 versus end June 2005*

Nationality	As at end June 1997				As at end June 2005			
	Faculty members		Research staff		Faculty members		Research staff	
	No.	%	No.	%	No.	%	No.	%
Singapore	862	61.0	252	29.9	849	48.1	232	21.3
Malaysia	181	12.8	125	14.8	191	10.8	98	9.0
India	56	4.0	93	11.0	99	5.6	112	10.3
China	63	4.5	271	32.2	121	6.9	461	42.4
Other Asian countries	76	5.4	31	3.7	151	8.6	78	7.2
US/Canada	75	5.3	28	3.3	138	7.8	23	2.1
Other countries	101	7.1	43	5.1	216	12.2	83	7.6
Total	1,414	100	843	100	1,765	100	1,087	100

Source: NUS Annual Reports.

even though it is still much lower than those of some of the top American universities, such as MIT (23 spin-offs in 2002), Stanford (13) and Harvard (7).

(f) *Attraction of foreign talent*

A marked increase in NUS' role in attracting foreign talent is also evident in terms of both student intake and recruitment of faculty members and researchers. During AY1996/97–FY2005/6, the proportion of foreign students in NUS' student population doubled from 13% to 33% (see Table 1 earlier). Although less dramatic, a significant increase is also evident in the proportion of foreigners among faculty and research staff recruitment during 1997–2005 (Table 10). The share of foreigners among faculty members increased from 39% in 1997 to over 50% by 2004, while the foreigners' share among researchers increased from 70% to al-

most 80%. The biggest source of foreign researchers came from Mainland China, representing more than half of all foreign researchers by 2004. Although Malaysia continued to be the most important foreign source for faculty in 2004, its share among research staff had been overtaken by India by 2004.

(g) *Benchmarking of NUS with universities in the Asia Pacific*

While the above sections have highlighted the changes in knowledge creation and commercialization outputs of NUS over the years, it is useful to benchmark NUS' science and technology outputs *versus* other leading universities in the Asia-Pacific region. Table 11 provides such a comparative benchmark analysis drawing upon data from a survey of 22 member universities of the Association of Pacific Rim Universities (APRU) conducted by one of the

Table 11. *NUS versus Asia-Pacific and North American APRU universities: Comparative indicators for FY2000*

	NUS	Asia-Pacific universities	North American universities
<i>Research input</i>			
Research expenditures per faculty member	US\$27,000	US\$55,000	US\$194,000
<i>Research output and commercialization</i>			
Disclosures per 100 faculty members	7.6	4.8	10.3
US patents granted per 1,000 faculty members	8.0	3.5	28.0
Patents granted in home country per 1,000 faculty members	14.8	5.7	26.1
Licenses executed per 100 faculty members	2.3	0.8	3.5
Cumulative spin-offs per 100 US patents	31.7	36.9	23.9

Source: APRU.

authors in 2000 (Allen & Wong, 2003). Ten of the 22 universities covered by the survey are from North America, with the remaining 12 from Asia. As can be seen in Table 11, NUS' research input is relatively by low as compared to other APRU member universities. In FY2000, NUS spent US\$27,000 per faculty member on research, about half of that spent on average by leading Asian universities, and only 13.9% of that spent by the leading North American universities. Despite this however, its scientific research output and technology commercialization indicators compare much more favorably. With an average of 7.6 invention disclosures per 100 faculty members and 8.0 US patents and 2.3 licenses per 1,000 faculty members in 2000, NUS scored above average among the sample of Asian universities, although it still lagged behind the North American universities. In common with the tendency of Asian universities to emphasize spin-offs promotion (Allen & Wong, 2003), NUS achieved a higher rate of start-ups per 100 US patents granted than leading US universities.

6. CONCLUSION

In summary, our empirical analysis indicates that NUS' contribution to national economic development has changed qualitatively in the period before and after 2000, shifting from being primarily a manpower provider and knowledge creator to take on a more visible role in knowledge commercialization through increased patenting, licensing to private industry and spinning-off new ventures. Although the shift toward an "entrepreneurial university" model may not be the sole cause, and some elements of the model may actually have begun in the early and mid-1990s, in parallel with the implementation of the first and second National Science and Technology Plan, the empirical evidence presented earlier are consistent with the hypothesis that universities need to adopt key elements of the entrepreneurial university model in order to contribute more effectively to the commercialization and transfer of university technology to private industry. While the specific governance model (e.g., the Enterprise Cluster approach) and initiatives/programs (e.g., the seed fund program) adopted may be unique to the Singapore context and may not be applicable to other contexts, the reform experience of NUS may nonetheless be

instructive for other East Asian universities seeking to develop their own entrepreneurial university model.

