SCIENCE & TECHNOLOGY IN SINGAPORE

PROFESSOR ANG HOW GHEE
Chairman (1978–1983)
Science Council of Singapore

1 National Profile

Singapore is a multi-racial nation where Chinese account for 77% of the population, Malays 15%, Indians 6% and other ethnic groups 2%. The population of Singapore stood at 2,413,945 as in June 1980. Of these 27% were below the age of 15. English is the language of administration. The other official languages are Chinese, Malay and Tamil. 84% of the population are literate in at least one of the official languages. The main religions are Islam, Buddhism, Christianity and Hinduism.

2 Economic Performance

Against a backdrop of global economic uncertainty and fluctuating oil prices, the Singapore economy achieved a real growth of 7.8% in 1977, 8.6% in 1978, 9.3% in 1979, 10.2% in 1980, 9.9% in 1981 and an estimated 6.3% in 1982.

The major sectors of growth were finance and business services which contributed 36% to the overall growth, transport and communications (27%) and construction (25%).

The number of new jobs created increased slightly at a rate of 4.3% compared to a 4.4% increase in 1981. A large number of the new jobs was generated by the expanding construction sector.

Industrial production fell by 6%. This was caused mainly by the decline in the major industries like electrical and electronic, and shipbuilding and oil rigs. Petroleum refining slowed down markedly. However, production of building materials like cement, concrete and iron and steel rose substantially to meet the stronger demand of the construction sector.

New investment commitments in manufacturing from foreign and local sources reached \$1.7 billion in 1982. Though this is \$200 million lower than the record level in 1981, it was substantially higher than those obtained in previous years. Foreign investments accounted for the major share of the total commitments. These investment commitments, apart from the capital intensive upgrading projects in the petroleum industry, were mainly for projects in the fast growing computer and computer related industries, fabricated metal products, and machinery and machine components industry.

3 External Trade

Singapore's external trade in real terms grew at a slower pace of 6% compared with 8% in the previous year. At current prices it grew by only 2% to reach \$105 billion. The slowdown is pronounced when compared to the average annual growth rate of 25% in the last three years.

The growth in external trade was due mainly to imports as exports grew marginally. Imports grew by 3% to \$60 billion while exports reached \$44 billion. A faster increase in imports vis-a-vis exports led to a widening of the trade deficit by \$2 billion from \$14 billion to \$16 billion.

Malaysia, Japan, the United States, Saudi Arabia and the EC continued to be Singapore's major trading partners. Their combined share of Singapore's total trade remained at 63%.

4 Balance of Payments

Singapore recorded an improved balance of payments surplus of \$2.5 billion in 1982 compared with \$1.9 billion in 1981. Capital inflows continued to be high while the current account deficit narrowed. Consequently the official foreign reserves increased to about \$17.9 billion at the end of 1982 from \$15.5 billion a year ago.

5 Development Policy Framework

Science and technology plays a vital role in Singapore. For the last two and a half decades, uninterrupted industrialisation has brought about a transformation of Singapore from a commercial centre to what is now called the newly industrialising country. Catalysed by the multinational companies in the early years of industrialisation, they continue to play a dominant role in introducing into Singapore productive technologies.

Although economic growth in the Seventies was creditable, it was achieved more through a quantitative input of workers than productivity increases. Industries and services hence remained too labour-intensive. By the end of the decade, the problem of labour shortage surfaced. With the danger of protectionism in advanced industrialised countries and a tight labour supply at home, the Government has to embark on an economic restructuring programme aimed at upgrading industries and services to produce high value-added products. The sectors that are earmarked as pillars of growth of the economy for the next ten years are manufacturing, trade, transport and communications, services namely, tourism, financial, medical and computer services.

Sectorial Objectives

Manufacturing

By the end of this decade, it is hoped that a commendable industrial base would have been established with industries ranging from the manufacturing of machine tools, aerospace components, petrochemicals to electronic and computer software developments. These are high value-added products that would be able to withstand better the pressures of protectionism.

Table 1: Contribution to Real Growth in Gross Domestic Product by Industry, 1980–1982

Industry	Percent		
	1980	1981	1982P
TOTAL	100	100	100
Goods Sector	27	28	8
Agriculture & Fishing	—	—	—1
Manufacturing	22	20	—17
Construction & Quarrying	5	8	26
Services Sector	73	72	92
Utilities	2	2	2
Trade	16	13	15
Transport & Communication	21	22	27
Financial & Business Services	29	29	36
Other Services	5	6	12

*P: preliminary**Source: Department of Statistics***Table 2:** Gross Domestic Product by Industry at 1968 Factor Cost, 1980–1982

Industry	1980	1981	1982P	1980	1981	1982
	\$ Million			Percentage Change Over Previous Year		
TOTAL	12,161	13,369	14,218	10.2	9.9	6.3
Goods Sector	3,724	4,122	4,209	11.1	10.7	2.1
Agriculture & Fishing	159	5	146	1.9	—2.3	—6.3
Manufacturing	2,910	3,192	3,013	11.8	9.7	—5.6
Construction & Quarrying	655	775	1,050	10.7	18.3	35.5
Services Sector	9,331	10,357	11,319	11.9	11.0	9.3
Utilities	357	383	402	7.7	7.3	4.8
Trade	3,139	3,319	3,475	7.2	5.7	4.7
Transport & Communication	2,335	2,656	2,942	13.9	13.8	10.8
Financial & Business Services	2,163	2,581	2,953	22.4	19.4	14.4
Other Services	1,337	1,418	1,547	5.7	6.0	9.2
Less: Imputed Bank Service Charge	894	1,110	1,310	na	na	na

