

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

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Abstract

In common with other Newly Industrialized Economies (NIEs) in Asia, Singapore is moving towards a knowledge-based strategy for economic growth. 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, attracting foreign talents and inculcating entrepreneurial mindsets. This paper examines the changing role of the National University of Singapore (NUS) in the Singapore economy as a case study of how universities in East Asia are responding to the globalization of the knowledge economy. In particular, the paper argues that a shift towards an “entrepreneurial university” model (Etzkowitz, 2000) is critical for NUS to contribute effectively to Singapore’s transition to a knowledge-based economy.

Keywords: University technology commercialization, university-industry link, Entrepreneurial University, Singapore

1. Introduction

In common with other Newly Industrialized Economies (NIEs) in Asia, Singapore is moving towards a knowledge-based strategy for economic growth (Wong and Singh, 2004). 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 talents and injecting an entrepreneurial mindset among her graduates. This paper examines how the National University of Singapore (NUS), the leading university in Singapore, changes her 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 her unique status as a relatively small city-state, where the pressure for globalization and the pace for shifting towards a knowledge-based economy to sustain economic survival are particularly intense. As such, the challenges that her university system faces are likely to be symptomatic of those that other small newly industrialized economies are likely to 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 towards an "entrepreneurial university" model to enable such economies to achieve a faster "catch-up" in the global innovation race.

2. Theoretical Framework: The Need for an "Entrepreneurial University" Model in the Transition towards Knowledge-Based Economic Development

As argued by Etzkowitz et. al. (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 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 the newly industrialized economies (NIEs), for three reasons. Firstly, the universities in most NIEs are relatively younger institutions compared to their counterparts in the 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 degree of autonomy than public universities in Europe, let alone the private universities in the

US. For example, competitive differentiation among local universities are often stifled in favour 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 towards a knowledge-based economy, rather than one based on low-wage and natural resource advantages, requires a significant increase in the indigenous capabilities of local enterprises to create and commercialize new knowledge, not just using knowledge imported from advanced countries. However, because 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 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 favourable pre-conditions that they start from. For example, the universities in NIEs may need to be more pro-active in commercialize her invention 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 towards 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 talents. Given the small local population, Singapore needs to be able to tap top foreign talents 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 talents, Singapore similarly needs to do likewise to differentiate herself 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 talents not only works through the increasingly globalized market for qualified technical professional specialists, it actually starts before the talents reach the labor market – through the attraction of top students from overseas. Indeed, top universities like Stanford, U.C. Berkeley, MIT, Cambridge and Oxford have for decades served as magnet 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 talents 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 talents through their universities, but for a small economy like Singapore, this economic role is likely to be critical.

This role of attracting foreign talents 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 US 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, i.e. not only does the university needs to take on new functions, the nature of her 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 et. al. 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 sector. With stable job opportunities and steady corporate career no longer guaranteed in the increasingly competitive global economy in the new millenium, the university in Singapore needs to urgently re-

orientate the students' expectation of the job market and to prepare them to have a more entrepreneurial mindset.

In summary, we have theoretically expanded the "entrepreneurial" university model of Etzkowitz et. al.(2000) and others to incorporate a number of additional emerging roles that the university needs to play to contribute effectively towards the transition of newly industrialized economies towards a knowledge-based economy. Collectively, these new roles requires 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 what impact these changes actually have on the university's 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. In particular, the paper examines how the National University of Singapore (NUS) has sought to reform her organizational structure and incentive system since the late 1990s, and the consequent impact that such changes had on the university's changing contributing role in the knowledge-based economic development in the island state.

3. Overview of Singapore's Transition towards a Knowledge Economy

As highlighted by Wong(2002, 2004), Singapore has achieved among the highest economic growth performance among newly-industrializing economies, with average GDP growth of over 8% per annum in the 4 decades between 1960 and 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 and 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 and Singh, 2005).

As highlighted in Figure 1, a distinctly new phase of economic development appears to be emerging in the new millennium, as strategic focus for economic growth increasingly shifts to making a transition towards a knowledge-based economy that incorporates three major sectors: (1) high tech manufacturing, comprising of 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 and Singh, 2004); (2) Knowledge-intensive business services (KIBS) that support Singapore's role as a value-adding regional business hub (Wong and 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 talents (Wong and Singh, 2004).

Figure 1: Stylized Stages of Singapore’s Economic Development and National Innovation System Changes

	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

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 towards knowledge commercialization. In particular, this calls for a fundamental re-examination of the traditional manpower development role of the university system in Singapore.

