3-4. Singapore

Measuring National Innovation System Performance of Singapore: An Integrated Research, Innovation and Enterprise (RIE) Framework

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AN INTEGRATED RESEARCH, INNOVATION AND ENTERPRISE (RIE) FRAMEWORK FOR MEASURING S&T PERFORMANCE IN SINGAPORE

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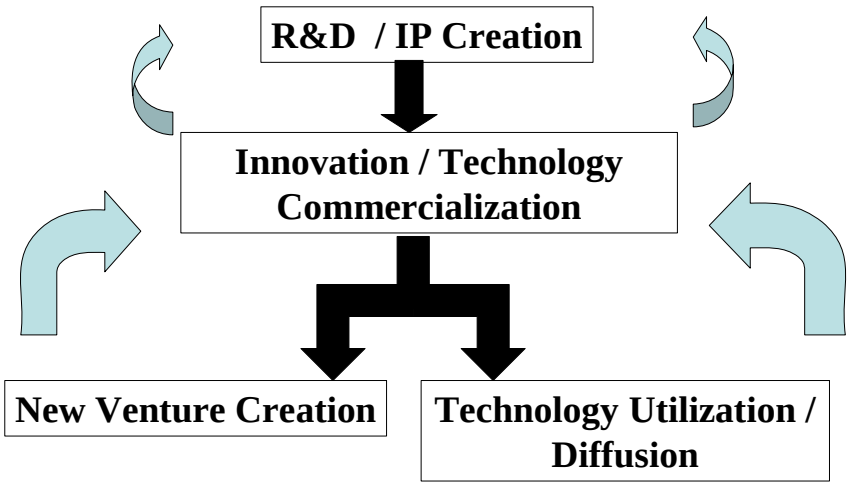
Outline of Presentation

- Conceptual Framework for Measuring Performance of a National Innovation System: The Integrated Research-Innovation-Enterprise (RIE) Framework
- Indicators of Singapore's National Innovation System Performance based on the RIE Framework
- Issues and Challenges for the Future

Dynamic Interactions between Research, Innovation & Enterprise



Dynamic Interactions among R, I and E

- Rapid diffusion & effective exploitation of existing S&T important for Enterprises in early stages of industrial development, while capacity to create own IP become more critical in later stages
- High R&D investment need not lead to high innovation (commercial exploitation of the knowledge/IP created through R&D)
- Innovation pattern drives enterprise dynamism, which in turn influences the intensities and nature of future R&D and innovation pattern
- Access to global technologies and talents can complement indigenous capability development
- Two related perspectives on dynamic interactions:
  - **National Innovation System perspective**
  - **Enterprise Ecosystem perspective**

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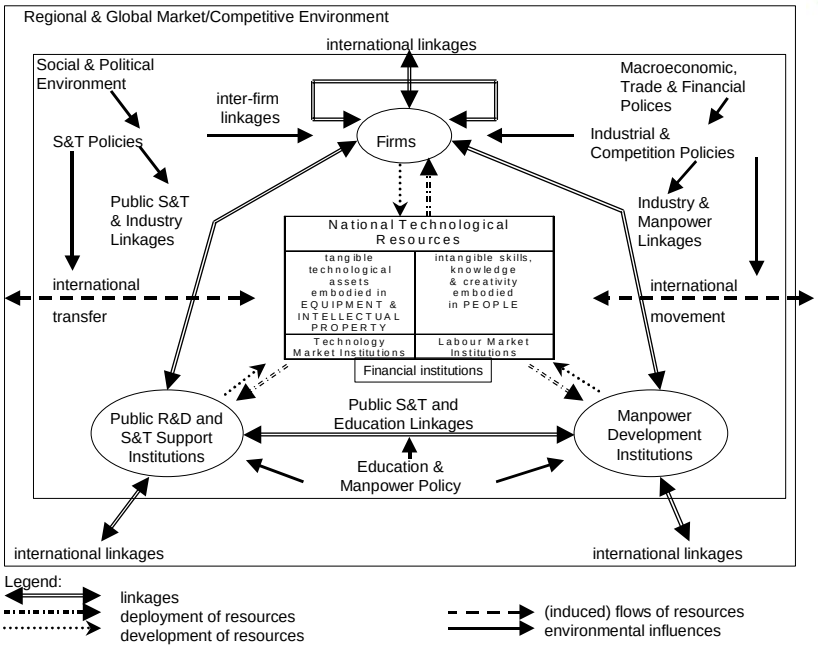
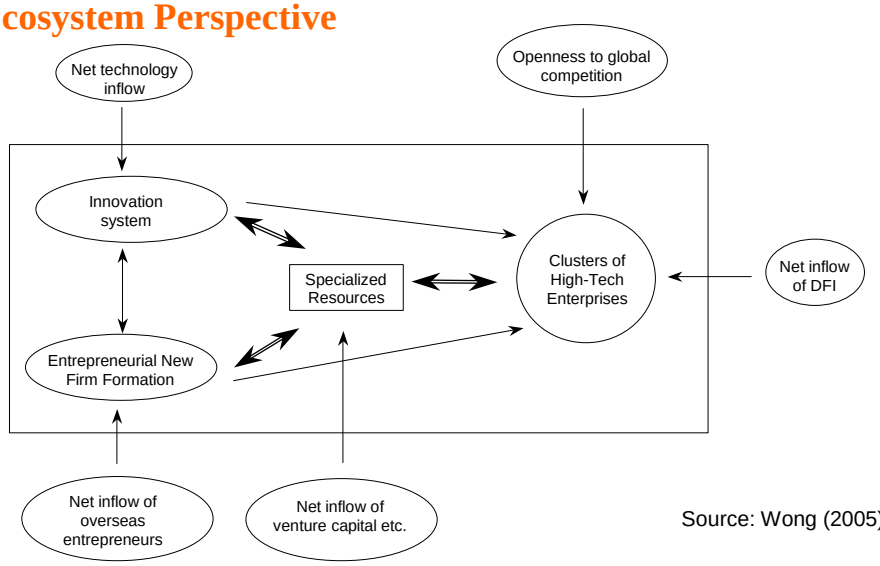
Dynamic Linkages: The National Innovation Systems Perspective

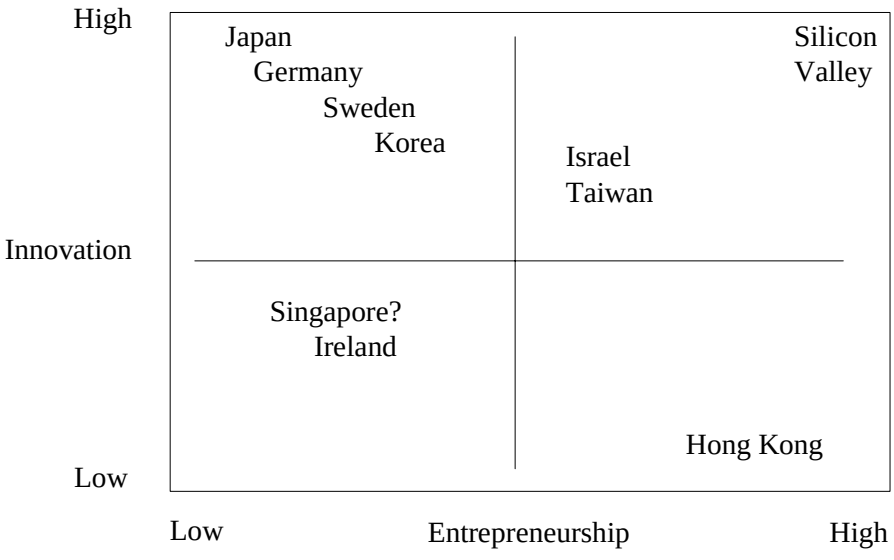


Source: Wong(2002)

Dynamic Linkages: The High-Tech Enterprise Ecosystem Perspective



Source: Wong (2005)



Stylized Patterns of Innovation – Entrepreneurship Nexus

Source: Wong (forthcoming)

Overview of Singapore's NIS Evolution

- **Four Phases of Development**
  - Initial industrial take-off (mid-1960s to mid 1970s)
  - Process technological capability upgrading (mid-1970s – mid-1980s)
  - Product innovation capability development (mid-1980s – late-1990s)
  - Shift towards basic R&D, IP Creation, and indigenous technology entrepreneurship (late-1990s -)
- **Continued high dependence on Foreign MNCs for investment and technology transfer/upgrading**
- **…Emergence of indigenous high tech ventures from late 1990s**

