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INDUSTRIAL TRANSITION IN THE MALAYSIAN ELECTRONICS INDUSTRY

FINAL REPORT

Prepared for the Government of Malaysia
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

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Volume I

Executive Summary

IMP2 uses a cluster perspective to inform a high value adding growth trajectory to the year 2020. This report builds on the cluster perspective to examine the growth dynamics of the Malaysian electronics sector within the context of global developments in electronics past, present, and future. The cluster perspective provides a framework for analyzing the strengths, weaknesses, challenges and opportunities of the Malaysian electronics industry in a global context.

The Malaysian electronics industry had been a powerful engine of growth for three decades even though electronics at the global level has undergone momentous change and upheaval. The 1970s and 1980s witnessed the rise of East Asian semiconductor and consumer electronic powerhouses in what had been American and European dominated sub-sectors. The late 1980s and 1990s saw the resurgence of American leadership as the personal computer and later the information and communications branches of electronics became the fastest growing. Today the convergence of data, voice and video media is yet again driving rapid industrial change and transforming the cutting edge scientific and technological research base of electronics into photonics or opto-electronics. The critical size dimensions of production in the industry has steadily moved from microns (millionths of a meter) to nano-technology (billionths of a meter) domains.

In chapter one we describe the historical evolution and state of the Malaysian electronics industry. We look closely at the evolution of its major product groups, the position of Malaysian electronics in the global industry, and focus attention on innovative capabilities of electronics companies within Malaysia. In a summary of the strengths and weaknesses of the Malaysian industry we focus attention on its competitive advantage in flexible mass-production capabilities. Malaysia is an electronics manufacturing platform for volume production and rapid ramp-up for specific and externally-designed product lines. We also introduce major challenges facing the industry given the compression of new product cycle times, the rapid pace of technological change in the industry, the changing sectoral composition within electronics, the emergence of new 'networked' business models, and the rise of new national competitors, particularly China.

In chapter two we examine the Second Industrial Master Plan, the cluster approach, and IMP2's Manufacturing ++ strategy. In chapter three we expand on the cluster approach by developing a cluster dynamics or regional growth dynamics model which captures the range of dynamic processes that constitute innovative clusters and drive intensive (high value-adding) growth. We use the experiences of the world's most innovative electronics enterprises and industries to draw implications for deepening and broadening the cluster approach. We give special attention to the role of technology management capability within companies and within regions as a powerful policy instrument for fostering growth. By integrating technology and technology management into cluster analysis we are able to examine more closely both the challenges and opportunities facing this rapidly changing industry. A major implication is the critical role of inter-firm networking capabilities in fostering growth and innovation. The successful electronics clusters use inter-firm networks to compress new product-development time and foster innovation. Networking systems and capabilities foster the decentralization and diffusion of design within a region and become a source of innovation, sectoral transition, and value-adding growth.

A major implication of the technology management framework is that rapid productivity-led growth does not come from marginal or piecemeal changes. It is the result of the development and institution of new processes driven by entrepreneurial firms. In fact, it involves synchronised step-changes in technology management, business model, and skill formation. This is the concept of the *productivity triad.* It has major implications for policymaking.

In chapter 4 we apply the extended cluster dynamics approach to the three major electronics regions within Malaysia. This gives new insights into each region's competitive advantage including its strengths, weaknesses, challenges and opportunities. We distinguish general challenges from challenges specific to each region.

Malaysia has regional electronics clusters. Ironically, they lack cluster dynamics. The three regional electronics clusters in Malaysia are all lead by multinational companies. To date, however, these firms (with a few exceptions) do not pursue the technology capability and market opportunity dynamic that defines the entrepreneurial firm *in their Malaysian operations.* They invest in plant and equipment and human resource development to run world class manufacturing platforms. This has generated extensive growth. But without entrepreneurial firm activities, the dynamic processes that drive regional growth dynamics are missing. The missing dynamics processes include techno-diversification, inter-firm networking, industrial speciation, and regional innovation.

The Malaysian electronics clusters are *externally integrated.* Operational units even within each of the three regional clusters are not networked. In most cases they are production units within a vertically integrated value chain coordinated in the home country of the multinational. Thus the Malaysian electronics clusters do not generate the productivity gains associated with specialization and integration. They are clusters populated by vertical *value chains* without overlap and cross-penetration. Cluster dynamics involve, instead, *value networks.*

Malaysia has world class electronics manufacturing capabilities *for a given product design.* It lacks the technology management capabilities to engage in the higher value-adding activities associated with new product design and development. The development of regional networking capabilities can leverage the existing production capabilities into new product development capabilities by the decentralization and diffusion of design capabilities. This involves the conversion of *external-integrated* into *region-integrated* clusters.[1]

[1] Region-integrated clusters represent a departure from both the vertical integration and the closed-system networking or the Japanese *keiretsu* models of inter-firm

In chapter 5 we review the existing incentives and promotional instruments. In chapter 6 we identify the major challenges facing the Malaysian electronics industry. These call for *integrative* policies to advance entrepreneurial firms, *capabilities* for networking, technology management, and technology transition, and for advanced and mid-level *skills*. Until these capabilities and skills are addressed Malaysian electronics will not be able to make the transition from price-led to product-led competition. Policy responses are then derived for each of the three regions. We emphasize processes that must be instituted for the electronics industry to meet the value-adding growth goals of the Manufacturing ++ strategy.

One challenge stands out for meeting the objectives of IMP2. Every region of the world in which electronics has achieved the goal of driving value-adding growth for a sustained period has simultaneously undergone a transition in skill formation capability at the graduate engineering and science level. The successful electronics regions all have over 20 scientists and engineers per 10,000 population. Malaysia has only 2.3. The major policy implication is that success in the electronics and electronics derived industries involves the decentralization and diffusion of new product development and innovation capabilities which, in turn, depends highly on graduates in natural science, engineering, mathematics and computer science. Making the transition from external-integrated to region-integrated clusters will involve an increase in the output of technical graduates by tenfold over the next two decades.

Ten appendices address a range of issues and present a number of case studies of companies, enterprise-level and region-level capabilities, skill development agencies, and regulatory models. They illustrate the capability challenges confronting the Malaysian electronics industry. Equally importantly, they offer policymakers a treasure trove of success stories, many involving Malaysian experiences, companies and skill development processes that, if converted into organizational change capabilities, can be ramped up and foster value-adding growth.

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coordination to an open-system networking model. Open-system networking is a system of inter-firm relations particularly hospitable to rapid new product *concept* development. Whereas the Toyota production system and the *keiretsu* closed-system networks enhanced production flexibility, the open network business model fosters the diffusion of design within a regional organizational infrastructure that facilitates new firm entry, technological experimentation, technological diversity and new technological combinations. These processes, in turn, quicken the pace of innovation.

Chapter 1: State of the Industry

1. Introduction

The Electronics Industry has been the springboard of economic growth in Malaysia. In the past three decades the industry has grown and contributed to the economic growth of the nation. The electronics industry grew within regions in Malaysia, notably Penang and the Klang Valley. This soon grew and created a spillover effect to other states. The growth of the industry was momentarily slowed down by the economic crisis. However there are signs that the industry is back on its feet.

In order to determine the current situation in the industry, as well as its continued growth and transition up the technology ladder, a detailed analysis has to be undertaken. This chapter will analyse the industry's past and current situation and the regional and global electronics environment. It outlines the threats, opportunities, strengths, and weaknesses of the Malaysian Electric and Electronics Industry and states key elements for future development and growth.

2. Past and Present

2.1 Output Trends

The Electric and Electronics Industry in Malaysia began in 1965 with the establishment of Matsushita Electric. Clarion became the first electronics component plant to relocate operations in Malaysia. This was followed by National Semiconductor in 1971, which established the first semiconductor factory in Penang. Within two and a half decades the Electric and Electronics Industry has been transformed into a modern industrial sector with over 850 companies, employing about 330,000 workers. Its total output value surpassed RM100 billion in 1998 and exports contributed to over 50% of overall export revenue.

The industry expanded rapidly in periods 1972 – 1974 and 1987 to 1995. The period 1995 – 98 showed a decrease due to a global industry-wide cyclical downturn. The nominal figures for 1997–98 indicate a gradual increase, but that is due to a sharply fallen ringgit (depreciating from 2.47 ringgit to a US dollar in July 1997 to 4.59 ringgit to a US dollar in December 1997) as output volume recorded a recovery only in 1999. Employment figures demonstrate these effects, recording a decline of -6.6 per cent in 1998 (see Table 1.1).

Table 1.1: Changes in the Electric and Electronics Industry

Year	Output		Employment		Exports		Imports	
	RM (Bil)	% Growth	No.	% Growth	RM (Bil)	% Growth	RM(Bil)	% Growth
1986	6.5	-	57,000	-	7.1	-	-	-
1987	8.9	36.9	89,000	56.1	9.2	29.6	-	-
1988	12.2	37.1	106,000	19.1	13.0	34.8	-	-
1989	15.9	30.3	123,000	16.0	17.9	38.7	-	-
1990	20.3	27.7	144,000	17.1	23.1	28.5	-	-
1991	26.1	28.6	171,000	18.8	30.4	31.6	24.7	38.8
1992	32.2	23.4	204,000	19.3	34.6	13.8	25.5	3.2
1993	42.1	30.7	231,000	13.2	46.7	35.0	32.9	29.0
1994	56.4	34.0	278,000	20.3	66.4	42.2	49.1	49.2
1995	71.0	25.9	313,000	12.6	85.0	28.0	63.8	29.9
1996	76.0	7.0	329,100	5.1	91.7	7.9	68.0	6.6
1997	85.6	12.6	343,300	4.2	107.3	17.0	75.7	11.3
1998	103.5	20.9	320,600	(6.6)	146.1	36.2	96.6	27.6
Average Annual Growth Rate 1991-1998	-	22.9	-	10.8	-	26.4	-	24.5

Source: MIDA, Malaysia

In terms of employment and export earnings, the Malaysian Electric and Electronics Industry has been a major success story. During the 1968 to 1990 period, electric/electronics output grew at 14% per annum, employment at 25% per annum, and as a share of manufacturing output, rising from 1.5% to 25%. The electric and electronics industry accounted for 67.5% of manufactured exports in 1996.

This spectacular growth has been mainly due to the huge annual inflows of FDI. Of the investments in electronics, components comprised about 75% of the total investments for the period 1985 to 1996, followed by industrial electronics (16%) and consumer electronics (9%). The period 1997 –98 showed a decrease in projects approved (133 and 121 respectively). Electronic components have consistently shown the largest number of applications approved and capital investment, followed by industrial electronics and consumer electronics. Table 1.2 illustrates this development.

Table 1. 2: Number of Electronics Projects Approved by Sub-sector

	Electronic Components				Consumer Electronics				Industrial Electronics				Total	
			Capital Investment				Capital Investment				Capital Investment			
Year	No	%	RM (mil)	%	No	%	RM (mil)	%	No	%	RM (mil)	%	No	RM (mil)
1985	17	46%	104	80%	9	24%	4.6	4%	11	30%	21.6	17%	37	130.2
1986	19	50%	47.6	41%	11	29%	63.2	54%	8	21%	6.7	6%	38	117.5
1987	29	55%	264	46%	11	21%	145.3	26%	13	25%	159.4	28%	53	568.7
1988	41	67%	582.9	56%	14	23%	322.2	31%	6	10%	134.3	13%	61	1039.4
1989	64	58%	1375.7	68%	28	25%	418.9	21%	18	16%	228.5	11%	110	2033.1
1990	143	69%	2778.4	62%	25	12%	1132.1	25%	38	18%	567.3	13%	206	4477.8
1991	102	62%	1733	76%	28	17%	87.8	4%	35	21%	466.6	20%	165	2287.4
1992	93	60%	535.5	55%	38	25%	249.8	26%	24	15%	181.3	19%	155	966.6
1993	88	52%	1559.2	75%	30	18%	107.8	5%	51	30%	413	20%	169	2080
1994	92	52%	4606.3	88%	41	23%	138.1	3%	43	24%	472.8	9%	176	5217.2
1995	95	55%	943.5	31%	29	17%	202.8	7%	50	29%	1942.3	63%	174	3088.6
1996	118	61%	11159.5	92%	28	15%	280.8	2%	46	24%	670.9	6%	192	12111.2
1997	71	53%	4,755.20	88%	18	14%	52.6	1%	44	33%	582.9	11%	133	5,390.70
1998	49	40%	1,071.90	65%	26	21%	208	13%	46	38%	370.2	22%	121	1,650.10
Total	1021		31516.7		336		3414		433		6217.8		1790	41,148.50

Source: MIDA, Malaysia

In 1987, a year after Malaysia passed the Promotion of Investment Act (PIA), the electronics sector re-established itself as the leading contributor to FDI investment. Investments in the electronic industry grew to 92% of approved investments in 1995. However, most of the investments were concentrated in assembly of components. In fact, most of the electronics companies are only assemblers of imported electronic parts and other components making Malaysia one of the world's biggest importers and exporters of electronics components.

Prior to the economic slowdown of 1997 – 98, the number of projects approved increased from 174 in 1995 to 192 in 1996 (10.3%) (see Table 1.2). This percentage change is negligible compared to the increase in total proposed capital investments, from RM3,088.6 million to RM12,111.2 million for the corresponding period. The numbers of projects approved, fell in the period 1997 – 98, 133 and 121 respectively. A detailed analysis of applications received and approved for the industry is shown in Appendix 1. Investments declined from RM9.2 billion in 1996 (at its peak) to RM2.9 billion in 1997 and to RM1.9 billion in 1998. Domestic investment in the Electric and Electronics Industry following the recession fell from RM3.8 billion in 1996 to RM3.3 billion in 1997 and to RM0.51 billion in 1998. While a recovery in world demand has raised investments and production, it is too early to predict a return to previous rates of growth.

The cyclical downturn and a glut in the market severely affected the Electric and Electronics Industry. Malaysian exports from the sector fell by approximately 27%, from RM85 billion in 1995 to RM62 billion in 1996. Nonetheless, Malaysia's electric and electronics exports are now gradually recovering from the recent recession as indicated in Table 1.1. The Malaysian Electric and Electronics Industry can be roughly classified into three broad sectors:

- Electronic components
- Consumer electronics
- Industrial electronics

As Table 1.3 indicates, the most important output generator in Malaysia's Electric and Electronics Industry is electronic components, which accounted for about half of the industry in 1996. The other half was almost equally divided between industrial electronics and consumer electronics until 1997. The period 1997 – 98 indicates swifter expansion in the industrial electronics sub-sector, which has grown to almost equal share with electronics component. Output for the consumer electronics sub-sector fell sharply in this period to 14.1% share of the electronics industry in 1998.

Table 1.3: Output Structure of the E&E Industry

Year	Electronic Components	Consumer Electronics	Industrial Electronics
1984	84.0	12.0	4.0
1988	71.9	18.3	9.8
1990	55.2	23.7	21.1
1992	43.8	26.6	29.6
1993	43.0	27.0	30.0
1994	41.0	27.0	32.0
1995	42.9	25.2	31.9
1996	49.7	24.4	25.9
1997	43.1	16.6	40.3
1998	44.6	14.1	41.3

Source: MIDA, Malaysia

Semiconductors, and other components for computers and telecommunications equipment, are by far the most significant segments of the electronic components sector, accounting for approximately 80% of total production. Assembly and final testing activities dominate electronic component production. Although significant discussion has occurred and the government has given much encouragement toward wafer fabrication in Malaysia, it is still limited to Malaysian Institute of Microelectronics Systems (MIMOS) production that produced 3,000 units of 1.0 micron wafers in 1998. MIMOS expects to fabricate 0.5 micron wafers by the end of 1999. Two other joint-venture chip-fabrication firms, i.e., 1st Silicon in Sarawak and Silterra in Kulim, expect to produce 0.25 micron and 0.18 micron wafers by 2000 and 2001 respectively. The former plans to move on to 0.18 wafers by 2001.