4. Overview of NUS and the Shift towards an “Entrepreneurial” University model

Overview of National University of Singapore

Established in 1905, National University of Singapore (NUS) is the oldest and largest public university in Singapore, with a total student enrolment of over 34,000 (two-third of which are undergrads). Although there are two other public universities in Singapore, both are newer (the Nanyang Technological University (NTU) was established in the 1980s (through a 2-step process of first merging a Chinese-medium based private university into NUS and later spinning it out as a separate entity) while Singapore Management University (SMU) was only established in the late 1990s) and not as comprehensive in scope as NUS – until very recently, NTU focuses primarily in engineering, applied science, accounting and business, while SMU primarily focuses on management and economics education. 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 universities to establish branch campus and other forms of operational presence in Singapore.

Table 1 provides a summary profile of NUS. With an annual R&D budget of about S\$165 million, NUS alone constitutes about 5% of total R&D spending in Singapore. With 139 US patents, NUS is also the third largest patent holder in Singapore, after Chartered Semiconductor (a local firm) and HP (a foreign MNC subsidiary).

As an indication of the premier status of NUS in the higher educational system in Singapore, Table 2 highlights the substantial lead that NUS enjoys versus NTU, the second largest university in Singapore. NUS not only enjoys higher reputation and a much stronger overall track record in terms of internationally refereed research publications, but it has also established a strong lead in terms of patenting records and spin-offs than NTU.

Table 1 Profile of National University of Singapore (NUS) (FY 2003/4)

Indicator	
Tenable and other teaching staff ¹	2,060
Research staff ¹	1,172
Undergraduate students enrolled ²	23,092
Graduate students enrolled ³	11,310
Total research funding	S\$165.2 mil
of which % industrial sponsored research ⁴	12%
Total no. of research projects funded	1,841
Research publications ⁵	6,470
of which % articles in refereed journals	42%
Patents filed	119
Patents granted	28
Cumulative patents granted (CY1990-2003)	139

¹ For faculties, schools and university research institutes/centres

² Figure as at 30 September 2003

³ Figure for FY2003

⁴ includes foundations and individuals

⁵ CY2002

Source: NUS Annual Research Report 2003-2004, National University of Singapore

NUS has historically played a large role in the 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 and 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 between 1997 and 2002. 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. NUS' 2003 R&D budget of S\$165 million, alone constituted about 5% of total R&D spending in Singapore.

Table 2 Comparison of NUS versus NTU

	NUS	NTU
Manpower		
- Research	1,151	652
- Academic	2,055	1,361
Research Funding, 2001/2002	\$ 210 million	\$ 44 million
Number of Patents Filed 2001/2002	83	31
Number of Spin-offs formed 2001/2002	5	3
Cumulative Number of Spin Offs as at March 2003	30	12
Cumulative Number of USPTO Patents Granted up to 2003	139	17
Cumulative Number of IPOS Patents Granted up to 2003	98	9

Source:

For NTU data - NTU website: www.ntu.edu.sg

For NUS data – NUS Annual Reports, NUS Research Annual & NUS Venture Support

For USPTO patents data – NUS patents database

For IPOS patents data – IPOS e-patents site: www.epatents.gov.sg/

As further evidence of NUS's position as Singapore's premier university in the areas of Science and Technology, Table 3 shows that NUS also makes a significant contribution to Singapore's R&D manpower. Following the formation of the National Science and Technology Board and the launch of the nation'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 some of the research institutes previously under university management were hived off into autonomous units reporting directly to NSTB. Nevertheless, by 2003, NUS' research staff strength of 974 still accounted for over 25% of the RSEs in Singapore's higher education sector and close to 6% of total national RSE manpower, as can be seen in Table 4. When the teaching faculty in the Science, Engineering and Medical faculties are included, NUS accounts for almost half of the RSEs in the Higher Education sector in 2003, and over 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 has also begun to attract international recognition of her research capabilities and educational standards. 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 (see Table 5), both overall as well as for individual faculties. As the 18th ranked university globally, NUS further achieved the distinction of being the fourth highest placed Asia-Pacific university in the list.

Table 3 Research funding at NUS, FY1997-FY2003

Year	R&D Expenditure (S\$ million)					NUS R&D Expenditure as % of Higher Education Expenditure
	Private Sector R&D Expenditure	Higher Education R&D Expenditure	Govt & PRIC R&D Expenditure	Total R&D Expenditure	R&D Expenditure in NUS	
1997	1314.5	277.7	512.3	2104.5	101.65	36.6
1998	1536.1	305.8	650.4	2492.3	106.07	34.7
1999	1670.9	310.0	675.5	2656.4	94.79	30.6
2000	1866.0	338.3	805.2	3009.50	122.8	36.3
2001	2045.0	367.0	820.7	3232.70	210.7	57.4
2002	2091.3	430.0	883.3	3404.67	205.5	47.8
2003	2081.2	457.5	885.8	3424.46	165.2	36.1

Note: Figures for NUS exclude NUS-hosted PRICs. If these figures are included, funding increases to \$156,644 in FY2000, \$308,878K in FY2001 and \$277,002K in FY2002. The decrease in funding in FY2003 is partly because A*STAR's Biomedical Research Council skipped one grant call, and its Science & Engineering Research Council issued no calls for Strategic Research Programme grants

Sources: National Survey of R&D in Singapore, various years; NUS Research Annual, various years.

