CHAPTER 10

Singapore: successful in research, striving for innovation

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INTRODUCTION

Across the World, governments subscribe to the thesis that investment in research is a worthwhile public good for a number of reasons. Such investments are generally predicated on the view that research will lead directly to innovation and, hence, to wealth and employment creation. This "linear" model is an over-simplification of a complex reality in which there are innumerable feedback loops. However, in broad terms, it is a truism that investment in research should support and encourage economic development and whilst sometimes not leading directly from one to the other, nevertheless it provides the essential "substrate" on which innovation grows.

Singapore, whose name translates as the "Lion City", is a unique state in the modern World and one which has experienced extraordinary economic growth over its 44 years of existence. In its economic development and, more lately, in its research development, it has certainly lived up to its name with a ferocious commitment to drive its economic development forward. This has been based on its basic nature and geography as a World entrepôt to which has been added a burgeoning economic sector (according to some measures, it now ranks only behind London and New York and ahead of Hong Kong in terms of trade volumes), a substantial tourism industry and, last but not least, a thriving manufacturing sector. Recognizing that, faced with competition

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from major players such as China, the latter sector has to evolve from one based on low employment costs to one which can provide high value goods, the Singaporean government has fully embraced the concept of the knowledge-based economy. As part of this aim, the government has lived up to its soubriquet to push forward to become one the World's poles of expertise of high level research. This has happened since the start of the millennium and Singapore is now playing in the top league for research, deservedly so given the huge public investment in research that has been made over the past decade.

The achievements are impressive, especially considering that Singapore is a geographically very small country with a population of only 4.5 million inhabitants. Furthermore, unlike city states of the past, it lacks a geographical hinterland. This is a unique situation and one which was recognized by Singapore's founding father and long-time Prime Minister, Lee Kuan Yew, when he has talked about the necessity to develop a global hinterland to compensate for its geographical disadvantage. Certainly nothing is more global than research.

The country has some natural advantages in terms of its vibrant, multi-cultural and cosmopolitan society with a strong business community, a strong work ethic and with its main language of administration and business being today's *lingua franca*, English. Furthermore, it is able to take advantage of its geographical position in South East Asia and act as a bridge between the rising economic powers of China and India; forming a cultural linkage between "the West" and "the East". In some respects it may be termed "Asia-'lite'."

A STRONG EDUCATION SYSTEM

Singapore benefits from having a strong school education system that provides the "raw material" for the universities, for employers and for the Singaporean "research project". Indeed Singapore ranks among the best Asian nations in terms of having the best brains in mathematics. The 2007 Trend in International Maths and Science Study (TIMSS) conducted by Boston College, U.S., puts Hong Kong, Singapore and Taiwan students scoring best in mathematics and with the best science students coming from Singapore, Taiwan, Japan and Korea.

However, one notable feature of the Singaporean educational system is its very vocationally minded approach and it is from such a base that one might discern some of the difficulties that we deal with later in this paper.

GLOBAL AND HISTORICAL COMPARISONS

Singapore has used these advantages effectively to propel itself forward in research to become a leading player in what is now a multi-polar World of

Asia, Europe and North America. Previously, there has been a tendency to look at World economy in terms of Europe and the U.S., including also Japan. However, historically this may not be a true picture as shown by Madison in his 2003 Statistical analysis for the OECD when he compared GDP figures for the major regions of the World over the past 300 years (see Table 1).

Table 1: Estimates of the percentage contribution to Global GDP, 1700-2003

	1700	1820	1952	1995	2003
China	22.3	32.9	5.2	11.1	15.1
India	24.4	16.0	4.0	4.6	5.5
Japan	4.1	3.0	3.4	8.1	6.6
Europe	24.9	26.6	29.3	23.8	21.8
United States	0.1	1.8	27.5	21.2	20.6