P: preliminary

Trade

The Trade Development Board (TDB) continues to be the key body to carry out the task of trade development. The TDB has been given the task to plan new trade development programmes to assist manufacturers particularly local ones to establish themselves in overseas markets. It is hoped that by 1990, manufactured goods will form about 60% of the country's exports.

Services

Financial Sector

The Eighties, will see Singapore develop into a financial supermarket offering a wide and sophisticated range of financial services. In line with this development as a financial centre, stamp duty on all cheques was abolished from 1 April 1983. Banks have been encouraged to improve their efficiency and productivity through automation. The Monetary Authority of Singapore (MAS) will be the key body to advance this objective.

Transport and Communications

Our role in air transportation will grow in its importance in the Eighties. Together with the continued upgrading of our port and telecommunications services, the growth of our national airlines and shipping lines and the establishment of aircraft and servicing industries, this sector should remain an important pillar of growth for the economy.

Tourism

The Singapore Tourist Promotion Board (STPB) continues to enhance Singapore as a tourist destination.

Computer Services

The promotion of computer services industries will form an integral part of our economic restructuring programme in the Eighties. Both the public and private sector has responded enthusiastically to the Government's call for computerisation. As an incentive, with effect from 1983, all expenditure on computers and office automation equipment can enjoy 100% depreciation. A key target is to make Singapore a software export centre by the end of the decade.

As a key policy instrument for economic restructuring, high wage increases of about 20% were introduced in May 1979 to discourage labour-intensive industries in carrying out their activities and assisting industries to mechanise and improve productivity. Fiscal incentives and manpower training were also noted to be essential tools for achieving economic restructuring. To assist companies to switch to high-skill industries, the Skills Development Fund (SDF) was established to provide financial assistance to meet the manpower training needs.

Singapore is committed to the course of industrial restructuring. Her Economic Development Board with its global network of overseas investment centres play a major role in the search for new technologies and in the promotion of foreign investments in fulfilment of Singapore's industrial strategy.

This eclectic approach will continue to serve Singapore well, as this will continue to have an impact on established firms who, becoming more international in outlook, seek out and select new technologies for diversification into new lines of production and for increasing productivity through mechanisation, automation and robotisation.

6 Science & Technology in National Development Policy

In 1979 the Singapore Government embarked on a new phase of industrial development which stressed on increased automation and higher-skilled industries in the manufacturing sector. This policy was aimed at achieving higher economic growth rates in the 1980s, increased productivity and development of higher-value added industries. Among the essential tools for achieving this economic restructuring were corrective wage increases, fiscal incentives and manpower training.

The Government in its efforts to upgrade the quality and competitiveness of Singapore's manufactured goods in world markets implemented a programme to promote industrial R & D. This programme introduced a number of key instruments, namely:

- (a) tax incentives for R & D;
- (b) special R & D financing schemes; ie
 - * Product Development Assistance Scheme – set up in 1978 to stimulate growth of local applied research and product development.
 - * R & D Block Vote – set up in 1981 for funding directed research in the Republic.
 - * Small Industries Technical Assistance Scheme (SITAS) – introduced in 1982 to assist local companies to obtain services of suitable experts from MNC's or consultancy agencies.
 - * Other financial incentives like pioneer status, capital assistance scheme and skills development grant.
- (c) Science Park – developed to accommodate R & D organisations whose activities are directed at high technology products. It will serve as a focal point for the location of industrial R & D facilities and related 'brain' services. The first tenants of the park will include a Marine Technology Centre and a Software Technology Centre. The National Computer Board and SISIR will be moving into the park. Other candidates under consideration for the science park include R & D orientated companies in biotechnology, robotics and polymer applications.

7 Policy Making Machinery for Science and Technology

Scientific and technological policies in the public sector are formulated along sectoral lines. Each ministry has within its sphere of interest and responsibilities a number of statutory boards and specialised departments which plan and implement their own scientific and technological programmes. Major decisions on scientific and technological programmes are however undertaken at the cabinet level. The various ministries and government institutions which undertake scientific and technological activities are summarised in Table 2.