Table 4 NUS share of RSEs in Singapore, 1991-2003

Year	Total RSEs in Singapore	Higher Education RSEs	NUS Research staff ¹	NUS Research Staff share of total Higher Education RSEs (%)	NUS Faculty in Science and Engineering	NUS Research Staff+ Sc & Eng Faculty share of Total Higher Education RSEs (%)
1991	5,218	1,851	274	14.8	670	51.0
1992	6,454	1,970	571	29.0	712	65.1
1993	6,629	1,965	628	32.0	742	69.7
1994	7,086	2,007	534	26.6	750	64.0
1995	8,340	2,558	735	28.7	740	57.7
1996	10,153	3,106	1002	32.3	735	55.9
1997	11,302	3,159	874	27.7	752	51.5
1998	12,655	3,358	860	25.6	786	49.0
1999	13,817	3,310	827	25.0	712	46.5
2000	14,483	3,087	758	24.6	792	50.2
2001	15,366	3,518	842	23.9	793	46.5
2002	15,654	3,473	1094	31.5	748	53.0
2003	17,074	3,717	974	26.2	773	47.0

¹ Figure is for all NUS research staff, including those in non-technical areas

Source: National Survey of R&D in Singapore (various years); NUS Annual Report (various years)

Table 5 Ranking of NUS in the World University Rankings by the Times Higher Education Supplement, 2004

	2004 ranking
Overall	18
Biomedicine	25
Science	35
Engineering and IT	9
Social Sciences	10
Arts and Humanities	17

Source: Knowledge Enterprise Online, various issues, downloaded from <http://newshub.nus.edu.sg/>; The Times Higher Education Supplement website: http://www.thes.co.uk/statistics/international_comparisons/2004/main.aspx

Recent Shift towards 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 her primary mission, with research as a secondary function (Etskowitz et. al., 2000). 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 Electrics) and research administration experience at an Ivy-League university in the US, 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 towards what Etskowitz 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 a 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 Centre 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 invention 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 program, the new Entrepreneurship Centre 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, while graduate-level elective courses in new venture creation targeted at Masters and PhD students interested in commercializing their inventions were introduced. The centre 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 centre 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 her faculty compensation and policy, making it more flexible to allow the university to pay more to attract top talents, as well as to reduce pay for the under-performing ones. Tenure and promotion policy was made much more stringent and performance-based in line with the benchmarks of leading universities in the US. 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 her 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 towards commercializable innovation, as well as influence their future career choices towards 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 towards, 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 a city to be determined in India in 2006. In steady state, the program aims to send 50 students per year per location. NUS Entrepreneurship Centre worked closely with NOC to provide the educational support to these overseas internship program by helping to develop the academic collaborations with the selected partner universities in the respective overseas location (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 Centre also began an “inward-bound” program to attract foreign students from abroad to come to Singapore for high-tech start-up internship and taking entrepreneurship courses at NUS. Starting with a program that brings about 50 graduate students a year to Singapore from Norway, the centre had also organized an intensive technology commercialization summer school for member universities of the U21 Consortium, as well as 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 towards 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 her educational mission.

5. Impact of NUS' Shift towards the "Entrepreneurial University" Model

Overview of Impacts

As the shift towards 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 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 towards the entrepreneurial university model.

The above caveat notwithstanding, Table 6 provides a summary overview of the key changes that NUS has undergone between 1996/7 and 2003/04. In essence, Table 6 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.

Table 6 Profile of Changes in NUS, before and after Shift to Entrepreneurial University Model

Indicator	AY1996/7	FY2003/4
Teaching staff	1414	1570
of which % foreign	39.0%	49.7%
Research staff	843	1,109
of which % foreign	70.1%	79.7%
Undergraduate students enrolled	17,960	23,092
Graduate students enrolled	4,478	8,754
Graduate students as % of total student enrolment	20.0%	27.5%
Percentage of foreign students studying at NUS	13% ¹	26.6%
Total research funding	na	S\$165.2 mil
of which % industrial sponsored research ¹	na	12%
Total no. of research projects funded	1,751 ²	1,841
Research publications	4,949 ³	6,470 ⁴
of which % articles in refereed journals	34.7%	42%
Patents filed	13	119
Patents granted	4	28
Cumulative patents granted by USPTO and IPOS	30 ⁵	242 ⁶

¹ Percentage of total student intake for 1997/8

² Includes foundations and individuals

³ CY1997 ⁴ CY2002

⁵ CY1990-1997 ⁶ CY1990-2003

Source: NUS Annual Research Report (various years), National University of Singapore

Manpower development

As Table 7 shows, NUS has 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. The number of graduates from NUS grew at an average rate of 14.5% per year between 1980 and 1985, faster than that of the total number of graduates (10.4%). As the number of tertiary institutions in Singapore has increased since the early 1990s, NUS' contribution to total national tertiary manpower output has understandably reduced since. However, as Table 6 shows, NUS' share of tertiary graduates remains significant at about 26-28% of total tertiary manpower output from the mid-1990s.