Exports of electronics items accounted for over 53% of total Malaysian exports in 1996 and about 10% globally. As noted, exports of semiconductors dominate Malaysia's electronics sector. The range of electronic components, and consumer and industrial electronic equipment assembled or produced in Malaysia is shown in Table 1.4.

Table 1.4: **Main Electronic Products Made or Assembled in Malaysia**

Semiconductor Devices	Other Electronic Components	Consumer/Industrial Electronic Equipment's
Linear and digital integrated circuits,	Capacitors, headframes, switches, Resistors	Colour TV Receivers
Memories and microprocessors,	Relays, Coils, Quartz Crystals,	Audio products
Opto-electronics,	Oscillators, Magnetic Heads,	Video Cassette Players and Recorders
Discrete devices	Connectors, Transformers,	Paging System, Walkie Talkies
Hybrids,	Wire Harness,	Telephone Sets,
Arrays,	Disc Drive Parts	Digital Transmission Equipment's, Satellite Receivers
High-reliability military products	Audio Cassette Mechanisms, Micro-Motors, Circuit Boards, Etc	Personal Computers, Monitors, CD-ROM Drives, Keyboards and Printers, Telecommunications Equipment's Etc

2.2 Trade Trends

Currently almost half of Malaysia's electronic exports are of low value-added component parts, although the process of structural change toward more high value items has been in progress since 1990. In 1990 exports of finished consumer electronics and industrial electronics began to narrow the gap with exports of electronic components. The gap, however, widened again after 1994 where exports of electronic components increased from 41% in 1994, to 43% of total exports in 1995 and about 50% in 1996. When one compares this with the 84% contributed by electronic components in 1986, there is evidence that the industry structure has changed and that Malaysia is moving toward higher value-added end-use products. Breakdowns of exports are detailed in Table 1.5.

Table 1.5: Exports FOB (RM mil)

Code	Description Year	94	95	96	97	98
751	Office Equipment	542	571	514	458	504
752	Automatic Data Processors	3089	5479	9874	16277	21078
759	Replacement Parts 751&752	9508	11954	12261	14937	24122
761	TV Receivers	4528	5614	5242	4601	5270
762	Radio Receivers	7421	8738	7713	6898	7947
762	Sound recording&reproducing eqpmt	6008	7000	6966	6278	7430
764	Telecommunications eqpmt	8258	9489	9982	11543	14561
771	Electrical machinery	1316	1351	1334	1564	1720
772	Electrical apparatus	2272	3011	3983	4980	9714
773	Electrical parts	699	884	1076	1028	1264
774	Electrical medical eqpmt	6	14	19	27	52
775	Appliances	505	578	657	732	871
776	Valves, tubes, photocells	24816	33197	35509	40887	54483
778	Electrical parts	1463	1788	1672	2130	3057
	Total	70431	89668	96802	112340	152073

Source: BNM, various issues

As indicated in Table 1.1, Malaysia's imports of electronic products amounted to RM68 billion or about 74.2% of the total electronics exports of RM91.7 billion in 1996. It has been estimated that 74% of the content of every electronic item made in Malaysia consists of imported components.

The industry is still dominated by a small number of multinational companies and is characterised by a high dependence on imported parts and components. In 1995, imported parts or components amounted to about RM39 billion or about 44.3% of the total imports of intermediate goods. Breakdowns of imports are detailed in Table 1.6.

Table 1.6: Imports CIF (RM mil)

Code	Description/Year	94	95	96	97	98
751	Office Equipment	218	269	219	204	119
752	Automatic Data Processors	1052	1425	2370	3165	3733
759	Replacement Parts 751&752	3677	5367	7363	10220	9979
761	TV Receivers	99	78	44	39	36
762	Radio Receivers	257	284	298	211	161
762	Sound recording&reproducing eqpmt	364	378	161	139	132
764	Telecommunications eqpmt	7609	9083	7752	8382	7463
771	Electrical machinery	1765	1753	2083	2213	2561
772	Electrical apparatus	6512	6806	6755	7364	9428
773	Electrical parts	1315	1563	1442	1553	1256
774	Electrical medical eqpmt	93	135	183	197	293
775	Appliances	391	424	344	283	242
776	Valves, tubes, photocells	28146	39258	42334	45812	64201
778	Electrical parts	4024	4671	4744	5262	5645
	Total	55522	71494	76092	85044	105249

Source: BNM, various issues

Table 1.7 shows the percentage of import to export for each category in the electrical and electronics industry. Imports still accounted for almost 70 per cent of exports in 1998. Electrical medical equipment, electrical parts, electrical machinery and valves, tubes and photocells still experienced net negative exports. Only TV receivers, radio receivers and sound recording and reproducing equipment showed a tiny share of imports over exports.

The performance of imports to exports showed a trend improvement from 1995. Electrical appliances, electrical parts and electrical medical equipment faced a continuous improvement of trade balance in the period 1994-98. Office equipment and replacement parts showed a big fall in 1998. Telecommunication equipment and electrical apparatus recorded a strong improvement in net exports from 1996. Radio receivers show a slight fall in 1997-98. Despite strong improvements in the trade balance involving some sub-sectors, interviews indicate that the import-content has remained high. Only Penang firms were reported to have increased considerably domestic sourcing of inputs.

Table 1.7: Percentage of Imports to Exports for E&E Industry (94 – 98)

Code	Description/Year	94	95	96	97	98
751	Office Equipment	40%	47%	43%	45%	24%
752	Automatic Data Processors	34%	26%	24%	19%	18%
759	Replacement Parts 751&752	39%	45%	60%	68%	41%
761	TV Receivers	2%	1%	1%	1%	1%
762	Radio Receivers	3%	3%	4%	3%	2%
762	Sound recording&reproducing eqpmt	6%	5%	2%	2%	2%
764	Telecommunications eqpmt	92%	96%	78%	73%	51%
771	Electrical machinery	134%	130%	156%	141%	149%
772	Electrical apparatus	287%	226%	170%	148%	97%
773	Electrical parts	188%	177%	134%	151%	99%
774	Electrical medical eqpmt	1550%	964%	963%	730%	563%
775	Appliances	77%	73%	52%	39%	28%
776	Valves, tubes, photocells	113%	118%	119%	112%	118%
778	Electrical parts	275%	261%	284%	247%	185%
	Total	79%	80%	79%	76%	69%

Source: Computed from BNM, various issues

3. Innovative Capabilities

3.1 Product Innovation

A range of innovative capacities has evolved in electronics firms in Malaysia. Foreign-based firms have been able to assemble state of the art products in Malaysia, given their access to their own capacities and those of others embedded in national innovation systems located abroad. For example, Intel and AMD assemble their microprocessors in subsidiaries in Penang, keeping their key innovation stages in the United States.

Production by local firms, largely without access to similar global innovative channels, has generally been limited to less sophisticated products. Nonetheless, local firms such as Sapura, have developed in-firm capacities to innovate products, involving extensions and enhancement of existing products, such as the voice activated telephone.

Interviews in 1993 revealed that no electronics firm in Malaysia, whether local or foreign owned, in industrial, consumer or components sectors, has been involved in product innovation activities at the technology frontier. Few firms undertook product R&D activities in 1993; only two industrial, two consumer and five component firms, comprising 11.1, 6.5 and 21.7 percent of responding firms respectively reported carrying out product R&D activities (see Table 1.8). Component firms, especially semiconductor device manufacturers, tend to participate primarily in product redesigning activities. Among local firms, Sapura has the most developed product R&D facilities. Interviews in 1998 showed that Sapura has moved further in the telecommunications products technology trajectory than its position in 1993.

The latest aggregate study aimed at firms was in 1993. Follow up interviews with 26 electronics firms in 1999 revealed that the 1993 findings generally held throughout the period 1993 – 98, though the specific numbers are likely to have changed. Hence, we have used this study here. Much of the latest data on the movement of firms in the technology trajectory appear as case studies in Appendix 2. Firms reported that R&D efforts fell in the period from late 1995 until 1998 due to the cyclical downturn in the industry.

Table 1.8: Product Research and Development Participation by Ownership, 1993

Ownership	Industrial		Consumer		Components		Total	
	Num	%	Num	%	Num	%	Num	%
FO_1	1	5.6	2	6.5	5	21.7	8	11.0
FO_2	0	0.0	0	0.0	5	21.7	5	6.8
LO	1	5.6	0	0.0	0	0.0	1	1.4
Total	2	1.1	2	6.5	5	21.7	9	12.3

Note: of responding firms in sub-category; FO_1 over 50 percent foreign equity ownership; FO_2 entirely owned by foreign capital; LO - over 50 percent local equity ownership.
Source: Rasiah (1996)

3.2 Product Design Innovation

A range of firms in component, industrial and consumer electronics are involved in product design innovations, including Intel, AMD, Litronix, Hitachi, Sony, Motorola, Matsushita, Grundig, and JVC. While most electronic firms in Malaysia undertaking product design innovations are MNCs, there is evidence of some diffusion of technology and the generation of product design capacity to local firms. For example Sapura reported having a special research plant with 37 engineers and technicians. This firm absorbed two key R&D engineers from Motorola Malaysia in the late 1980's highlighting the potential role of foreign firms as a training ground for local firms.[2]

3.3 Process Innovation

Electronics firms in Malaysia appear closer to the universal process technology frontier than the product technology frontier. However this process of technology

2 Rasiah, Rajah (1996)

advancement only applies to the area of assembly and test operations. Process R&D was reported by three firms in industrial electronics, five in consumer electronics and 15 in components (comprising 16.7, 9.7 and 65.2 percent of responding firms) (see Table 1.9). Interviews also indicated that R&D support for process innovations is strongest in semiconductor and telecommunications component manufacturers.

Table 1.9: Formal Process Development Participation by Ownership, 1993

Ownership	Industrial		Consumer		Components		Total	
	Num	%	Num	%	Num	%	Num	%
FO_1	2	11.1	3	9.7	13	56.5	18	24.7
FO_2	1	5.6	2	6.5	13	56.5	16	21.9
LO	1	5.6	0	0.0	2	8.7	3	4.1
Total	3	16.7	3	9.7	15	65.2	21	28.8

Note: Percentage of responding firms in sub-category; FO_1 over 50 percent foreign equity ownership; FO_2 entirely owned by foreign capital; LO - over 50 percent local equity ownership.
Source: Rasiah (1996)

Foreign firms again showed higher incidence of participation in process innovation activities than local firms. Again the process of technology diffusion from MNCs to local firms is beginning to occur, on a limited basis. Intel initially developed prototypes entirely in its automation workshop before subcontracting them to local vendors. The development of local vendors' productive capacity led to gradual sharing development tasks between Intel and local vendors. Advanced Micro Devices, Motorola Malaysia, Hewlett Packard, Hitachi Semiconductor, and Litronix also reported jointly developing machinery innovations with local firms, though with much less intensity.

3.4 Incremental Innovation

In the field of incremental innovations, especially minor improvements, there was a high level of activity reported; 14 industrial, 28 consumer and 23 component firms reported recording some kind of innovation over the year 1992 until mid 1993 (comprising 77.8, 90.3 and 100.0 percent of responding firms) (see Table 1.10). Given their participation in cutting edge technologies, all component firms regarded their entire workforce as capable of innovation - generating at least minor process improvements that improve work organisation and lower relative costs. Indeed, operators in semiconductors require a high level of statistical and technical proficiency to handle manufacturing, quality control, and preventive maintenance activities.

All component firms interviewed in 1999 have also introduced substantial process improvements that have made their production organisation flexible and lean to meet volatile market fluctuations. Cellular manufacturing, statistical process controls, integrated materials resource planning, total quality management, total productive maintenance, and quality control circles (through informal small group activities) were adopted gradually in the early 1980s, and more rapidly since the mid-1980s. The infusion of such process techniques is most widespread in component firms. The composition of personnel exposed to such techniques in component firms varied. Consumer and industrial electronics firms, down strongly due to labour shortages in the 1990s' had introduced considerable amounts of favourable manufacturing techniques in the 1990s. Industrial electronics firms had a high level of application of flexible production systems, but they showed relatively low levels of innovations due to their newness.

Table 1.10: Firms Reporting Incremental Innovations by Ownership, 1993

Ownership	Industrial		Consumer		Components		Total	
	Num	%	Num	%	Num	%	Num	%
FO_1	10	55.6	25	80.0	20	87.0	55	75.3
FO_2	8	44.4	19	61.3	20	87.0	47	64.4
LO	4	22.2	3	9.7	3	13.0	10	13.7
Total	14	77.8	28	90.3	23	100.0	65	84.0

Source: Rasiah (1996)

Within Intel, Advanced Micro Devices, Fairchild, Hewlett Packard, and Hitachi Semiconductor, between 80 and 100 percent of their permanent personnel, from operators to managers, were classified as potentially innovative in the period 1993 - 98. This is because they generate ideas on the improvement of production organisation, training, and material utilisation. Employees at all levels are motivated to participate in decision making by utilising the concept of TQM. Formal and informal channels exist to ensure the tapping and direction of innovative capacity aiding in the success of their firms.