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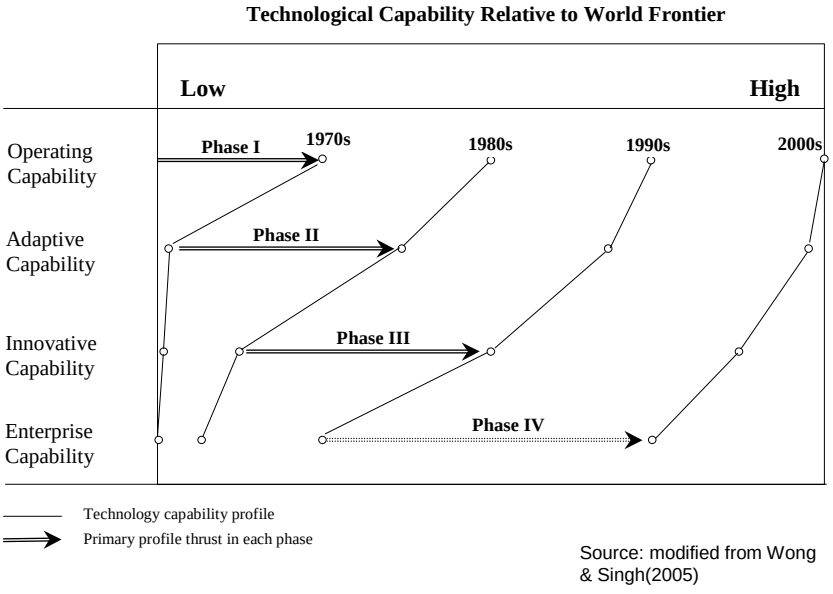
Stylised Profile of Technological Capabilities of Singapore over the Four Phases of NIS Development



Source: modified from Wong & Singh(2005)

Evolution of National Policy

- National S&T Policy has been traditionally driven by Manufacturing Industrial Development Strategy (particularly Electronics manufacturing) in the 1960s-1980s; Services industries were promoted to attract foreign DFI investment and to support manufacturing upgrading & growth
- ICT diffusion policy was strongly promoted since the 1980s
- Cluster development approach emphasize integrated, pro-active development of infrastructures, manpower, supporting industries and services
- Increasing broadening of promotional policy focus to cover not just manufacturing industry, but also services, leading to a comprehensive conceptualization of knowledge-based economy
- Life science industry and Creative media industry became major new growth clusters since the early 2000s
- Recent Formation of a high level Research, Innovation and Enterprise Council (RIEC) chaired by the Prime Minister signals the shift towards adoption of an Integrated Research-Innovation-Enterprise (RIE) Policy Framework

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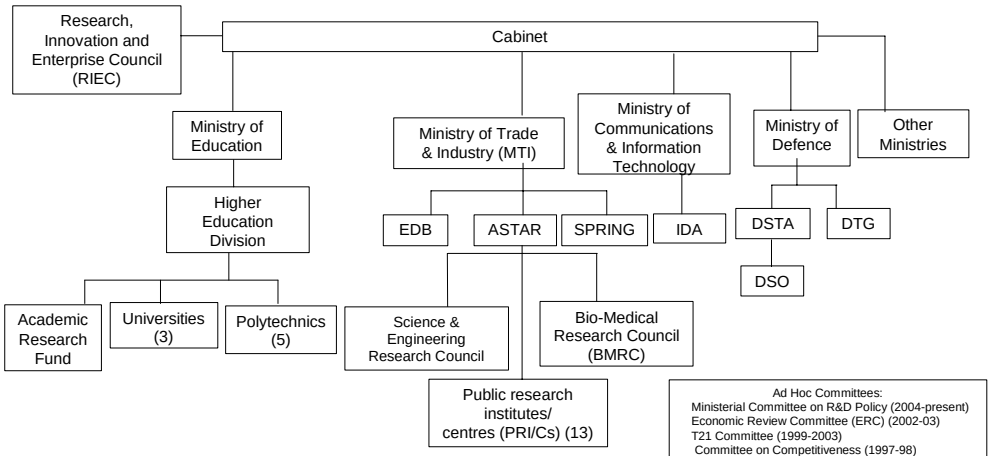
Emerging Institutional Framework for S&T Policy in Singapore



Source: Updated from Wong & Singh(2005)

RIE Framework Indicators for Singapore

- R&D and IP Creation
- Innovation & Technology Commercialization
- Enterprise Dynamism
- Environmental Factors affecting R, I and E
- Dynamic Causal Links among R, I and E ?

R&D Indicators

Research Indicators -- Inputs

- **R&D Intensity**
  - R&D as % of GDP (GERD)
  - Composition of R&D Expenditure
    - **By sector**
    - **By industry**
    - **By indigenous vs. foreign firms**
    - **By type of Research & Development**
- **R&D Manpower**
  - Number of Research Scientists and Engineers (RSEs)
  - Researchers (RSEs) per 10,000 Labour Force
  - Number of Technical Manpower from Tertiary Institutes
  - International Inflows of R&D Manpower
- **Scientific Output from R&D**
  - Number of Published Scientific Papers
  - Number of Citations received by scientific publications

Growth of R&D in Singapore, 1978-2003

Year	GERD (S$ m)	GERD/GDP (%)	RSEs	RSE/10,000 labour force
1978	37.80	0.21	818	8.4
1981	81.00	0.26	1,193	10.6
1984	214.30	0.54	2,401	18.4
1987	374.70	0.86	3,361	25.3
1990	571.70	0.85	4,329	27.7
1991	756.80	1.01	5,218	33.6
1992	949.50	1.17	6,454	39.8
1993	998.20	1.06	6,629	40.5
1994	1,174.98	1.09	7,086	41.9
1995	1,366.55	1.15	8,340	47.7
1996	1,792.14	1.38	10,153	56.3
1997	2,104.56	1.49	11,302	60.2
1998	2,492.26	1.82	12,655	65.5
1999	2,656.30	1.90	13,817	69.9
2000	3,009.52	1.88	14,483	66.1
2001	3,232.68	2.10	15,366	72.5
2002	3,404.66	2.15	15,654	73.5
2003	3,424.47	2.15	17,074	79.4
	Compound average growth rate per annum (%)			
1978-1990	25.4		14.9	
1990-1995	19.0		14.0	
1995-2000	17.1		11.7	
2000-2003	4.4		5.6	
1995-2003	12.2		9.4	

Source: National Survey of R&D Expenditure and Manpower (various years), Science Council of Singapore (prior to 1990); National Survey of R&D in Singapore (various years), National Science & Technology Board (for 1990-2000) and Agency for Science, Technology & Research (2001 to 2003)

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Comparative R&D Indicators, Singapore and Selected OECD/Asian NIEs

Grouping	Country	Year	R&D/GDP (%)	Researchers per 10,000 Labour Force
G-5	Japan	2002	3.1	99
	Germany	2002	2.5	69
	U.S.A	2002	2.7	86[a]
	U.K	2002	1.9	55[b]
	France	2000	2.3	75
Industrialized Small Countries	Finland	2002	3.5	140[c]
	Switzerland	2000	2.6	63
	Sweden	2001	4.3	106
	Ireland	2001	1.1	51
	Netherlands	2001	1.9	55
	Denmark	2002	2.5	93
	Norway	2002	1.7	78[a]
	Australia	2000	1.5	68
	New Zealand	2001	1.2	70
Asian NIEs	Korea	2002	2.5	64
	Taiwan	2001	2.2	61
	Hong Kong	2002	0.6	na
	Singapore	1990	0.8	28
	Singapore	1996	1.4	56
	Singapore	2003	2.2	79[d]

a 1999 figure b 1998 figure c 2001 figure d RSEs per 10,000 labour force

Source : Wong and Singh 2005

Composition of R&D Expenditure by Sectors, 1978-2003

Year	Private Sector (S$ m)	Higher Education Sector (S$ m)	Government Sector (S$ m)	Public Research Institutes (S$ m)	Total (S$ m)
			Percentage		
1978	67.5	21.7	10.8	na	100.0
1985	54.6	30.0	15.4	na	100.0
1990	49.8	32.5	17.7	na	100.0
1995	62.0	15.8	10.7	11.6	100.0
2000	61.6	12.3	12.0	14.1	100.0
2003	60.8	13.4	12.7	13.1	100.0

Source: National Survey of R&D Expenditure and Manpower (various years), Science Council of Singapore (prior to 1990); National Survey of R&D in Singapore (various years), National Science & Technology Board (for 1990-2000) and Agency for Science, Technology & Research (2001 to 2003)

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Distribution of Private Sector R&D Expenditure by Industry, 1993-2003 (%)

	1993	1998	2003
MANUFACTURING	81.1	86.9	74.9
Electronics	51.4	48.3	53.6
Chemicals	5.6	10.8	3.4
Engineering	16.8	22.7	13.1
Precision Engineering	11.2	19.2	9.1
Process Engineering	1.2	0.6	na
Transport Engineering	4.3	2.9	4.0
Life sciences	4.0	4.2	2.9
Light Industries/Other Manufacturing	3.4	1.0	1.8
SERVICES	18.9	13.1	25.1
IT and Communications	3.2	9.2	5.1
Finance & Business	4.3	1.4	2.8
Other Services	11.3	2.5	17.2
ALL INDUSTRY GROUPS	*100.00*	*100.0*	100.0

