TECHNOLOGY DEVELOPMENT IN MALAYSIA AND THE NEWLY INDUSTRIALIZING ECONOMIES: A COMPARATIVE ANALYSIS

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Taking the Republic of Korea, Singapore and Taiwan Province of China as the reference economies for comparison, the study focuses on the policy lessons for Malaysia in pursuing technology-based economic growth. The key elements examined are human capital, research and development (R&D), science and technology (S&T) parks, foreign technology transfer and government research institutes (GRIs). The analysis shows that the availability of skilled human capital in Malaysia is not sufficient for technological development to progress. The paper makes a number of recommendations to promote technological development in Malaysia.

Malaysia is an emerging Asian economy aspiring to move towards a technology-driven and high-tech production-based pattern of development and thus replicate the experience of the newly industrializing economies (NIEs) of Asia. In fact, Malaysia has been categorized in the group of countries that have the potential to create new technologies on their own (Mani, 2000). The prospects remain promising despite the 1997 Asian financial crisis, although no country in the region was spared.

The rapid technological development of the NIEs over the past two decades has caught the attention of both developing and developed economies (Hobday, 1995). Coincidentally, Malaysia and the NIEs are not only located in the same region, but to a large extent have similar economic regimes and trade structures. In view of that, Malaysia has a strong basis to consider formulating its own technological development strategy based on those in the NIEs with appropriate adaptations to accommodate the economy's uniqueness.

Nevertheless, it is non-optimal for Malaysia to import wholesale a technological development model from any of the NIEs. Given that each of these economies used dissimilar technological development routes to make their way into high-tech markets, this suggests that there is no single strategy that can guarantee successful technological upgrading in Malaysia. Clearly, their patterns of technological

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development would need to be adapted in order for Malaysia to make the best use of them. Drawing upon their successful experience in pursuing technology-based economic growth, the object of this study is to come up with policy lessons for Malaysia. The organization of the paper is as follows. Section I comprises the methodology, followed by section II that analyses and contrasts the technological catch-up strategies and the strategic resources that are currently being used by Malaysia and the NIEs. Finally, sections III and IV provide the policy lessons and overall conclusions, respectively.

I. METHODOLOGY – AN ANALYTICAL FRAMEWORK

The NIEs that are taken as the reference countries for comparison are the Republic of Korea, Singapore and Taiwan Province of China. The two main objectives of the comparative study are, firstly, the technological catch-up strategies within the context of their national technological innovation systems; and, secondly, the strategic resources that have been utilized in the course of their technological upgrading.

Technological catch-up strategy

The strategic dimension to be used for analysing the technological catch-up strategies of Malaysia and the NIEs is the technological development capability of the latecomer firms with the resource-based view. The technological capabilities of a firm can be conceptualized as having product technological capabilities and process technological capabilities[1] (Wong, 1999). The resource-based view suggests that the superior performance of a firm is derived from its pursuit of strategies that best exploit its unique resource position. Considering that strategic resources are heterogeneously distributed across firms and that these differences are stable over time, there is a link between firm resources and sustained competitive advantage. One needs to delineate the unique resource positions of these firms in order to understand why certain latecomer firms are able to achieve rapid technological catch-up (Barney, 1991).

Strategic resources

The strategic resources to be analysed are as follows: human capital, R&D, S&T parks, foreign technology transfer and GRIs. The success of a nation's technological development hinges on the planned use of these strategic resources and the formulation of policies and their implementation at the national level. Two caveats

[1] Product technological capabilities cover the abilities to create, design and commercialize new products and services whereas process technological capabilities cover the abilities to make multiple copies of a product or to deliver repeatedly a service once the product or service performance specifications are given.

are in order. First, data are compiled from various national and international official publications and thus may not be strictly comparable. The latter include the Human Development Report (HDR), the World Competitiveness Yearbook (WCY) and the World Development Report (WDR). Second, some data series do not cover complete periods and missing data have to be estimated to compile a series.

II. ANALYSIS

Technological catch-up strategy

Both Malaysia and the NIEs have mounted elaborate strategies to identify and act upon strategic technologies (Dodgson, 2000; Chang and Cheema, 2001). They have used trade and domestic credit policies to different extents and in different combinations to influence resource allocation, infrastructure development, firm size and cluster formation, skill development, technological activity and FDI attraction, to build local technological capabilities (Lall and Teubal, 1998). Also, national technology development plans have been formulated to systematically guide their nations to match the technologically advanced economies.

While the national innovation model of Malaysia remains elusive, the one in the Republic of Korea is characterized by large and vertically integrated conglomerates (*chaebol*). Meanwhile, Singapore and Taiwan Province of China are seen to be following the small- and medium-sized enterprise-public research institute (SME-PRI) innovation network model and the foreign direct investment (FDI)-leveraging model, respectively (see table 1). Over the years, Malaysia has attempted to emulate the three models but none of these has produced significant results thus far.

If development proceeds by stages, Taiwan Province of China should have preceded the Republic of Korea into high-tech production. In fact, the Republic of Korea has now overtaken Taiwan Province of China in many respects. This can be traced principally to differences in industrial and firm structures in the two countries. The conglomerate organizational mode of the Republic of Korea accelerates entry into many markets while the smaller Taiwan Province of China firms have been unable to sustain themselves in these markets (Mody, 1990).

Nevertheless, technological development in the Republic of Korea has its downside (Ernst, 2000). A fundamental problem of its industries, especially electronics, is the narrow and sticky product specialization on segments that require huge investment outlays and sophisticated mass production techniques for homogeneous products. Also, its narrow domestic industrial technological knowledge base remains constrained by an insufficient critical mass of R&D and patenting, inefficiency of corporate technology management and an ineffective technological innovation system in the public domain.