Table 7 NUS' share of total tertiary manpower output in Singapore, 1980-2003

	NUS	Total	NUS share
	No. of graduates		%
1980	1,916	5,680	33.7
1985	3,774	9,299	40.6
1990	4,516	14,113	32.0
1995	5,809	21,444	27.1
1996	6,257	23,003	27.2
1997	6,779	25,421	26.7
1998	7,447	27,770	26.8
1999	7,813	29,128	26.8
2000	8,532	31,054	27.5
2001	9,191	32,912	27.9
2002	9,633	34,116	28.2
2003	9,111	34,361	26.5
	Average compound growth rate (%)		
1980-85	14.5	10.4	
1985-90	3.7	8.7	
1990-95	5.2	8.7	
1995-2000	8.0	7.7	
2000-03	2.2	3.4	

^a Excludes graduates from Singapore Institute of Management, Institute of Systems Science and Singapore Institute of Human Research Management

Calculated from: Singapore Yearbook of Labour Statistics (various years), Singapore Yearbook of Manpower Statistics (various years)

While the number of total graduates coming out of NUS appears to have stabilized around 9,000+ in the 2000s, NUS has shifted the emphasis of her contribution to manpower development in Singapore towards the training of graduate research students, in line with her increasing emphasis on knowledge creation. As can be seen from Table 8, NUS has seen a steady increase in the number of research graduate students enrolled, from 2,763 in 1997 to over 5,000 in 2003. The bulk of these students are enrolled in the engineering and science faculties, (37% and 20% in FY2003), followed by the medicine faculty (13%).

Table 8 NUS Research graduate students enrolled, 1999-2003

	No. of research graduate students
1997	2,763
1998	3,665
1999	4,321
2000	4,507
2001	5,005
2002	5,209
2003	5,407

Note: Figures for research graduate students are for FY and include students who have withdrawn/terminated/graduated during the specified year

Source: NUS Research Report 2003-2004

Knowledge creation

Research publications

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 9). 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.

Table 9 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	1446	4,313	33.5
1997	1716	4,949	34.7
1998	1886	5,274	35.8
1999	2230	5,571	40.0
2000	2294	6,099	37.6
2001	2555	6,275	40.7
2002	2619	6,470	40.5
2003	3160	na	na

Knowledge Commercialization

Whereas the rate of new knowledge creation has increased moderately between 1997 and 2003, the pace of knowledge *commercialization* has changed more significantly. Annex Figure B shows the pattern of flows of knowledge created by NUS towards 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.

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 1998-2003 appear to be somewhat erratic, fluctuating between 59 to 83 per year (Table 10). 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.

Table 10 NUS invention disclosures, 1998-2003

	No. of disclosures
1998	76
1999	65
2000	68
2001	83
2002	59
2003	78

Source: INTRO

Patenting

Reflecting the late entry of Singapore into innovation activities compared to the advanced OECD countries, the absolute cumulative number of Singapore-based inventions receiving patent grants is still relatively low as of 2003. 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 468 during 2000-2003. The number of US patents granted in the four years 2000 to 2003, 1871, is higher than the total number of patents granted in all prior years. In terms of patenting intensity per 10,000 population, Singapore already exceeds several OECD countries by the early 2000s (see Wong and Ho (2003) for more details).

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 INTRO 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 2000-03 registered a higher average of over 100 applications a year (Table 11). The number of patents granted also registered a distinct increase in the period 2000-03, averaging 25 per year vs. 13 per year in the period 1997-99.

With 139 US-granted patents, NUS has by 2003 become the third largest holder of Singapore-based inventions granted US patents (Table 13), up from 7th ranking in 1995, when NUS had only 13 patents to her name. (Table 12). By 2003, 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 2.8% in 1990-1994 to 4.3% in 1995-99 and 5.3% in 2000-2003 (Table 14).

Table 11 Number of patents filed by and granted to NUS, FY 1997-2003

Financial Year	Patent Applications	Patents Granted
1997	52	9
1998	75	18
1999	103	12
2000	130	21
2001	83	17
2002	91	34
2003	119	28