Source: National Survey of R&D in Singapore (various years), National Science & Technology Board (for 1993-2000) and Agency for Science, Technology & Research (2001 to 2003)

Deepening of Singapore's R&D System 1993-2003

	1993	1997	2000	2003
Percentage of Masters and Ph.D. holders among RSEs (FTE)	39.3	41.6	43.8	48.9
Percentage breakdown of R&D exp (%)				
Basic research	16.1	12.8	11.8	17.3
Applied research	39.1	43.8	35.0	36.0
Experimental development	44.9	43.3	53.2	46.7

Source: National Survey of R&D in Singapore (various years), National Science & Technology Board (for 1993-2000) and Agency for Science, Technology & Research (2001 to 2003)

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Foreign Companies' Share of Industry R&D Expenditure, 1993-2003

Year	Share in total private R&D (%)
1993	67.6
1994	74.5
1995	64.3
1996	67.0
1997	61.2
1998	55.8
1999	55.8
2000	57.9
2001	57.6
2002	52.9
2003	59.8

Source: National Survey of R&D in Singapore (various years), National Science & Technology Board (for 1993-2000) and Agency for Science, Technology & Research (2001 to 2003)

Foreign Companies' Share of Industry R&D Expenditure, 1996-2003

	1996	2003
	Foreign firms' share of private sector R&D (%)	
MANUFACTURING	69.1	63.6
Biomedical sciences	71.6	68.2
Electronics	68.8	68.1
Chemicals	90.9	72.5
Engineering	51.1	45.9
General manufacturing	12.7	34.5
SERVICES	51.8	49.5
R&D	na	43.2
IT and Communications[1]	54.7	41.0
Logistics	na	1.1
Finance & Business[2]	67.1	48.5
Other Services	16.2	63.0
ALL INDUSTRY GROUPS	67.0	*59.8*

1 Post & telecommunications; IT and related services
2 Financial intermediation and other business activities
Source: National Survey of R&D in Singapore (various years), National Science & Technology Board (for 1993-2000) and Agency for Science, Technology & Research (2001 to 2003)

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Average Output of Technical Manpower from Tertiary Education Institutions in Singapore, 1970–2003 (No. of graduates per year)

	1970-79	1980-84	1985-89	1990-94	1995-99	2000-2003
University level[a]	680	1,040	2,162	3,215	5,027	7,787
Polytechnic level[b]	1,516	2,463	4,836	6,686	8,595	10,692
Total	*2,197*	*3,504*	*6,998*	*9,901*	*13,622*	*18,479*
	University graduates as percentage of total					
	31.0	29.7	30.9	32.5	36.9	42.1

a Includes degree courses from SIM
b Includes diploma courses from ISS and SIM
Calculated from: Singapore Yearbook of Labour Statistics (various years), Singapore Yearbook of Manpower Statistics (various years)

Research Indicators -- Outputs

- **Scientific Output from R&D**
  - Number & Intensity of Published Scientific Papers
  - Number & Intensity of Citations received by scientific publications
- **Technology Output from R&D - Patents**
  - Number & Intensity of Patents Granted
  - Proportion of firms owning patents, average number per firm
  - Ownership of patents (foreign vs. local)
  - Number & Intensity of Citations received by patents
  - Other indicators of patent quality (e.g. share of most highly cited patents, science linkage)
- **Other forms of IP Outputs (e.g. Copyrights, Intangible Intellectual Capital)**

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Paper Publications and Citations, January 1995 - April 2005

	No. of papers	No. of citations	Citations per paper
China	324,483	1,088,453	3.35
Hong Kong	17,000	159,081	9.36
India	189,192	668,764	3.53
Indonesia	4,295	25,640	5.97
Japan	742,438	5,774,258	7.78
Korea	147,069	658,522	4.48
Malaysia	9,612	33,623	3.50
Philippines	3,977	26,435	6.65
Singapore	38,125	186,751	4.90
Taiwan	107,367	510,235	4.75
Thailand	14,088	71,222	5.06
Switzerland	145,467	1,986,677	13.66
US	2,739,417	35,494,704	12.96

Note: Includes ISI-indexed journal articles only
Source: *Essential Science Indicators*

Growing Scientific Competence of East Asia

(source: King 2004)

	% of world publications		% world pub. citations		% of world top 1% most cited	
Period	**1993-1997**	**1997-2001**	**1993-1997**	**1997-2001**	**1993-1997**	**1997-2001**
USA	**37.46**	**34.86**	**52.3**	**49.43**	**65.6**	**62.76**
Switzerland	**1.73**	**1.84**	**2.65**	**2.95**	**3.45**	**4.12**
China	**2.06**	**3.18**	**0.95**	**1.56**	**0.44**	**0.99**
India	**2.19**	**2.13**	**0.76**	**0.86**	**0.32**	**0.54**
Korea	**0.81**	**1.53**	**0.44**	**0.88**	**0.28**	**0.78**
Taiwan	**0.98**	**1.25**	**0.52**	**0.69**	**0.26**	**0.51**
Singapore	**0.27**	**0.42**	**0.15**	**0.25**	**0.11**	**0.26**

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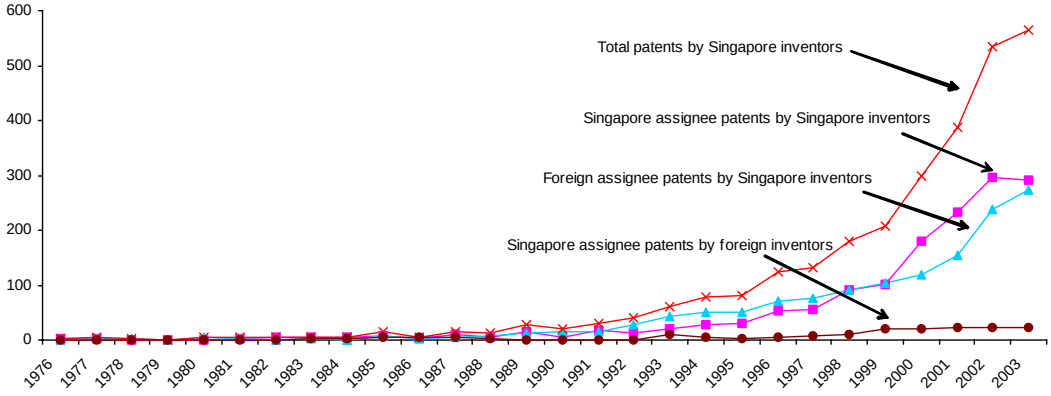
Total Singapore Patents (1976-2003)



	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	TOTAL
Patents by Singapore Inventors																													
Singapore Assignee	2	3	0	0	1	3	6	4	4	7	3	10	5	16	6	17	13	19	29	30	54	55	90	102	179	233	296	291	1478
Foreign Assignee	1	2	3	0	5	2	0	2	0	7	2	6	7	12	15	14	28	42	50	51	70	77	91	105	120	154	237	273	1376
Total	***3***	***5***	***3***	***0***	***6***	***5***	***6***	***6***	***4***	***14***	***5***	***16***	***12***	***28***	***21***	***31***	***41***	***61***	***79***	***81***	***124***	***132***	***181***	***207***	***299***	***387***	***533***	***564***	***2854***
Patents by Foreign Inventors Assigned to Singaporean Organizations																													
	1	0	0	0	0	0	0	3	3	4	4	4	2	1	0	0	0	10	6	3	6	7	10	21	20	22	22	24	173
Total	***4***	***5***	***3***	***0***	***6***	***5***	***6***	***9***	***7***	***18***	***9***	***20***	***14***	***29***	***21***	***31***	***41***	***71***	***85***	***84***	***130***	***139***	***191***	***228***	***319***	***409***	***555***	***588***	***3027***

Wong, P.K. and Y.P. Ho (2004)

Cumulative No. of US-granted Patents, 1977-2003

	Cumulative no. of patents 1977-2003
China	1,996
Hong Kong	5,808
India	1,544
Indonesia	139
Japan	537,833
Korea	31,002
Malaysia	454
Philippines	237
Singapore	**2,234**
Taiwan	50,399
Thailand	320
Switzerland	35,397
US	1,631,426

Source: USPTO. (2003). *Historic Patents By Country, State, and Year - All Patent Types (December 2003),* downloaded from http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_allh.htm

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No. of US Patents Granted per Million Population, 1980-2003

	1980	1990	2000	2003
Indonesia	0.01	0.02	0.07	0.06
Philippines	0.04	0.13	0.16	0.31
Thailand	0.06	0.05	0.49	0.76
Malaysia	0.07	0.33	2.02	2.54
China	0.00	0.04	0.13	0.33
India	0.01	0.03	0.13	0.33
Hong Kong	9.72	26.47	80.62	97.29
Korea	0.24	6.76	73.44	86.26
Singapore	1.24	5.25	60.23	106.98
Taiwan	4.02	42.56	266.61	295.40
Japan	63.36	167.91	259.39	291.93
Switzerland	202.51	200.69	202.92	193.65
US	179.02	211.92	352.23	339.06