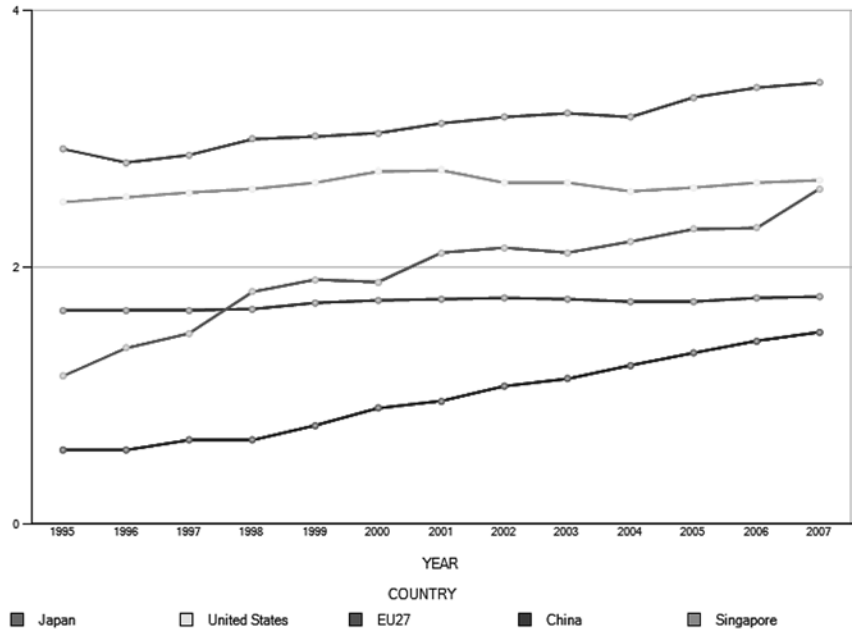
Source: Madison, A. (2003). The world economy: historical statistics. Paris, France: Development Centre of the Organisation for Economic Co-operation and Development.

In other words, in the historical long-term we have been part of a multipolar World and may be returning to this "ground state" for global economies in the 21st century. Working through successive 5 year plans, Singapore has set itself a very ambitious target of 3% for both public and private investment in GERD (gross domestic expenditure on research and development) within its GDP by 2010. If this target is achieved, and there is every likelihood of this happening, then Singapore will join an elite group of countries with this or a higher GERD investment level, i.e. Finland, Israel and Sweden. It is noteworthy that this is the same ambitious target as that set for itself by the European Union within the Lisbon Process. However, the likelihood is that Singapore will succeed, while the E.U. has already acknowledged that this target is beyond its current capacity. Figure 1 shows recent trends in the development of GERD in selected countries.

DEVELOPMENT OF THE SINGAPOREAN RESEARCH SYSTEM

Singapore has an added advantage of having a well integrated Government system and where there is a strong inclination to take and plan for the longer view. Currently, the most recent quinquennial plan for Science and Technology is ending (2006-2010) and the Government is actively planning for the next five years. During the current plan period, there has been an impressive additional investment of $S13 billion (€6.5 billion) which may be compared with the E.U. Framework Programme which has an expenditure of just over €7 billion per annum for a population some 100 times larger than that of

Figure 1: R&D intensity (GERD as % of GDP) in the major world regions, 1995-2007



Source: OECD, Main Science and Technology Indicators 2009-10.

Singapore. This investment has been principally apportioned between the Agency for Science, Technology and Research (A*STAR) Institutes and the universities (see Figure 2), with for the latter, the introduction of very competitive schemes such as that for Research Centres of Excellence (RCEs) with an investment level of $S150 million each over 10 years and with around five Centres being created in the first five-year period, other highly competitive and strategic funding and the highly prestigious National Research Foundation's (NRF) Research Fellowships for young and very talented post-doctoral researchers. In fact, the Plan saw the creation of the NRF within the Prime Minister's Office to oversee this investment in research in the higher education sector. It is noteworthy that the NRF's mandate is not simply the funding of excellence, but to do so with one eye on the ultimate benefit for the Singaporean economy. It is also noteworthy that part of the investment is to the Economic Development Board as part of its activities to stimulate research coupled with inward investment.

Singapore has rapidly developed its university sector to be research-intensive and should be proud that its two major science and technology universities rank within the top 100 in the World, according to the latest *Time Higher*

Education/QS rankings. Now there is an advanced plan to create a fourth university to cater for an increased entry cohort of up to 30% and which will also be devoted to science, technology and design.

Figures 2 and 3 illustrate the structure of the Singaporean research "ecosystem" and its academic research performers.