Singapore's FDI-leveraging model strongly pushes into the specialized high-tech industry for export markets and subcontracting promotion for SMEs to raise

Table 1. National innovation models of the NIEs

National innovation system models	*Dominant technological catch-up routes*
Republic of Korea's large firm internalization model	• Reverse product life cycle strategy
Singapore's FDI-leveraging model	• Process specialist strategy, followed by reverse value chain strategy on a smaller scale • Application pioneering strategy strong among service firms • Emergence of reverse product life cycle strategy and product pioneering strategy in the 1990s
Taiwan Province of China's SME-PRI innovation network model	• Reverse value chain strategy, followed by process specialist strategy • Strong emergence of product pioneering strategy since the late 1980s

Source: Wong (1999).

local content. Besides, there is an aggressive targeting and screening of multinational corporations (MNCs) to direct them into high value added and R&D intensive activities (Lall and Teubal, 1998; Wong, 1999). More often than not, its success lies in the capability of SMEs in engineering positive spillovers from MNCs.

The NIEs today share common structural characteristics in technology because they made use of the same sources of FDI, notably the United States and Japan, in the early stage of their technological development. However, only the Republic of Korea has successfully deepened and broadened its technology base, not only in the electronics industry, but also in the automobile, shipbuilding and steel industries. Meanwhile, to date, Singapore and Taiwan Province of China have only become the forerunners in the electronics industry. This can be arguably attributed to the difference in the role of Government. Taiwan Province of China's Government has been supportive rather than interventionist whereas the Republic of Korea's Government has been collaborative and even coercive in relations with the private sector (Yung, 1990).

Strategic resources

Human capital

Compared to the NIEs, Malaysia's human capital is relatively scarce and less qualified (Mani, 2000). Table 2 shows that both the education index and human resources ranking of Malaysia were relatively low in comparison with those of the NIEs in 1990 and 2000. Also, both the literacy rate and enrolment ratio of Malaysia have trailed behind the NIEs over the past two decades (see tables 3-6). However, during the period, Malaysia progressed quite rapidly in terms of both youth and adult literacy rates. In fact, this is somewhat in line with Lau's (2000) findings (see table 7).

Table 2. Education index (EI) and human resources ranking (HRR)

	EI		*HRR**	
	1990	*2000*	*1990*	*2000*
Republic of Korea	0.92	0.95	66.7	67.9
Singapore	0.83	0.87	68.3	70.7
Taiwan Province of China	n.a.	n.a.	67.1	69.0
Malaysia	0.75	0.80	63.4	66.5

Sources: HDR, WCY* (various issues).

Table 3. Percentage of 20-24 year olds enrolled in tertiary education

	1990	*2000*
Republic of Korea	37	43
Singapore	18	53
Taiwan Province of China*	22	52
Malaysia	7	13

Sources: WCY (various issues), NSF*.

Table 4. Youth literacy rate, ages 15-24

	2000	*Index (1985=100)*
Republic of Korea	99.8	100
Singapore	99.7	102
Taiwan Province of China	n.a.	n.a.
Malaysia	97.3	105

Source: HDR (2002).

Table 5. Combined primary, tertiary gross enrolment ratio

	1990	*2000*
Republic of Korea	81	90
Singapore	68	75
Taiwan Province of China	n.a.	n.a.
Malaysia	61	66

Source: HDR (various issues).

Table 6. Adult literacy as percentage, ages 15 and above

	1990	*2000*
Republic of Korea	97.6	97.8
Singapore	90.3	92.3
Taiwan Province of China	n.a.	n.a.
Malaysia	82.2	87.5

Source: HDR (various issues).

Table 7. Average annual rates of human capital growth

	Period	*Growth rate*
Republic of Korea	1960-95	6.2
Singapore	1964-95	5.9
Taiwan Province of China	1953-95	5.3
Malaysia	1970-95	7.7

Source: Lau (2000).

As shown in tables 8-10, the technical enrolment as a percentage of all secondary students, S&T graduates as a percentage of all graduates and engineering enrolments as a percentage of the population in Malaysia trailed significantly behind the NIEs over the past 10 years. With such poor S&T enrolment numbers, the research scientists and engineers (RSEs) per 10,000 labour force in Malaysia were not surprisingly outnumbered almost 15 to one by the NIEs during the period (see table 11). Also, it is worrisome that Malaysia is still very short of S&T human resources despite the increasing number of S&T degree holders from the local educational institutions during the period 1971-2000 (see table 12). This suggests that demand has actually outstripped supply. The other side of the coin is that technology development in Malaysia has been so rapid that even the incremental increase in S&T human resources supply fails to meet the demand. Nonetheless, findings suggest an undesirable imbalance in terms of RSEs in Malaysia.

Table 8. Technical enrolment as percentage of all secondary students

	1988-1991	*2000*
Republic of Korea	18.6	18.6
Singapore	n.a.	5.6
Taiwan Province of China	n.a.	n.a.
Malaysia	2.2	2.2

Source: HDR (various issues).

Table 9. S&T graduates as percentage of all graduates

	1990	*2000*
Republic of Korea	42	44
Singapore	53	63
Taiwan Province of China*	48	56
Malaysia	32	39

Sources: HDR (various issues), NSF*.

Table 10. Engineering enrolment as percentage of population

	1990	*2000*
Republic of Korea	0.46	0.68
Singapore	0.45	0.65
Taiwan Province of China	0.51	0.70
Malaysia	0.02	0.16

Source: WDR (various issues).