Source: Wong & Ho (2004)

Innovation/Technology Commercialization Indicators

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Innovation Indicators - Innovativeness

- **Propensity of firms to innovate (% of firms that have introduced new product or process in last 3 years)**
  - Product Innovation
  - Process Innovation
- **Type of innovation activities engaged in by firms**
- **Innovation Intensity - input**
  - Expenditure on Innovation as % of sales
- **Innovation Intensity - Output**
  - Sales from new products/services as % of total sales
  - Sales from new processes as % of total production output
- **Contribution of patents to turnover (% of sales attributable to usage of patents and other IP)**
  - Sales of products and services using patents/IP invented in-house as % of total sales
  - Royalty from patents/IP licensed out as % of total sales

Proportion of Innovating Companies in Singapore Manufacturing and KIBS Sectors 1999

	Innovating companies (%)
Manufacturing	31.7
Electronics	68.8
Chemicals	38.0
Precision and Process Engineering	28.5
Transport Engineering	18.2
KIBS	56.9
IT and related services	73.0
Market research, business & management consultancy	58.0
Architectural, engineering, land surveying, other technical	40.0
R&D, advertising, publishing, exhibitions & conferences	70.0

Source: Singapore National Innovation Survey: Manufacturing; Singapore National Innovation Survey: Knowledge-Intensive Business Services

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Incidence of Product and Process Innovation in the Singapore Manufacturing and KIBS Sectors 1999

	Product innovation	Process innovation
	Percentage of companies	
Manufacturing	24.1	22.4
KIBS	44.4	49.4

Source: Singapore National Innovation Survey: Manufacturing;
Singapore National Innovation Survey: Knowledge-Intensive Business Services

Innovation Activities Engaged by Companies 1999 (Percentage of Innovating Firms)

	Manufacturing	KIBS
R&D	66.4	43.3
Acquisition of R&D services	18.3	11.5
Acquisition of machinery and equipment	80.2[1]	31.1
Acquisition of software, external technology	22.4[2]	61.5
Industrial design, market research & marketing expenses for innovations	37.9	na
Preparations to introduce new or significantly improved services or methods to deliver them	na	75.7
Training	61.2	58.3
Market introduction of innovations	na	50
Adoption of e-commerce applications	na	46.7

1 Acquisition of machinery, equipment and software
2 Licensing of external technology
Source: Singapore National Innovation Survey: Manufacturing
Singapore National Innovation Survey: Knowledge-Intensive Business Services

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Innovation and R&D Intensities of Innovating Firms 1999

	Total expenditure on innovation as a percentage of sales					
	<2%	2%-4.9%	5%-9.9%	10%-19.9%	20%-39.9%	≥40%
Manufacturing	28.2	26.4	20.9	15.5	7.3	1.8
KIBS	18.5	10.5	18.3	21.5	21.2	9.9
	Total expenditure on R&D as a percentage of sales					
	<1%	1%-2.9%	3%-4.9%	5%-9.9%	10%-19.9%	≥20%
Manufacturing	36.1	25.0	20.8	9.7	4.2	4.2
KIBS	8.7	19.4	15.9	12.3	25.3	18.4

Source: Singapore National Innovation Survey: Manufacturing
Singapore National Innovation Survey: Knowledge-Intensive Business Services

New/Improved Products/Services as a Percentage of Total Sales 1999

	Less than 10%	10% - 24%	25% - 49%	50% - 74%	≥75%
Manufacturing	32.3	28.8	19.3	7.2	12.4
KIBS	21.7	25.3	20.5	14.5	18.1

Source: Singapore National Innovation Survey: Manufacturing
Singapore National Innovation Survey: Knowledge-Intensive Business Services

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Proportion of Enterprises Engaging in Innovation Activities in Singapore 1999 vs Selected European Countries

	Manufacturing sector		Knowledge-Intensive Business Services Sector
Country	Percentage of enterprises engaging in innovation activities	Percentage of product innovators' turnover due to new or improved products in last 3 years†	Percentage of firms engaging in innovating Activities††
Ireland	73	32	75
Germany	69	43	63
Austria	67	31	41
Netherlands	62	25	58
United Kingdom	59	23	56
Sweden	54	31	50
Norway	48	20	42
France	43	21	46
Luxembourg	42	na	83
Finland	36	25	44
Singapore	**32**	**29**	**57**
Spain	29	27	na
Belgium	27	14	42

Note: European figures are for 1996 except for Norway, which are for 1997
† Singapore value for proportion of turnover is derived from mid-point estimate of categorised variable
†† European figures are for NACE 72 (computer and related services) and 742 (architectural and engineering activities and related technical consultancy) only. As such, they are not wholly comparable with the Singapore results
Source: Wong (2004), Wong, P.K., Kiese, M., Singh, A. and Wong, F. (2003). "The pattern of innovation in Singapore's manufacturing sector", *Singapore Management Review*, 25(1). Wong, P.K., and Singh, A. (2004). "The pattern of innovation in the knowledge-intensive services sector of Singapore", *Singapore Management Review*, 26(1).

Innovation Indicators - Technology Utilization/Adoption

- **Proportion of firms that have adopted given technologies (Speed and scope of diffusion of advanced technologies)**
- **Proportion of firms that have licensed in patents & other IP**
- **Contribution of licensed-in patents to turnover (% of sales attributable to usage of licensed in patents)**
- **Capability to imitate and reverse engineer advanced technologies**
- **Capability to apply advanced technologies in new industries and services**

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ICT Diffusion Indicators 2003

Country	Investment in telecoms (% GDP)	Telephone (main) lines in use per 1000	Computers per 1000 [a]	Internet users per 1000 [a]	Mobile telephone subscribers per 1000	Broadband subscribers per 1000
Indonesia	na	39	16	53.92	87.4	0.18
Malaysia	1.21	182	192	428.80	442.0	4.40
Philippines	0.91	41	30	69.11	269.5	0.68
Thailand	0.28	105	57	116.70	394.2	0.70
China	1.89	209	41	78.53	214.8	8.14
India	0.69	46	12	34.71	24.7	0.13
Japan	0.47	472	543	612.70	679.0	116.86
Hong Kong	0.66	559	503	612.30	1,079.2	180.97
Korea	1.33	538	539	649.70	700.9	233.22
Singapore	0.49	450	573	574.80	852.5	100.76
Taiwan	1.24	591	375	464.20	1,141.4	134.63
Switzerland	0.59	727	712	607.90	843.4	95.78
Ireland	0.19	491	560	456.40	879.6	2.70
Germany	0.23	657	562	508.00	785.2	38.87
US	0.17	624	763	632.20	545.8	86.27

a Figures are for 2004
Source: World Competitiveness Yearbook 2005, IMD

Enterprise Indicators

NUS ENTREPRENEURSHIP CENTRE

Enterprise Indicators – Productivity & Growth of Leading High Tech Clusters

- **Composition of Industry by Technology Intensity**
- **Share of High Tech Products in Total Manufacturing Output/Export**
- **Value Added and Labor Productivity Growth of Leading High Tech Industrial Clusters**

Distribution of Singapore Manufacturing Exports by Technological Categories, 1980-1999

	1980	1990	1999
Sector	Percentage		
Resource-based	44.4	26.9	13.2
Labor-intensive	10.6	10.3	7.6
Scale-intensive	9.3	5.9	5.5
Differentiated	20.5	22.3	21.2
Science-based	15.1	34.6	52.5

SOURCE: Wong, P.K. (2001)

NUS ENTREPRENEURSHIP CENTRE

Electronics Manufacturing Industry Growth in Singapore, 1960-2000

Year	Output $mn	No. Workers	Value Added $mn	Fixed Asset $mn	Val.Add / Labour $'000	Val.Add / Output %	Capital/ Labour $'000
1960	17.1	1,252	7.9	na	6.3	46.2	na
1970	212.9	11,251	99.1	na	8.8	46.5	na
1980	5,344.0	71,727	1,668.9	585.1	23.3	31.2	8.2
1990	27,878.1	122,797	7,716.6	3,757.3	62.8	27.7	30.6
2000	83,950.7	102,320	17,228.3	14,885.9	168.4	20.5	145.5

Sources: Economic Development Board, Report on the Census for Industrial Production, various years; Economic Development Board, Report on the Census of Manufacturing Activities 2000