Table 2 – Policy Making Machinery for Science & Technology

Organ	Function	Linkages		Major Collateral
		Upstream	Downstream	
1. Ministry of Education	Coordination, executive and advisory. Formulation and implementation of educational policies.	1. Cabinet 2. Parliament	1. Technical colleges (2) 2. Vocational & Industrial Training Board 3. Institute of Education 4. Science Centre Board 5. National University of Singapore	Other ministries
2. Ministry of Trade and Industry	Control, coordination, executive and advisory.	1. Cabinet 2. Parliament	1. Singapore Institute of Standards & Industrial Research 2. Economic Development Board 3. Jurong Town Corporation 4. Science Council of Singapore	Other ministries
3. Ministry of Health	Policy direction, control and administrative support services, and administers legislation.	1. Cabinet 2. Parliament	1. Hospitals (13) 2. Pathology Department 3. Department of Scientific Services	Other ministries
4. Ministry of Communications	Direction and coordination of activities and agencies involved in the provision of land, sea, and air transport as well as postal, telecommunications and telephone services.	1. Cabinet 2. Parliament	1. Meteorological Services Department 2. Telecoms	Other ministries
5. Ministry of the Environment	Control, coordination and executive	1. Cabinet 2. Parliament	1. Sewerage Department 2. Vector Control & Research Department 3. Quarantine & Epidemiology Department	Other ministries
6. Ministry of National Development	Control and executive	1. Cabinet 2. Parliament	1. Public Works Department 2. Primary Production Department	Other ministries
7. Ministry of Finance		1. Cabinet 2. Parliament	1. National Computer Board	

8 Scientific & Technological Manpower Resources

The key to industrial development in Singapore lies in its manpower resources. With a shift towards industrialisation and high technology the government placed great emphasis on training and development of manpower needs at all levels. Consequently, the educational system was orientated towards vocational and technical subjects.

Tertiary institutions, technical institutes and vocational schools provide the main supply of scientific and technological manpower in Singapore. The student enrolment figures (1982) for the National University of Singapore stood at 11,090. The Nanyang Technological Institute, established in 1981 to train practice orientated engineers had its first intake of 580 students.

Technical manpower is provided by the two polytechnics. Together they have a current enrolment of 9,210. Three other technical training institutes have been set up. The German-Singapore Institute, providing training for technicians and vocational instructors in production engineering, had its initial intake of 103 students in February 1982. At the same time the Japan-Singapore Institute of Software Technology also took in its first batch of 48 students for computer training at technician level. The third institute, the French-Singapore Institute will become operational in the third quarter of 1983 to train highly skilled technicians in the fields of electro-technology and electronics.

While skills training are being provided by the Vocational & Industrial Training Board's, 17 training institutions; specialised skills training come under a Joint Company-Government Training Scheme administered by the Economic Development Board (EDB). The Joint Industrial Training Centres have a combined output of 677 in 1982. VITB institutions contributed 6,863 graduates from January–September 1982.

The output of graduate, technical and skilled manpower from the various institutions are summarised in the following table:

Table 3: Output of Graduate, Technical and Skilled Manpower (1977–82)

Manpower	Year					
	1977	1978	1979	1980	1981	1982
Graduate (University)						
Science (including Pharmacy) and Engineering	625	587	800	861	931	997
Medical, Dentistry and Architecture	266	295	261	296	235	310
Arts and Social Sciences, Law Accountancy and Business Administration, and others	1,466	1,540	1,702	1,488	1,178	1,274
Technical (Singapore Polytechnic and Ngee Ann Polytechnic)	2,800	3,103	3,155	2,549	2,648	3,658
Skilled						
VITB	6,785	6,446	5,893	8,162	10,108	6,863*
EDB Training Centres	270	302	294	326	583	677
TOTAL	12,212	12,273	12,105	13,682	15,683	13,779

* Figures up to September 1982

To cater for the increased student population, more teaching staff (local and overseas) are being recruited. The NUS is aiming for a staff-student ratio of 1:10 for all faculties except medicine and dentistry which, because of their service functions to the public, will have a lower ratio of 1:4 and 1:6 respectively.

The university has revised its research scholarship scheme to attract more students to do research and postgraduate work and initiated a senior research scholarship scheme for graduates with outstanding academic records interested in research. This is in addition to the existing senior tutorship scheme in which outstanding graduates interested in an academic career are appointed to the university.

To upgrade the training of practising engineers, four postgraduate Master's courses – Civil Engineering, Industrial Engineering, Electrical Engineering and Mechanical Engineering are currently offered.

The improvement in overall productivity in all sectors of the economy is vested with the National Productivity Board (NPB) which organises regularly a series of training courses to upgrade managerial and supervisory skills in technology and productivity-related areas.

The upgrading of skills of workers is being encouraged with the financial assistance given to employers under the Skills Development Fund. Training grants committed up to the end of 1982 stood at \$110 million for 86,059 workers. 49.4% of the grants was awarded for technical training, 16.2% for computer related training and 11.8% for supervisory and management programmes.