It is true that our finding of relatively low commercialization impacts of NUS before 2000 may be incomplete, due to lack of data collection by NUS on most aspects of technology commercialization activities until the late 1990s. Nevertheless, the picture appears to be corroborated by the finding of Wong (1999), which found from a survey of manufacturing firms in Singapore in 1997 that the propensity for technological collaborations between universities and private industry was still relatively low, and that universities were not highly regarded by industry as an important source of technology. The inadequate collection of official statistics on NUS' knowledge commercialization activities in the earlier period itself reflects a lack of strategic focus on knowledge commercialization as a key mission of the university in the earlier period.

It is also true that, given that the change in innovation and commercialization performance has been quite recent, it is unclear whether they represent long-term sustainable changes. Indeed, to-date, there has as yet been no outstanding success achieved in terms of major technological breakthroughs leading to substantial licensing revenue, or spin-offs that become significant commercial success. While it is thus by no mean certain that NUS' shift toward the entrepreneurial university model will eventually lead to significant economic payoffs, we can take heart from the fact that some of the leading US universities in terms of technology commercialization had also taken a long time to achieve commercial viability in terms of their technology licensing office operations (Shane, 2004).

Besides knowledge commercialization, our findings of a high and increasing level of recruitment of foreign students, researchers and faculty members by NUS are also consistent with our argument that an entrepreneurial university model for universities in small, open economies needs to incorporate the additional role of attracting foreign talent. While the level of involvement of foreigners in NUS is probably exceptional by the standards of East Asian universities and perhaps even when compared to Anglo-Saxon universities, it does suggest that an ability to compete for talent on a global scale is likely to rank as an important feature of any entrepreneurial university model for newly industrializing economies. Indeed, the recent ranking of leading universities in the world by

The Times Higher Education Supplement (2005) has incorporated two sub-indices to measure the extent of internationalization of faculty and students, respectively.

Last, but not least, NUS' experiment in injecting a more entrepreneurial dimension to the educational experience of its students, particularly those in technical fields, may be instructive for many universities facing a similar challenge of making their technical graduates more business savvy and entrepreneurially minded. The conventional solution of concentrating on technical specialization and leaving the injection of business skills and entrepreneurial acumen to a later stage (e.g., through an MBA education) may not be optimal for the increasingly dynamic labor market of a global, knowledge-based economy, where creativity, entrepreneurial mind-set, social skills, and international networking take on increasing importance.

In conclusion, the case of NUS in Singapore illustrates an attempt by a university from a small, newly industrialized economy to transform itself to contribute more effectively to the dynamic shift of the country toward a regional knowledge-based economic hub. The approach adopted is admittedly risky: making technology commercialization an explicit goal of the university will invite inevitable public scrutiny of the actual performance of the university in commercializing technologies. Given that many leading universities in the world have not yet been successful in promoting tech commercialization, the chance of NUS failing to meet such raised public expectation is significant. Moreover, the pursuit of technology commercialization as an objective of the university will require extensive organizational changes and encounter considerable resistance. Nonetheless, these risks are worth taking, for the rewards to success will be substantial.

NOTES

1. NTU was established in the 1980s through a 2-step process of merging a Chinese-medium based private university into NUS and later spinning it out as a separate entity. SMU was only established in the late 1990s.
2. Until very recently, NTU focused primarily on engineering, applied science, accounting and business,

while SMU primarily focused on management and economics education.

3. In 2004, there was a sudden reversal of this, with NUS having no patents jointly owned with industry. It remains to be seen whether this is the beginning of a trend, or merely an anomaly.