ICT Services Growth in Singapore, 1986-2001

Total ICT Services

	Establishments	Employment	Turnover	Value Added	Operating Surplus	Value add/ Labour	Value add/ Turnover
	No.	No.	$million	$million	$million	$	%
ICT Services							
1986	155	15,661	1,223	894	539	57,067	73.06
1990	360	16,379	2,293	1,692	1,144	103,296	73.79
2000	2,544	32,897	9,591	4,719	2,689	143,448	49.20
2001	2,898	36,106	10,956	5,361	2,911	148,479	48.93
			Growth (%)				
1986-1990	23.5	1.1	17.0	17.3	20.7	16.0	0.2
1990-2000	21.6	7.2	15.4	10.8	8.9	3.3	-4.0

Sources: Department of Statistics, Economic Survey Series: Real Estate & Business, various years; Department of Statistics, Economic Survey Series: Transportation & Communications, various years; Department of Statistics, Economic Survey Series: IT and Related Services. Reference Year 2001; Department of Statistics, Economic Survey Series: Post & Telecommunications. Reference Year 2001

NUS ENTREPRENEURSHIP CENTRE

Enterprise Indicators – Entrepreneurial Dynamism

- **Total Entrepreneurial Activity (TEA) rate**
  - Proportion of adult population engaged in start-up activities (nascent entrepreneurs) or running new business less than 3.5 years old
    - **Necessity vs. Opportunity, Low vs. High Growth Aspiration**
- **New Business Formation rates**
  - Number of new establishments formed each year
  - Rate of change in enterprise formation
- **Enterprise Cessation rates**
  - Number of establishments ceasing operations each year
  - Rate of change in number of establishments ceasing operations
- **Enterprise Survival Rates:**
  - Proportion of firms registered in Year X still in operation in Year Y

Enterprise Indicators – Entrepreneurial Dynamism

- **Impact of Entrepreneurship**
  - Jobs created by start-ups as % of national employment/ labour force
  - Value added of start-ups as % of GDP
  - Revenue Growth of start-ups
- **Degree of domination of key sectors by large, established firms**
- **Degree of domination of key sectors by foreign owned firms**
- **Dynamic Churn Rate among the Leading Firms in the country**
  - % of top 500 firms by revenue in year X that still remain in top 500 listing in year Y
  - Changes in composition by industrial sectors (new vs. matured sectors)
- **Number and revenue share of high growth "Gazelle" firms**

NUS ENTREPRENEURSHIP CENTRE

TEA Prevalence Rate & Rank in OECD and East Asia

	2004		2003	
Country	Rate (%)	Rank	Rate (%)	Rank
NEW ZEALAND	14.7	1	13.6	1
ICELAND	13.6	2	11.2	4
AUSTRALIA	13.4	3	11.6	3
UNITED STATES	11.3	4	11.9	2
CANADA	8.9	5	8.0	6
IRELAND	7.7	6	8.1	5
NORWAY	7.0	7	7.5	7
UNITED KINGDOM	6.3	8	6.4	11
FRANCE	6.0	9	1.6	21
GREECE	5.8	10	6.8	9
SINGAPORE	5.7	11	5.0	14
DENMARK	5.3	12	5.9	12
SPAIN	5.2	13	6.8	10
NETHERLANDS	5.1	14	3.6	17
GERMANY	4.5	15	5.2	13
FINLAND	4.4	16	6.9	8
ITALY	4.3	17	3.2	18
SWEDEN	3.7	18	4.1	15
BELGIUM	3.5	19	3.9	16
HONG KONG	3.0	20	3.2	19
JAPAN	1.5	21	2.8	20
Overall	6.6		6.8	

Rank among subset of OECD and East Asian countries that participated in both GEM 2003 and 2004 surveys.

Source: Wong et al. (2005) GEM Singapore 2004 Report

Necessity TEA Prevalence Rate & Rank 2004 in OECD and Advanced East Asia

Country	Rate	Rank	Country	Rate	Rank
Poland	**3.1**	**1**	**Iceland**	**0.7**	**14**
Australia	**2.5**	**2**	**Netherlands**	**0.7**	**15**
New Zealand	**2.1**	**3**	**United Kingdom**	**0.6**	**16**
Greece	**1.7**	**4**	Singapore	0.6	17
United States	**1.5**	**5**	**Spain**	**0.6**	**18**
France	**1.4**	**6**	**Denmark**	**0.4**	**19**
Canada	**1.4**	**7**	**Sweden**	**0.3**	**20**
Hungary	**1.2**	**8**	**Italy**	**0.3**	**21**
Germany	**1.2**	**9**	**Finland**	**0.3**	**22**
Portugal	**1.0**	**10**	**Belgium**	**0.2**	**23**
Ireland	**1.0**	**11**	**Japan**	**0.2**	**24**
Hong Kong	**1.0**	**12**			
Norway	**0.9**	**13**	Mean	1.0	

Source: Wong et al. (2005) GEM Singapore 2004 Report

NUS ENTREPRENEURSHIP CENTRE

Opportunity TEA Prevalence Rate & Rank 2004 in OECD and Advanced East Asia

Country	Rate	Rank	Country	Rate	Rank
New Zealand	**12.3**	**1**	**Netherlands**	**4.3**	**14**
Iceland	**12.0**	**2**	**Greece**	**3.8**	**15**
Australia	**10.7**	**3**	**Finland**	**3.5**	**16**
United States	**9.5**	**4**	**Sweden**	**3.3**	**17**
Canada	**7.3**	**5**	**Germany**	**3.1**	**18**
Ireland	**6.6**	**6**	**Italy**	**3.1**	**19**
Norway	**5.8**	**7**	**Portugal**	**3.0**	**20**
Poland	**5.7**	**8**	**Belgium**	**2.9**	**21**
United Kingdom	**5.5**	**9**	**Hungary**	**2.8**	**22**
Singapore	5.0	10	**Hong Kong**	**2.0**	**23**
Denmark	**4.8**	**11**	**Japan**	**1.1**	**24**
France	**4.6**	**12**			
Spain	**4.5**	**13**	Mean	5.3	

Source: Wong et al. (2005) GEM Singapore 2004 Report

High Employment Growth Potential TEA Prevalence Rate & Rank 2004 in OECD and Advanced East Asia

Country	Rate	Rank	Country	Rate	Rank
Iceland	2.2	1	Germany	0.4	14
New Zealand	1.5	2	Hungary	0.4	15
Australia	1.2	3	Sweden	0.4	16
Singapore	1.1	4	Norway	0.4	17
United States	1.0	5	France	0.3	18
Canada	0.9	6	Belgium	0.3	19
United Kingdom	0.8	7	Spain	0.2	20
Ireland	0.8	8	Greece	0.1	21
Denmark	0.8	9	Japan	0.0	22
Poland	0.6	10			
Italy	0.6	11			
Netherlands	0.6	12			
Hong Kong	0.4	13	Mean	0.6	

Source: Wong et al. (2005) GEM Singapore 2004 Report

NUS ENTREPRENEURSHIP CENTRE

Summary of Level of Entrepreneurial Activity in Singapore (2000 – 2004)

	2000	2001	2002	2003	2004
Total Entrepreneurial Activity (TEA)	4.2	6.6	5.9	5.0	5.7
Necessity TEA	-	1.2	0.9	1.0	0.6
Opportunity TEA	-	5.1	4.9	3.9	5.0
Male 18-64 TEA	5.8	9.7	9.3	6.5	8.2
Female 18-64 TEA	2.7	3.6	2.7	3.5	3.4
Nascent Start-up	2.3	4.2	4.0	3.0	3.0
New Business <3.5 years	1.9	2.4	2.0	2.3	2.8
Polytechnic	2.9	4.0	4.2	6.4	8.6
University & above	4.0	9.7	4.1	9.6	10.0

Source: Wong et al. (2005) GEM Singapore 2004 Report

Number and Growth of New Firm Formations

	Year of Registration							
	1998	1999	2000	2001	2002	2003	2004	1st Half 2005
	Number							
Start-Ups	**29,870**	**34,604**	**36,457**	**33,202**	**36,675**	**39,337**	**41,164**	**20,744**
Companies	**6.524**	**8,018**	**11,032**	**8,511**	**11,338**	**13,542**	**16,637**	**8,803**
Businesses	**23,346**	**26,586**	**25,425**	**24,691**	**25,337**	**25,795**	**24,527**	**11,941**
	% Change over previous years							
Start-Ups	**-**	**15.8%**	**5.4%**	**-8.9%**	**10.5%**	**7.3%**	**4.6%**	**0.8%**
Companies	**-**	**22.9%**	**37.6%**	**-22.9%**	**33.0%**	**19.4%**	**22.9%**	**10.0%**
Businesses	**-**	**13.9%**	**-4.4%**	**-2.9%**	**2.6%**	**1.8%**	**-4.9%**	**-5.1%**

Source: Wong et al. (2005) GEM Singapore 2004 Report and Singapore Department of Statistics