4. Malaysia's Location in the Value-Added Chain

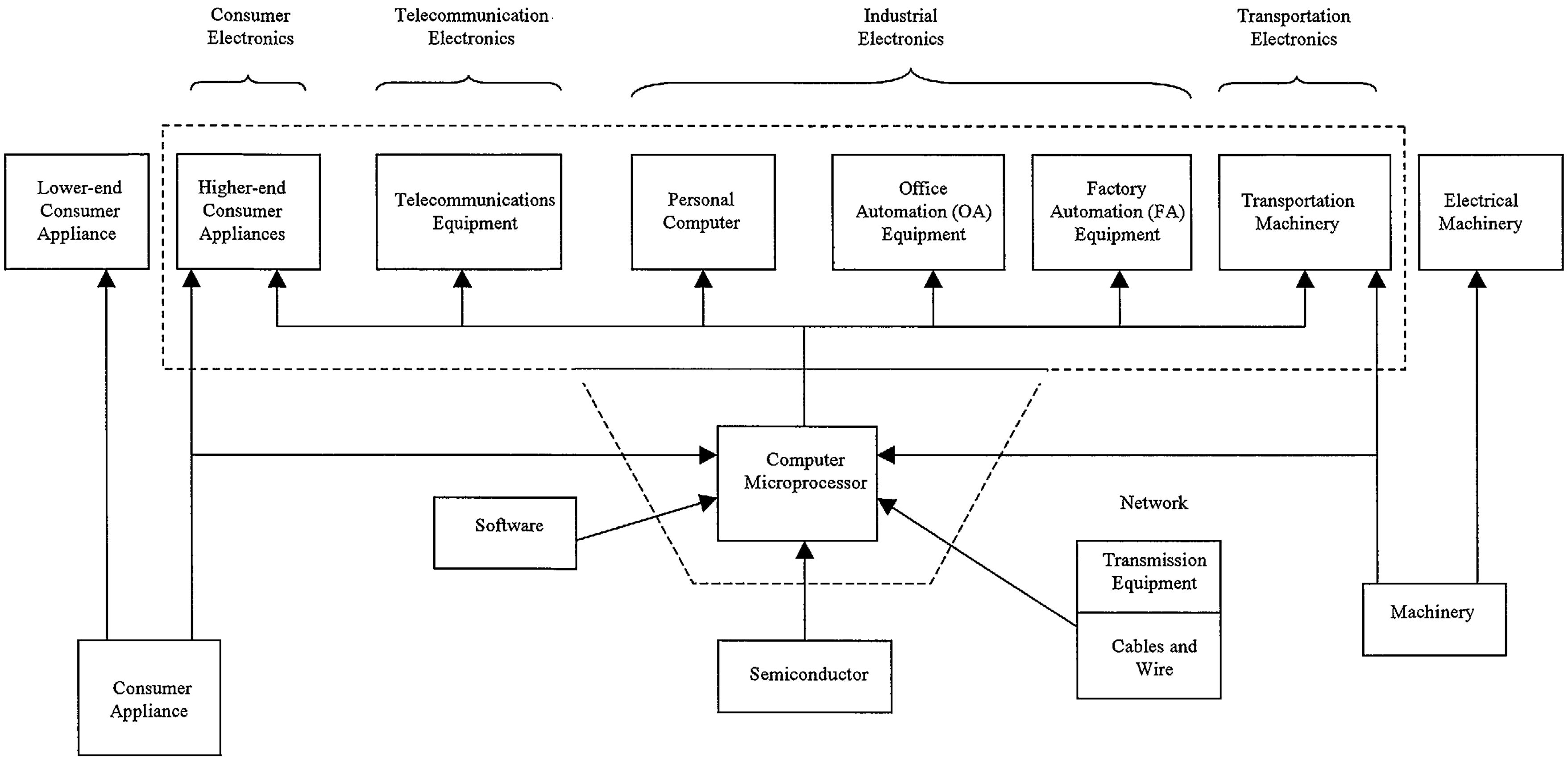
According to estimates, the total global market for the Electric and Electronics Industry in 1995 was US$820 billion, expanding at a rate of about 10% growth per annum. This market is projected to expand to over US$ 2,000 billion by 2002. The relative global market for various electronics products is as follows:

- Electronic Products — Approximately US$ 690 billion
- Personal Computers — Approximately US$ 100 billion
- PC Peripherals — Approximately US$ 30 billion

The United States and Japan still lead in controlling the key stages of the Electric and Electronics Industry, thereby holding the larger share of value-added activities. Korea and Taiwan have managed to develop some products and now enjoy co-ordination over the entire value added chain for these items.

Despite Malaysia's involvement in the production of almost the entire range of electronics products, its participation in the value chain is generally confined to low value-added segments (see Figure 1.1). Only a limited amount of engineering and product redesigning is carried out locally. The few Malaysian firms engaged in R&D still languish far from the technology frontier. Even the narrow supplier chains developed have been confined to servicing low value-added niches. Most innovative activities even in design and process R & D are undertaken by MNCs.

Figure 1.1: Product Groups of the Electronic Industry



Although strongly dependent on the semiconductor sector, electronics firms in Malaysia are also involved in a wide range of electronics production. With the recovery of the global electronics market the industry in Malaysia has begun to record positive growth since the second quarter of 1999. However, the industry is heavily dominated by MNCs specialising in low valued added assembly and testing activities.

Globally, in all sectors of electronics technology, the cost of manufacturing is rising, causing a fall in profit margins. This is due to both surface mount technology and current generations of PCB fabrication, which requires expensive, highly automated, process control intensive facilities, and considerably more experience than is necessary in traditional assembly and single and double sided PCBs. There is a need for the development of more flexible production systems in order to respond to rapidly changing production demands.

4.1 Asian Rivals with Superior Production Capabilities

Japanese firms enjoy control of the entire value-added chain, whether located within or outside Japan. A significant share of the assembly and testing activities of Japanese firms are located outside in developing economies. Korean and Taiwanese firms enjoy control over the whole product chains for a number of electronics goods.

Most of the SMEs of South Korea and Japan are third and fourth tier suppliers within closed supplier systems; the industrial district model of Silicon Valley and Route 128 does not exist in East Asia. Nevertheless, Japan and the NICs all have a population of "focal firms" or system integrators with independent design and product development capabilities. These firms are critical to sustaining growth. They form the population out of which emerge new, rapidly growing firms that carry with them new principles of production and organisation. With the exception of MNCs, Malaysia still lacks competitive focal firms. Because MNCs enjoy such support in their parent locations, the conditions for effective systems integration that characterise the Silicon Valley and Route 128 are seriously constrained.

4.2 Asian Rivals with Lower Wages

Malaysia's low cost competitive position is increasingly being eroded by competition from newcomer sites in similar segments, especially China. Rising production costs and serious labour shortages have undermined its competitiveness in a number of segments, which have relocated to China, Indonesia, the Philippines, and Thailand. The current financial crisis is threatening to drive more firms to China and Thailand. Interviews show that at least one disk drive company moved aspects of production to Thailand in the period 1996 – 98.

Other competing economies that are entrenched in assembly, test, and shipment activities in East Asia are Thailand, China, and to a less extent Indonesia and the Philippines.

China is a major threat to the Malaysian Electric and Electronics Industry with or without rapid restructuring. If state enterprise reform is slow and growth declines, China's authorities will be under pressure to devalue their currency thus fostering cut-throat competition. If state enterprise modernisation is fast, China could well build a powerful production system with a competitive advantage in low wages that could be hard to compete against. The decline in wages and rise in labour reserves in Thailand, Indonesia, as well as a resurgent Philippines has also made their economies lucrative for labour intensive production.

5. Product Groups

5.1 Semiconductor Sub-Sector

The semiconductor sub-sector still remains a solid platform for growth. According to the Second Industrial Master Plan (IMP2), it was estimated, prior to the recent recession, that the global market for semiconductors would grow at a rate of 16% per annum. In 1995, the world trade for semiconductors was approximately US$ 135.8 billion and by year 2000, it was expected to expand to about US$ 285 billion.

Malaysia's share of exports in semiconductors is quite sizeable comprising about 10% of the total global exports against only about 2% for PCs and peripherals. These exports are almost wholly dominated by locally based foreign MNCs. The share of exports by the indigenous sector is less than 10%.

Many of the largest semiconductor makers globally such as, Intel, NEC, Motorola, AMD, Hitachi, Texas Instruments, Fujitsu, and Samsung. Fairchild, Hewlett Packard, Intersil have several years of operations in Malaysia. Almost all of them operate primarily as assembly and test or production bases with little R&D. Their expertise could be transferred to local firms. Indeed, the local firms of Unisem, Carsem and Globetronics were started with personnel transferred from foreign MNCs. The MNCs could also be stimulated to expand their manufacturing up the Value Added chain.

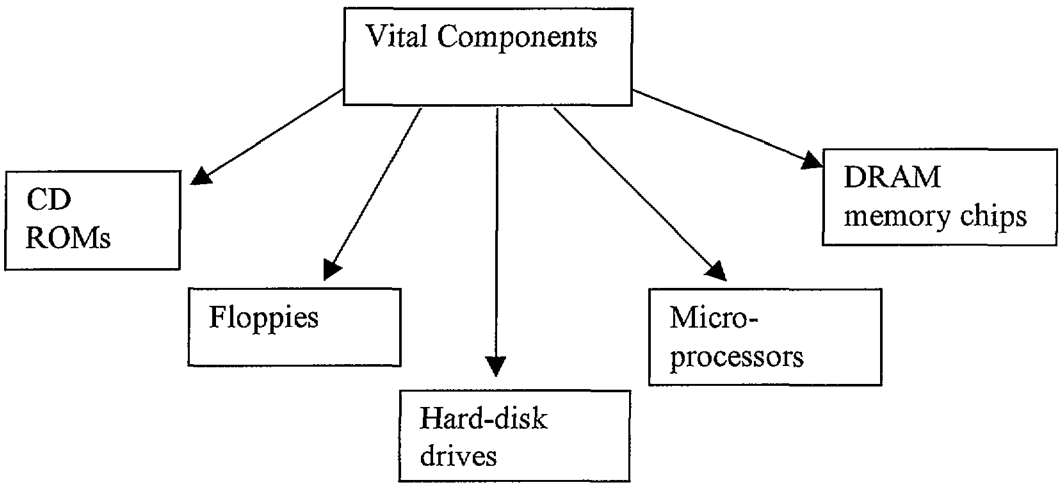
In terms of application markets, the semiconductor industry covers a wide range, including the following:

- Computers - 46%
- Consumer Electronics - 22%
- Telecommunications - 15%
- Industrial uses - 10%
- Automobiles - 5%
- Military - 2%

Source: RHB Research Institute.

Malaysia produces, or its products have applications, for all the above. The rapid growth of certain complementary user industries globally, shown in Figure 1.2, has substantially boosted the semiconductor industry world-wide.

Figure 1.2: PC Components Manufacturing



Source: RHB Research Institute

5.2 Electronics Contract Manufacturing (ECM)

ECM is the largest segment of the global electronics manufacturing services (EMS) industry. The world-wide market for ECM was US$60 billion in 1997 and estimated to reach US$125 billion by the year 2000, growing by about 28% per annum. With older firms preferring to move out from manufacturing to R&D and marketing, the demand for ECM activities has steadily grown.

Competition in the ECM industry is based on price, quality, reliability of delivery, range of available services, manufacturing capacity, and technological capabilities. Customers are also interested in geographic coverage with increasing interest in vendors who can provide low-cost facilities in both Europe and Asia.

In spite of these positive global trends in ECM, the challenges to local Malaysian electronics enterprises to actively participate and benefit from ECM are formidable. This is due to the following problems:

- Limited exposure in product focus and technology
- Excessive cost structure
- Limited flexibility of responses and just-in-time (JIT) delivery capability
- Capital pressures are increasingly intensifying
- Organisational limitations
- Very narrow range of services

Nevertheless, ECM represents a strong and growing market in the global electronics sector. A few local companies in Malaysia are already in the ECM business; prominent among them are Globetronics, Shinca, Trans Capital, Unisem, Carsem, and Unico. While ECM activities remain lower added than R&D and marketing, it is an important segment for efficient firms to move through the learning curve. Efficient operations can still make such ventures profitable. Foreign owned Solectron is an ECM, and its share prices soared far more over the last few years than that of Microsoft and Intel.

Flexible Production Systems. Foreign MNCs enjoy cutting edge process capabilities and are able to meet with technology, design, product, and market changes because of direct connections with their overseas plants and networks. The indigenous firms do not have such connections and networks. As product cycles are increasingly becoming shorter, now measured in months rather than in years, indigenous firms have been unable to grapple with the problems of evolving product cycles, obsolescence, changing technology, and market demands.

Among the most important technological issues are the growing requirements to:

- Develop new packaging designs to accommodate higher pin counts and increasing integration in smaller components
- Develop technological competence to respond to quick changes and to overcome the problems of product obsolescence
- Develop efficient production capabilities that are agile and swift to meet changes in product design.

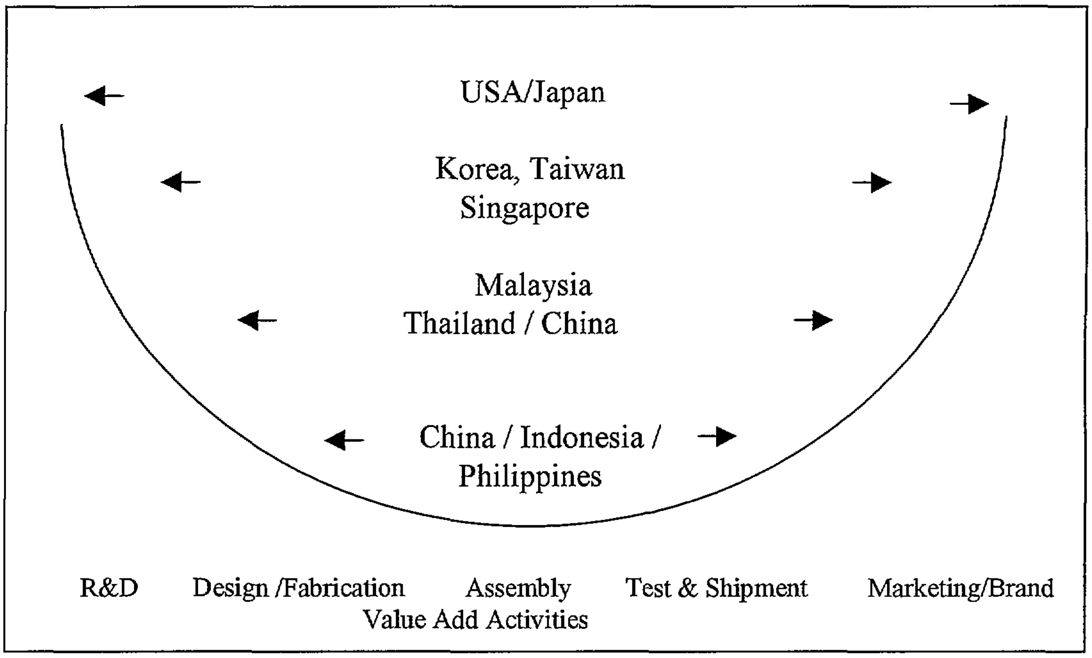
MNCs were neither creating significant amount of new product technologies nor have they equipped their subsidiaries in Malaysia to develop them in an unending stream. It is extremely difficult for any electronics firm without the requisite capacity in Malaysia to generate rapid innovations so as to enable its transfer to local personnel. MNCs have continued to retain their key R&D activities in their parent locations. Rapid technology changes are also occurring in automated tape bonding, chip on board, flip chip, multi-chip modules, and ball grid array. All of these new technologies require significant research and capital investments.

None of the new technologies were invented in Malaysia nor are there innovative and indigenous Original Equipment Manufacturers (OEM) that can challenge competitively in the global market. The limited OEM capabilities developed by local assemblers do not include such technologies. Carsem, Unisem, and Globetronics come the closest to acquiring such technologies.

5.3 Personal Computer (PC) Sub-Sector

The PC market is a major sub-sector of opportunity. As indicated in Figure 1.3 the global growth rate of the PC industry market was, on average, 18% per annum from 1985 to 1994. The total world trade of PCs and peripherals was estimated at US$ 130 billion in 1995. Despite the 1996-98 recession, it was expected to expand to US$ 249 billion by the year 2000. The strong recovery seen in 1999 suggests that the industry will achieve such a target.