The projections for the yearly output of graduate and technical manpower is given in the table that follows:

Table 4: Projected Enrolments of Tertiary Institutions 1983–1990

	1983	1984	1985	1986	1987	1988	1989	1990
A National University of Singapore								
(a) Science/Pharmacy	2,561	2,879	3,088	3,167	3,179	3,180	3,180	3,180
(b) Engineering/Building/Architecture	3,055	2,886	3,071	3,292	3,363	3,419	3,475	3,504
(c) Medicine/Dentistry	1,032	1,102	1,161	1,221	1,249	1,271	1,273	1,273
(d) Arts & Others	5,869	6,384	6,618	6,700	6,727	6,746	6,764	6,766
Total	12,517	13,251	13,938	14,380	14,518	14,616	14,692	14,723
B Nanyang Technological Institute (Engineering)								
	1,340	2,196	2,442	2,568	2,645	2,722	2,799	2,799
C Ngee Ann Polytechnic								
	4,854	6,823	8,197	9,016	9,016	9,016	9,016	9,016
D Singapore Polytechnic								
	5,972	6,916	7,536	7,623	7,623	7,623	7,623	7,623

9 Research and Development Manpower and Expenditure

A National Survey of Research and Development conducted by the Science Council of Singapore in 1982, revealed that 177 firms/institutions were engaged in R & D activities in 1981/82. Of the 177 firms/institutions surveyed, 133 firms were in the business enterprise sector, 2 in the private-non-profit sector, 17 government departments/institutions and 25 departments in the higher education sector. In the business enterprise sector, 68 firms were wholly/majority local firms, 59 were wholly/majority foreign firms and 6 had equal local/foreign participation. The survey covered data for either calendar year 1982 or fiscal year 1981/82 and it encompassed activities in the fields of natural sciences, engineering and technology, medical and agricultural sciences.

R & D Expenditure and Manpower

The *gross national expenditure* for R & D was \$81.9 million, which formed 0.31% of the gross national product. The total R & D manpower involved was 2,741, forming 0.24% of the Singapore's labour-force population. 44% of the manpower were research scientists and engineers, 29% were technicians and the remainder were other supporting staff. In terms of full-time equivalent (FTE) the total R & D manpower was 1,814.

The business enterprise sector accounted for 52.5% of the gross national R & D expenditure and 47% of total R & D manpower (Figure 1).

Figure 1: Total R & D Expenditure and Manpower

1981/82 gross national R & D expenditure = \$81.9 million

1981/82 total R & D manpower = 1814 FTE personnel

Key

- Business Enterprise Sector
- General Government Sector
- Higher Education Sector
- Private Non-Profit Sector

In terms of intramural (current and capital) expenditure for R & D, 52.4% (\$42.9 million) was for experimental development. The business enterprise (BE) sector accounted for the largest fraction of experimental development expenditure (Figure 2).

Applied research, also performed mainly in the BE sector, accounted for 37.8% (\$31 million) of intramural R & D spending. Basic research accounted for only 9.8% (\$8.0 million) of intramural R & D expenditure and was conducted largely in the higher education (HE) sector (Figure 2).

Figure 2: Intramural R & D expenditure by character of activity

Since a country's technological capability depends on its ability to absorb sophisticated knowhow and on its efforts in original R & D, the role played by research scientists and engineers (RSEs) is vital in developing R & D capabilities. Of the total number of RSEs involved in R & D activities, 400 were PhD holders, 175 Master degree holders and 598 bachelor degrees or professional diploma holders. The greatest number of RSE were in the fields of engineering and technology (Figure 3).

**Figure 3: Research scientists and engineers by field and qualification
(Full and Part-time)**

(i) The Government Sector

Government support for R & D activities can be broken down into two major categories: national defence and civilian R & D. In 1981/82, civilian R & D in the government sector accounted for 16% (\$12.9 million) of total intramural R & D expenditure and 34% (609 FTE) of total R & D manpower. The areas with the greatest intramural expenditure and manpower have development of agriculture and promotion of industrial development as their major objective.

Figure 4: R & D in the Government sector by major objective

(ii) The Business Enterprise Sector

Figure 5 shows the current annual sales of the R & D firms in the BE sector. Among those companies which had annual sales of over \$10 million, 6 indicated that they spent over \$1 million in 1981/82 on R & D. Figure 6 shows that most firms doing R & D have 1–100 workers in their organisations. Of these, one was purely concerned with R & D and was not a profit making but a cost centre. Very few firms had above 1,000 workers.

Figure 5: Current annual sales of R & D firms in the business enterprise sector **Figure 6: Number of workers in R & D firms in the business enterprise sector**

The importance of the BE sector in Singapore's total R & D effort is emphasised by the fact that it accounted for 52.5% (\$43.1 million) of the total intramural R & D expenditure, and 47% (858 FTE) of the total R & D manpower (Figure 7). The electronics/electrical industry performed the most R & D, accounting for 64% of the intramural expenditure and 57% of the manpower. The other BE industries conducted relatively less R & D, each accounting for between 1–18% of manpower in this sector.

Figure 7: R & D in the Business Enterprise sector by Industry Group

(iii) The Higher Education Sector

This sector accounted for 30% (\$24.6 million) of total intramural R & D expenditure and 18% (322) of the FTE personnel. R & D expenditure is highest in the field of engineering and technology (Figure 8). The R & D manpower however, is distributed fairly evenly between engineering & technology, natural science and medical science. No R & D was reported in the agricultural science field. Of the 322 FTE personnel, 177 were RSE's. These RSE's were mainly in applied research work and done on a part time basis.

Figure 8: R & D in the Higher Education sector by field of science

10 Growth in National R & D

The effectiveness of the Government's schemes to promote R & D and the results of R & D activities are at this stage too early to be assessed. However there is clear indication that the level of R & D activities and resources have increased considerably since 1978.

The number of firms/organisations conducting R & D increased from 90 in 1978 to 177 in 1981/82.