NUS ENTREPRENEURSHIP CENTRE

Number of Enterprise Cessations and Rate of Change in Enterprise Cessations

	Year of Cessation						
	1998	1999	2000	2001	2002	2003	2004
	Number						
Start-Ups	**26,373**	**28,052**	**29,511**	**28,114**	**18,219**	**18,101**	**18,150**
Companies	**5,049**	**5,835**	**5,303**	**5,593**	**6,952**	**7,745**	**6,540**
Businesses	**21,324**	**22,217**	**24,208**	**22,521**	**11,267**	**10,356**	**11,610**
	% Change over previous years						
Start-Ups		**6.37**	**5.20**	**-4.73**	**-35.20**	**-0.65**	**0.27**
Companies		**15.57**	**-9.12**	**5.47**	**24.30**	**11.41**	**-15.56**
Businesses		**4.19**	**8.96**	**-6.97**	**-49.97**	**-8.09**	**12.11**

Source: Statistics Singapore Newsletter, Singapore Department of Statistics

NUS ENTREPRENEURSHIP CENTRE

Enterprise Survival Rates

Proportion of firms still in operation as at mid 2004

	Year of Registration								
	1996	1997	1998	1999	2000	2001	2002	2003	1H 2004
All Industries	41.6	44.5	46.6	54.9	71.9	83.0	92.1	98.0	98.9
Non High-Tech	41.5	44.3	46.3	54.6	71.7	82.8	92.0	98.1	98.9
High-Tech	43.4	46.4	50.4	57.8	73.3	84.2	93.0	97.9	98.7

Source: Singapore Department of Statistics

NUS ENTREPRENEURSHIP CENTRE

Annual Contribution of New Firms to National Job Pool, 2000-2002

	% of national employment		% of national employment		% of national employment
JAPAN	1.7	NORWAY	4.1	ICELAND	5.9
FRANCE	1.7	UK	4.2	MEXICO	6.3
BELGIUM	1.9	INDIA	4.2	IRELAND	6.4
FINLAND	2.0	GERMANY	4.3	AUSTRALIA	6.7
S AFRICA	2.4	SLOVENIA	4.4	N ZEALAND	7.0
SWEDEN	2.4	POLAND	4.5	ISRAEL	7.1
H KONG	2.5	CROATIA	4.6	ARGENTIA	7.3
SINGAPORE	3.0	CANADA	4.9	THAILAND	7.7
PORTUGAL	3.2	HUNGARY	5.0	US	7.8
DENMARK	3.4	RUSSIA	5.1	CHILE	10.9
SPAIN	3.8	C TAIPEI	5.4	CHINA	11.4
ITALY	3.8	GREECE	5.6	KOREA	13.2
SWITZERLAND	3.9	BRAZIL	5.7	VENEZUELA	14.9
NETHERLAND	3.9				

Source: Wong et al. (2004) GEM Singapore 2003 Report

Environmental Indicators

NUS ENTREPRENEURSHIP CENTRE

Environmental Factors for Innovation

- **Government Promotional Policies and Programs**
- **Manpower and skills**
- **Culture and Attitudes**
- **Supporting Services (e.g. industrial design services, IP legal services)**
- **Enabling Infrastructures (e.g. IP protection laws and enforcement effectiveness)**

Evaluation of Innovation Environment of Singapore by Existing Manufacturing Firms, 1999

How do you assess the current business environment in Singapore for innovation activities? (1=poor to 5=good)	Mean Scores		
	Foreign	Local	Average
Availability of government incentives for innovation	3.32	3.36	3.35
Openness of government departments & regulatory authorities to innovation	3.40	3.32	3.35
Availability of suitable manpower in scientific-technical sector	2.84	2.91	2.89
Availability of suitable manpower in business sector	3.01	3.05	3.04
Consultancy support services	2.94	3.08	3.03
Local universities for technical support and R&D collaboration	3.08	3.06	3.06
R&D institutions for technical support and R&D collaboration	3.05	3.00	3.02
Availability of other technical supporting services	2.94	2.96	2.96
Tolerance for failure	2.65	2.71	2.69
Attitude of people towards innovation	3.15	3.08	3.11
Openness of customers to innovation	3.26	3.22	3.24
Openness of suppliers to innovation	3.15	3.14	3.14
Intellectual property protection	3.44	3.37	3.40
Quality of telecom. & IT services for enabling innovation	3.93	3.89	3.91
Availability of finance for innovation (e.g., venture capital)	2.93	3.00	2.98
Listing requirements on local stock exchange	3.27	3.14	3.19

Source: He, Z.L. and Wong, P.K. (2003). "Host Country Environment and Innovation Intensity of Foreign Subsidiaries: Evidence from Singapore and Thailanc
To be submitted to *World Development* for publication. Wong (2004)

NUS ENTREPRENEURSHIP CENTRE

Environment for Enterprise Dynamism

- **Financing availability**
  - Bank financing to start-ups
  - Venture Capital (VC) for high tech start-ups
  - Informal Investors/Business Angels
- **Social & Cultural Attitudes towards Entrepreneurship**
  - Perception of Social Status of Entrepreneurs
  - Attitudes towards risk-taking, fear of failure
- **Government Policies and Programmes**
  - Public policies facilitating new entrants and start-ups (e.g. anti-trust, competition policy)
  - Public assistance programs for SMEs and start-ups
- **Entrepreneurship Education and Training**
  - Entrepreneurship education for science and engineering students in tertiary institutes
  - Business skills training for working professionals
- **Ease of technology transfer from public research institutes/universities**
- **Cost of Doing Business**
  - Compliance costs (e.g. Number of procedures for business registration)
  - Corruption, Bureaucratic Inefficiencies, infrastructure costs etc.

Venture Capital Investments in Singapore

	2000	2001	2002	2003
Venture Capital (VC) investments in Singapore companies (million)	S$ 601.3	S$ 384.4	S$ 155.0	S$ 185.0
Gross Domestic Product (GDP)* (million)	S$157,700	S$152,065	S$155,726	S$159,135
VC Investment/GDP Ratio	0.38%	0.25%	0.10%	0.12%
Average VC per investment (million)	S$3.3	S$5.3	S$2.4	S$2.3
No. of companies invested	182	73	65	82

Note: exchange rate US$1 is S$1.73 in 2000, S$1.79 in 2001, S$1.79 in 2002, S$1.76 in 2003
** GDP at current market price*
Source: Economic Development Board

NUS ENTREPRENEURSHIP CENTRE

Business Angel Prevalence Rate & Rank in OECD and Advanced East Asia

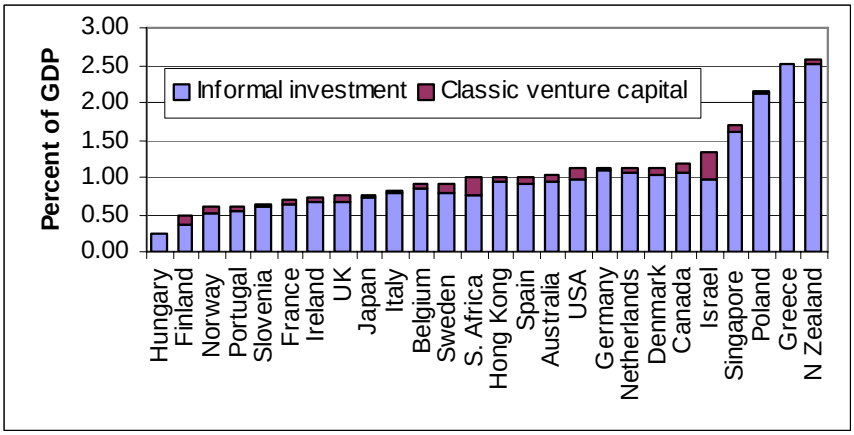
Country	Rate (%)	Rank
Iceland	**8.8**	**1**
France	**4.9**	**2**
New Zealand	**4.8**	**3**
United States	**4.3**	**4**
Norway	**4.3**	**5**
Poland	**3.9**	**6**
Italy	**3.0**	**7**
Denmark	**2.9**	**8**
Australia	**2.7**	**9**
Singapore	**2.7**	**10**
Canada	**2.7**	**10**
Germany	**2.7**	**12**

Country	Rate (%)	Rank
Greece	**2.7**	**13**
Spain	**2.6**	**14**
Sweden	**2.4**	**15**
Ireland	**2.3**	**16**
Hungary	**2.2**	**17**
Hong Kong	**2.1**	**18**
Finland	**2.1**	**19**
Belgium	**1.6**	**20**
United Kingdom	**1.4**	**21**
Netherlands	**1.3**	**22**
Portugal	**0.9**	**23**
Japan	**0.3**	**24**
Mean	**2.9**	

Singapore's 95% confidence interval is 2.4 to 3.0, hence countries ranked from Sweden to Italy are within the same band as Singapore