Table 11. Research scientists and engineers per 10,000 labour force

	1990	*2000*
Republic of Korea	53	45
Singapore	30	85
Taiwan Province of China*	31	80
Malaysia	2	10

Sources: HDR (various issues), NSF*.

Soon (1992), Mani (2000) and Lall (2001) explain that Singapore has arguably one of the most well-developed systems of industrial and vocational training that has enabled the rapid transformation of its unskilled workforce into a highly skilled one over a short period of two decades. Interestingly, as shown in table 13, there is not much difference between the training and skills development in all of these countries

Table 12. Malaysia: output of S&T degree holders from local institutions

	1971-1975	*1976-1980*	*1981-1985*	*1986-1990*	*1991-1995*	*1996-2000*
Science	4 451	6 513	9 317	17 510	19 642	40 077
(per cent)	(31.8)	(33.5)	(34.7)	(33.1)	(24.8)	(27.8)
Technical	498	1 566	2 719	7 550	10 508	21 953
(per cent)	(3.6)	(8.1)	(10.1)	(14.3)	(13.3)	(15.2)
Total	4 949	8 079	12 036	25 060	30 150	62 030
(per cent)	(35.4)	(41.6)	(44.8)	(47.4)	(38.1)	(43.0)

Source: Five-Year Malaysia Plan (various issues).

Note: Science includes medicine, agricultural sciences and pure sciences; technical includes engineering, architecture and surveying.

Table 13. Training and skills development in Malaysia and the NIEs

	Incentives for in-service training	*Coordinating body for vocational training*	*Composition of coordinating body*
Republic of Korea	Tax levied on firms failing to train required proportion of workforce	Vocational training and management agency	Government led, limited autonomy from Ministry of Labour
Singapore	Levy-subsidy	Institute of Technical Education	Governors drawn from industry, labour organizations and government
Taiwan Province of China	Subsidy from general taxation	Employment and vocational training administration	Government body, some informal consultation with industry
Malaysia	Levy-subsidy (large firms); double deduction of training expenses for tax purposes (others)	Technical and vocational division of the Ministry of Education	Government body

Source: Tzannatos and Johnes (1997).

except for the composition of the coordinating body, in which Singapore is more private sector driven and governed. Most specialized technical training programmes are run as a collaborative venture with reputed overseas partners, either in the form of well-known MNCs or highly regarded industrial training institutes. In addition, Singapore has also successfully adopted a very liberal immigration policy to attract foreign scientists and engineers to work in the island State.

If one measures a country's human capital by public education expenditure, Malaysia was actually on par with the NIEs, if not outperforming them, over the past two decades (see tables 14-15). As pointed out by Mani (2002), if one goes by standard indicators of the Government's commitment towards human capital efforts, Malaysia compares very favourably with the NIEs and indeed even with developed countries, such as Japan and the United States.

Table 14. Public education expenditure as percentage of Government expenditure

	1985-1987	*1995-1897*
Republic of Korea	n.a.	17.5
Singapore	11.5	23.3
Taiwan Province of China	n.a.	n.a.
Malaysia	18.8	15.4

Source: HDR (various issues).

Table 15. Public education expenditure as percentage of GNP

	1985-1987	*1995-1997*
Republic of Korea	3.8	3.7
Singapore	3.9	3.0
TaiwanProvince of China*	2.1	5.7
Malaysia	6.9	4.9

Sources: HDR, UNESCO* (various issues).

The order of priority in the budget allocations for primary, secondary and tertiary levels in the NIEs is not the same (see table 16). This suggests that public education expenditure by level is not crucial for human capital development. After all, these three levels of education are equally important as none of them is dispensable in the course of human capital formation.

As the output of degree courses shows a continued preference for arts and humanities, the increase of human capital that has the right quality and knowledge in Malaysia is not sufficient for technological upgrading to become self-sustaining. While such human capital can be augmented via domestic initiatives, these efforts have been

Table 16. Public education expenditure by level as percentage of all levels

	Pre-primary Primary		*Secondary*		*Tertiary*	
	1985-1986	*1995-1997*	*1985-1986*	*1995-1997*	*1985-1986*	*1995-1997*
Republic of Korea	47.0	45.3	36.7	36.6	10.9	8.0
Singapore	30.5	25.7	36.9	34.6	27.9	34.8
Taiwan Province of China	n.a.	n.a.	n.a.	n.a.	n.a.	n.a
Malaysia	37.8	32.7	37.1	30.6	14.6	25.5

Source: HDR (various issues).

partly offset by the brain drain problem. Although this is not insurmountable, the fact that all countries in the region are competing head-on for this scarce intangible capital will pose a challenge to Malaysia's S&T human capital growth. Therefore, Malaysia needs to come up with a set of liberal immigration policies to attract more foreign scientists and engineers to work in the country.

Research and development

With a gross expenditure on R&D (GERD)/GDP of less than 0.5 per cent during the period 1990-2000, certainly Malaysia's R&D investment was considered as insignificant (see table 17). The number of patents granted to Malaysia in the United States was also quite small during the period (see table 18). The number would be even smaller if the patents granted to the MNCs that operate in Malaysia had not been included. The two common internal factors that limit R&D activities in Malaysia are insufficient financial resources and lack of skilled R&D personnel. Inadequate market research has also been cited as an important external factor that greatly curtails R&D activities in the private sector. Lack of emphasis on the importance of R&D for long-term benefit also seems to have impeded higher growth of R&D activities in the GRIs and institutes of higher learning (IHLs) (MoSTE, 2000).