Source: NUS Research Report 2003-2004

Note: Figures include patents filed in multiple countries,

Table 12 Top 20 Organizations with Singapore Patents¹, cumulative to 1995

No.	Company	Country	No. of patents 1976-1995
1	Molex Incorporated	United States	26
2	Hewlett-Packard Company	United States	24
3	Motorola, Inc.	United States	24
4	Texas Instruments	United States	20
5	Thomson Consumer Electronics, S.A.	France	15
6	Chartered Semiconductor Manufacturing	Singapore	14
7	National University of Singapore	Singapore	13
8	U.S. Philips Corporation	United States	11
9	Metro Plastic Industry	Singapore	8
10	Chartered Industries of Singapore	Singapore	7
11	Sun Industrial Coatings	Singapore	7
12	Eastern Oil Tools	Singapore	6
13	General Electric Company	United States	6
14	Mobil Oil Corporation	United States	6
15	E. I. du Pont de Nemours and Company	United States	5
16	Otis Elevator Company	United States	5
17	Rohm and Haas Company	United States	5
18	Advanced Materials Technologies	Singapore	4
19	AT&T Corp.	United States	4
20	Sumitomo Chemical Company	Japan	4

¹Patents where at least one inventor is a Singaporean. Includes patents which are jointly assigned.

Note: If patents owned by Singapore assignees but without Singapore inventors are included, two more companies (Blue Box Toy Factory Pte Ltd and Western Digital (Singapore) Pte Ltd) would be included in this list

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

Table 13 Top 20 Organizations with Singapore Patents¹, cumulative to 2003

No.	Company	Country	No. of patents 1976-2003
1	Chartered Semiconductor Manufacturing	Singapore	597
2	Hewlett-Packard Company	United States	159
3	National University of Singapore	Singapore	139
4	Texas Instruments	United States	92
5	Motorola Inc	United States	89
6	Seagate Technology	United States	86
7	Institute of Microelectronics	Singapore	65
	<i>Tri-tech Microelectronics **</i>	<i>Singapore</i>	<i>56</i>
8	Matsushita Electric Industrial Co.	Japan	52
9	ST Assembly Test Services	Singapore	42
10	Advanced Micro Devices	United States	40
11	Molex Incorporated	United States	35
12	STMicroelectronics	Italy/France	29
13	Creative Technology	Singapore	28
14	U.S. Philips Corp.	United States	27
15	Thomson Consumer Electronics	France	22
16	Koninklijke Philips Electronics., N.V.	Netherlands	20
17	Black & Decker Inc.	United States	18
18	Nestec S.A.	Switzerland	17
19	Telefonaktiebolaget LM Ericsson	Sweden	17
19	Shimano	Japan	16
20	Data Storage Institute	Singapore	15

¹Patents where at least one inventor is a Singaporean. Includes patents which are jointly assigned.

Note: If patents owned by Singapore assignees but without Singapore inventors are included, two more companies (Blue Box Toy Factory Pte Ltd and Western Digital (Singapore) Pte Ltd) would be included in this list

** *Tritech Microelectronics has been liquidated and has ceased operations.*

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

Table 14 NUS' share of Singapore patents granted by the USPTO: NUS vs Singapore

	NUS	Singapore	NUS share of Sg patents (%)
1990-94	7	249	2.8
1995-1999	33	772	4.3
2000-2003	99	1871	5.3
<i>Total</i>	<i>139</i>	<i>2892</i>	<i>4.8</i>

The engineering faculty's dominance in NUS patenting is apparent from the technological fields in which the patents fall. Of the 139 US patents granted to NUS by the end of 2003, over one-third were in the electric and electronic technological category, with another 20% in computer technology and 17% in chemicals (Table 15).

Biomedical patents represent only 15.8% of all patents granted to NUS, a much lower proportion compared to many leading comprehensive universities in the world that have a medical school.

Table 15 Compositiion of NUS patents by technology category, 1990-2003

Technology category	No. of patents	%
Electrical & Electronic	50	36.0
Computers & Communications	28	20.1
Chemical	24	17.3
Life sciences	22	15.8
Mechanical	12	8.6
Others	3	2.2
<i>Total</i>	<i>139</i>	<i>100</i>

Source: Calculated from USPTO database

The patenting data also reveal that there has been an increase in collaborative innovation activities between NUS and private sector organizations in Singapore from 2000. Up to 1998, only 1 patent had been jointly-invented with a private sector organization. Since then, however, the proportion of NUS patents jointly-owned with private sector companies had increased substantially (see Table 16).

Table 16 Proportion of US Patents Invented by NUS in Collaboration with Private Sector

Year of Grant	Proportion of Patents Jointly Owned with Private Sector
1990-1998	3.1
1999	10.0
2000	42.9
2001	63.6
2002	13.6
2003	25.0
Overall	25.7

Of the 79 NUS inventors who accounted for the 139 patents granted, the majority had only 1-2 patents each (60% and 22.8% respectively), but a significant minority (14, or 17.8%) can be regarded as prolific inventors, having 3 or more patented inventions.

Licensing

A clear increase in the intensity of technology commercialization from 2000 is evident from Table 17. As of the end of FY2004, NUS had made 145 technology licensing agreements. Of these, only one-third were issued before 2000; the remaining two-thirds were signed in the last five years 2000-04. The majority of NUS licenses up to 2003 were signed with commercial companies (44.8%) or NUS start-ups (29.5%), with the remaining quarter being signed with government bodies or public research institutions/centres.