Source: Wong et al. (2005) GEM Singapore 2004 Report

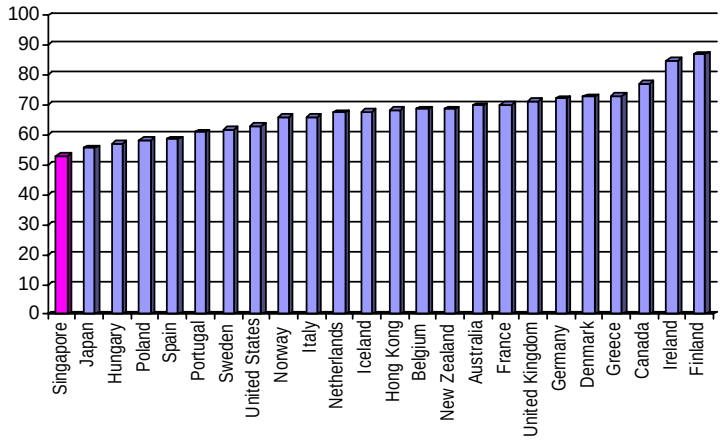
Informal Investment and Classic Venture Capital, Percent of GDP (2003)



Source: Wong et. al. (2005) GEM Singapore Country Report 2004

NUS ENTREPRENEURSHIP CENTRE

Perception of Prestige: % agreeing that "New business success is high status"



Source: Wong et al. (2005) GEM Singapore 2004 Report

Composite Indicators

NUS ENTREPRENEURSHIP CENTRE

Selected Indicators of IP Creation and Usage 2005

	Non-innovating	Innovating	All firms
		% of firms	
IP creation indicators			
Firms which have applied for patents	21.3	43.2	37.6
Firms which own patents	12.8	33.1	28.0
Firms which own non-patent IP	40.4	52.1	49.2
% whose patent usage contributes = 2% of turnover	0.0	10.7	8.0
% whose royalties from licensing-out patents = 2% of turnover	0.0	2.9	2.1
% whose royalties from licensing-out non-patent IP contribute = 2% of turnover	2.1	10.7	8.6
IP usage indicators			
Firms which license-in patents	10.6	20.1	17.7
Firms which license-in non-patent IP	12.8	16.5	15.6
% whose products/services which use licensed-in patents contribute = 2% of turnover	0.0	8.6	6.4
% whose products/services which use licensed-in non-patent IP contribute = 2% of turnover	4.3	9.3	8.0

Note: Data is based on firms which have some form of R&D activities
Figures are confidential and subject to approval from IP Academy for public release

Source: Wong et al (2005). *Survey Of Innovation & Intellectual Property Creation And Usage Among Singapore Firms: Final Report*.

Singapore's Relative Ranking in Technological Capability-Related Indicators, World Competitiveness Yearbook, selected years

	Ranking		
	1996	2000	2005
Overall competitiveness ranking	2	2	3
Overall technological development indicators			
Overall Science & Technology competitiveness ranking	12	9	na
Technology using capability indicators			
Scientific environment	2 [a]	6	16 [b]
Science and education is adequately taught in compulsory schools	1	1	1 [c]
Science and technology interests the youth of the country	1 [a,d]	2	2 [e]
Technology management	5	3	3 [f]
Technological co-operation is common between companies	9	8	7 [g]
Technology transfer between companies and universities is sufficient	4 [h]	3	7 [i]
Lack of sufficient financial resources does not constrain tech development	10	3	1 [j]
Development and application of technology is supported by the legal envmt	1 [a]	1	1
Relocation of R&D facilities is not a threat to the future of your economy	31 [a]	9	41
Qualified engineers are available in your country's labour market	17	9	8
Qualified IT employees are available in your country's labour market	na	6	15 [k]
Employee training is a high priority in companies	na	2	11
University education meets the needs of a competitive economy	1 [l]	4	7

[a] 1997 ranking [b] Scientific infrastructure [c] Science in schools is sufficiently emphasized [d] Science and technology arouse the interest of youth
[e] Youth interest in science is strong [f] Technological infrastructure [g] Technological co-operation is developed between companies
[h] Research cooperation between companies and universities is sufficient [i] Knowledge transfer is highly developed between companies and universities
[j] Funding for technological development is generally sufficient [k] IT skills are readily available [l] The educational system meets the needs of a competitive econ
Source: World Competitiveness Yearbook (various years), IMD

NUS ENTREPRENEURSHIP CENTRE

Singapore's Relative Ranking in Technological Capability-Related Indicators, World Competitiveness Yearbook, selected years (contd)

	Ranking		
	1996	2000	2005
Technology creation capability indicators			
R&D expenditure	26 [a]	15	na
Total expenditure on R&D per capita	na	16 [b]	17 [c]
Total expenditure on R&D (% of GDP)	24 [d]	14 [b]	15 [c]
Business expenditure on R&D per capita	na	14	15 [c]
R&D personnel	38 [a]	13	na
Total R&D personnel nationwide per capita	na	16 [b]	13 [c]
Total R&D personnel in business enterprise per capita	na	17 [b]	16 [c]
Intellectual property	19 [a]	22	na
Number of patents granted to residents	na [e]	34 [f]	32 [g]
Number of patents secured abroad by country residents	23 [h]	35 [i]	na
Patent and copyright protection is enforced in your country	5 [j]	15	6 [k]
Number of patents in force per 100,000 inhabitants	na	12 [i]	4 [c]
Creation of firms is common in your country	na	15	26 [c,l]
Managers generally have a sense of entrepreneurship	22 [m]	19	35 [n]

a 1997 ranking b Based on 1998 figures c Based on 2003 figures d Based on 1994 figures e Based on 1993-94 figures (average annual number)
f Based on 1996-97 figures (average annual number) g Based on average for 2000-2002 h Based on 1993 figures, (per 10,000 residents)
i Based on 1997 figures j Intellectual property is adequately enforced in your country k Intellectual property rights are adequately enforced in your economy
l Entrepreneurship is common in your country m Managers generally have a good sense of entrepreneurship and innovation
n Entrepreneurship of managers is widespread in your economy
Source: World Competitiveness Yearbook (various years), IMD

Assessing Causal Links between R, I and E: Findings from Two Recent Studies

NUS ENTREPRENEURSHIP CENTRE

Estimating the Impact of R&D on Macroeconomic Growth in Singapore (Ho, Wong & Toh(2005))

•From standard Cobb-Douglas functional form, assuming constant return to scales, derived TFP as part of 'Solow residual' contributing to economic growth:

•Long Run Relationship between TFP and S (knowledge capital stock):

- $TFP = \log B + \gamma \log S + \phi \log Z$
-

•Short Run Error Correction Model:

- $TFP_t = \beta + \lambda_1 TFP_{t-1} + \ldots + \lambda_x TFP_{t-x} + \gamma \log S_t + \ldots$
- $+ \gamma_y \log S_{t-y} + \phi \log Z + \ldots + \phi_y \log Z_{t-y}$

•Knowledge Capital Stock (S) computed using perpetual inventory method, using stream of R&D expenditure and assuming 10% depreciation rate

Long Run Relationship between R&D capital and TFP

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.556	0.081	6.876	0.000
Log(S)	0.080	0.011	7.507	0.000
R-squared	0.71925	Mean dependent var		1.15417
Adjusted R-squared	0.70649	S.D. dependent var		0.12085
Cointegration Test : Between TFP and Log(S)				
ADF Test Statistic	-2.90306	1% Critical Value*		-2.67429
		5% Critical Value		-1.9572
Result	Cointegrated			

Estimated equation:
$TFP = \log B + \gamma \log S$

- **Unit root test on residuals show that TFP and log (S) are cointegrated – long run relationship between R&D capital stock and TFP**

Short Run Error Correction Model

- **Estimated the tested down model:**
- $TFP_t = \beta + \lambda\, TFP_{t-1} + \gamma \log S_t$
- **Results:**
- $TFP_t = 0.097 + 0.837 * TFP_{t-1} + 0.013 * \log S_t$

- **1% increase in R&D capital stock leads to 0.013% increase in GDP**
- **In long run, 1% increase in R&D capital stock leads to 0.0814% increase in GDP**
- **For year 2001, oin short run**
  - 1% increase in R&D capital = $122 mn
  - Yields $1,803 mn increase in GDP
  - $14.78 of GDP for every dollar of R&D

Summary of R&D Impact on GDP

Parameter	Value
Lambda λ	0.8366
Short Term Gamma γ (Short Term Elasticity of R&D Capital Stock)	0.0133
Long Term Gamma γ (Long Run Elasticity of R&D Capital Stock)	0.0814
Internal Rate of Return (over last 10 years)	8.24%
Internal Rate of Return (over last 5 years)	5.89%
Mean Lag	5.12 years
Median Lag	3.89 years

- **Median lag = 3.9 years; takes 3.9 years for half of effect from R&D to be realised in terms of GDP growth**
- **Mean lag = 5.1 years; on average, takes 5.2 years for R&D to have impact on GDP**
- **IRR of 5.9% (5 years) and 8.2% (10 years) compares to market rates of 5-6% for debt funding – R&D investment is profitable, especially in long term**