Table 17. GERD/GDP, 1990-2000

	1990	*1992*	*1994*	*1996*	*1998*	*2000*
Republic of Korea	1.90	2.03	2.44	2.60	2.55	2.69
Singapore	0.90	0.97	1.13	1.45	1.76	1.92
Taiwan Province of China	1.70	1.75	1.82	1.88	1.98	1.96
Malaysia	0.37	0.37	0.34	0.22	0.39	0.49

Source: MoSTE (2002).

Table 18. Patents granted in the United States, 1990-2000

	Pre-1986	*1990*	*1992*	*1994*	*1996*	*1998*	*2000*
Republic of Korea	213	225	538	943	1 493	3 259	3 314
Singapore	62	12	32	51	88	120	144
Taiwan Province of China	742	732	1 001	1 443	1 897	3 100	4 667
Malaysia	0	3	5	10	12	23	30

Source: United States Patent and Trade-Mark Office (2002).

Surprisingly, while the number of patents granted in Malaysia was much smaller than the ones in the Republic of Korea and Taiwan Province of China, it was significantly larger than the one in Singapore, especially during the period 1992-1996 (see table 19). This implies that countries that leverage foreign sources for technological upgrading tend to be less successful in promoting local patenting activities. Also, an NIE that records higher GERD/GDP does not necessarily indicate that it has a larger patent intensity. For instance, during the period 1990-2000, the Republic of Korea's GERD/GDP was significantly higher than second-placed Taiwan Province of China but the number of patents granted to the former in the United States was smaller than to the latter.

Table 19. Patents granted locally, 1990-2000

	1990	*1992*	*1994*	*1996*	*1998*	*2000*
Republic of Korea	7 930	8 308	8 457	11 835	9 579	10 475
Singapore	40	44	58	91	130	285
Taiwan Province of China	22 601	21 264	19 011	29 707	25 386	26 958
Malaysia	518	1 002	1 629	1 801	586	350

Source: United States Patent and Trade-Mark Office (2002).

Bloom (1992), Kim (1995) and Kim (1997) attribute this paradox to the weaknesses that lurk in the *chaebol's* innovation management system. While the Republic of Korea's external technology sourcing strategies are highly sophisticated, the organization of innovation within these firms follows a centralized R&D model that produces rigid procedures concerning information management and decision-making, product design cycles and speed-to-market. This would inevitably result in weak domestic linkages, either with foreign companies or what can be internalized by the *chaebol*.

In terms of sector-wise distribution, the R&D expenditure in both Malaysia and the NIEs is not equally distributed. Throughout the period 1990-2000, the lion's share of the R&D expenditure went to the private sector while both the GRIs and IHLs held only a moderate and very low share, respectively (see table 20). The R&D role of private enterprise is expected to be increasingly important, eclipsing both GRIs and IHLs in the future.

While several research grants and tax incentives are offered in Malaysia and the NIEs to promote R&D activities in their respective countries (see table 21), most R&D schemes in the former are offered only to the locally controlled and owned companies (at least 51 per cent local equity holding). Obviously, this is a disincentive for foreign-owned companies to carry out R&D activities in Malaysia. Consequently, foreign R&D investment remains low in the country and it was exceeded by about six

Table 20. R&D expenditure by sector (in per cent), 1990-2000

	Private sector		*GRIs*		*IHLs*	
	1990	*2000*	*1990*	*2000*	*1990*	*2000*
Republic of Korea	71	75	22	15	8	10
Singapore	54	63	15	19	31	18
Taiwan Province of China	67	73	24	14	9	13
Malaysia	37	66	55	22	8	12

Sources: Ministry of Science and Technology (Republic of Korea), Executive Yuan Council (Taiwan Province of China), National Science and Technology Board (Singapore) and Ministry of Science, Technology and the Environment (Malaysia).

Table 21. Key research grants and projects provision

Republic of Korea	• 21st century Frontier R&D Programme • Highly Advanced National Project • Creative Research Initiative • National Research Laboratory Programme • Strategic National R&D Project
Singapore	• Research Incentive Scheme for Companies • Innovation Development Scheme • Funds for Industrial Clusters • Promising Local Enterprises
Taiwan Province of China	• Leading Product Subsidiary Programme • Technology Development Programme • Small Business and Innovation Research Programme • Industrial Technological Development Programme
Malaysia	• Industry Research and Development Grant • Technology Acquisition Fund • Intensification of Research in Priority Areas • Commercialization of R&D Fund

Sources: Ministry of Science and Technology (Republic of Korea), Ministry of Economic Affairs (Taiwan Province of China), National Science and Technology Board (Singapore), Ministry of Science, Technology and the Environment (Malaysia).

to four by local R&D investment during the period 1990-2000. While such a shareholding restriction has also been implicitly imposed on some of the R&D schemes offered in the NIEs, locally incorporated companies are defined as those which have a substantial connection to their economies and substantial parts of their production, R&D, management or general business activities are located in the host countries.

The R&D expenditure by type of research in Malaysia is dissimilar to that in the NIEs. While most research in the NIEs is concentrated on experimental development, the biggest portion of the R&D expenditure in Malaysia is used for applied research. Meanwhile, basic research constitutes the smallest portion of the total R&D expenditure in both Malaysia and the NIEs. This suggests that they all mainly focus on a particular application or use rather than to increase the general knowledge base. According to Wong (1999), while applied research can solve the current and immediate future needs of industry today, only basic research capabilities can provide more radical or breakthrough solutions.