Figure 2: Singapore: Research Funding Ecosystem

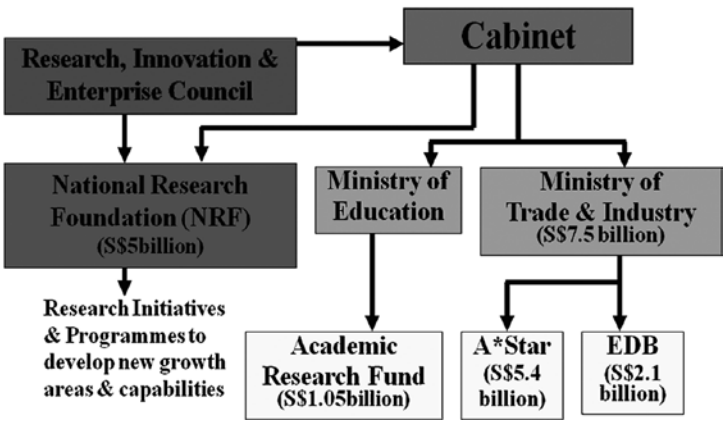
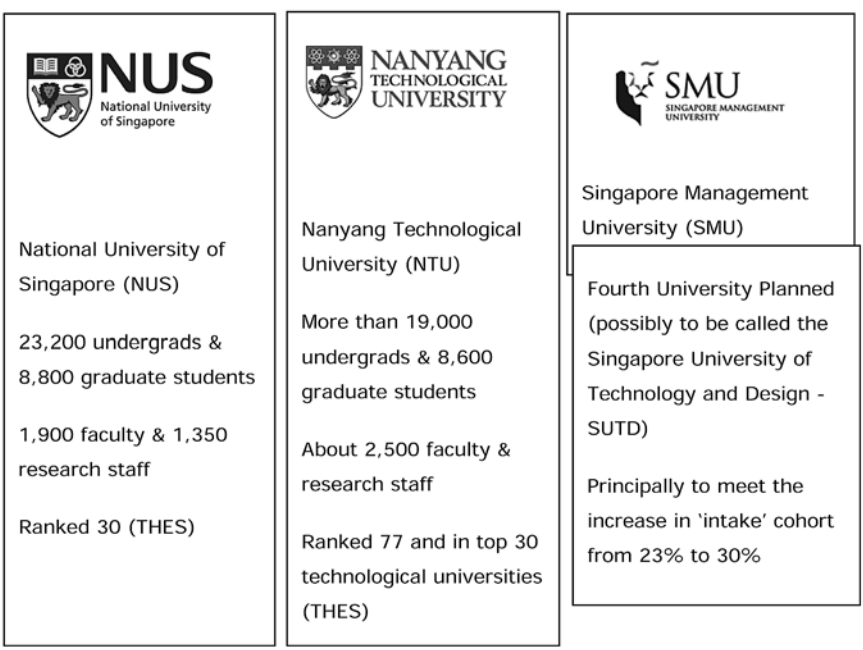


Figure 3: Singapore's Higher Education Institutions — the main research performer



IMPORTING TALENT

Singapore has developed a tradition of importing talent in a number of ways. This is partly because of the difficulty of attracting Singaporeans themselves into research and may be demonstrated by the origins of the intake of students into the universities. At the undergraduate level, 20% of the students are incomers to Singapore (coming principally from its neighbours — Indonesia and Malaysia). This rises sharply to 60% at the postgraduate level including 80% undertaking Ph.D.s (many of the latter come from China, as well as those coming from other parts of the World on the very generous SINGA scholarships).

This unprecedented and massive research investment in global terms has served to attract top research talent into Singapore through both the A*STAR institutes and the universities. In the latter case, this comes from the recruitment policies of the universities and from the NRF funding schemes, especially the RCE, which demands the bringing in of top, senior researchers from overseas. In this manner, Singapore has been able to "leap-frog" into the top level of World research. For example, the RCE on the Earth Observatory of Singapore, based at NTU, has catapulted Singapore overnight from a place with virtually no Earth Sciences into a centre having some of the World's leading researchers in seismology, tectonics and volcanology.

It is this pro-active recruitment at the very top levels coupled with what may be termed "institutional recruitment" that has propelled Singapore into this upper echelon of World research. Through partnerships and direct recruitment, Singapore has brought in an impressive list of institutions including MIT, Stanford and Cornell Universities from the USA, Imperial College London and Cambridge University from the UK, the Technical University of Munich, Germany, ETH Zurich, Switzerland, INSEAD from France and Technion, Israel.