Table 5: Number of establishments conducting R & D (1978 & 1981/82)

Sector of Performance	Year	
	1978	1981/82
Private	63	133
Private Non-Profit	—	2
Government and Higher Education	27	42
Total Number of Establishments	90	177

The number of private sector establishments conducting R & D has more than doubled (from 63 to 133) since 1978. It is significant that more than half of the 133 private establishments were wholly/majority local firms.

Table 6: Number of Private Sector R & D establishments by ownership

Type of Participation	1978	1981/82
Wholly/majority local	27	63
Equal local/foreign	—	6
Wholly/majority foreign	36	59
Total	63	133

R & D Manpower Growth

Table 7: R & D Manpower by Full-time and Part-time

R & D Personnel	Research Scientists and engineers			Technicians			Other Supporting Staff			Total		
	1978	1981/ 82	% in- crease	1978	1981/ 82	% in- crease	1978	1981/ 82	% in- crease	1978	1981/ 82	% in- crease
Full-time	328	468	43	175	403	130	—	497	—	503	1368	172%
Part-time	490	725	48	330	404	22	480	244	-49%	1300	1373	6%
Total	818	1193	46	505	807	60	349	741	112%	1672	2741	64%

In 1978, the total manpower (full-time and part-time including personnel in social sciences and humanities) involved in R & D was 1,672, of which 818 were research scientists and engineers, 505 were technicians and the remainder other supporting staff. By 1981/82 there were 2,741 full-time and part-time workers, an increase of 1,069 or 64%. A much more significant increase was seen in the full-time R & D personnel than in the part-time.

In terms of FTE, R & D manpower in 1981/82 was 1,814 comprising 724 RSEs, 535 technicians and 555 other supporting staff. This is an increase of 149% over 1978. (table 8)

Table 8: R & D Manpower by Full-time equivalents

Year	Personnel	Research Scientists and Engineers	Technicians	Other Supporting Staff	Total
1978		461	267	—	728
1981/82		724	535	555	1,814
% increase		57%	100%	—	149%

In 1978 most of the R & D manpower was concentrated in the business enterprise sector with the HE sector ranking second. Though the absolute numbers have increased significantly, the sectoral distribution has remained relatively the same between 1978 and 1981/82. (table 9)

Table 9 shows the increase in full and part-time RSE, technicians and supporting staff in the 4 performing sectors. The biggest increase in RSE was in the HE sector (53%) followed by the BE sector (45%) and Government sector (25%).

Table 9: Increase in R & D manpower by sector of employment

Full and part-time

Sector of employment	RSE			Technicians			Other supporting staff			Total		
	1978	1981/82	% increase	1978	1981/82	% increase	1978	1981/82	% increase	1978	1981/82	% increase
Government	163	204	25%	133	179	36%	117	357	240%	413	740	79%
										(24%)	(27%)	
Business Enterprise	357	517	45%	196	366	87%	186	207	11%	739	1,090	47%
										(44%)	(40%)	
Private Non-Profit	NS	16	—	NS	8	—	NS	1	—	NS	25	—
											(1%)	
Higher Education	298	456	53%	176	254	44%	46	176	283%	520	886	70%
										(32%)	(32%)	
Total	818	1,193	46%	505	807	60%	349	741	112%	1,672	2,741	64%
										(100%)	(100%)	

RSE = Research scientists and engineers

NS = Not separately available but included in total

Figures in () give percentage of total

R & D Expenditure Growth

The gross national expenditure on R & D (GNERD) increased from \$37,177,000 in 1978 to \$81,020,000 in 1981/82 – an increase of 118%. All 4 performing sectors increased their R & D expenditure significantly.

Table 10: Gross national expenditure for R & D by performer*current dollars in million*

Year	Government	Business Enterprise	Private-Non Profit	Higher Education	Total
1978	4.081 (11%)	24.860 (67%)	–	8,236 (22%)	37.177 (100%)
1981/82	12.534 (15%)	42.914 (53%)	1.323 (2%)	24.248 (30%)	81.020 (100%)
% increase	295%	73%	–	194%	118%

Figures in () give percentage of total

The GNERD to Gross National Product (GNP) ratio increased from 0.21 in 1978 to 0.31 in 1981/82.

Table 11: Gross national R & D expenditures as a percent of GNP*current dollars in million*

Year	GNERD	GNP	GNERD as a % of GNP
1978	37.177	17,462	0.21
1981/82	81.020	26,389	0.31

As indicated in Table 12, the intramural expenditure has climbed from \$27.775 million in 1978 to \$81.900 million in 1981/82 – an increase of 195%. By contrast, there was a decrease in the extramural expenditure. In 1978, the extramural expenditure was \$9.402 million as compared to only \$2.622 million in the year 1981/82. However, with the large increase in the intramural expenditure over the years, the total R & D expenditure has gone up from \$37.177 million in 1978 to \$84.522 million in 1981/82.