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 (Table 18). 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.

Table 17 NUS licensing agreements 1897-2004

Year of license	No.	%
1987-1990	8	5.9
1991-94	9	6.7
1995-1999	28	20.7
2000	25	18.5
2001	10	7.4
2002	17	12.6
2003 ¹	18	13.3
2004 ¹	20	14.8
<i>Total</i>	<i>135</i>	<i>100.0</i>

Note: Excludes 10 licenses for which data on year of signing is missing

¹ Data is for financial year

Table 18 NUS licensing royalties, 1998-2004

	Licensing Royalties
1998	\$25,065
1999	\$113,959
2000	\$588,935
2001	
2002	\$194,022
2003 ¹	\$290,000
2004 ¹	\$100,200

¹ Data is for financial year

Entrepreneurial Spin Offs

The results of NUS' change in policy to encouraging technology commercialization through spin-off and start-up formation after 2000 is evident from Table 19. Of the 68 spin-offs and start-ups formed between 1980 to 2003, 60% 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's average spin-off formation rate of 4-5 per year in recent years is creditable, 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) (Table 20).

The Engineering Faculty produced the most number of spin-offs (12), followed by the School of Computing (eight) and School of Medicine (five). The vast majority of spin-offs (83.3%) originated from a single faculty rather than resulting from inter-departmental collaboration

Table 19 Number of NUS spin-offs and start-ups, 1980-2003

	Spin-offs	Start-ups	TOTAL
1980 - 1996	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
<i>Total</i>	<i>32</i>	<i>36</i>	<i>68</i>

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, while start-ups refer to companies formed by NUS faculty/researchers that do not involve IP owned by NUS

Table 20 Comparison of no. of spin-offs formed in 2002: NUS vs selected US universities

University	No. of spin-offs in 2002
MIT	23
Stanford University	13
University of Illinois, Chicago at Urbana	12
University of Pennsylvania	12
Harvard University	7
Columbia University	8
NUS	6

Source: NUS INTRO and AUTM Annual Survey 2002

Reflecting their dominance of the technological fields of NUS patenting, more than half (53.2%) of NUS spin-offs are involved in IT/electronics (Table 21), but biomedical science-related companies appear to have a stronger representation (31.3%) than reflected in the share of patents in life sciences.

Table 21 NUS Spin-off Companies by Nature of Business

Nature of Business	No.	%
Information Technology	14	43.8
Biochemical/ Medical	10	31.3
Electrical and Electronic	3	9.4
Mechanical and Machines	3	9.4
Chemicals	1	3.1
Geotechnical	1	3.1
Total	32	100

Source: NUS INTRO

Attraction of foreign talent

A marked increase in NUS' role in attracting foreign talents is also evident in terms of both student intake and recruitment of faculty members and researchers. Between AY1996/7 and CY2003/4, the proportion of foreign students in NUS' student population doubled from 13% to over 26% (see Table 6 earlier). Although less dramatic, a significant increase is also evident in the proportion of foreigners among faculty and research staff recruitment between 1997 and 2004 (Table 22): The share of foreigners among faculty members increased from 39% in 1997 to almost 50% by 2004, while the foreigners' share among researchers increased from 70% to almost 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 staff in 2004, its share among research staff had been overtaken by India by 2004.

Table 22 NUS faculty members and research staff by nationality as at end June 1997 vs end April 2004

	As at end June 1997				As at end April 2004			
	Faculty members		Research staff		Faculty members		Research staff	
	No.	%	No.	%	No.	%	No.	%
Singapore	862	60.96	252	29.89	790	50.3	225	20.3
Malaysia	181	12.80	125	14.83	179	11.4	105	9.5
India	56	3.96	93	11.03	76	4.8	109	9.8
China	63	4.46	271	32.15	104	6.6	514	46.3
Other Asian countries	76	5.37	31	3.68	135	8.6	64	5.8
US/Canada	75	5.30	28	3.32	114	7.3	20	1.8
Other countries	101	7.14	43	5.10	172	11.0	72	6.5
<i>Total</i>	1,414	100	843	100	1,570	100.0	1,109	100.0

Source: NUS Annual Reports

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 23 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 authors in 2000 (Allen and 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 from Table 23, NUS' research input is relative 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 1000 faculty members in 2000, NUS scored above average among

the sample of Asian universities, although it still lagged behind the North American universities.

As highlighted elsewhere (Allen and Wong, 2003), the Asian member universities of APRU focused more on technology commercialization via start-up formation as opposed to licensing, unlike the North American universities which put a greater emphasis on licensing. Reflecting this bias even more strongly than other Asian universities, NUS had a higher ratio of startups to patents and startups to licenses than the average for all Asian member universities.