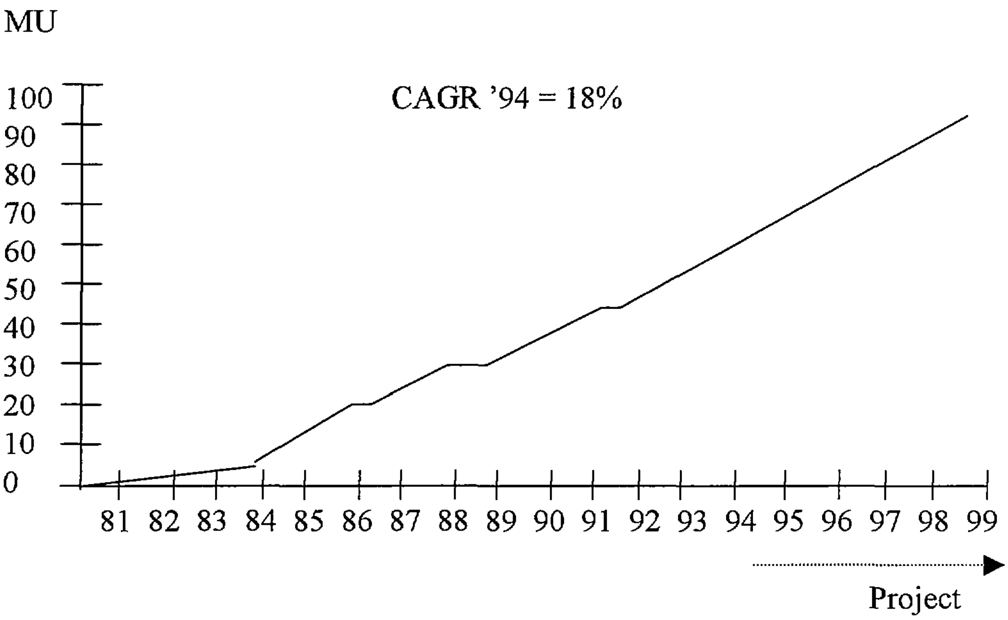
Figure 1.3: Location of Electronics Firms in Value - Added Chain, 1997



The PC is the "body" of the semiconductor industry. The chip is like the heart and brain that powers the PC. One significant characteristic within the PC industry is rapid product evolution. This requires heavy and continuing investments, and up-to-date integration of what is taking place within the Electric and Electronics Industry.

An important area that is crucial to the PC industry sub-sector is vital components, as indicated in Figure 1.4. These components offer the Malaysian Electric and Electronics Industry the opportunity to develop stronger linkages between local suppliers/manufacturers and MNCs producing PCs locally. Malaysia's PC industry, though still small in comparison to its semiconductor and consumer electronics sub-sectors, is nevertheless growing rapidly in line with projected growth trends. Strategies to achieve such targets will make the industry more integrated, thereby unleashing substantial synergies.

Figure 1.4: PC industry growth



5.4 Chip Sub-Sector

After a period of panic and uncertainty following a glut and depressed prices, the chip industry showed a recovery from the mid-1990s. The strong decrease in semiconductor prices in the second quarter of 1998 left chipmakers worldwide reeling. Malaysian-based companies are no exception. This is especially true for the Dynamic Random Access Memory (DRAM) chips. Prices of the DRAM chips, a benchmark for the semiconductor industry, fell over 25% in the April-June quarter of 1998. End-user demand has virtually dried up in Asia due to the economic downturn further depressing a market where excess supply already existed.

The recent recession has had a strong negative impact on chipmakers in Singapore, South Korea, Taiwan, and even the US. Singapore-based chipmakers reported sliding revenues and utilisation levels in 1997. The slowdown in the chip making and assembling industries led to downsizing from 1995 to 1998. Singapore's exports of integrated circuits, which account for about 13% of its non-oil domestic exports grew just 1.4% in the second quarter down from 21.7% in the first. South Korea's two largest chip-makers, Samsung and Hyundai, were only working at half capacity and Taiwan's largest chip-making companies have reported falling sales, several months in a row. Even US chipmakers have not been spared, with most announcing weaker than expected earnings and chip-related companies are already in the process of retrenching staff. In 1998 alone, about 5,000 staff had been laid off in the US.

The decline in the chip-making industry brought bad news for Malaysia. Questions were raised about previous plans to build a number of wafer fabrication plants on the strength of past estimation of global demand as well as on the anticipated advance of the local Electric and Electronics Industry. The turnaround in global demand since the second quarter of 1999 suggests that demand had bottomed and that the industry is poised to ride an upswing. Indeed electric and electronics output and exports has been one of the prime drivers of Malaysia's recovery seen from mid-1999.

6. WTO and AFTA

In the late 1960's, government development strategy shifted from import substitution to export growth. Generous incentives were shifted to exporting firms, including pioneer status and investment tax allowances. Foreign investment and employment in the Electric and Electronics Industry increased rapidly.

The first big wave of electronics firms were dominated by multinationals, many from Silicon Valley and Japan, seeking low wages to build labour intensive assembly branch plants. A second wave of Asian electronics firms arrived in Malaysia in the late 80's. This was driven by the Plaza Accord of 1985 which drove the yen appreciation from 150 to 80 yen to the dollar and secondly, the withdrawal of the generalised system of preferences from the Asian NICs in February 1988. The first wave of foreign investments in electronics was almost entirely devoted to components (over 80% of value-added until 1986) while the second wave expanded the consumer and industrial sub-sectors of the industry.

Malaysia has continued to offer a variety of incentives to encourage the development of the Electric and Electronics Industry but this will be influenced by current WTO and AFTA agreements. If Malaysia continues with its deregulation schedules, as required under WTO, it will have to abandon trade-balancing incentives by 2003. As a consequence, the government must phase out incentives gradually so that export incentives - the export credit refinancing scheme, subsidised insurance schemes for exports (including use of warehouse) and double deduction exemptions for exports, will be removed by the year 2003. It will also have to avoid reintroducing tariffs exceeding 5 percent after 2003. Additionally the WTO does not allow privileged treatment of local and indigenous firms over foreign owned firms in the provision of sales tenders, offer of indirect incentives such as R&D, and allocation of infrastructure support services.

Government instruments that are allowed include incentives for indirect support, such as training and R&D incentives and controls on environmental pollution. Such provisions cannot discriminate against foreign firms over local firms. To prevent the sale of local firms to foreign interests that may work against the interest of the country, the WTO allows for legislation regarding the operations of firms. The WTO conditions allow for government capitalisation of firms, which can be an important channel for local and indigenous firms to access scarce capital. While AFTA is WTO-consistent, it also allows for countries to slowdown or temporarily suspend deregulation initiatives when faced with an economic crisis. Since the WTO is more important, it is critical that Malaysia co-ordinate its operations taking cognisance of this broader trade body. Changing incentive schemes will also influence the basis for FDI in Malaysia. Previous incentives have successfully resulted in attracting MNC for manufacturing operations. Changes due to the WTO and AFTA agreements mean that many of these incentive schemes will need to be revised. Chapter five examines incentives in detail.

7. Changing Basis of Competitive Advantage

7.1 Production Management Teams and Rapid Ramp-up

Also, foreign MNCs continued to stay even during the recession, in part, because three decades of electronics production in Malaysia have created a new competitive advantage. This advantage is the organisational capability to combine low lost, high volume production with short cycle times to set-up, ramp-up, and operate replica plants to identical plants and product lines located near corporate headquarters. The managing director of an American company explains that his company takes over a decade to build a loyal and talented staff of 30 to 50 mid-level technicians and managers. This local management team would be hard to replicate in short notice in lower wage regions and the total cost would be three to four times more for an equally capable team in the United States.

The competitive advantage of the local team is the capability to recreate a production plant originally established elsewhere or to ramp up a product that previously was only produced on a pilot plant elsewhere. This also involves the management ability to achieve high performance standards from a low paid labour force operating with expensive machinery.

Three decades of electronics production in Malaysia have also led to regional advantages. The existence of a critical mass of electronics producers, particularly in Penang and the Klang Valley, has resulted in the development of a transportation infrastructure and a supplier base that facilitates local procurement and ease of importing and exporting. However virtually all of the first and second tier suppliers to assemblers are also MNCs. These firms do most of their product design, new product development, and technology management activities at their home base. The indigenous companies, except for a handful, feature insignificantly in this respect. Thus, the competitive advantage of Malaysia has shifted from low wages and taxes to low cost, high volume production in replica of first and second-generation plants. Growth from productivity gains are limited because high value-added activities are done elsewhere. Also, with unemployment likely to fall back to around 3.0% from the 3.9% in 1998, the potential to drive the growth of manufacturing through the employment of low-skilled workers has become limited. The unemployment rate at the time the financial crisis struck in 1997 was 2.5%.

MNCs product design and development capabilities have not been diffused to local companies. New products are only transferred to Malaysia after they have been manufactured successfully in full-scale plants located near headquarters. Such replica plants generate considerable export revenues, but does not require the development of a multi-skill labour force capable of running a flexible production system. A classification of the types of electronics firms in Malaysia suggests why. Four types of firms in electronics can be distinguished.

The first group is the first and second tier MNCs. These firms export virtually all of their production. The second group is the sub-contractors to the first group. These firms are small and medium-scale enterprises (SMEs) but, unfortunately, are few in numbers and located mainly in Penang. Most sub-contractors to the MNCs are in non-electronics activities such as plastics and metalworking. The third group is the large, fast growing local firms that both export and sell domestically. Most of these are spin-offs from the MNCs. Again, unfortunately, this is a small group made up of less than 20 companies. Nevertheless, they are critically important to any comprehensive electric and electronics industry strategy. The fourth group is the SME industries. Here, there are hundreds if not thousands of relevant firms, many of which are not listed as electronics companies but which are foundation firms for the industry. This group is also fundamental to the future of the Electric and Electronics Industry because making the production transition to systems integration involves the proliferation of SMEs and these firms are particularly dependent upon well-designed strategic industrial policies.

Generally local and indigenous plants in Malaysia are high-volume, single-product plants closer to the Ford single-product production system than the Toyota multi-product system. Henry Ford's mass production system drove down costs of production by an order of magnitude. This was price-led competition and it remains equally valid today. However it does not provide the organisational capabilities to be able to produce a range of products on the same production line or to introduce new products rapidly. These capabilities are critical in the highly dynamic Electric and Electronics Industry. Only a handful of local firms that have benefited from hiring staff generated from the rising levels of learning while working in MNCs, and hence installed multi-product lines, albeit with little integration of R&D and marketing.

The development of the Toyota production system, including both the technical and organisational advances, introduced into the world economy firms that could compete on the basis of three inter-related performance criteria: cost, quality, and time. Later, the drive to reduce time, in the form of production cycle time, spread to new product development time and to technology diffusion time. This virtuous dynamics drives the leading consumer electronics regions today.

There is an urgent need for Malaysia to move up the electronics ladder to higher valued added production activities. Moving to a new high growth path means making the transition from level three to levels four and five along the production capabilities spectrum (Appendix 3). This means developing a competitive advantage in complex production activities. The successful newly industrialised economies that have made the transition to indigenous production in a range of electronic components and intermediate goods have done so by building variants of the Toyota production system.

Moving to a new, more comprehensive performance criteria is fast becoming a requirement at every level of the global production chain. The provision of technology related services are rapidly becoming a basis of success. In the recent past, electronics suppliers could be successful by offering world class performance in cost, quality, and delivery times. Today, the same supplier must meet technology related service requirements as well. For example, Cary Kimmel, a Xerox executive, lists the engineering services demanded of a "model" supplier: design services, test engineering and equipment design, component qualification, failure analysis, value analysis/value engineering, and prototyping.[3] Kimmel reports that Xerox survey of suppliers in East Asia conducted over the 1985-87 period revealed the following:

> Companies that provide S&T [factors related to service and technology] experienced a growth rate of over 400 percent during the three-year period compared with only 30 percent for the more traditional contract manufacturing companies. It is more than passing interest that the greatest growth was experienced by those companies located in countries with well-defined national policies that encouraged the growth of S&T capabilities.

To compete in the higher value added production areas Malaysian Electric and Electronics Industry must upgrade their electronics production capabilities to meet the new performance criteria. Such capabilities will provide a competitive advantage based on organisational capabilities required of product-led competition. Malaysia's current situation reveals a number of strengths and weaknesses.

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3 Kimmel (1993), p. 156.

7.2 Strengths

Malaysia has built up unique capabilities in assembling and packaging chips over a history of two or three decades. Strong teams can march quickly into production of a product and process design elsewhere. This capability can and is being applied in other products including disk drives and, more recently, personal computers.

Malaysia enjoys an emergent R&D capability in product redesign for Asian markets around Intel, HP, Dell and Motorola. Each of these companies has built up R&D staff in Malaysia that could foster the integration of new product development and production.

Malaysia is part of a global production system spearheaded by the MNCs linking technology development centres in Silicon Valley and Tokyo with a regional system composed of Singapore, Malaysia, and surrounding lower wage areas. Malaysia has an opportunity to both upgrade production capabilities and to be a procurement centre for local component productions.

Malaysia enjoys an untapped resource in its MNC's. Besides Silicon Valley, MNCs from Japan, Europe, South Korea and Taiwan are also represented in force here. The knowledge embedded in these companies represents a potential resource that can, with appropriate policies, be tapped to local advantage. The resource here is not simply the enterprise capabilities of leading firms but the ideas of industry leaders which can be used as inputs into the production of a technology policy that can, in turn, feed back into investment decisions in the industry. In isolation, this knowledge does not contribute to the emergence of a clear concept for development of competitive advantage in a specific region's industry. The knowledge gains substance when it is collectively shared in the exchange of ideas and the emergence of shared concepts. It then becomes real knowledge and a powerful input into technology policy, which, in turn, can drive technology management, the source of regional growth.

The Penang Development Corporation is a world-recognised model of successful local industrial policy. The PDC has succeeded in attracting the leading electronics companies in developing skill-upgrading programs at the technician level, in promoting and assisting in the finance of spin-off companies. The PDC model can be applied in other parts of Malaysia. It can also be extended within Penang to target a third group of companies, the large/fast growing companies seeking to develop independent product development and technology management capabilities.

Some small and medium-scale industries (SMI's) have increasingly developed the capability as component suppliers to the MNCs. This has been achieved through government support and MNC assistance through better supplier-MNC assistance. Some SMI's have even developed the potential for export. They are, therefore, moving up the value chain, although at a slow pace.

The Malaysian government has undertaken technical management planning to develop and implement industrial policies. The IMP2 and a number of related government programs are aimed at assisting in the development of the local Electric and Electronics Industry. The IMP2 is examined in detail in chapter two.

7.3 Weaknesses

The Malaysian Electric and Electronics Industry is losing its traditional competitive edge. Labour shortages and increases in wage rates relative to other countries are eroding Malaysia's competitive advantage as a low-cost assembly and testing location. These problems will be increasingly compounded by regulatory changes required in following WTO and AFTA agreements that will result in the phasing out of export incentives and local production incentives.

While electronic exports are substantial most electronic exports are comprised primarily of imported component parts. The local industry is dominated by foreign MNC's with most value-added activities and research and development activities occurring in overseas locations. These weaknesses are symptomatic of underlying structural limitations in the Malaysian electronic industry. These weaknesses must be addressed for Malaysia to make the required transition to higher valued-added electronic production.

While Malaysia's electronics exports account for a significant percentage of total exports, imports of component electronic parts has continued to burden the balance of payments. This balance of payments dilemma is a manifestation of deeper, structural problems confronting Malaysian industrial development. The foreign share of fixed asset ownership in electronics was 91% in 1994. As part of global networks, the production of electronics in Malaysia has been geared nearly entirely to foreign markets. Despite several efforts by the government especially since the late 1980's much of the country's operations still remain as export processing platforms using imported inputs.

A general complaint of MNCs is that few indigenous firms are able to supply the goods the MNCs want; particularly those of the right quality, specifications, prices, and service. On the other hand, many indigenous firms do not actually take the serious efforts nor do they have the capital adequacy and skills required to firmly develop market niches with the MNCs. Yet, this integration, from many international experiences, is crucial to encourage effective clusterisation, complementation, and linkages to support indigenous entrepreneurship development, upgrade indigenous technology and R&D initiative, and to develop a more meaningful partnership between the indigenous sector and the MNCs.

Malaysian industry is lodged in low-skill labour. FDI in electronics has introduced limited, complex production process activities. The foreign owned electronics companies have not widely diffused or, as yet, triggered the diffusion of, complex production process activities within Malaysia. Instead, they have located in Malaysia activities such as the assembly and testing of chips.