In the NIEs, most government R&D research funds are given to the electronics manufacturing industry, the largest contributor in their national GDPs. In contrast to the NIEs, the R&D expenditure by field of research in Malaysia is not in accordance with the importance of the economic sectors. For instance, while the share of the agricultural sector to GDP dropped from 18 per cent in 1990 to 8 per cent in 2000, the bulk of IRPA (the largest government R&D grant scheme) still went to this sunset sector. While the share of the manufacturing sector to the GDP increased from 25 per cent to 35 per cent during this period, its percentage spending in IRPA was merely one third of that disbursed to the agricultural sector (see table 22). This is worrisome as manufacturing is the sector that has been driving the nation towards being a high-tech exporter in the world (see table 23). As shown in table 24, the high-tech exports of Malaysia have indeed been improving tremendously over the past 10 years. Considering that both Malaysia and the NIEs are heavily dependent on electronics exports, there is little reason for the former not to follow the same strategy in terms of R&D budgetary allocation.

Malaysia’s R&D productivity remains low as capital expenditure constitutes a larger share than labour costs in R&D expenditure by type of costs. During the period 1990-2000, capital expenditure accounted for over 40 per cent of the total R&D expenditure in Malaysia whereas it constituted not more than 25 per cent in the NIEs. While labour costs accounted for less than 20 per cent of the total R&D expenditure in Malaysia, in the NIEs they hovered at around 40 per cent.

Among the NIEs, Taiwan Province of China is the only economy that has successfully used R&D consortia to enhance its R&D capability (Mathews, 1999). Such consortia are a series of collaborative R&D ventures that exist within a distinctive institutional framework. Technological learning, upgrading and catch-up are the main objectives of the collaborative exercises. As explained by Hou and Gee (1993) and Lin (1994), with relatively small budgets, such alliances bring together firms and public sector research institutes, with the input of trade associations and financial assistance from the Government. They span many industries, target several specific technologies and vary in size.

Table 22. Malaysia: IRPA programme approvals by area of research

Area	*US$ million*	*Percentage*
	1991-1995	
Agricultural sciences	111.6	49.2
Applied sciences and technologies	68.1	30.0
Medical sciences	20.0	8.8
Others	27.2	12.0
Total	226.9	100.0
	1996-2000	
Agro industry	49.6	25.6
Construction	6.6	3.4
Energy	14.9	5.3
Environment	13.1	6.7
ICT	9.7	5.0
Manufacturing	19.9	10.3
Medical	26.9	13.9
Material and geoscience	4.2	2.1
Science engineering	31.8	16.4
Services	15.0	2.1
Socio-economic	4.2	2.3
Biotechnology	8.0	4.1
Photonics	5.2	2.7
Total	209.1	100.0

Source: Five-Year Malaysia Plan (various issues).
Note: It has been reclassified in the Seventh Malaysia Plan (1996-2000).

Table 23. Percentage share of high-tech exports to total manufactured exports

	WDR		*UNU/INTECH*
	1990	*2000*	*2000*
Republic of Korea	22	36	27
Singapore	51	67	57
Taiwan Province of China	n.a.	n.a.	n.a.
Malaysia	49	64	49

Sources: WDR (various issues) and UNU/INTECH.

Table 24. Malaysia: Performance of high-technology exports (millions of US dollars)

	Exports	*Share (per cent)*	*Ratio to the United States*	*Ratio to the world*
1990	6 050	38.2	0.07	0.016
1995	25 409	46.1	0.20	0.034
2000	38 335	57.3	0.20	0.039

Source: Extracted from Mani (2002).

Science and technology parks

Among the NIEs, the Republic of Korea was the first that set up an S&T park, followed by Singapore and Taiwan Province of China (see table 25). While the S&T parks in the Republic of Korea specifically cater for R&D, the ones in Singapore and Taiwan Province of China are mainly focused on high-tech manufacturing. The typical activities in the three S&T parks in Malaysia are high-tech manufacturing, R&D and software and IT services. Although the first S&T park in the Republic of Korea was established earlier than the one in Taiwan Province of China, today the latter is regarded as the only one in the world that has successfully replicated the

Table 25. Science and technology parks

Republic of Korea	• Daeduck Science Park (DSP). Established in 1973. Occupies 27 square kilometres. Caters to R&D. • Ansan Technopark (ANTP). Established in 1998. Occupies 110,000 square metres. Caters to R&D.
Singapore	• Singapore Science Park (SSP). Established in 1981. Occupies 30 hectares. Caters to high-tech manufacturing.
Taiwan Province of China	• Hsinchu Science-Based Industrial Park (HSIP). Established in 1981. Occupies 580 hectares. Caters to high-tech manufacturing. • Tainan Science-Based Industrial Park (TSIP). Established in 2000. Occupies 680 hectares. Cater to high-tech manufacturing.
Malaysia	• Kulim High-Tech Park (KHTP). Established in 1993. Occupies 1,486 hectares. Caters to high-tech manufacturing. • Technology Park Malaysia (TPM). Established in 1995. Occupies 120 acres. Caters to R&D. • Multimedia Super Corridor (MSC). Established in 1996. Occupies 750 square kilometres (takes 20 years for the full implementation and execution). Caters to software and IT services.

Sources: S&T park administrations of the respective countries.

Table 26. Progress made by science and technology parks

	Turnover (US$ billion)		*Number of tenants*		*Number of institutions**		*Number of employed*
	1990	*2000*	*1990*	*2000*	*1990*	*2000*	*2000*
DSP	n.a.	n.a.	43	86	22	33	15 000
ANTP	n.a.	n.a.	n.a.	40	n.a.	7	n.a.
HSIP	2.2	21.7	121	292	18	23	75 000
SSP	n.a.	n.a.	67	307	15	19	7 000
MSC	n.a.	0.9	n.a.	429	n.a.	53	13 000
KHTP	n.a.	n.a.	n.a.	24	n.a.	1	n.a.
TPM	n.a.	n.a.	n.a.	105	n.a.	4	n.a.