Table 12: Intramural and Extramural R & D Expenditure*Current dollars in million*

Intramural Expenditure			Extramural Expenditure			Total		
1978	1981/82	% increase	1978	1981/82	% increase	1978	1981/82	% increase
27.775	81.900	195	9.402	2.622	–72	37.177	84.522	127

The intramural R & D expenditure per RSE has also increased significantly for all performing sectors. Overall, the intramural R & D expenditure per RSE went up from \$68,000 in 1978 to \$113,000 in 1981/82. The highest investment per RSE is in the HE sector followed by the BE sector.

Table 13: R & D expenditure per FTE research scientist and engineer

Sector of Performance	FTE number of RSE		Intramural R & D Expenditure (\$ in thousands)		Intramural R & D Expenditure for RSE (\$ in thousands)	
	1978	1978/82	1978	1981/82	1978	1981/82
Government	78	123	4,069	12,897	52	105
Business enterprise	239	408	15,470	43,075	65	106
Private non-profit	0	16	0	1,323	0	83
Higher education	91	177	8,236	24,600	91	139
Total	408	724	27,775	81,895	68	113

11. International Comparisons:

R & D Resources of Various Countries

This section deals with international comparisons on R & D personnel and expenditure.

R & D has an influence on economic growth and is in turn affected by economic conditions. Increased R & D expenditure and manpower reflect national scientific and technical capabilities and are viewed as important future investments.

R & D Manpower

The scientific and engineering workforce is one of the most important component of any country's scientific and technological (S & T) system. Properly trained and innovative scientists and engineers (S & E) help to ensure that technological efforts are effective and dynamic.

In order to compare the relative size of the S & E work-force in each country, the number of S & E engaged in R & D as a proportion of the labour force is examined. Figure 9 shows the research scientist and engineers engaged in R & D per 10000 labour force by country.

Figure 9: Research scientists and engineers engaged in R & D per 10,000 labour force, by country

The ratio is low for Singapore when compared to advanced industrialised countries like Japan, West Germany and US ie 8.4 for Singapore in 1978, 49.4 (1977/78) for Japan, 40.0 (1977) for West Germany, and 60.4 (1980) for US. However, since 1978, Singapore has had a slight increase in the proportion of S & E engaged in R & D in the labour force. For 1981/82, the ratio was 10.4 per 10,000 labour force population. The medium R & D performing countries like Israel, Sweden and Netherlands have ratios of 48.0 (1976/77), 33.8 (1977/78) and 31.9 (1977) respectively. Taiwan has a ratio of 35.3 (1979).

The size of the R & D labour force is only an approximate measure of a nation's R & D capacity. It does not address itself to such factors as the level of sophistication or specialisation, utilisation, or productivity of a country's R & D personnel. The level of both general and advanced S & T education is another factor influencing a nation's R & D capacity, and has been the concern of several countries including Singapore. Singapore has placed a great deal of emphasis on scientific and technical training at all levels of education.

Figure 10: Singapore and Taiwan Graduates and US Bachelor Degrees from higher educational institutions, by major fields of study

*Medical & agricultural science graduate figures are not available but are included in the total

Figure 10 compares, by major field of study, Singapore's graduates from universities and colleges as compared to Taiwan's graduates and US bachelor degrees. The percentage of graduates in Singapore for the S & E fields were 61.8% and 57.1% in 1978 and 1981 respectively whereas Taiwan was 49.1% (1979/80). Although the US produced more graduates, only 18% of these received bachelor degrees in S & E fields.

R & D Expenditure

The US spends more on R & D than other advanced industrialised countries like Japan and West Germany. In 1978, national expenditures for R & D in the US totalled US\$48.0 billion, compared to US\$15.2 billion in West Germany and US\$20.1 billion in Japan. The national expenditure for R & D (excluding defence) for Singapore in 1978 was US\$0.016 billion while that for Taiwan in 1979 was US\$0.2 billion. For 1981/82, Singapore's national expenditure for R & D was US\$0.034 billion.

The ratio of gross national expenditure for R & D to the GNP has become a traditional relative indicator of national R & D activity because it reflects the proportion of a nation's resources devoted to R & D. This indicator is a convenient way to compare each country's R & D efforts because it takes into account the size of a nation's economy and compensates for fluctuating rates of inflation. (Comparisons would be more precise if adequate national R & D deflators were available, but at present they are only at the experimental stage of development.)

Figure 11 shows that the Singapore ratio of gross national expenditure for R & D to GNP was 0.21 (civilian R & D) in 1978 and 0.31 in 1981/82. This is lower when compared to other newly industrialising countries like Taiwan whose ratio is 0.63 (civilian R & D) in 1979 and the Republic of Korea whose ratio is 0.66 in 1981. For the medium R & D performing countries and the advanced industrialised countries, the ratio is much higher, showing that there is a high proportion of R & D being performed in these countries relative to their economies. For example, the Netherlands ratio is 1.97 (1978), Japan is 1.93 (1978), and US 2.23 (1978) and Israel 1.5 (1976/77).

Figure 11: Gross National Expenditure for R & D as a percent of Gross National Product, by country.