The success of the Malaysian Electric and Electronics Industry in the first two and a half decades was based on attracting FDI. A range of foreign-owned Malaysian production sites, especially in Penang, the Klang Valley and Johor, have introduced modern manufacturing practices including just-in-time production and variants of total quality management. However, few have made the transition from simple assembly to more complex production that requires a labour force with technical, problem-solving, and managerial skills. The highest skills that are introduced tend to be associated with tending automated machinery rather than with kaizen and multi-task activities. Furthermore, new production methods have not been diffused to create a critical mass of local and indigenous firms. Malaysian owned business enterprises have not converted the stimulus of FDIs into domestic production capabilities in the form of vibrant vendor-based firms, supplying intermediate, component, and capital goods on scale enough to achieve substantial gains in import substitution.

FDI has provided access to international markets and to labour intensive activities but, with some exceptions, it has not resulted in the introduction of integrated production systems into Malaysia or even the high value-added or advanced manufacturing links in the industrial chain. This introduction does not occur without the intentional creation of an interactive (vs. inter-passive) relationship between the host economic development agencies and foreign business enterprises, which together advance the production capabilities and skill base of the nation. Consequently, despite its tremendous potential, FDI, on its own, is not and never has been sufficient for diffusing new production and business practices and thereby developing indigenous innovation, production and marketing capabilities in the absence of concerted complimentary local initiative. The development of greater regional synergies, and local capabilities require initiatives to complement and eventually enable production, R&D and marketing networks linking equally interdependent foreign and local firms.

There is a lack of inter-firm networking in the Electric and Electronics Industry. While MNCs produce a whole range of parts and sub-components for the electronics industries, they do not co-ordinate locally but with global production networks. The lack of inter-firm networking using electronics is one dimension of industrial fragmentation. A second is the lack of linkages between electronics and other sectors within Malaysia. Here the contrast with either the industrial districts of Taiwan or the closed production networks of Japan and South Korea is pronounced.

There is a lack of industry diversity. Exports of semiconductors accounted for about RM35 billion or 38.2% of total exports from the electronics sector. This is a clear indication of the significant position of semiconductors in the country's Electric and Electronics Industry. This reflects a very successful sector of the Electric and Electronics

Industry. However, it also reveals a basic weakness where the industry is overwhelmingly dependent on exports of semiconductors.

Although a number of electronics appliances are presently being produced in Malaysia to cater for domestic needs and for export, many are still being imported, due to the market needs for products of different designs and capacities. Products being imported include vacuum cleaners, grinders, mixers, juice extractors, washing machines, ovens, floor polishers, shavers, hair dryers, dehumidifiers and cooking pots. On the positive side, increasing convergence of trade deregulation offers the opportunity for reaping economies of scale of production to produce these items through exports.

The expanded GDP and diversified structure offer significant opportunities to support large-scale production and complementary linkages within and across the sector in Malaysia. Malaysia can be very competitive in the world market, as evidenced by being the largest exporter of room air-conditioners in the world. It is possible to extend this competitive edge to a wide range of electronics products.

Given the current status and development of the electronics industry in the country, Malaysia is now targeting the development of Malaysia's own brands of industrial and household appliances particularly for the export market. However there are certain threats of which Malaysia can turn into opportunities.

In the area of technology management, the Electric and Electronics Industry in Malaysia has been an accidental sector. It has been treated no differently than textiles or primary products until the 1990's. From there on, it has been treated only superficially better due to the shift in the emphasis from export-oriented to strategic. In contrast, technology policy development in local firms has been a central goal in government industrial policy in Japan, South Korea, and Taiwan for decades. In each of these cases, a range of intermediary agencies implemented key aspects of institutional development required by governmental technology management policy.

There is a shortage of skills pervading the Electric and Electronics Industry and a need to train entrepreneurs, engineers, technologists and skilled professionals for the industry. These personnel are crucial for the modernisation of the industry but unfortunately, the indigenous sector has not been very successful in providing the breeding ground for entrepreneurship development and for the development of skilled personnel in areas of innovation, R&D, design, and new product development.

There is a lack of requisite human resources particularly in engineering and science related areas. For example, Malaysia has only 400 R&D scientists and technicians per million people in contrast to 6,000 for Japan, 2,200 for South Korea, and 1,900 for Singapore. Similarly, only 7.2% of Malaysia's higher education age population were enrolled compared to 37.7% for South Korea.

The lack of skilled personnel, knowledge, and technology has had an inhibiting impact to productivity within the industry. Most local electronics companies and the supporting and ancillary enterprises cannot afford state-of-the-art automation largely due to financial constraints and lack of innovative skills and human resources.

Malaysia has few indigenous entrepreneurial firms to drive the transition to higher value added production processes. A recent survey of product innovation starkly concluded: "...no electronics firm in Malaysia – whether local or foreign owned – in industrial, consumer or components sectors, has been involved in product innovation activities at the technology frontier."[4]

8. Addressing the Critical Impasse: Chapter Outline

Malaysia's electronics industry is at a critical impasse. It has strong manufacturing capabilities but the industry is dependent upon MNC's and is embedded in low cost, low value-added activities. In these areas Malaysia is gradually losing its competitive advantage. The Malaysian electronics industry must develop policies to reorient its competitive advantage. Chapter 2 examines the Second Industrial Master Plan. A set of cluster and transformational growth dynamics which can facilitate the realisation of the goals of IMP 2 are explored in Chapter 3. Other country experiences are described briefly in Chapter 3 and in Appendix 4 and policy implications are drawn.

The variation in models and policies suggests that, in principle, more than one path to a new competitive advantage is possible. At the same time, the variation suggests that a successful strategy must be developed given the unique circumstances of Malaysia, Other countries provide lessons, not blueprints for success. A successful strategy must be anchored in an objective assessment of the strengths and weaknesses of the current industry. Chapter 4 examines the three major electronics regions in Malaysia from a cluster dynamic and technology management perspective. Chapter 5 assesses the extent to which the government's Second Industrial Master Plan (IMP2) addresses the critical issues outlined in the cluster dynamics and technology management perspective. Chapter 6 turns to policy recommendations.

4 Rasiah, R (1996). Institutions and Innovations: Moving Towards the Technology Frontier in Malaysia's Electronics Industry, *Industry and Innovation*, 3 (2), p. 11. Seventy-three companies responded to the survey.

Chapter 2: The Second Industrial Master Plan (1995-2005)

1. Introduction

The Malaysian electronics industry has reached a critical impasse: it is caught between lower-wage rivals that are imitating Malaysia's present production capabilities and higher-performance rivals with superior production capabilities. Sustained growth depends upon making a transition up the production capability spectrum.

This critical impasse and the need for structural change within the Malaysian electronics industry has been recognised by the government. The Malaysian government under the Second Industrial Master Plan (IMP2) and the 7th Malaysia Plan has proposed an integrated supply chain and clusterisation as important strategies to move the electronics industry ahead. The IMP2 aims to achieve this transition through a range of methods, outlined in this chapter.

The IMP2, posits that sustained growth demands that the Malaysian electronics industry make a transition "...to more automated operations involving high technology and knowledge-driven processes. It won't be simple: ...this internationally-linked group (the electronics industry in Malaysia) which has been driven by; rapid changes in technology, product development and innovation, changing consumer preferences and a short product life cycle, faces a number of challenges" [5]

2. The Shift from IMP to IMP2

The IMP2 re-emphasises Malaysia's effort to propel itself forward and become an industrialised nation in the twenty-first century. This is proposed to be achieved through the use of the concept of cluster development. Cluster development's aim is to develop greater linkages and complementation between firms in the electric and electronics industry. It emphasises the *Manufacturing* ++ orientation, which highlights the need to move beyond looking at manufacturing processes alone to recognise the need for the strengthening of industrial linkages in enhancing value-added production activities. Unlike the IMP (1986-95) which focussed on achieving sectoral growth as the means of achieving growth, the IMP2 emphasises clusterisation as the basis of sustainable movement towards the industrialisation frontier.

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5 MITI (1996), p. 63.

The IMP had three broad objectives, *viz.*,[6]

- To ensure the continued expansion of the economy through the accelerated growth of the manufacturing sector in order to meet the objectives of the New Economic Policy (NEP).
- To promote the optimal and efficient use of the nation's natural resources through value-added manufacturing.
- To lay the foundation for the development of indigenous technological capabilities

The IMP2 was designed to build on the successes of the IMP. It aims to address the issues and challenges that have been identified in order to sustain and enhance the momentum of growth in the manufacturing sector.

The government aims to achieve this through the following strategic thrusts of the IMP2.[7]

- Global Orientation.
  The IMP2 is designed to reorientate the local industry from being purely export driven, to an industry based on global orientation. This is to be achieved through:
  - The development of indigenous companies to become world scale and world class manufacturers by;
    - Developing their global marketing capabilities
    - Developing their ability to compete internationally while not relying only on cost advantages

- Enhancing Competitiveness.
  The IMP2 will foster competitiveness in industries through a;
  - Focus on clusters through the deepening and broadening of industrial linkages
  - Productivity enhancement

- Improving the requisite economic foundation.
  The IMP2 has recognised the need for the development of a strong base in the requisite economic foundation. This is to be achieved through the development and management of;
  - Human resources
  - Technology acquisitions
  - Enhanced absorptive capacities
  - Physical infrastructure
  - Supportive administrative rules/procedures

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6 IMP2, p. 7

7 IMP2, p. 11

- Fiscal and non-fiscal incentives
- Business support services

- Malaysian owned manufacturing companies.
  The IMP2 recognises the importance of foreign MNCs that have contributed towards the electric and electronics industry's success. However the IMP2 posits that Malaysian indigenous firms must assume greater importance and become larger companies. The intended result is a higher percentage of the electronics income being retained within Malaysia and an increase in the domestic share of the value added activities. This is to be achieved by:
    - Increasing participation of indigenous companies in a broad range of manufacturing activities, especially in cluster based activities
    - The development of indigenous firms into large companies geared towards regional and global markets

- Information-intensive and knowledge-driven processes.
  This is to be achieved through a concentration on:
    - R&D
    - Product design
    - Marketing
    - Distribution and procurement
    - Electronic commerce

The macroeconomic assumptions and framework of the IMP2 was based on some key factors. The first is that the economy was expected to maintain the momentum of an average annual growth rate of 8% throughout the period 1996-2005. It is also expected that there would be a continuance of the attractive climate for investment. A third assumption is that the momentum of growth achieved in the first half of the 1990s in the manufacturing sector will be maintained. The last assumption for the framework is that OECD countries register a growth rate of 2%. These assumptions have been jolted by the 1997-99 economic crisis although the focus on cluster development can be continued without some of them.

3. Clusterisation in IMP2

The defining characteristic of a cluster is the high degree of connectivity between firms. Clusters are an agglomeration of inter-linked or related activities comprising industries, suppliers, critical supporting business services, requisite infrastructure and institutions. The existence of a mature cluster requires the development of ancillary industries and economic foundations in support of the core industry.

The IMP2 has proposed clusterisation as an important strategy to move the electronics industry forward. The IMP2's basic proposals have advanced clusterisation of electronics and electronics associated industries based on industrial synergies, complementation, and linkages. It incorporates electronics companies, supplier firms, R&D organisations, electronics associated service facilities, training and HRD institutions, infrastructure and amenities, and relevant government agencies. All these would work together complimenting and linking with one another to drive the electronics industry ahead to greater innovation, R&D, competitiveness, and new product development along the value-added chain.

The IMP2 identified two antecedents to be considered in the process of developing clusters in the electronics and electrical industry:

- Finding the missing links and promoting investment in these areas. The missing links are the core activities currently absent in the local industry that are required for the industry to have control over the complete value added chain
- Creating a cluster that is closely knit through information networks that possess flexible manufacturing capabilities

3.1 Potential Industry Clusters[8]

Three broad types of potential industrial clusters have been identified.

- Internationally linked clusters. These are clusters that are based and driven by foreign MNCs. The electric and electronics industry cluster is placed under this category. It has a high concentration of foreign MNCs whose products are for the global market. It has been noted by the EPU that "...the primary source of technology will continue to be foreign enterprises..."[9] in the electronics sector. This sector is dependent on global factors for growth and sustainability
- Resource-based clusters. These are industries that are based on Malaysia's natural resources. These industries have a high degree of indigenous firm involvement.
- Policy-driven clusters. These are industries that are technology-driven and identified through government policy initiatives. It is these industries that are believed to be critical for the development of particular capabilities.

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8 IMP2, p. 31 - 32

9 EPU (1996), p. 2

3.2 Malaysia's Industrial Clusters

The IMP2 has categorised eight Malaysian industrial groups of into clusters. Some of these groups are well defined and noticeable as clusters while others have the potential to become clusters.

These groups are the;[10]

- Electrical and Electronics Industry Group
- Transportation Industry Group
- Chemicals Industry Group
- Textiles and Apparel Industry Group
- Resource-Based Industry Groups
- Materials and Advanced Materials Industry Group
- Agro-Based and Food Products Industry Group
- Machinery and Equipment Industry Group

3.3 Existing Regional Industrial Groupings

The cluster concept in the IMP2 looks at regional concentrations based on the premise that industries require high degrees of employment concentration, buyer/supplier linkages, specialised services, access to technology and sources of innovation. A regional Distribution Index was designed and used under the IMP2. This index has identified Penang as possessing the largest concentration of workers in the electrical and electronics industry. Other areas of concentration are Selangor and Johor with spillovers into Kedah, Negeri Sembilan, and Melaka.

3.4 Existing Foundations of Supplier – MNC Networks

Penang has a good foundation of viable supplier-MNC networks and development toward clusterisation. Many MNCs in Penang are already sourcing materials, components, services, training facilities, and other equipment from local suppliers. Further development of this supplier network will depend on how well the indigenous supplier companies are able to meet the requirements of MNCs in terms of quality, new product development, and competitiveness of products.

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10 IMP2, p. 32 - 33

The umbrella concept that some MNCs have developed will aid this process. Ideally this concept in the electronic industry will follow the Proton example. Although the form and essence of relationships is still debatable, Proton's umbrella concept whereby indigenous suppliers are trained and nurtured to produce certain Proton components. There are dozens of suppliers within the Proton umbrella. Intel also has an umbrella concept but unfortunately it trains and nurtures only Globetronics Technology personnel and some other personnel from its subsidiaries for these organisations to be niche suppliers. Intel's other suppliers are mainly independent.

4. Critical Elements of the Cluster Approach

The IMP2 recognises four key elements to a cluster based industrial development approach. They are:[11]

- Clusters
  In accordance with the IMP2, the government would like to direct local industries within the concept of cluster development in order to develop greater linkages and complementation. The local electronics industry is a suitable candidate for this development. Many subsidiary industries are either directly or indirectly linked and complement the electronics industry. The Malaysian electronics industry has the diversity in various product groups to create the critical mass of networking and linkages crucial to the eventual development of clusters (See Appendix 4 for Institutional Audit).

- Value added and Value chain.
  The key to the clusterisation process as proposed in the IMP2 is to increase the value added activities resulting from the transformation of intermediate inputs into final goods or services.

  It is perceived that the local electronics industry has the potential to expand extensively along the value-added chain. The various segments of the electronics industry are expected to continue to develop depth as their supply chains and links expand across a wide variety of activities. These activities are expected to form an additional segment in the electronics cluster, namely the information technology segment. Thus, while the MNCs expand their value-chain and supply network, the local supporting and ancillary industries as well as the second tier electronics industry are envisaged to enhance their status from simple subcontractors, to Original Equipment Manufacturers (OEM), to Original Design Manufacturers (ODM), and eventually to Original Brandname Manufacturers (OBM). Some local electronics

11 IMP2, p. 25 - 30

companies are already moving in this direction but a critical mass of such firms needs to be nurtured in order to develop an eventual self-sustaining movement.