Coupled to this has been the ability to attract top level technologically based multi-national companies and again the list is impressive: General Electric, EADS, Rolls-Royce, Siemens, Robert Bosch, Infineon, Panasonic, Novartis, GlaxoSmithKline to name but a few. These companies provide high quality employment, but they are also attracted by the availability of a highly educated and "research-savvy" work force and the very positive and company friendly business environment that has been created.

INNOVATION — SOME GLOBAL COMPARISONS

Having demonstrated the rapid rise of Singapore in the "research league" and its very sound educational base, one also needs to examine the innovation record of the country as the third side of the so-called "knowledge triangle".

Figure 4: Examples of major infrastructure investment to house the A*STAR institutes: On the left is Biopolis and on the right is the recently opened Fusionopolis, both at the One North academic and research complex

Biopolis

Fusionopolis

As shown in the above paragraph, Singapore is a natural home for high technology industry. It is also a centre of economic endeavour and entrepreneurialism and its citizens are business-minded. Singapore ranks as having one of the most business-friendly environments with full intellectual property protection. In terms of Global Competitiveness measures, Singapore ranks in fifth place and yet the technological innovation process falls below the high standards of research and research investment.

We have looked at a number of international comparisons as part of a study into the promotion of commercialization of research, specifically that at NTU.

In terms of Global Competitiveness, as shown in the Global Competitiveness Report, 2008-2009, World Economic Forum, Geneva 2008, Singapore ranks fifth in the World (the highest of any Asian country and moving up two places from the 2007-2008 survey behind the USA, Switzerland, Denmark and Sweden). The upward progression of the overall ranking is a result of a strengthening across all aspects of the institutional framework. Singapore is placed among the top two countries for the efficiency of all of its markets — goods, labour, and financial — ensuring the proper allocation of these factors to their best use. However, if one examines the innovation factors themselves in this study, the picture is much more uneven — Singapore drops to 11th place for innovation factors and patents per million of population (see Table 2).

Although substantial gains can be obtained by improving institutions, building infrastructures, reducing macroeconomic instability, or improving

Table 2: 2008-9 Global Competitiveness Index Rankings — Top Ten Performers

	Overall 2008-9		Basic Requirements		Efficiency Enhancers		Innovation Factors		Patents/ Mil. Pop1.
	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
United States	1	5.74	22	5.50	1	5.81	1	5.80	2
Switzerland	2	5.61	2	6.14	8	5.35	2	5.68	6
Denmark	3	5.61	4	6.14	3	5.49	7	5.37	14
Sweden	4	5.58	6	6.00	9	5.35	6	5.53	8
Singapore	5	5.53	3	6.14	2	5.52	11	5.16	11
Finland	6	5.50	1	6.18	13	5.51	5	5.53	4
Germany	7	5.46	7	5.96	11	5.22	4	5.54	9
Netherlands	8	5.41	10	5.81	7	5.38	9	5.20	13
Japan	9	5.38	26	5.36	12	5.22	5	5.65	3
Canada	10	5.37	8	5.84	5	5.44	16	4.96	10

the human capital of the population, all these factors eventually run into diminishing returns. The same is true for the efficiency of the labour, financial and goods markets. In the long run, standards of living can be expanded only with **technological innovation**. Innovation is particularly important for economies as they approach the frontiers of knowledge and the possibility of integrating and adapting exogenous technologies tends to disappear. Although less advanced countries can still improve their productivity by adopting existing technologies or making incremental improvements in other areas, for countries such as Singapore, which has reached the "innovation stage" of development (Porter and Schwab define three stages of economic development, largely correlated to national per capita GDP. These stages — or economic phases are: a. Factor-Driven Economies, b. Efficiency-Driven Economies, and c. Innovation-Driven Economies. Singapore, with a per capita GDP of US$35,163 is in this third stage) this approach is no longer sufficient to increase productivity. Firms in countries such as Singapore must design and develop cutting-edge products and processes to maintain a competitive edge. This requires an environment that is conducive to innovative activity, supported by both the public and the private sectors. In particular, this means sufficient investment in R&D, the presence of high-quality scientific research institutions, extensive collaboration in research between universities and industry, and the protection of intellectual property. The other key pillar for ensuring innovation competitiveness is a sophisticated financial market.