Table 23 NUS vs Asia-Pacific and North American APRU universities: Comparative indicators for FY2000¹

	NUS	Asia-Pacific universities	North American universities
<u>Research input</u>			
Research expenditures per faculty member, FY2000	US\$27,000	US\$55,000	US\$194,000
<u>Research output and commercialization</u>			
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 1000 faculty members	14.8	5.7	26.1
Licenses executed per 100 faculty members	2.3	0.8	3.5
Cumulative startups per 100 US patents (weighted by FY2000 research expenditures ²)	17.6	10.7	2.1
Cumulative startups per 100 patents granted by home country (weighted by FY2000 research expenditures ²)	27.0	6.8	2.2
Cumulative startups per 100 licenses (weighted by FY2000 research expenditures ²)	9.9	6.7	2.8

¹ Unless otherwise stated

² Ratio is calculated per \$100 million FY2000 research expenditures

6. Conclusion

In summary, our empirical analysis indicates that NUS's 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 towards 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. More importantly, we believe that our problem in constructing an empirical database on NUS' knowledge commercialization activities in the earlier period suggests that it is a common for most East Asian universities, and this fact itself holds important policy implications: unless the top leadership of a university puts in place clear governance and policy framework for promoting and managing knowledge commercialization, it will not be able to generate reliable information on the knowledge commercialization activities of her academic staff. Vice-versa, the fact that a university does not have reliable information on knowledge commercialization probably reflects a lack of strategic focus on knowledge commercialization as a key mission of the university.

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 talents. 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 talents on a global scale is likely to rank as an important feature of any entrepreneurial university model for newly industrializing economies.

Last, but not least, NUS' experiment in injecting a more entrepreneurial dimension to the educational experience of her 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.