REFERENCES

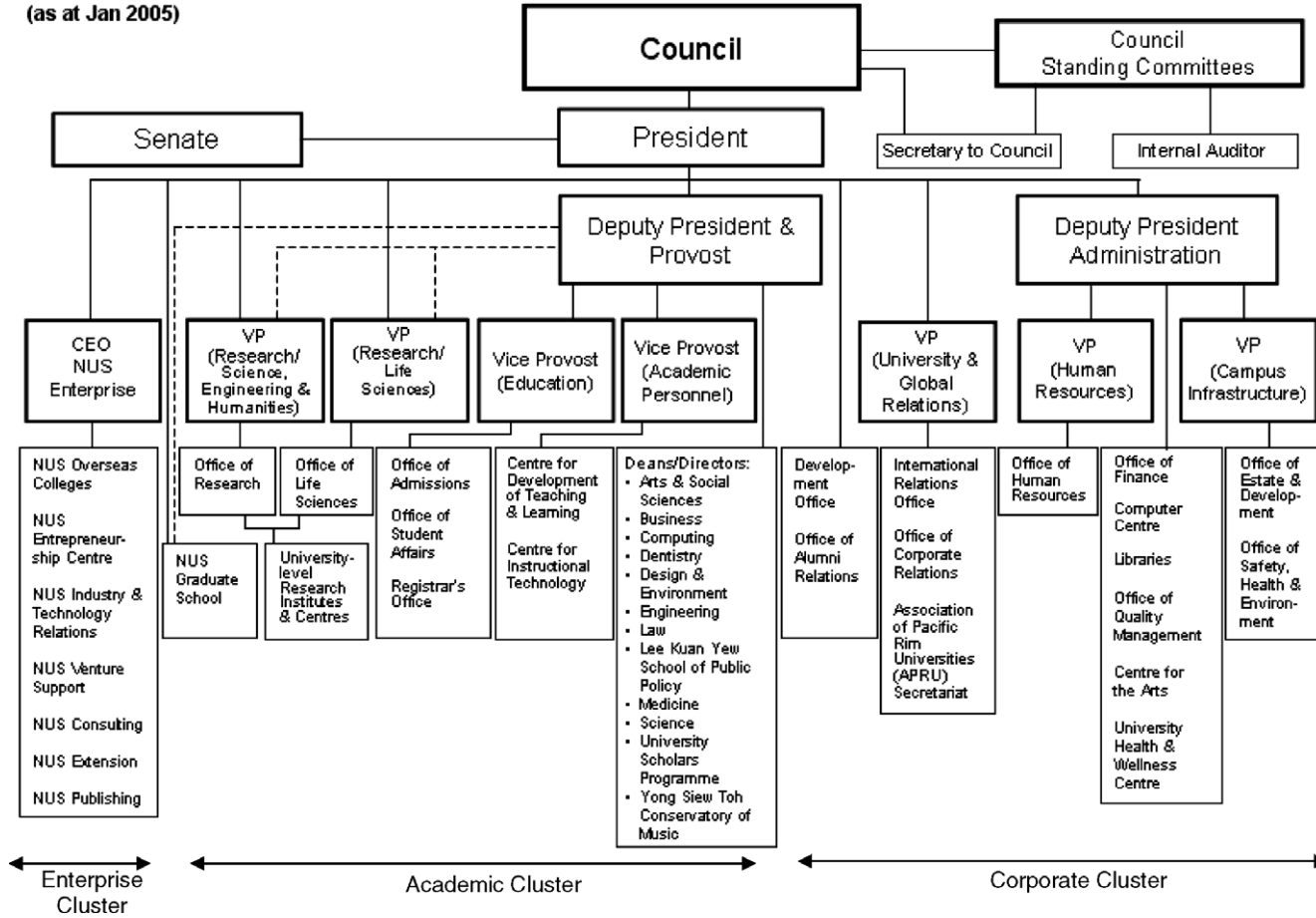
- Agency for Science, Technology & Research (various years). National Survey of R&D in Singapore. A*STAR, Singapore.
- Allen, K., & Wong, P. K. (2003). Technology spin-offs from Pacific Rim Universities: Entrepreneurial context and economic impact. Paper presented at the 23rd Babson-Kauffman entrepreneurship research conference, 3–5 June 2003.
- Etzkowitz, H., Webster, A., Gebhart, C., & Terra, B. R. C. (2000). The future of the university and the university of the future: Evolution of ivory tower to entrepreneurial paradigm. *Research Policy*, 29(2), 313–330.
- Ministry of Manpower (various years). Singapore year-book of manpower statistics. Ministry of Manpower, Singapore.
- National University of Singapore (NUS) (various years). Annual report. NUS, Singapore.
- National University of Singapore (NUS) (2004). Quest for knowledge: NUS annual research report 2003/4. NUS Office of Research, Singapore.
- Saxenian, A. (2000). *Silicon Valley's new immigrant entrepreneurs*. San Francisco, CA: Public Policy Institute of California.
- Saxenian, A. (2002). *Local and global networks of immigrant professionals in Silicon Valley*. San Francisco, CA: Public Policy Institute of California.
- Shane, S. (2004). *Academic entrepreneurship: University spin-offs and wealth creation*. UK: Edward Elgar.
- The Times Higher Education Supplement (2005). The top 200 world university rankings, published 21st October 2005. TSL Education, UK.
- Wong, P. K. (1999). University-industry technological collaboration in Singapore emerging patterns and industry concerns. *International Journal of Technology Management*, 17, 270–284.
- Wong, P. K. (2004). The re-making of Singapore's high tech enterprise ecosystem. accepted chapter In H. Rowen, W. Miller, M. Hancock (Eds.), *Asia's high tech regions*. California: Stanford University Press, forthcoming.