Sources: S&T Park administrations of the countries.

* These include GRIs and public universities.

Silicon Valley in the United States (Lubman, 1999; Saxenian, 2000). As shown in table 26, the progress of the HSIP has indeed been ahead of the others.

The success of the HSIP can be attributed to active Government involvement, rapid accumulation of knowledge and skills, and specific focus on manufacturing and demand-motivated R&D (Xue, 1997). Saxenian (1999) explains that its dynamism is due to the increasing interdependencies between Silicon Valley in the United States and Hsinchu-Taipei in Taiwan Province of China. A community of United States-educated Taiwan Province of China engineers has coordinated a decentralized process of reciprocal technological upgrading by transferring capitals, skills, and know-how, and facilitating collaborations between specialist producers in the two regions. In fact, over 40 per cent of the start-up companies in the HSIP are owned by these engineer-entrepreneurs (Chan, 2001).

Contrary to the HSIP, the DSP is more domestically oriented and there is no deliberate effort to attract foreign companies to locate there. Its positive aspects include a good physical environment, emerging spin-off companies and high-quality research and educational activities, while its negative aspects are limited collaborative research among the institutions, no synergistic effects among research institutions and few linkages between the institutions and local industries. Also, there is not much industrial activity in the park as most of the tenants are government laboratories (Shin, 2001).

According to Kahaner (1995), there are three similarities between the S&T parks in Malaysia and the NIEs. First, they have become a new strategy to develop S&T and ensure a rapid transfer of R&D results to high-tech industries. Second, Government plays the leading role in promoting their development. These include providing funds for infrastructure building and offering various tax incentives to the tenants. Third, universities play relatively minor roles in them. This is in contrast with the ones in the United States and Europe where universities are typically among the key players.

Wang (2000) notices that although both the HSIP and SSP have strength in physical and institutional infrastructure, FDI, venture capital (VC), overseas market, technology, universities or institutes, high-tech talents and administration, their domestic markets are weak. Meanwhile, the MSC has strength in physical and institutional infrastructures, FDI and administration, but its VC, domestic market, overseas market, technology, universities or institutes and high-tech talents are weak.

Even if most of the key success factors are available in Malaysia, it still faces stiff competition from other S&T parks in the region in attracting foreign investors. Especially with the entry of China into WTO, many world class high-tech companies from the developed countries may consider shifting their investments to the S&T parks in that country.

Foreign technology transfer

Foreign technology transfer is important to the technological upgrading in Malaysia and the NIEs (Lim and Maisom, 2000; Carr et al., 2001; Keller, 2001). As shown in the Global Competitiveness Report (2002), Singapore recorded the highest technology transfer index (1.95), followed by Malaysia (1.08), Taiwan Province of China (0.90), and the Republic of Korea (0.82) in 2001. The index is in fact positively correlated with the FDI inflows to these countries (see table 27).

Japan and the United States were the two key FDI sources in the early technological development of both Malaysia and the NIEs (Hobday, 1995; Banik, 2000). However, due to increasing production costs in the NIEs (especially Taiwan Province of China), they have gradually emerged as an important source of FDI for Malaysia since the early 1990s (see table 28). During the period 1980-2000, foreign technology inflows to Malaysia were mostly transferred to both the electronics and petrochemical industries via technical assistance and licence, trademark and patents (see tables 29 and 30).

Table 27. Net FDI inflows, 1970-2000 (billions of US dollars)

	1970	*1980*	*1985*	*1990*	*1995*	*2000*
Republic of Korea	0.20	0.34	0.53	0.79	1.78	15.69
Singapore	5.58	7.21	5.46	3.67	5.22	6.37
Taiwan Province of China	0.29	0.42	0.58	1.33	1.56	5.27
Malaysia	0.04	0.19	0.13	2.33	4.13	5.22

Source: HDR (various issues).

Table 28. Source of foreign direct investment to Malaysia by rank, 1980-2000 (millions of US dollars)

	1980	*1985*	*1990*	*1995*	*2000*
Republic of Korea	4	32	360	1 403	446
Singapore	96	288	1 220	4 195	570
Taiwan Province of China	17	57	3 611	6 159	293

Source: Malaysia Industrial Development Authority (2002).

Table 29. Technology inflows by industry group, 1980-2000 (n.o.s)

Industry	*1980*	*1985*	*1990*	*1995*	*2000*
Electrical and electronics	16	21	41	25	48
Chemical products	21	17	24	22	25
Transport equipment	n.a.	n.a.	18	9	15
Fabricated metals	14	0	4	4	5
Food manufacturing	12	10	4	2	2
Rubber products	14	4	8	3	2
Non-metallic minerals	4	0	7	1	5
Basic metals	10	0	4	0	5
Textiles and apparel	5	1	7	1	2
Hotels	2	4	3	0	0
Plastic products	6	0	5	6	12
Wood products	n.a.	n.a.	6	1	0
Pulp and paper	0	3	4	4	1
Machinery	n.a.	n.a.	6	4	1
Beverages and tobacco	n.a.	n.a.	10	1	5
Petroleum and coal	3	0	0	1	3
Leather	n.a.	n.a.	1	0	0
Miscellaneous	13	16	3	0	0
Total	120	76	155	84	131

Source: Five-Year Malaysia Plan (various issues).