- Key suppliers
  Large and small firms are out-sourcing their sub-assemblies and services. This allows both firms to focus on their core competencies but rely on their extensive network of suppliers. The IMP2 has identified nine key supplier categories that require development in order for the clusterisation process to be carried out efficiently. They are:
  - Parts and components
  - Critical business support services
  - Logistic services
  - Technical business services
  - Electronic commerce
  - R&D
  - Manufacturing materials
  - Machinery, and
  - Packaging

- Requisite economic foundation.
  There are four factors to be considered under these requisites.
  - The generation of the human resources required as well as the ability to advance and renew the skills required fulfilling the demands of specific clusters.
  - To assist the degree to which industries are able to acquire new technology and develop and commercialise applications.
  - The right policies, incentives, and business friendly services to allow for a conducive environment for trade and investment
  - The provision of advanced transportation, telecommunication, information, power and environment protection systems, as well as industrial parks that facilitate the efficient operations of the clusters

5. The Need for Cluster Based Development[12]

The government has recognised numerous benefits of clusterisation. The cluster based industrial development approach addresses the issues of linkages and complementation in an industry. The requisite economic foundation must be noted and tied in with the central competencies of the industry cluster that are to be developed. Malaysia's electric and electronics industry's competencies lies in its low cost labour, mass assembly, and testing

12 IMP2, p. 22

capabilities. This current economic foundation is under attack especially after the recent crisis.

IMP2 seeks to deepen, broaden, and enhance industrial linkages based on a comprehensive and integrated network of activities. This is to be carried out via the opportunities provided to indigenous corporations, including SMI's, to achieve necessary economies of scale. It is posited that indigenous firms that have increased their economies of scale will be able to co-operate with MNCs providing products for MNC's and developing themselves to the same potential. The growth of indigenous firms is aimed at bringing benefits such as a reduction in the flow of funds out of the country.

The government has noted the current trend towards trade liberalisation and its effect on the electric and electronics industry. On one hand, many new economies are opening to up as markets for Malaysia's industrial products. On the other, the new economies are a threat to the local industry as they offer low-cost manufacturing bases with the potential to erode Malaysia's electric and electronics industry's current low-cost competitive advantage. Subsequently the electric and electronics industry must progress upwards and along the technology value chain into areas of product development and innovation.

The current IMP2 states that there may be a requirement for a third round of import substitution strategies to further encourage the manufacture of intermediate and investment goods. However as noted in Chapter 1, 74% of what the electric and electronics industry exports is made up is of imported components.

The IMP2 proposes that with a cluster based strategy further opportunities for the development of new industrial areas away from the traditional areas will arise. This will create opportunities for the generation of a range of wealth creating businesses.

With a strategy based on the IMP2, policy-makers and industrialist will be able to operate within a focussed, integrated and comprehensive framework. Synergy is expected to be created between both bodies. This will further add to the value-added activities and enhance competition in the electric and electronics industry.

A closely-knit cluster through IT, together with the flexible manufacturing equipment, can make the cluster efficient. This brings forth benefits such as: saving costs for the companies; bringing more interaction to speed up product designs; inducing innovations; cultivates trust - a decisive factor to business relations; and overall, allowing the cluster to be able to deal with the volatility of markets and stay competitive internationally.

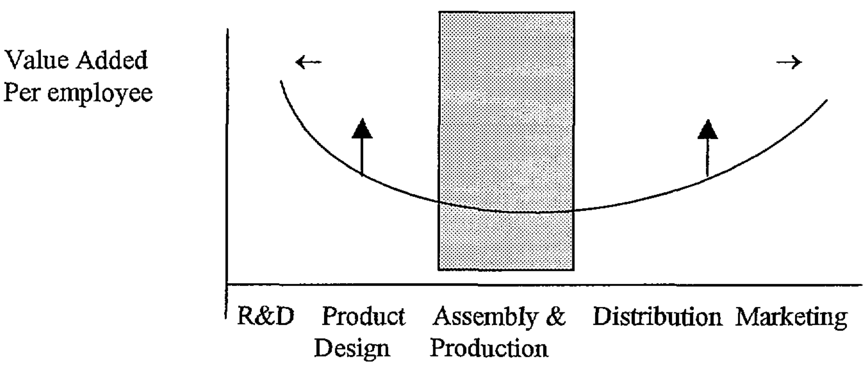
It is posited that with a strong supporting base in Malaysia, the electronics and electrical industry will be more willing to make Malaysia a production base and find it harder to leave as suppliers are established here. This is the "lock-in-effect" of a cluster. To tap the potential of this cluster, companies over the world may consider coming to Malaysia and participate in the cluster. A cluster formation will improve the linkages among companies creating greater multiplier effects from any increase in investments or increased demand for computers. The cluster will result in a complete value chain. There could also be interaction between the suppliers and assemblers in product designs and higher value-added activities.

6. Manufacturing ++ Strategy[13]

The Second Industrial Master Plan is based on a "cluster-based Manufacturing ++ strategy."

> The *Manufacturing* ++ strategy for Malaysia will entail not only moving along the value chain but more importantly place emphasis on productivity-driven growth such that the value-added per employee improves to a higher plane at all levels of the value chain.
>
> Cluster-based industrial development provides a basic framework that addresses the issue of markets, linkages and networks and relates them to the underlying core competencies that are central to the competitiveness of industrial clusters.

Figure 1.5: Manufacturing ++ Strategy



The IMP2 emphasises moving beyond manufacturing operations to include R&D and design capability, development of integrated supporting industries, packaging, distribution, and marketing activities.[14] The IMP2 focus is on the cluster based industrial development to improve on the existing industrial foundation of the manufacturing sector. The strategy calls for a further strengthening of industrial links in terms of breadth and depth across the value chain. This strategy entails not only the move along the value chain but also to place emphasis on productivity-driven growth, so that the value-added chain will shift to a higher plane (see Figure 1).

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13 IMP2, p. 31
14 IMP2, p.3

The strategy calls for two basic thrusts:

- a move along the value chain to increase the degree to which value added activities are undertaken locally
- the shift of the entire Malaysian chain to a higher level of activity

These thrusts are to be achieved through a number of policies following the strategic direction laid out in IMP2.

7. Policies and Strategic Directions of IMP2[15]

The IMP2 has identified six policies and strategic directions. They are:

- Developing the Value Chain. The electronic and electrical industry is dominated by foreign MNCs who have located their production in Malaysia. However most of these operations are in assembly and testing operations. The IMP2 strategy is to encourage these foreign MNC's to increase the extent to which these MNCs undertake higher value added activities in Malaysia. This is to be achieved through;
    - The encouragement and establishment of integrated manufacturing centres
    - Reviewing laws governing Free Zones (FZs) and Licensed Manufacturing Warehouses (LMWs)
    - Reviewing financial encumbrances that hinder the establishment of Operational Headquarters, World Headquarters, and International Procurement Offices in Malaysia

- Deepening the Supply Chain. The development of indigenous firms in order to develop domestic capabilities is one of the areas that the IMP2 intends to promote. This is to be carried out by;
    - Strengthening supply chains vertically and horizontally
    - Enhancing cluster linkages
    - Reviewing equity and export conditions

- Move to a Higher Technology Plane. The IMP2 has stated that it intends to move value added activities both upwards as well as along the value chain. The acquisition of necessary emerging technologies and core competencies are critical for R&D, product development activities, and to enhance productivity. This it to be achieved by:
    - Acquiring technology to design and fabricate wafer production
    - The development of local technological capabilities
    - Providing specialised Technology Parks for High-Tech Industries

15 IMP2, p. 79 - 85

- Establishing Wafer Fabrication Facilities. This strategy calls for;
  - At least one project of each of the main types of integrated circuits manufacturing
  - Fabless chip companies to be established in Malaysia
  - Technology acquisition based on the MIMOS model
  - Promotion of wafer fabrication
  - The conversion of silicon ingots from basic materials
  - Government support systems

- Develop World Class Malaysian Owned Companies. There is an assertion that due to the high rate of foreign MNC's in the electronics and electrical industry sector, Malaysian companies have acquired quality international standards. These quality standards can be used to create world class and world scale producers and suppliers. This is to be carried out by developing Malaysia's firms' capabilities as OBM.

  IMP2 suggests that this can be carried out by:
  - Supporting indigenous subcontracting companies in order to become OEM and OBM.
  - Providing government incentives to indigenous firms to assist in developing skills in high value added activities.
  - Liberal policies to allow expatriates with technical or specialised skills to enter the country.
  - MATRADE to organise promotional programmes for Malaysia brand name products to be sold regionally and globally.

- Develop the information technology (IT) and multimedia industry. The IMP2 expects this sector to be the next engine of growth and has stated applications for immediate development in the Multimedia Super Corridor (MSC). They are:
  - Electronic government.
  - Telemedicine.
  - R&D.
  - Remote Manufacturing.
  - Borderless Marketing Centre.
  - Multimedia Funds Heaven.
  - Multipurpose Smart Card.
  - Smart Schools.

8. Existing Action Plans to Boost the Industry

Given the foregoing and in view of various problems and challenges facing the local electronics industry, the government has launched a number of Action Plans to move the industry along the technology and value-added chain. In particular, emphasis will be given to indigenous R&D, product and design innovations, and new product developments of high quality and technologies capable of competing internationally.

Some of these Action Plans include:

- To complement the IMP2 plan, the Malaysian Industrial Development Authority (MIDA) set up a special division to assist the electronics industry. This assistance is in the form of incentives, information dissemination, and special assistance to investors in respect to rapid project approval, advice on factory locations, and liaison with respective state governments.

- The government has established the MSC, Cyberjaya, and several new high-tech parks, particularly the Kulim Hi-Tech Park, which will emphasise the promotion of the electronics industry. The MSC and Cyberjaya, in particular, will stress R&D in electronics and information technology (IT). To expedite these, the government has set up the Multimedia Development Corporation and has introduced a number of special incentives for firms that qualify for MSC status. To highlight the importance of the MSC, it is placed within the ambit of the Prime Minister's Department.

- MIMOS, an agency set up by the government and recently privatised, is to be an instrumental in creating various start-ups in the electronics industry. Its small wafer fabrication plant and various facilities for testing and packaging as well as initiatives for design innovation and R&D, will hopefully provide the catalyst for spin-off effects. MIMOS is situated in the MSC area and the government will actively co-ordinate with MIMOS on the future direction of the electronics industry in Malaysia. In particular, it is hoped that MIMOS with the assistance of the Malaysian Technology Development Corporation (MTDC), will be able to create numerous start-ups among the indigenous electronics sector.

- To develop the sector more rapidly and to spearhead R&D, the government has also provided allocations for financial assistance. Some examples of these assistance funds are the Industrial Technical Assistance Fund (ITAF) and the Intensification of Research in Priority Areas (IRPA) Fund. The funding assistance can be sourced through MITI, MIDA and Small and Medium-Scale- Industry Development Corporation (SMIDEC).

- The government has made a RM100 million allocation for a Multimedia Grant Scheme. The purpose of the scheme is to help SMI companies to participate in the

MSC. SMIs involved in multimedia, telecommunications, and IT are eligible for up to 50% funding if they qualify for MSC status, and also in case of joint venture companies where Malaysians have majority equity. The funding is primarily meant for SMI electronics firms to conduct research. At the end of 1998, the Multimedia Corporation received 270 applications for MSC status of which 201 (74%) have been approved. Of the 201 applications, 136 companies are already in operation. In terms of activities, 35% of the approved firms are involved in software, 19% in content development, 16% in systems integration, 10% in telecommunication, 8% in post production/animation/film, 6% in electronics, 3% in training/education, and 3% heavy users.

- The Multimedia Super Corridor (MSC) is another initiative to provide new impetus to the further development and modernisation of the electronics industry in Malaysia. It is a strategic project to attract organisations by providing the infrastructure to draw in Information Technology (IT) and electronics projects. The MSC is expected to spawn spin-off effects for research, development, IT innovations, and R&D in product development. It will also provide spin-offs in the development of service industries in IT and in the electronics and electrical sectors. In effect the MSC aim is to herald the formation of a compact electronics cluster where close linkages and complementation would be imperative. There has been a strong response to the MSC. International and locally based companies have expressed interest to participate in the MSC. [16]

- The development of the MSC and Cyberjaya and several high-tech industrial parks in the country with a high priority and emphasis on R&D will provide seedbeds to the efforts to create a cluster in the electronics industry. Further trends in the electronics industry point to the development of increasingly high-tech applications in the electronics industry.

These initiatives are aimed at developing clusters within the industry and transforming Malaysian Electronics from a low-cost assembly site toward more advanced value added activities. A series of governmental technology-policy related measures have been introduced. The take-up rate of government incentives aimed at stimulating private sector involvement in productivity driven strategies has been low and science and technology indicators have not shown the desired advance.[17] The pace of adoption and diffusion of technology has stayed low in Malaysian electronics. The easy answer to the question of why the limited take-up of such programs is that Malaysian enterprises lack the technology management capabilities required to make the transition to a productivity-driven strategy. This must change if the transition to productivity-driven growth is to take place. This report is aimed at developing strategies to complement the existing government initiatives.

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16 This report will not undertake a detailed analysis of the Multimedia Super Corridor (MSC) and Cyberjaya.

17 Rasiah (1998)

9. Complementing the IMP2

Clusterisation has become an important strategy to enhance Malaysia's electronics industry along the value-added and technology chain. The IMP2 has recommended this strategy. This study also recommends clusterisation and takes off from where the IMP2 ends. However, to maximise cluster synergies, this study proposes adaptations to the original IMP2 framework. In addition to the identification and governance of effective co-ordination relationships between firms, institutions and individuals, the study also posits the need for locating strategies within open system clusters that stimulate innovations across a range of diverse firms. The systems integration model that characterises Intel's operations is arguably the most cutting-edge framework to target.

It is for these reasons, the study adopts Best's technology management (TM) [18] approach (see chapter 3). With increasing technology and value-added advancement, the nature of clusterisation will change, requiring accompanying co-ordination mechanisms to evolve accordingly. A industry based upon strong dynamic individuals working in strong clusters with collaborative horizontal knowledge structures, supported by government bodies that foster the development and exchange of ideas would generate innovations superior to past organisational forms.

The study notes that clusterisation is something that is dynamic which will have to evolve as rapidly as technologies and product cycles change. In this respect, electronics clusters as we envisage currently would be very different from those that would evolve in the future as new products and new technologies would demand new requirements in the clusterisation development process.

Much of the strength of the Penang Development Corporation and former government policy initiatives has been derived from their ability to disseminate information to the electronics community in the various regions as a whole. This process assists in fostering collaborative horizontal based entrepreneurial practices. This is generally in keeping with the IMP2. However, despite considerable deepening, the cluster structures and co-ordination mechanisms in Penang still remain far from the institutional technology frontier. In a highly flexible dynamic industry, such as electronics, the Silicon Valley model of collaborative-shared development is an essential blueprint for success. The incorporation of these essential industry drivers into the IMP2 can greatly assist the Electronics Industry in its transition to a leading edge future orientated industry.

There is a need to foster communication not just within organisations, but also between organisations, so that shared knowledge can contribute to the overall success of this

18 Best (1998)

dynamic industry. Chapter three analyses models of clusterisation and regional models of industry transformation to a higher up production capability spectrum in order to provide insights into strategies that can assist the IMP2.