- Wong, P. K., & He, Z. L. (2005). A comparative study of innovation behavior in Singapore's KIBS and manufacturing firms. *Service Industries Journal*, 25(1), 21-42.
- Wong, P. K., & Ho, Y. P. (2003). IP creation pattern and economic impact in Singapore. Research Report commissioned by Ministry of Law, Singapore, April.
- Wong, P. K., Ho, Y. P., & Singh, A. (2005). Singapore as an innovative city in East Asia: An explorative study of the perspectives of innovative industries. World Bank Policy Research working paper no. 3568, 2005, World Bank, Washington, DC.
- Wong, P. K., Lee, L., Ho, Y. P., & Wong, F. (2005). Global entrepreneurship (GEM) 2004 Singapore report. NUS Entrepreneurship Centre, National University of Singapore.
- Wong, P. K., & Singh, A. (2005). The National System of innovation in Singapore. Chapter In C. Edquist *et al.* (Eds.), *Small economy innovation systems: Comparing globalization, change and policy in Europe and Asia*, Elgar, forthcoming.

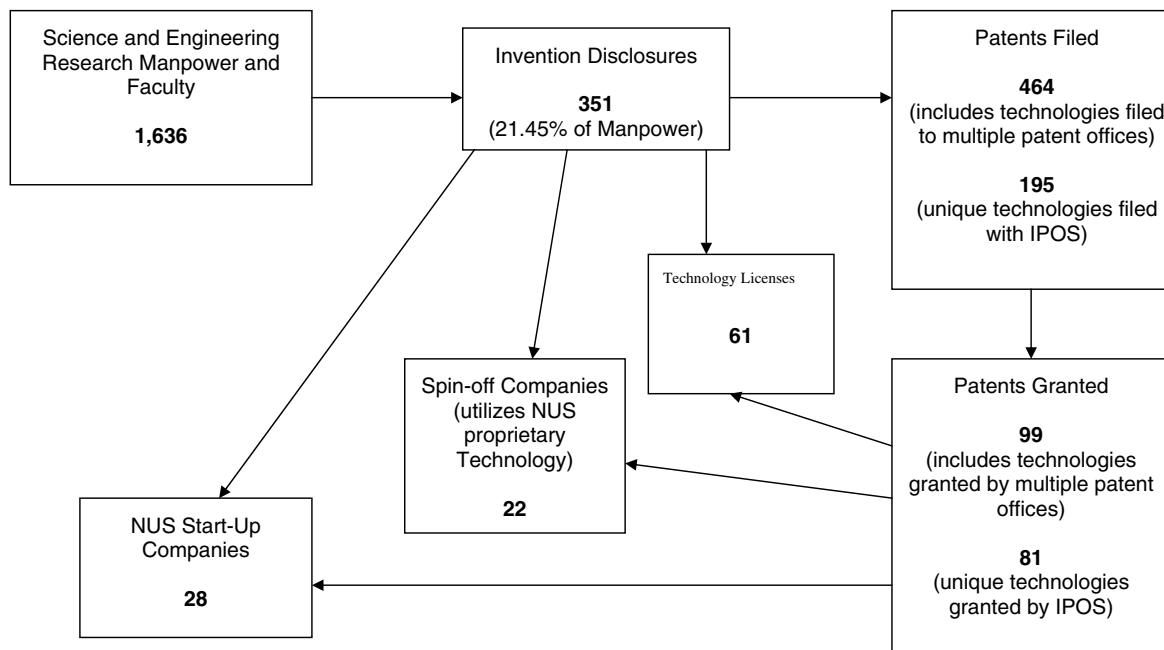
APPENDIX A

See [Annex Figure A](#) and [Annex Figure B](#).

NUS Organization Chart
(as at Jan 2005)



Annex Figure A. NUS organizational chart. Source: NUS staff intranet, <http://my.intranet.nus.edu.sg/SAPPORTAL/>.



Annex Figure B. *Flow of NUS technology commercialization, 1998–2002.* Notes: Average of Research Manpower and Faculty over 1998–2002. Assume lag of 2 years between filling and granting of patents.

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