Table 30. Technology inflows by type of agreement, 1980-2000 (n.o.s)

Type of agreement	*1980*	*1985*	*1990*	*1995*	*2000*
Joint venture	22	9	15	3	0
Technical assistance	64	51	72	36	78
Licence, trademark and patents	8	5	36	26	43
Know-how	n.a.	n.a.	12	4	4
Management	6	6	5	1	0
Turnkey and engineering	n.a.	n.a.	1	1	0
Services	7	1	6	5	6
Sales, marketing/distribution	n.a.	n.a.	5	1	0
Supply and purchase	n.a.	n.a.	2	0	0
Others	19	24	1	6	0
Total	126	96	155	83	125

Source: Five-Year Malaysia Plan (various issues).

Both the externalization and internalization strategies for technology transfer have been successfully implemented in the NIEs. The externalization strategy adopted in the Republic of Korea and Taiwan Province of China is aimed at restricting the role of FDI, promoting inflows in other forms, and supporting domestic enterprises in mastering increasingly complex activities. Lall (2001), however, argues that such a strategy is difficult and risky and few other countries can replicate it. It requires a strong base of technological skills, entrepreneurs who are able and willing to undertake risky technological effort and an incentive regime that protects learning while imposing export discipline. Also, it needs a bureaucracy that is able to handle these tools efficiently and flexibly without being hijacked by particular interests. Meanwhile, the internalization strategy practised by Singapore is to rely heavily on internalized technology transfer via FDI, but not to leave resource allocation and technology to markets. This requires the Government to target complex technologies and induce MNCs to upgrade local functions. Also, it calls for a strong skill base and an administrative structure that is able to select technologies, target and bargain with MNCs and handle incentives efficiently.

Despite the widespread perception that FDI plays a minor role in the Republic of Korea development model, the country's electronics exports started taking off only when it became a final export platform for American semiconductor firms (Ernst 2000). In fact, in the early 1970s, foreign firms accounted for one third of the Republic of Korea's electronics production and 55 per cent of its exports, before falling below 30 per cent in the 1980s (Bloom, 1992). Nevertheless, the Republic of Korea has now one of the lowest rates of inward investment in East Asia, even after the crisis-induced attempts by the Republic of Korea Government to bring foreign investment back into the country as a vehicle for accelerated technology diffusion. Ernst (2000) attributes this to the increasingly demanding requirements by the Government on foreign firms to contribute to local value added and increase the transfer of technology. By creating fears of a possible boomerang effect through involuntary technology leakage, this accelerated the withdrawal of foreign firms that faced increasingly stiff competition from the *chaebol*.

Each NIE has to a certain extent adopted somewhat dissimilar foreign technology transfer strategies. For instance, GRIs are the main facilitator in the Republic of Korea and Taiwan Province of China but not in Singapore and Malaysia. In the Republic of Korea, the *chaebol* with ready access to financial resources are the main channel to transfer foreign technology via licensing. Under licensing deals, *chaebol* pay royalties for patent rights, as well as product, process and components technologies (Hobday, 1995). Instead of allowing foreign firms to establish local subsidiaries and determine the speed and scope of technology diffusion, some of the leading *chaebol* are encouraged to focus on learning and knowledge accumulation through a variety of links with foreign equipment and component suppliers, technology licensing partners, original equipment manufacturing (OEM) clients and minority joint venture partners. Meanwhile, SMEs that play the main bridging role in Singapore and Taiwan Province of China and to a large extent Malaysia are seen to be leveraging on the MNCs for foreign technology transfer. Their home-grown conglomerates and SMEs merely play a complementary role in promoting technology transfer (Ernst, 2000).

Given that the progress of technological upgrading in Malaysia trails far behind Singapore, this suggests that the former’s strategy lacks specific policy instruments to engineer positive spillovers from the MNCs that mostly operate in the manufacturing sector. Actually, this can be attributed to its weak technology-based SME sector that is of paramount importance to technology diffusion (Mani, 2002). As pointed out by Amsden et al. (2001), MNCs in Singapore are reputed to undertake not only R&D locally but applied and possibly even basic research, although it is typically Government-induced. For instance, the Local Industries Upgrading Programme in Singapore has successfully encouraged MNCs to adopt a group of SMEs and transfer technology and skills to them. This programme pays the salary of a full-time procurement expert to work for specified periods with the adopted firms and help them upgrade their production and management capabilities to the required standards.

Thanks to the successful technological upgrading from OEM to original design manufacturing (ODM) and original brand manufacturing (OBM), the Republic of Korea and Taiwan Province of China are now less dependent on foreign technology transfer. While Singapore and Malaysia still depend heavily on it for technological upgrading, it is only the former that has rapidly moved up the manufacturing value added chain.

Government research institutes

In the NIEs, GRIs act as the vehicle or gateway for their local companies to access technology that would otherwise be beyond their capability. For instance, the Republic of Korea lacked technological capabilities for industrialization in the 1960s. Besides imports of foreign technologies, the more radical solution was the establishment of R&D institutes. This had led to the establishment of the first GRI in 1966, namely the Republic of Korea Institute of Science and Technology. Meanwhile, in the 1970s, Taiwan Province of China's industry mainly comprised SMEs that ran on limited capital. This compelled the Government to establish the first technology research institute in 1972, namely the Industrial Technology Research Institute, to carry out innovative R&D technologies and transfer research results to the marketplace.

At present, Singapore has more industrial technology-based GRIs than Taiwan Province of China and the Republic of Korea (see table 31). While the difference is insignificant, this suggests that the number of GRIs in a country does not necessarily reflect its true technological capability. This in fact explains the reason behind the consolidation of 15 GRIs in the Republic of Korea under various ministries into nine large research institutes under the Ministry of Science and Technology during the 1980s.