R & D investments and economic growth seem to be mutually dependent. Past R & D investments have contributed greatly to GNP growth, while at the same time, healthy economies tend to encourage R & D expenditure. However, adequate growth accounting methods and causal models that directly link all contributions of R & D with rates of economic growth are not available. The economic effects of R & D are cumulative, occur through a complex set of interactions over long periods of time, and are difficult to trace. Another problem in clearly defining the link between R & D and economic growth occurs because countries are not limited to the use of domestically produced R & D but can utilise foreign technology. Japan is an example of a country which has in the past successfully built upon other nations' R & D activities.

Civilian R & D Expenditure

There are some major differences in the purposes and sponsors of R & D supported by individual countries. A gross differentiation which can be examined is between defence and space R & D and civilian R & D. Although defence and space R & D does have important economic impacts, it is primarily aimed at attaining other public goals. On the other hand, because civilian R & D is directly oriented towards economic and social needs or the expansion of general knowledge, it has a direct impact on economic growth. National civilian R & D expenditures are presented in Figure 11 as a fraction of GNP.

West Germany and Japan have high ratios and they have been taken as a important factor for their high productivity and technology-intensive trade performance.

A large percentage of government R & D funds in these two countries is devoted to energy production and areas of economic development, including manufacturing, mining, telecommunications, agriculture, forestry and fishing. The lower ratio of civilian R & D to GNP in the US is related to the large percentage of government R & D funds devoted to defence and space programmes. The concentration is associated with major international defence obligations carried by the US that require large R & D expenditures to ensure future capabilities.

R & D Expenditure by Character of R & D Activity

Figure 12 shows that applied research and development form a major proportion of all R & D that is conducted. This may be due to the concern in most countries about carrying out research that has shorter term economic and social benefits.

Figure 12: R & D expenditure by character of R & D activity.

¹ Breakdown by current expenditure

Only in 3 countries have basic research been above 20%: in the Republic of Korea (24% in 1982), in Israel (42% in 1976/77), and in West Germany (24% in 1975). In Japan and the United States basic research accounted for 14% (1975/76) and 13% (1978) respectively of total R & D expenditure. However, in absolute terms the advanced industrialised countries like the United States, Japan and West Germany spend the greatest amounts on basic research as compared to the other countries.

Basic research in Singapore was 13% in 1978 and 10% in 1981/82, a decrease of 3%. Thus, most of Singapore's R & D is geared towards applied R & D, especially product development. Because Singapore is a small, newly-industrialising country, it does not have the financial nor human resources to concentrate on basic research. Its efforts must therefore be on applied R & D. The country can however, look for definite discoveries from basic research carried out by the advanced industrialised countries and apply these discoveries through the subsequent stages of applied R & D to be embodied later into commercial products. Examples would be in high technology industries like electronics and chemicals.

Singapore, through its Economic Development Board, is providing the Product Development Assistance Scheme cash grants for majority locally-owned companies doing development projects. Various tax incentive scheme are also being provided to stimulate R & D into new products and processes.

12 R & D and Patent System

Singapore's existing patent system is based on re-registration of patents, first granted in the UK or granted by the European Patent Office designating the UK. The question now faced by Singapore and many developing countries is whether there is a need for more advanced or sophisticated patent system to serve the needs of an increasingly innovative industrial sector.

In support of the Government's policy to promote R & D and high technology industries, the Science Council of Singapore is presently undertaking studies on the establishment of a national patent system most appropriate for the country's needs and resources.

13 Scientific & Technological Cooperation

Singapore participates in a number of activities in the fields of science and technology at both regional and international levels. Regional cooperation among ASEAN member countries is being conducted through its Committee on Science and Technology (COST) and the Association for Science Cooperation in Asia (ASCA). At the international level, technical assistance has been rendered through various United Nations Programmes, the International Atomic Energy Authority and the United Nations Educational, Scientific and Cultural Organisation (UNESCO).

Singapore plays an active role in the ASEAN Committee on Science & Technology (COST) established within the ASEAN framework in 1972 to foster and promote regional cooperation in science and technology.

In 1975, COST initiated research projects on development of low cost protein foods to combat malnutrition.

The Australian Government has provided substantial fundings for these projects, under the ASEAN-Australian Economic Cooperation Programme. The projects have entered its third phase. Singapore continued to undertake projects on:

- * Food Packaging
- * Development of Low Cost High Protein Food
- * Maintenance of Bacteria Culture Collection.

Australia is also funding under this Economic Cooperation Programme two other ASEAN projects on:

- * Food Waste Materials and
- * Food Technology Research & Development.

During the period 1980-82, a joint project on the ASEAN Climatic Atlas and Compendium of Climatic Statistics was completed. The preparation of these 2 volume publications took about 3½ years. The project was financed by ASEAN countries with technical assistance from UNDP and World Meteorological Organisation.

Several of ASEAN's dialogue partners including Australia, Canada, EEC, Japan, New Zealand and the US have also expressed interest in cooperation with ASEAN on non-conventional energy research. COST has identified several research areas, of which the US has committed US\$1 million towards:

- * Coal training
- * Energy conservation in buildings
- * Water pumping technologies

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and Australia A\$3.2 million towards:

- * Energy Conservation Technologies
- * Coal Technologies
- * Biomass for Heat & Power.

New Zealand has as a first step sent a technical mission to ASEAN countries in December 1982 to study the prospects for ASEAN-New Zealand Cooperation on Non-conventional Energy.