Chapter 3: The Capabilities and Innovation Perspective

1. Introduction

The challenge set by IMP2 is to sustain a high rate of growth and to improve the value-adding performance of the Malaysian electronics industry for the next two decades. The IMP2 deploys a cluster-based model (see Chapter 2). The question is how do clusters drive growth and improve productivity? Effective policy depends upon impacting on the forces that drive growth and improve productivity. Our task in this chapter is to provide and analysis of cluster dynamics and growth processes so that the policy challenges can be identified.

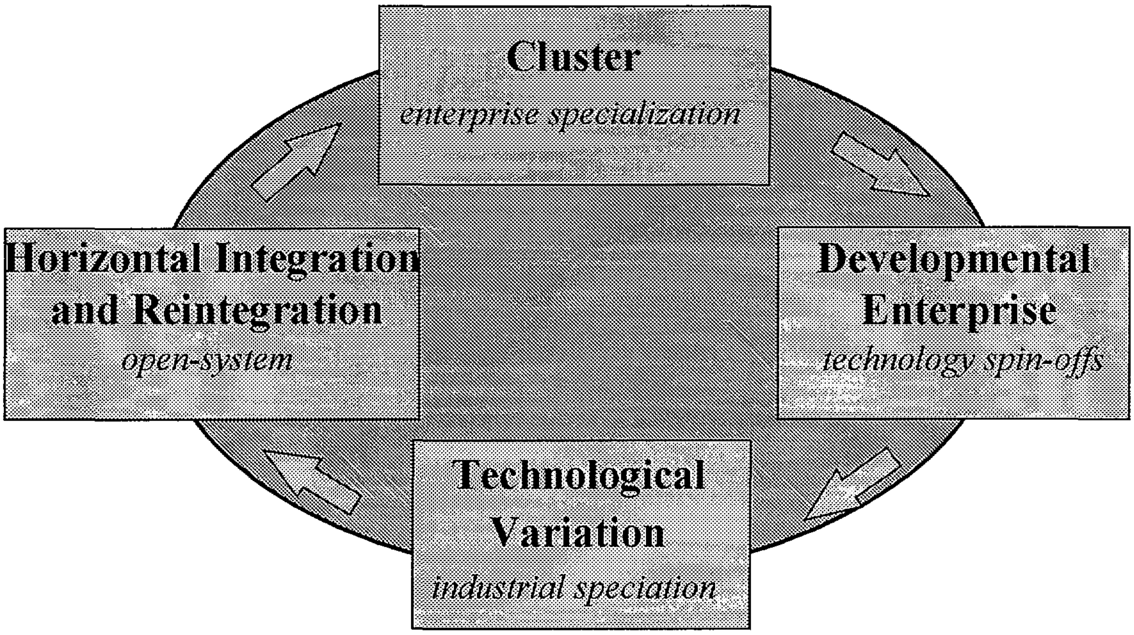
Rapid growth that also improves value-adding performance is technology driven. Adding to labor and capital can achieve high growth rates, but technological progress accounts for advances in value added. In this chapter we integrate capabilities and innovation into a cluster analysis in order to answer the question of how a cluster-based strategy can achieve the goals of IMP2. The starting point for integrating technologies, cluster development, and growth is the firm.

Clusters are made up of firms, each of which seeks to differentiate from others by developing unique capabilities. From a high growth perspective, unique technology capabilities have high priority. Advances in technological capabilities are central to driving and understanding growth. Introducing technology into the explanation of growth introduces a dynamic between technology capability and market opportunity. The entrepreneurial firm is defined in terms of this internal growth dynamic and becomes a driver of economic growth processes. But firms compete in the global marketplace as members of clusters or networked groups of firms. The second step, then, in understanding clusters and the relationships between clusters and growth is explore the dynamic relationships amongst firms that foster technology adoption, development, diversification, and diffusion within a cluster. Each of these is an aspect of technology management at the enterprise and regional levels.

2. Cluster Growth Dynamics

Figure 3.1 characterizes the extension of the technology/market growth dynamic of the firm to the region by way of inter-firm networking processes. Together they drive cluster dynamics. The figure identifies the processes required for clusters to add value to a region's resources. Each sphere and process will be examined.[19]

Figure 3.1 Model of Cluster Dynamics



2.1 Entrepreneurial Firms

The entrepreneurial firm, represented by the sphere at the right of Figure 3.1, is driven by a *technology/market dynamic*. The term dynamic connotes an ongoing historical process in which both technology and market are mutually redefined, a process that is built into the ongoing operations of a firm. Firms pursue unique capabilities, often of a technological form, but the process of developing such capabilities creates market

[19] It is, at the same time, an extension of Adam Smith's principle of increasing specialization from skills and occupations to capabilities as mediated by business and industrial organization.

opportunities in the form of a new, refined match between product offering and customer desire in which both have been altered. In the process of redefining the product, the market, too, is recharacterized. These new 'market' opportunities feed back to motivate changes in productive capabilities setting in motion a new technology and market dynamic.

The internal dynamics of entrepreneurial firms enhance regional growth potential. Whether or not the potential is realized depends, in part, upon strategic choices made within the entrepreneurial firm and the extent of inter-firm networking capabilities. Firms that experiment and develop unique and/or new capabilities simultaneously must choose which of the new possibilities to pursue as the basis of their competitive advantage. Given the inherent uncertainty regarding technological change, firms are required to place bets on which technological possibilities to be pursued and which to be abandoned. No firm, no matter how big, can pursue all technological possibilities. To do so would make it impossible to develop the unique capabilities upon which sustainable competitive advantage depends. Technological change is uncertain, but technological capabilities are developed in a cumulative process. This dilemma is inescapable for the firm, but not for a region. In a region of entrepreneurial firms, the winners and losers in placing bets on the path of technological change will tend to cancel out. If the region has a degree of enterprise and labor 'churn', the region as a whole will gain from greater experimentation and technological diversity. Churn refers to the flexibility of the regions entrepreneurial and human resources to respond to emerging market opportunities.

The firm's dilemma can be either a cluster's constraint or opportunity. The firm faces a dilemma: unique capabilities are both the source of competitive advantage and a constraint on future development. New opportunities, which require activities that are not consistent with reinforcing the firm's basic position, risk devaluing the firm's unique capabilities. The firm's dilemma is a *cluster constraint* in a region populated by enterprises that are either externally or vertically-integrated. Externally-integrated enterprises are defined as productive units coordinated within 'closed-system' inter-regional networks, value chains, or global enterprises. But the firm's technology choice dilemma is a *cluster opportunity* in a region in a region with 'open-system' networks.

Open-system networks convert the inescapable dilemma of the individual entrepreneurial firm into a growth opportunity for a region's collective enterprises. Abandoned possibilities are simultaneously opportunities for new divisions within subsidiaries or spin-offs or for new firm creation. The pursuit of new capabilities also opens new possibilities for partnering for complementary capabilities. Ease of entry for new firms, as well, enhances the regional capability for firms, existing and new, to respond to new market and technological opportunities. Each of these processes contribute to *potential* regional techno-diversification which, if activated, can trigger industrial 'speciation" or the emergence of new industrial sub-sectors. We will explore these processes in more detail.

2.2 Techno-diversification

The link between the box at the right and bottom in Figure 3.1 represents a 'techno-diversification' dynamic between entrepreneurial firms and 'new firms' or new activities within companies specializing in the requisite capabilities. As noted, in the process of pursuing its own goals the entrepreneurial firm simultaneously propagates new productive opportunities that can be either pursued internally or pushed outside the firm. Those not pursued internally become 'market' opportunities for other firms to advance their productive capabilities.

The originating firm can generate three types of new productive opportunities to other firms that can, in turn, foster secondary internal dynamics in follow up firms. First, because of the inherent uncertainty about future technological pathways, the entrepreneurial firm must place its R&D and new product-development bets on specific opportunities and forsake internal development of others. The choice to abandon certain opportunities may speak less to the odds for future success than to sustaining the value of firm's existing knowledge base. Second, the new opportunities may not offer the scale required by the existing organization.[20] In both cases productive opportunities that have been created but not pursued represent market opportunities in the market 'interstices'.[21] They are potential productive opportunities for new enterprises, spin-offs, or existing enterprises with capabilities in similar activities.

Third, if the entrepreneurial firm is part of a networked group of firms each specializing on a complementary capability, a technical change at one link in the chain will create new pressures and opportunities for specialists in each of the complementary capabilities. In this way advances in design and technology are both diffused and interactive across production networks. In some cases the induced effect may be one of induced technical change which, in turn, may set off a secondary internal dynamic and consequent pressures for change across the network.

New firms are often the path to techno-diversification. Moreover, new firms and spin-offs can trigger a process of industrial 'speciation' or the emergence of new industry sub-

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[20] Gordon Moore, a co-founder of Intel, makes the point that a single firm can not pursue multiple technological capabilities simultaneously:

> integrated circuits, MOS transistors, and the like proved too rich a vein for a company the size of Fairchild to mine, resulting in what came to be known as the "Silicon Valley effect". At least one new company coalesced around and tried to exploit each new invention or discovery that came out of the lab (Moore 1996: 167).

[21] Interstice is Penrose's term for niche-market opportunities that have not yet been pursued.

sectors. Classic examples are the transistor, the telephone, the laser, and the personal computer. The companies that sponsored the original research developed none of the key technological innovations even though all became the basis for the emergence of a vast range of new enterprises better positioned to read and seize the opportunities. In most cases, the new companies were not saddled with already existing capabilities in competing technologies. Unlike the originating enterprises, they were not forced to make a decision between supporting core technologies and associated skills and new technologies and the new skills.

The process of techno-diversification can operate on a much smaller scale. In any case, new firm creation is often critical to the emergence of new industrial sectors and business models. For example, new firms pursuing new technologies with new business models drove the resurgence of Massachusetts' Route 128 following the demise of the minicomputer industry. The new open-system business model fostered much greater technical diversity and industrial speciation.[22]

Finally, the exploitation of interstice opportunities by small and new firms limits the tendency to industrial concentration.[23] Ease of entry is critically important to regulating industrial districts given the structural link between ever-greater specialization and increasing returns.

In these ways the growth dynamic of entrepreneurial firms is propagated to the larger industrial system. But the story does not stop here. A growth impact is not automatic; it depends on choices made within the originating firm, inter-firm organization, and extra-firm infrastructure. Furthermore, the relations between firm and regional growth dynamics are not one way; as we shall see they too are interactive.

2.3 Open-Systems Networking

Three types of inter-firm relations can be distinguished: market, closed-system or keiretsu, and open-system networking. Inter-firm relations are structurally linked to intra-firm organization: Big Business and arms-length, market-driven supplier relations, the *kaisha* business model and *keiretsu*, long term supplier relations, and entrepreneurial firm and open-systems networking. The *kaisha* business model fostered the principle of multi-product flow and achieved performance standards (cheaper, better, faster) which established the New Competition of the 1970s and 1980s. But the 'open-systems' networking model has proven effective at both rapid new product development and

[22] These themes are developed in Best (1999, forthcoming)

[23] This led Penrose to conclude "...in a steadily growing economy, or in an economy where expansion is more prevalent than stagnation, the process of concentration will come to an end and eventually reverse itself"(Penrose 1995: 258).

innovation and, consequently, became the New Competition of the 1990s. The open-systems model depends upon inter-firm networking capabilities.

The box at the left of Figure 3.1 represents open-systems networking, commonly referred to as "horizontal integration", multi-enterprise integration, cooperation, networking, or affiliated groups of specialist enterprises. Open-systems networking is inter-firm counterpart to increasing specialization of the entrepreneurial firm.

Inter-firm networking has evolved with the shift from price-led to product-led competition. This entails integration of manufacturing and new product development processes. But rapid new product development is not simply adding a product (multi-divisional diversification); increasingly it involves a whole group of specialist companies operating at different links along the product chain or nodes in the value networks.

Open-systems networking is a model of industrial organization that fosters specialization and innovation. Historically, open-systems prevailed in the design-led industrial districts of the Third Italy. More recently, the emergence of systems integration capabilities in technology has both fostered open-system networks and developed because of them. In both cases the business model of specialization and inter-firm networking form an internal/external dynamic that fosters innovation and growth.

Inter-firm networking offers greater flexibility for new product development and innovation than does vertical integration.[24] Ironically, networking can foster the social relations necessary for effective co-location of specialist but complementary activities more easily than can vertical integration. While a vertically integrated company operates under a single hierarchy which can direct departments to co-locate, it does so within a bureaucracy and a set of technologies that were originally designed for different purposes. They become embedded in social systems and individual career paths within the firm which can offer resistance to organizational change. Open-systems-networking offers a range of co-design possibilities without locking an enterprise into any one design possibility. The open-system organizational model is fostered by open systems in the form of standardized interfaces and shared design rules at the technological level.[25]

[24] Horizontal integration, the term used by Andrew Grove of Intel to describe open-systems networking can be considered an inter-firm consequence of Intel's production concept of integrated manufacturing (Grove 1996, Best 1998).

[25] The idea of system integration suggests a common design principle which enables the integration of independently, designed components. The term open system suggests that the system design rules are openly published. A closed system, in contrast, suggests the challenge of integration is achieved by a overarching design principle which leaves no space for independently designed components. The IBM 360 computer, for example, was a closed system before an anti-trust ruling forced the publication of the system design principle and thereby began a process that led to an open system. The embedded and private operating system of Massachusetts mini-computer companies is another example.

The internet is a great facilitator of the open systems networking. In fact, the internet is an archtypical open-systems technology. It establishes interface rules that enables design modularization. The internet makes it possible to manage supplier relations by seamlessly integrating information across different computer systems, parts lists, and even design programs. Virtually seamless integration across businesses enhances the simultaneous increase in specialization and integration that Adam Smith identifies as the principle of increasing specialization.

As an easy plug-in system for specialist companies, the internet lubricates the internal/external dynamics that spawn entrepreneurial firms. But it can also be seen as a metaphor for networking in general and thereby a target for policymakers seeking to increase entrepreneurial firms. In this, the internet is the new invisible hand but one that assists the creation of entrepreneurial firms and regional innovation.

The *new firm creation process* is itself an aspect of mutual adjustment. Just as the dynamics associated with new product development involve a continuous redefinition of product concept, carrying out the process can foster a proliferation of firms concepts. Diversity and the principle of variation, or increased speciation, means the creation of new firm concepts. This process is enhanced in open-system networks in which new specialist firms can readily plug into pre-existing product chains. This process suggests that strategy of firms are themselves shaped in the ongoing practice of refining a firm's concept or specific characteristic that distinguishes itself from other firms and thereby gives it market power.

The entrepreneurial firm start-up system is particularly strong in the Silicon Valley and Route 128 high tech regions in the United States and in the design-led and the fashion industries of the 'third Italy'. Taiwan, Ireland, and Israel have all established variants if on a smaller scale. Most attention has been focused on financial markets as the enablers of entrepreneurial firm emergence and development. Venture capital and IPO capability are certainly contributors to the high new firm creation rates in both Silicon Valley and Route 128/495. As important as financial commitment is, the driving force must be the technological and market opportunities for establishing a firm with the profitability to make an attractive return to suppliers of finance.

The resulting open-systems business model is a business system that expands opportunities for yet more entrepreneurial firms. Collectively the open-systems business model sets higher performance standards in rapid new product development and disruptive innovation (as distinct from continuous improvement or incremental innovation). It is a driver of growth. Wealth creation involving technological advance and techno-diversification is a process analogous to Adam Smith's principle of increasing specialization but applied to technological capability.