There is now concern expressed in Government circles about the low output of innovation as measured by start-ups and income for the higher education sector. Whilst 11th position is still very creditable, one has to ask what the reasons are for this comparative failure. Is it cultural or is it systemic? We believe that one may discount the latter given the encouragement to move to innovation and the very business friendly conditions that prevail.

Table 3 illustrates the position of Singapore within the Global Competitiveness Survey by components of the "innovation factors".

Table 3: Global Competitiveness Index Rankings — Innovation Factors

Performance Factors	Singapore's position/134
Quality of Education System	2
Quality of Math and Science Education	2
Secondary Enrolment	21
Tertiary Enrolment	31
Quality of Science and Research Institutions	13
Availability of Scientists and Engineers	12
University — Industry Research Collaboration	5
Foreign Direct Investment in Technology Transfer	1
Intellectual Property Protection	2
Brain Drain	13
Capacity for Innovation	19
Quality of Management Schools	7
Availability of Venture Capital	12

Source: The Global Competitiveness Report 2008-2009, World Economic Forum, Geneva, Switzerland 2008.

Innovation — cultural issues

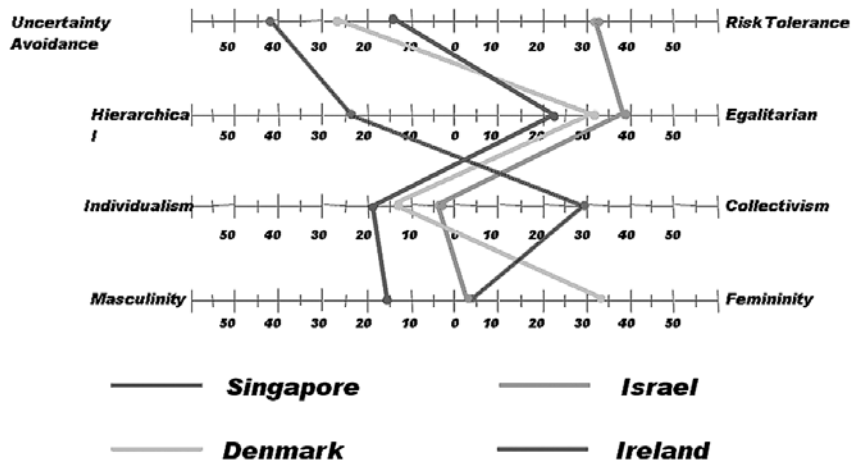
Low Kim Cheng Patrick identified four obstacles or impediments that tended to discourage the setting up of businesses among Singaporeans. These were being overly compliant, being too "left-brained", over-pampering and the fear of failure. Low suggested that Singaporeans need to make a "paradigm shift", adopt a "backpack mentality", embrace globalized thinking and networking and tapping into their own rich cultural diversity.

National cultures can be described according to the analysis of Geert Hofstede. These ideas were first based on a research project into national culture differences across subsidiaries of a multinational corporation (IBM) in 64 countries. Subsequent studies by others covered students in 23 countries,

elites in 19 countries, commercial airline pilots in 23 countries, up-market consumers in 15 countries, and civil service managers in 14 countries. Together these studies identified and validated four independent dimensions of national culture differences, with a fifth dimension added later.

Such an analysis leads to interesting results when comparing Singapore with small, developed economies such as Denmark, Hong Kong, Israel and Ireland (see Figure 5).

Figure 5: Comparison of cultural factors related to Innovation between Singapore and a selection of small developed countries



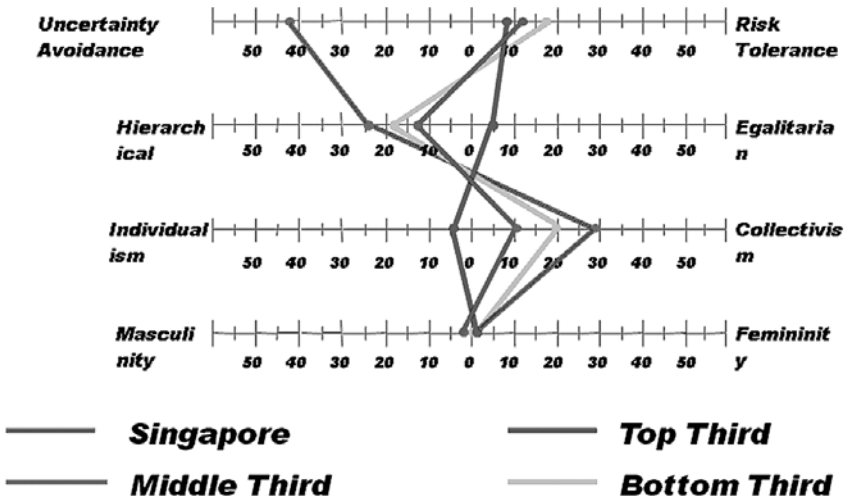
Source: Variables derived from Geert Hofstede's National Cultural Differences IBM Dataset.