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Comparing Elasticity of Output wrt GDP in Singapore with Other Countries

Parameter	Singapore	16 OECD Countries (Guellec and van Pottelsberghe de la Potterie (2001))	53 countries (Lichtenberg (1992))
Lambda λ	0.8366	0.82	NA
Short Term Gamma γ (Short Term Elasticity of R&D Capital Stock)	0.0133	0.024 (private R&D) 0.028 (public R&D)	NA
Long Term Gamma γ (Long Run Elasticity of R&D Capital Stock)	0.0814	0.13 (private R&D) 0.17 (public R&D)	0.068 to 0.077
Mean Lag	5.12	4.55	NA
Median Lag	3.89	3.49	NA

- **R&D capital in Singapore appears less productive than OECD countries**
- **Short and long term elasticities are lower than in OECD**
- **Mean and median lag are also slightly lower than in OECD**

Estimating the impact of Innovation & Entrepreneurship on Economic Growth (Wong and Ho(2005))

$$\text{Economic Growth} = \alpha_0 + \alpha_1 \text{ Base year GDP per worker} + \alpha_2 \text{ Growth in Capital per worker} + \beta_1 \text{ Entrepre-neurship} + \beta_2 \text{ Technological Innovation intensity}$$

Controls | Predictors

- **Model is extension of new-classical growth model based on variant of Cobb-Douglas production function with Constant Returns to Scale**
- **Analysed using data on 37 countries that participated in GEM 2002**
- **Innovation & Entrepreneurship as independent explanatory variables**

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Variables in Estimation Model

Variable	Measure	Expected sign
Dependent		
Economic Growth	**Growth in GDP per employed person 1997/98-2001/02**	
Controls		
Base year GDP per worker	**GDP per employed person 1998**	**Negative**
Growth in Capital per worker	**Growth in Gross Capital Formation per employed person, 1997/98-2001/02**	**Positive**
Predictors		
Entrepreneurship	**- Overall TEA in 2002**	**Positive**
	- Opportunity TEA in 2002	**Positive**
	- Necessity TEA in 2002	**Negative**
	- High Growth Potential TEA in 2002	**Positive**
Technological Innovation Intensity	**Ratio of Patents granted by USPTO to GDP, 1997-2001**	**Positive**

Regression Results

	Type of Entrepreneurship			
	High Growth Potential TEA	Opportunity TEA	Necessity TEA	Overall TEA
Adj R sq (control)	0.559	0.559	0.559	0.559
Adj R sq	0.648	0.603	0.605	0.602
F	17.571**	14.676**	14.769**	14.634**
Independent Variables (values are standardised coefficient estimates)				
(Constant)	t=5.995**	t=4.048**	t=4.019**	t=3.593**
Log of Base year GDP per worker	-0.536**	-0.475**	-0.529**	-0.491**
Growth in Capital investment per worker, 1997/98 – 2001/02	0.602**	0.625**	0.597**	0.614**
Entrepreneurship (TEA)	*0.207**	0.029	-0.066	-0.007
Innovation (Ratio of USPTO granted patents to GDP, 1997-2001)	*0.284**	*0.275**	*0.268**	*0.275**

* significant at 10% ** significant at 5%

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Interpretations of Findings

- **Higher degree of entrepreneurship does not guarantee enhanced economic performance**
  - At microeconomic level, only certain activities and functions of entrepreneurs stimulate growth
  - Some entrepreneurial activities do not contribute to growth, consistent with the "refugee" or "shopkeeper" phenomenon
- **Technological Innovation contributes more strongly to economic growth than entrepreneurship**
- **High Growth Potential TEA is the sole form of entrepreneurship that has impact on economic growth. Truly significant contributions to economic growth are made by high growth potential firms ("gazelle") rather than new firms in general. Need for more work focused on such entrepreneurial efforts and what policies can be drawn to stimulate such activities**

Future Challenges

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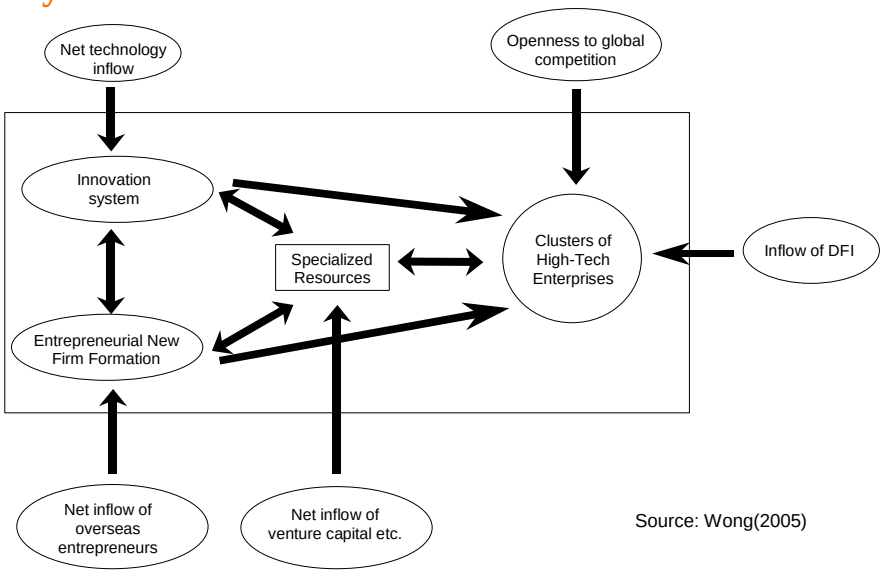
Some Key Future Policy Challenges

- **Increasing R&D Investment intensity: target of GERD/GDP ratio to reach 3% by 2010?**
- **Greater shift from applied R&D towards basic & IP-creating R&D**
- **Global benchmarking of R, I and E performance**
- **Reinforcing positive dynamic interactions among R, I and E through public policies & programs**
- **Assessing the causal impact and effectiveness of public policy/programs on R, I and E**
- **Scanning for future R, I and E opportunities**
- **Growing new high tech clusters to capitalize on these opportunities**

Stylized Model of Silicon Valley Enterprise Ecosystem



Source: Wong(2005)

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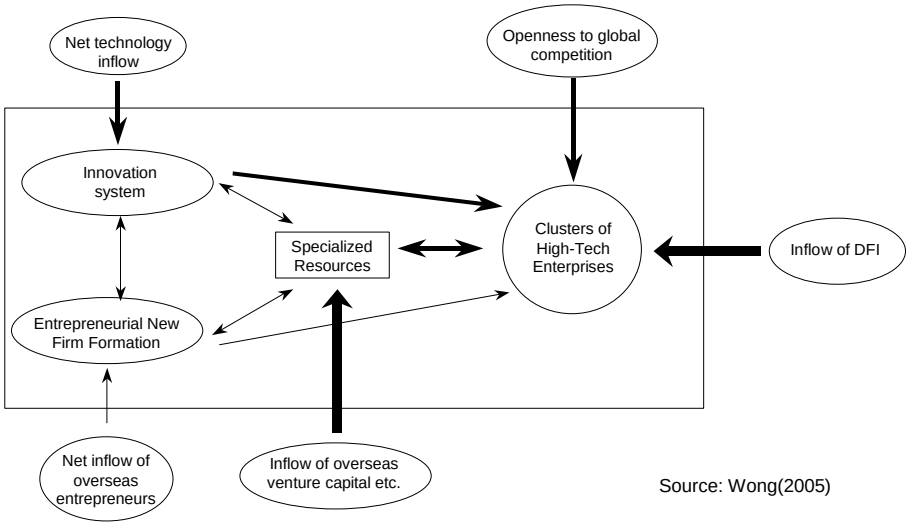
Stylized Model of Singapore's Enterprise Ecosystem in the 1980s-1990s



Source: Wong(2005)

Shifting to a new Enterprise Ecosystem in 2010?

- **How to transform Singapore's High Tech Enterprise Ecosystem in 2010 to become more like Silicon Valley?**
- **How to grow new high tech clusters in Life Science and Creative Media etc. to complement existing Electronics/ICT clusters?**
  - Promoting indigenous high tech entrepreneurship to complement attraction of global high tech MNCs
  - Growing importance of local universities and public research institutes as engines for new RIE growth
  - Adoption & development of Integrated RIE Framework for global benchmarking, policy design, implementation and assessment

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Science & Engineering Research Council's (SERC) Tech Scan -- Priority Technology Areas 2005-2010

- **Information Management**
- **Harnessing Broadband**
- **Advancing Science through the Grid**
- **Niche Opportunities in Manufacturing**
- **Intelligent Systems and Sensor Networks**
- **Exploiting Nanotechnology**
- **Information Storage**
- **Semiconductors**
- **Energy**
- **Frontiers in Chemicals and Materials**
- **Environmental Technologies**
- **Engineering Science in Medicine**

Source: A*STAR(2005)

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