In the areas of environment, a working group was established to formulate and implement an ASEAN environmental programme. Funding for the various projects were obtained mostly through the United Nations Environmental Programme (UNEP) and the United Nations Development Programme (UNDP).

An ASEAN-EEC Cooperation Programme on Science & Technology was established in 1981 whereby the EEC has committed 2.8 million ECU to finance COST projects in the fields of energy, environmental management and manpower development. The projects comprise a 2 year programme of training, studies, technical assistance and seminars. ASEAN & EEC will jointly formulate the next 3 year programme.

ASEAN COST is also having dialogues with third parties including Canada, UNDP, New Zealand and Japan with a view to establishing cooperation in the fields of:

- * biotechnology,
- * marine sciences,
- * corrosion,
- * materials processing,
- * non-conventional energy research.

COST has also agreed on the establishment of an ASEAN Journal on Science & Technology for Development and an ASEAN Science & Technology Week.

Singapore also participates in a number of programmes organised under the auspices of the United Nations and its specialised agencies as well as the Colombo Plan Technical Cooperation Scheme.

Under the Colombo Plan, Singapore received many experts from various countries of the UN in the past decade. Experts under the Colombo Plan were made available by Australia, Canada, India, Japan, New Zealand, and the UK. The main fields of expertise embraced technical education, industrial development, urban renewal, telecommunications, hotel catering, primary production and horticulture.

Singapore also offers training awards under the Colombo Plan. A total of 1,000 awards were offered for 1975-77. Trainees came from ASEAN member countries, Bangladesh, Bhutan, Burma, Nepal, Pakistan and Sri Lanka. Training was offered in various technical, industrial and administrative fields.

Technical assistance from the UNDP were received by way of experts, fellowships and equipment. Expertise and training were received in fields such as industrial development, technical education, primary production, telecommunication and port management. The major UNDP assisted projects involved the Telecommunications Training Centre, the Singapore Polytechnic and the National Productivity Board.

Under the scheme, Singapore provided training facilities for overseas candidates from the ASEAN member countries, Burma, Ghana, Guyana, India, Pakistan, Sri Lanka, and other countries in the UN with fellowships financed by UN agencies.

Two projects were undertaken by the Singapore Institute of Standards &

Industrial Research (SISIR) under the UNDP scheme. These were the Applied Metrology Programme and the project in Industrial Supporting Services. A third project proposed was the development of a Materials Technology Application Centre (MTAC). The Centre is expected to evolve over the next 5 years and will eventually provide a full range of services covering applied research and development, consultation, testing and process engineering for manufacturers.

In addition a SINTESD Agreement (Agreement for Industrial, Technical and Scientific Cooperation between Singapore and New Zealand) between Singapore and New Zealand is currently running into its fifth year. The Agreement has proven to be successful in promoting cooperation between Singapore and New Zealand parties in the areas of Trade, Investment, Educational and Technical Training, and Consultancy.

In the areas of electrical product testing and evaluation, metallurgical diagnostics and failure analysis, and solar energy research and applications, SISIR has also concluded a Technical Agreement with the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) of West Germany. Other organisations that have ties with SISIR include the Production Engineering Research Association of the United Kingdom, the Bundesanstalt für Materialprüfung (BAM) of West Germany, and the Central Organisation for Applied Scientific Research (TNO) of Holland.

UNDP has also assisted in the expansion of the School of Industrial Technology and the School of Nautical Studies in the Singapore Polytechnic.

Singapore is a member of the Commonwealth Science Council (CSC) of which the Science Council of Singapore is the Republic's official representative. Currently the CSC is supporting 8 regional collaborative research and development programmes. The projects on metrology and rural technology are participated by members in the Asia/Pacific region. Singapore takes part in the metrology programme.

Need for National Policy

There is a need for Singapore to work towards a national science and technology policy. This involves the integration of science and technology into the policy process.

Two basic elements need consideration. The first is the so-called policy for science which concerns itself with formulating programmes for future science and technology. The other element is science and technology for public policy which integrates science and technology into public policy for the attainment of social and economic objectives.

The Science Council is working on a number of scientific and technological statistics and indicators. The national R & D survey which it has conducted according to the OECD format generate the establishment of a scientific and technological data bank, which will assist the Government in its co-ordination and planning, and in its policy formulation.

Conclusion

The importance of science and technology as an instrument for the restructuring of Singapore's economy will continue to grow. But as technology become more advanced, Singapore depends more and more on the skills, capacity, innovativeness and attitude of its people.

Ultimately, it is how well and efficient technology is selected, developed and put to use that will determine how fast productivity will grow. The most crucial factor therefore is our ability to reinforce technology with the human factor.

I do not suggest in this article that life in Singapore should be completely dominated by science and technology or by the aberrant philosophy of scientific materialism. The value of science and technology is what society decides to give. Herein lies the importance of Singapore's continuing campaigns of matching the best of western technology with the best of eastern cultures and values. Singapore's future is dependent upon it.

Paper presented at the ASEAN-EEC SEMINAR ON SCIENCE & TECHNOLOGY INDICATORS AND SCIENCE POLICY (Royal Society, London 13-17 June 1983)