It is informative to note that Singapore is significantly the most risk avoidant of the states considered, hierarchical and more prone to collectivism. This is further emphasized when combining both the Hofstede analysis and the WEF Capacity for Innovation Ranking. Again, this results in similar conclusions when comparing Singapore against the average figures for the top, middle and bottom third of the countries ranked (see Figure 6).

Turning now to patent statistics, the overall picture shows that, despite giving what appears to be a reasonably healthy income stream, it is one that could be considerably improved.

In analysing the situation further, especially in terms of the output from the academic institutions in terms of the Global Competitiveness Report, one sees that, in comparison with the U.S., the usual benchmark, patents per million of population are 89.3 for Singapore against 261.7. Looking at a comparably sized country with an enviable innovation record, Israel, the figure is 158.1. (see Table 4)

Figure 6: Capacity for Innovation Ranking — Comparison of Singapore against the top, middle and lower third of the rankings



GCR Capacity for Innovation: In your country, companies obtain technology (1 = exclusively from licensing or imitating foreign companies, 7 = by conducting formal research and pioneering their own new products and processes)

Source: Variables derived from Geert Hofstede's National Cultural Differences IBM Dataset, Rankings from the Global Competitiveness Report 2008-9, World Economic Forum.

A particularly telling statistic is that the top research performers in Singapore (all the A*STAR institutes plus the National University of Singapore and the Nanyang Technological University) **collectively** created only as many start-ups as the top U.S. academic institutions such as Harvard or Stanford and have fewer start-ups than the relatively small but very research-intensive California Institute of Technology (CalTech). In fact, one can extend this comparison further to include the Canadian universities in British Columbia and Toronto (see Table 5).

Despite the encouragement of the system to create value from the research investment, there still seems to be an "innovation deficit" within the Singaporean research system. How can this be addressed?

Evidence from interviews

A series of interviews with NTU faculty members was conducted during Spring 2009 which showed up a series of perceived impediments to innovation within NTU. A simple cluster analysis was undertaken of the notable comments "harvested" during the interviews. The cluster of highest frequency

Table 4: International comparison of patent production/population

Global Competitiveness Report	
Top Performers 2007	Patents/Mil Pop
Taiwan, China	270.4
United States	261.7
Japan	260.0
Finland	160.4
Israel	158.1
Switzerland	141.8
Korea, Rep	130.9
Sweden	116.6
Germany	109.4
Canada	100.9
Singapore	89.3

Government spending on university R&D has yet to realize an economic return one year on

National Survey ofR&D in Singapore 2007		
Aggregate results: all Higher Education Institutions		
	Actual	PerMil.Pop
Granted Patents	67	15.2
License Revenue	$560,000	
Salaries	$1,120,000	

Sources: Global Competitive Index 2009; NRF R&D National Survey, 2007

Table 5: Comparison of the Academic Output of Start-up Companies in Singapore and selected leading North American Institutions

Name of Institution	2007 Start-ups
Singapore Academic and Research Institutions (Nanyang Technological University/ National University of Singapore/A*STAR Research Institutes)	8
California Institute of Technology (CalTech)	11
Georgia Institute Of Technology	9
Harvard University	6
Massachusetts Institute of Technology	24
Stanford University	6
University of British Columbia	5
University of Toronto	8

related to culture and risk aversion. Without exception, these comments were shared as examples of impediments to innovation and are highly consistent with the ideas cited in the work of Low Kim Cheng. These quotes indicate that a challenge to innovate in Singapore may be the tendency to avoid "disruptive development" arising from new ideas.