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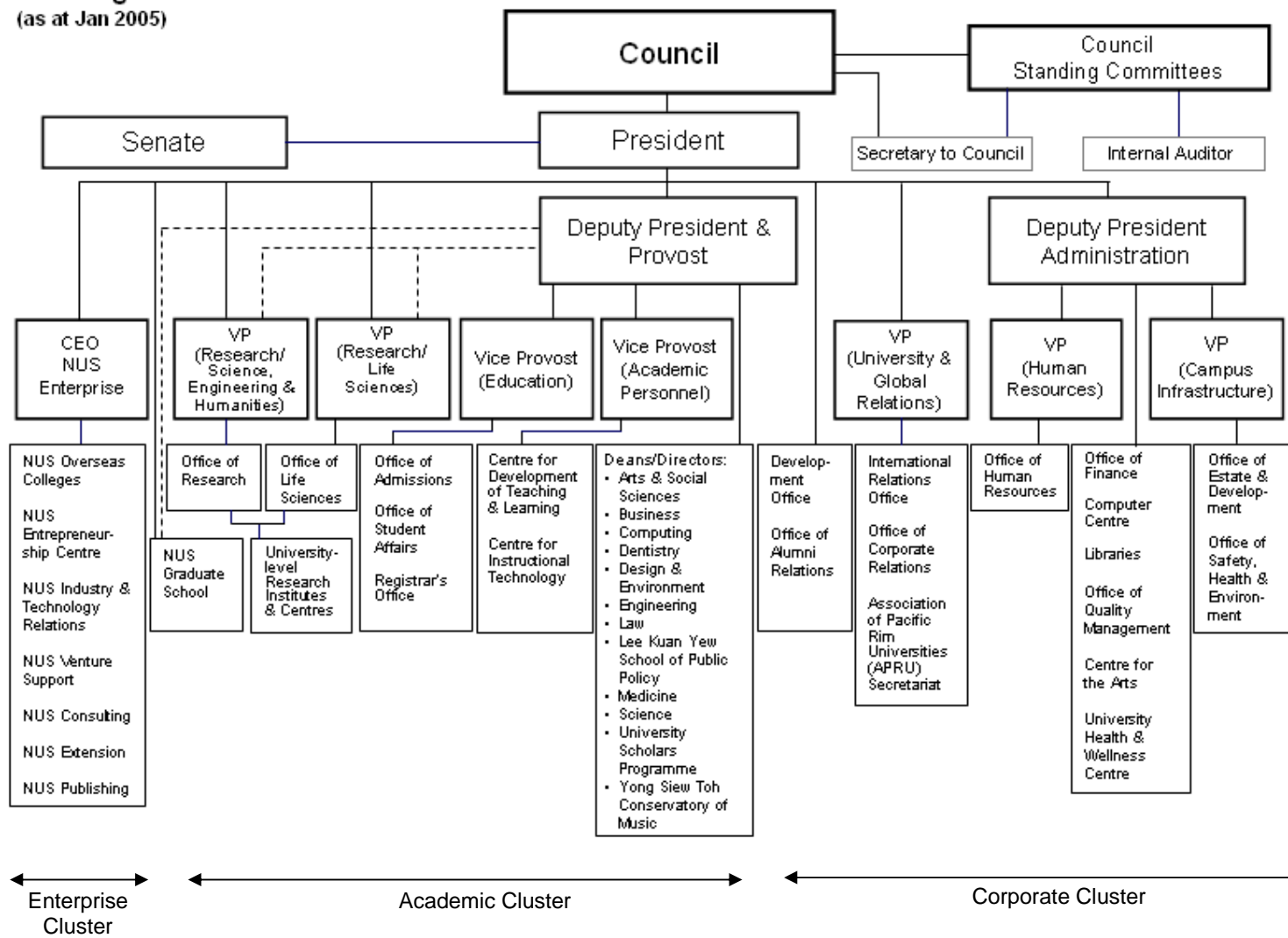
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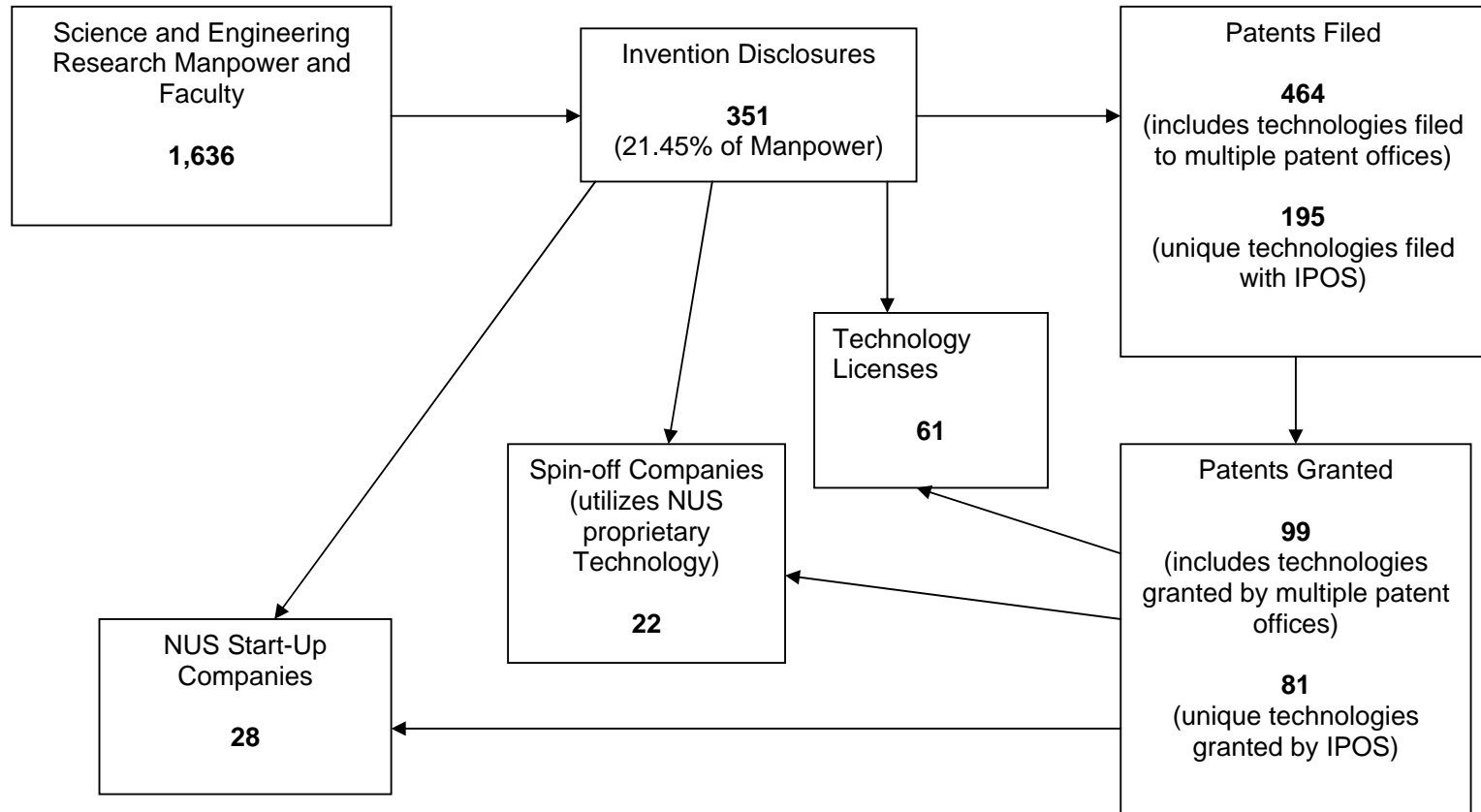
NUS Organization Chart
(as at Jan 2005)



Annex Figure A: NUS Organizational Chart

Source: NUS staff intranet, <http://my.intranet.nus.edu.sg/SAPPORAL/>

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 Filing and Granting of Patents