It is a statistical truth that Malaysia has more GRIs than the NIEs. As pointed out by Mani (2000), only two out of the existing 33 GRIs available in Malaysia are devoted to industrial technology research, namely the Standards and Industrial Research Institute of Malaysia (SIRIM) and the Malaysian Institute for Microelectronic Systems (MIMOS); the other two GRIs, namely the Malaysian Technology Development Corporation and Malaysian Industry Group of High Technology, also responsible for industrial technology development in Malaysia, only act as catalysts.

The functional roles of Malaysia's GRIs are generally not very different from those in the NIEs. They generate new areas of technologies, provide a critical labour pool to the industry, analyse industrial development, conduct and review feasibility studies for new industrial technologies, collect foreign scientific and technology information and encourage local industries to take up R&D projects in collaboration with them.

III. POLICY LESSONS AND RECOMMENDATIONS

National innovation system model

Taking a forward-looking perspective Malaysia may first adopt the DFI-leveraging model, followed by the SME-PRI innovation network model and the large firm internalization model. Given that the second is in fact a pillar of strength to the first, Malaysia may initially implement these two in Johor and Penang,

Table 31. Industrial technology-based GRIs in Malaysia and the NIEs

Republic of Korea	• Republic of Korea Institute of Science and Technology • Republic of Korea Electronics and Telecommunications Research Institute • Republic of Korea Institute of Industrial Technology • Republic of Korea Research Institute of Machinery and Materials • Republic of Korea Electro-technology Research Institute • Republic of Korea Research Institute of Chemical Technology • Republic of Korea Institute of Oriental Medicine • Republic of Korea Food Research Institute
Singapore	• Data Storage Institute • Environmental Technology Institute • Gintic Institute of Manufacturing Technology • Kent Ridge Digital Labs • Institute of Molecular Agro-biology • Institute of Molecular and Cell Biology • Institute of Microelectronics • Institute of Materials Research and Engineering • Bio-process Technology Centre • Centre for Remote Imaging, Sensing and Processing • Centre for Wireless Communications • National Supercomputing Research Centre • Centre for Signal Processing
Taiwan Province of China*	• Industrial Technology Research Institute • Electronic Research and Service Organization • Energy and Resources Laboratories • Centre for Measurement Standards • Materials Research Laboratories • Union Chemical Laboratories • Opto-electronics and Systems Laboratories • Centre for Pollution Control Technology • Centre for Aviation and Space Technology • Centre for Industrial Safety and Health Technology • Computer and Communication Research Laboratories • Mechanical Industry Research Laboratories
Malaysia	• Standards and Industrial Research Institute of Malaysia • Malaysian Institute for Microelectronic Systems

Sources: Ministry of Science and Technology (Republic of Korea), Ministry of Economic Affairs (Taiwan Province of China), National Science and Technology Board (Singapore) and Ministry of Science, Technology and the Environment (Malaysia).

* All of the public research institutes and centres are organized and coordinated by the Industrial Technology Research Institute.

respectively. After all, SMEs are an important nexus in the industrial cluster in the former while the latter's industrial structure is mainly dominated by MNCs. Taking these two industrial states as the test-bed, the two models can then be gradually implemented in other states over time. This would not only provide more policy options for the Government to apply, but also help Malaysia to avoid taking the risk of adopting a single model across all the industrial states. Upon building a relatively strong technological base, Malaysia may then start embarking on the large firm internalization model.

Human capital

- Both the public and private IHLs need to reverse the present ratio of science to arts students from 40:60 to at least 60:40.
- The composition of the coordinating body for training and skills development needs to be more privately driven and governed, so that more technical training programmes can be run as collaborative ventures with MNCs or industrial training institutes.
- Strengthening the Government recruitment programmes and introducing more liberal immigration policies are vitally important to alleviate the brain drain problem.

Research and development

- The existing shareholding restriction that is presently imposed on most of the R&D schemes needs to be lifted in order to promote more foreign-based R&D activities.
- R&D expenditure by field of research ought to be in accordance with the importance of the economic sectors and labour cost has to be given the top priority in terms of R&D expenditure by type of cost.
- Strategic partnerships such as collaborative R&D ventures and alliances are vitally important in spearheading R&D activities.

Science and technology parks

- More stringent rules and conditions have to be imposed in the process of selecting tenants.
- Enhancing the interdependencies and collaborations between the S&T parks in Malaysia and the NIEs is an effective process of reciprocal technological upgrading.
- A private sector managed coordinating body needs to be set up to promote strategic alliances between the S&T parks in Malaysia and help form network linkages between their tenants.

Foreign technology transfer

- The strength of a technology-based SME sector is the key success factor.
- Malaysia is expected to be less dependent on it as the country moves up the value added chain. Therefore, it is required that the country shifts its strategies from internalization to externalization so as to restrict the role of FDI in mastering advanced technologies.

Government research institutes

- The present number of establishments is not sufficient and more need to be established.
- GRIs have to be established according to scientific disciplines and technological specialization so as to carry out R&D and transfer results to the marketplace more effectively.

IV. CONCLUDING REMARKS

Both Malaysia and the NIEs have mounted elaborate strategies to identify and act upon strategic technologies. Without having strong strategic resources, the results of these strategies in Malaysia have, not surprisingly, been less impressive thus far. Admittedly, the existing strategic resources are necessary and useful, but might not be sufficient for the local technological upgrading to take off. More committed and concerted efforts are needed to strengthen each of these resources, both structural and non-structural. Given its sound macroeconomic fundamentals, there is little reason for Malaysia not to succeed in this endeavour and to put it on the path of technologically-driven development.

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