Following in order of importance were comments about a perceived dilemma concerning the need to publish to secure tenure-ship versus withholding public disclosure to be able to maintain some competitive advantage with commercialization of IP in mind. Typical of this sentiment is the following quote:

"Key Performance Indicators (KPIs) drive all behaviour at the university. Professors still prefer to publish rather than patent in order to fulfil requirements to secure tenure".

The third most prevalent type of comment concerned collaboration. Generally, interviewees suggested that collaboration across disciplines on campus is limited and acknowledge that much more is needed. Several interviewees discussed the need for "translators" to build bridges across disciplines as a means of overcoming this limitation. The following quote expresses well this idea:

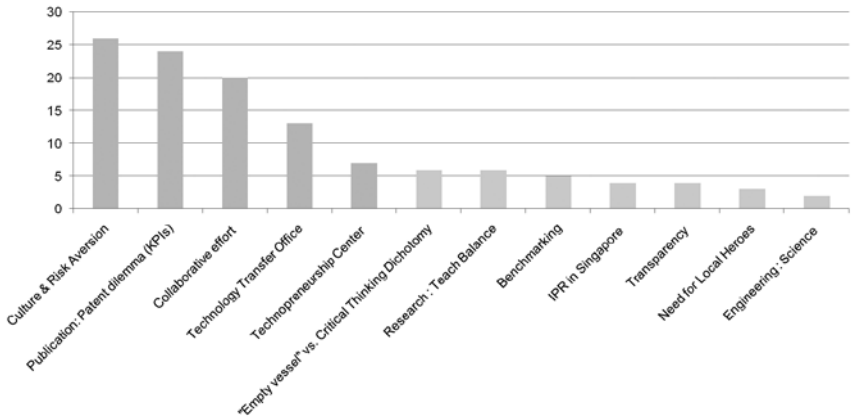
"There is a vital role to play for 'translators' between 'links in a value chain', i.e., between pioneering research, applied research and applications development. The individual 'links', as pools of domain expertise, tend to be narrowly focused but deep. This often hinders progress as concepts move from theory to commercial reality as the 'warlords' in each domain 'fiefdom' tend not to share a common lexicon".

The frequency of these comments is shown in Figure 7 and again they demonstrate a cultural rather than a systemic problem.

In recognizing this problem and in trying to provide a new incentive to change academic habits, the NRF has introduced a new scheme to encourage the universities to develop new and more pro-active measures to encourage more entrepreneurial thinking by faculty members. These include provision for each university to establish an "Enterprise Board" to manage a generous Innovation Fund totalling some $S25 million which supports entrepreneurship education, technology incubators and "entrepreneurs-in-residence" to promote the commercialization of university technologies. Within the enterprise support structures, the fund provides for Proof-of-concept grants; Technology incubation schemes; Early-stage venture funding; support for Disruptive Innovation (DI) incubators; and Special innovation overheads from research grants.

While all these measures are to be welcomed, there still remains the cultural resistance to be overcome. Perhaps, ultimately, it has to be recognized that this is a long-term process and that only with a profound cultural shift will Singapore be able to take full advantage of its far-sighted vision to fund research as a major tool of economic development. Given the nature of Singaporean society as it has developed over the past 40 years, this is something for which the Government has to take responsibility. Financial incentives and the provision of entrepreneurial training can only go so far without endeavouring to change the mindsets of the technocracy within the country.

Figure 7: Frequency of Unsolicited Interview Comments on Innovation Processes at NTU, 2009



CONCLUSION

Despite the far-sighted decision to treat research investment as a key part of economic development and its commitment to a knowledge-based economy, the Singaporean government still struggles to reap the rewards of this policy in encouraging increased risk-taking and the development of an entrepreneurial academic society. However, it has to be recognized that the policy of research investment, based on a first class education system, has paid off in allowing Singapore to very rapidly leap-frog into the top echelons of World science and to attract high class, technologically-based inward investment and to provide the infrastructure to support this advanced economy. However, it must also be recognized that the whole research-innovation "enterprise" is still very young and that it may have been over ambitious in expecting its innovation returns to match that which could be expected from more "mature" systems. Nevertheless, there does appear to be difficulties in developing a truly entrepreneurial approach in terms of high technologically based innovation emanating from its academic institutions. Now it has to address how to change mindsets in its quest to economic advancement and to maximize the return on the investment made on behalf of its citizens for their future benefit.

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