Techno-diversification enhances both new product-development and industrial speciation, or the creation of new industrial sub-sectors. The protean character of technological capability, particularly evident in high tech sectors, is a feature of industrial change even in the oldest sectors. The electronics industry morphs into, for example, an information and communications sector. Furniture becomes interior design and furnishing. The process of industrial speciation can not be done within a single firm. In fact, the very success of a firm's pursuit of one technology trajectory can create obstacles to technological transition.[26] Hence the role of networks by which new entrants can focus on a technological capability and partner for the complementary capabilities. Regions with open-systems networks have low barriers to entry for new, specialist firms. This process drives down the time for technological change and the process of new sub-sector formation.

2.4 Regional Capabilities and Models of Innovation

The upper box in Figure 3.1 signifies the extent of capability specialization and diversity within a regional population of networked industrial enterprises. The figure highlights a range of intra- and inter-firm dynamic processes that underlie capability development at both the enterprise and regional levels. Regional specialization results from cumulative capability development and the unique combinations and patterns of intra- and inter-firm dynamics that underlie enterprise and regional specialization.

The process of enterprise capability development is also a potential process of regional capability development. A firm's own capabilities are developed as parts in a dynamic, inter-firm process of capability development. Regional capabilities are different from physical infrastructure, they are akin to regional 'social capital' in the form of shared production capabilities. But regional production capabilities are more than the networks and extra-firm institutions that support enterprises. They are constitutive of a region's industrial organization like teamwork to a sports team; 'social capital' enables participants to advance specialist skills that could not be accomplished alone. They make the whole greater than the sum of the parts because the whole accounts for the effects of unique inter-relationships on skills and capabilities. Regional production capabilities underlie distinctive patterns of regional specialization.[27]

Regional production capabilities lie behind the competitive advantage of 'low-tech', high-income industrial districts common to the 'third Italy'. Such districts have developed a competitive advantage in design capabilities that have fostered industrial leadership in a range of design-led or "fashion industries".

Greater diversity is particularly relevant to innovation. An industrial district, unlike any single firm, offers the potential for new and unplanned technology combinations that tap a variety and range of research and production related activities. Open-systems offer wider

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[26] Christiansen, Utterback, etc.

[27] Elsewhere I have developed the idea of technology management capability to explain changing patterns of industrial leadership (Best 1998).

opportunities to foster creativity, fill gaps, replenish the knowledge pool, and match needs to research.[28]

Recently, high tech regions have developed similar capabilities for rapid design changes and industrial innovation. In fact, regions such as Silicon Valley and Route 128 have developed regional innovation capabilities embedded in virtual laboratories in the form of broad and deep networks of operational, technological and scientific researchers which cut across companies and universities. Silicon Valley project teams are continuously combining and recombining across a population of 6000 high tech firms making it an unparalleled information and communication technology industrial district.[29]

Models of innovation are associated with different business models. The *kaisha* variant of the entrepreneurial firm decentralizes design and continuous change into the operating units. The rapid gain in Japanese market share in many industries in the 1970s and 1980s was achieved, in part, by designing a complementary incremental innovation capability into production. It fostered a technology-pull model of innovation. An American variant, and perhaps advance, is the leadership and design dynamic which combines top-down and bottom-up actions captured by Andrew Grove's 'dynamic dialectic'[30]. The 'dynamic

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[28] The regional model of innovation offers a decentralized, self-organizing explanation of the success of high tech regions but of industrial districts in general as an alternative to the linear, science-push model of innovation. In the latter, technology is thought of as applied science; in the regional model, technology is part of the industrial process. It is built into the process by which firms establish unique capabilities and network with other firms. The science-push model, in contrast, fails to capture the extent to which research is woven into the production, technology, and networking fabric of a region's industrial system as distinct from being an external, autonomous sphere of activity.

[29] Intel is not the only driver of new products. Approximately 1 in 5 of the Silicon Valley (and Route 128 in Massachusetts) publicly traded companies were gazelles in 1997 which means they have grown at least 20% in each of the last 4 years (the number for the U.S. is 1 in 35). See Massachusetts Technology Collaborative (1998).

[30] A variant of the technology/market is Intel's 'dynamic dialectic' as described by co-founder Andrew Grove (1996). Grove's "dynamic dialectic" is built into a business model organized to combine recurrent phases of bottom-up experimentation and top-down direction. Phases of experimentation, which stimulate new ideas and innovation, are fostered by decentralization of decision-making. The challenge of leadership is to allow enough time for free reign to stimulate the development of new ideas before managing a new phase during which the most promising ideas are pursued and the weaker ideas are abandoned. The challenge of leadership is to balance the phases of experimentation and direction so that the enterprise can benefit from the advantages of both bottom-up initiatives and top-down decision-making. Too much experimentation can result in chaos; too much direction can stultify innovation. Built into the challenge of leadership is the ability to manage organizational change; leaders must gain personal commitments to new directions, technologies, processes, and products. Without personal commitments from top to bottom, human energies will not be mobilized to drive the

dialectic' model of business organization is a 'learning firm' which can drive rapid new product development.

A third, regional model of innovation derives from the open-system, regional growth dynamics (the diffusion and development of a range of growth dynamics ensuing from the entrepreneurial firm). Techno-diversification, technology integration, new technology combinations, and industry speciation are all elements in processes that advance the technology capabilities of a region.

The regional growth dynamics model fosters combined development and diffusion on innovation. Regional innovation refers to processes of that not only trigger the regional growth dynamics but which reshape it via the process of industrial speciation. Thus the regional growth dynamics are an infrastructure for new industry incubation and formation.

The concept of regional innovation dynamics suggests a *collective entrepreneurial capability* as a basis for regional competitive advantage which, like its enterprise level counterpart, can be conceptualized as a technology market dynamic but at the regional level. Industrial districts compete against one another. Given different paces of technological development or a shift by one region to a higher model of technology management or a new technology platform, the losing region risks losing a whole swathe of enterprises.

As networking capabilities of a region become more robust, the more the region takes on the semblance of a collective entrepreneur. The virtual collective entrepreneurial firm is a self-organizing change agent composed of networked groups of mutually adjusting enterprises.[31] The collective entrepreneurial firm is a composite of networking firms that collectively administer the regional growth dynamic processes of Figure 3.1.

While the high tech districts are unique in terms of specific technologies and research intensity they exhibit regional innovation characteristics in an exaggerated form that are common to the virtuous circle of regional growth. Examples follow.

First, the high-tech, open-system industrial district is, as well, a collective experimental laboratory. Networked groups of firms are, in effect, engaged in continuous experimentation as the networks form, disband, and reform. Both the ease of entry of new firms and the infrastructure for networking facilitate the formation of technology integration teams in real time. However successful the industrial district as a mode of economic coordination has been in international competition, heretofore, it has been considered appropriate only to "light" industry such as the design-led, fashion industries

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redirection of organizational resources. While experimentation demands turning everyone into a designer, direction demands that everyone enthusiastically accept the winning designs. This is no small organizational challenge.

[31] See Best 1990, pps. 207-8.

of the "Third Italy" and the machine tool and metal working regions of Baden Württemberg in Germany.

Second, an open-system district expands the number of simultaneous experiments that are conducted. A vertically integrated company may carry out several experiments at each stage in the production chain but a district can well exploit dozens simultaneously. In this way a district counters the barriers to introducing new ideas in firms that already have well-developed capabilities around competing technologies.

Third, an open-system district fosters the decentralization and diffusion of design capabilities. Design modularization in the personal computer industry is an example. IBM got the process underway with the modularization of the 360 computer that created an open system. This was greatly enhanced when Microsoft and Intel developed the design modules for the operating system and the microprocessor.[32] The resulting standards have created enormous market opportunities for specific applications software. But in addition the concept of design modularization combines common interface design rules with decentralization of component design. This diffusion of design capability increases collective innovation capacity. It can also strengthen the district model of industrial organization, even enhance conversion from a closed to an open system.

3. Technology Management and Transformational Growth

Transformational growth involves the transition of a region to more advanced production capabilities. A higher level of production capabilities means that a region can compete more successfully in across a greater range of production activities and product applications and with more versatile competitive strategies.[33]

A range of generic production capabilities is shown in the Production Capabilities Spectrum (see Table 3.1). A survey of a region's industrial enterprises in terms of the production-capabilities spectrum indicates relative levels of enterprise development and productivity. Growth in organisational productivity is about making advances along the spectrum.

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[32] See Katz (1996: 15). Katz also describes network economies and increasing returns.

[33] The productivity of the 'factors of production' of labor, capital and natural resources depends upon capabilities of the organizations within which they are embedded. Efforts to explain productivity and competitive advantage in terms of measures of inputs of 'factors of production' ignore the mediating role of capabilities. The failure to account for capabilities explains the large unexplained 'residuals' in growth accounting exercises.

Table 3.1 Production Capabilities Spectrum

1. **Pre-flow, pre-interchangeability**: Craft production, by itself, offers no basis for flow. Each drawer is custom fit. The task is to develop product engineering skills. Jamaica and Honduras.
2. **Interchangeability** (*TM 1*): product engineering without process engineering, hence low inventory turns and working capital productivity. Cyprus and Slovenia in the 1980's.
3. **Single product flow** (*TM 2*): plants with economies of speed for a single product or range of products with dedicated lines. Workers are not multi-skilled; tend 1 or several homogeneous machines. (Training does not include continuous improvement, rapid changeover, or blueprint reading skills.) Multi-national electronics production in Indonesia.
4. **Single product flow with continuous improvement** (*TM 3*): involves problem solving work *self-directed* work teams. Common training programs involve Plan-Do-Check-Act, the 7 problem-solving tools, 5S's or TQM at shop floor level.
5. **Single product flow with process innovation** (*TM 3*): personnel include maintenance and process control technicians with skills to identify, fix and redesign machinery and production lines. Bottleneck analysis determines priorities. This may involve reconfiguring product design parameters at main office as required by DFM. Singapore in the mid-1980s, Malaysia MNCs in early 1990s.
6. **Multi-product flow** (*TM 3*): the Toyota system. Kanban, JIT, and SMED are introduced in large plants. High throughput and flexibility are combined. Cellular production with self-directed work teams.
7. **Multi-product flow and product development** (*TM 4*): Japan and Taiwan both excel at concurrent engineering and design for manufacturability. Skills include reverse engineering, prototype development, and pilot runs.
8. **New product design and technology fusion** (*TM 4*): Japan's Toshiba and Canon are leaders in linking development to operations at the plant level and linking research in generic technologies to product development. Core technologies are developed, often via fusion in generic technology labs. Technology management involves world-wide sourcing of the existing technology base in pursuit of novel applications.
9. **Systems integration and disruptive innovation** (*TM 5*): 3 M, HP and Motorola use cross-disciplinary teams to identify new technology drivers for product development. Disruptive or breakthrough innovations are pursued but within an organizational context of process integration. Hardware and software integration drives product concept development.
10. **Open systems and design modularization** (*TM 5*): focus and network strategies are supported by standard inter-face rules and diffusion of design capability. Fosters technology deepening R&D and techno-diversification.

3.1 A Model of Sectoral Transitions

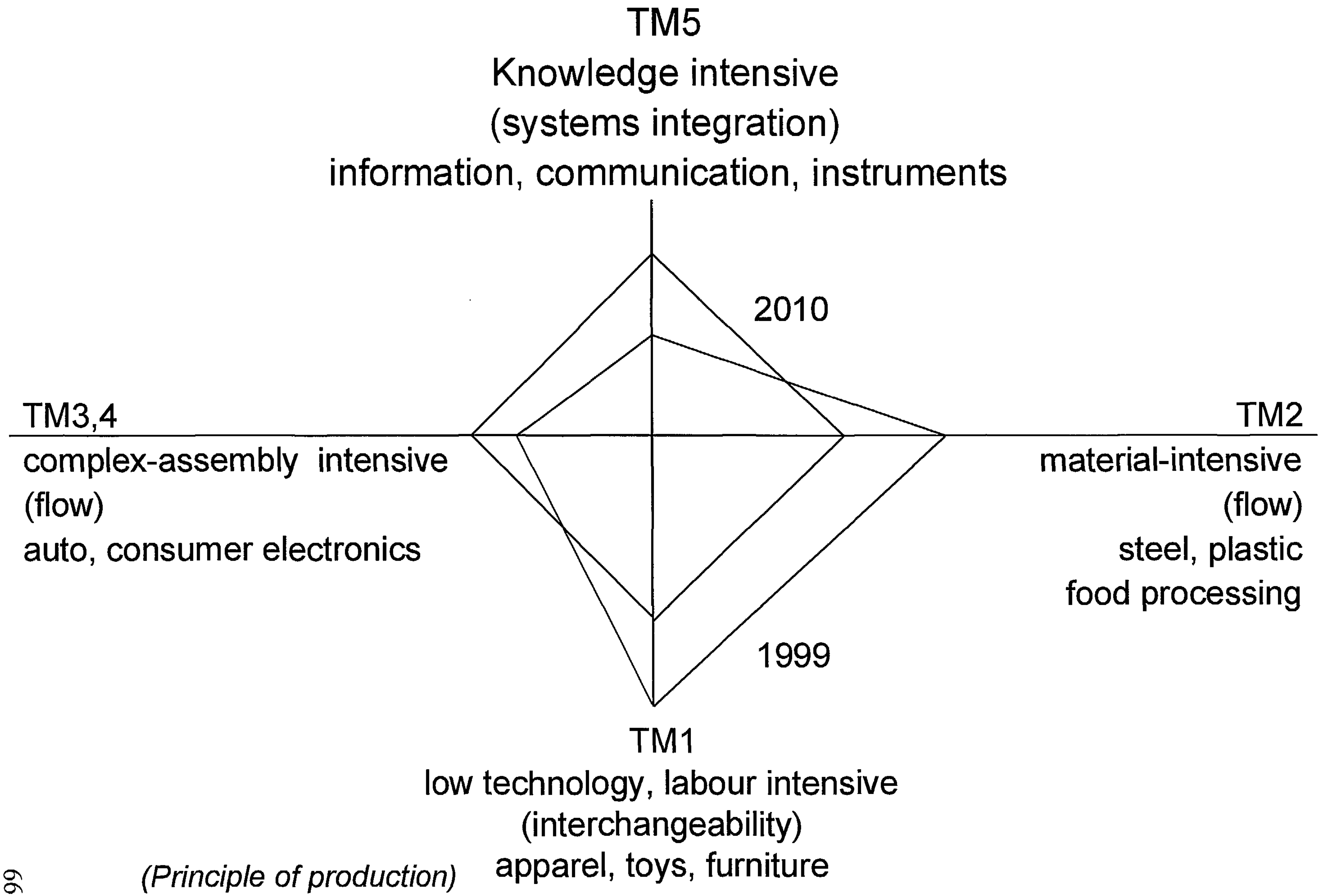
Three universal principles of production can be identified: interchangeability, flow and system integration. The claim is that if a critical mass of firms within a region make the transition to more advanced principles of production they can trigger a regional growth dynamics of techno-diversification, industrial speciation, networking economies, and innovation induced by new combinations.

The link between production principles and competitive advantage is illustrated in Figure 3.3.

Figure 3.2 Technology Management and Sectoral Transition

(See next page)

Figure 3.2 Technology Management and Sectoral Transition



Each advance in production capabilities increases the range potential to move toward more advanced production activities represented by movement in the northwesterly direction of the diamond. Making the transition from craft-based production processes to *interchangeability* increases productivity in a range of labour intensive, relatively low-technology activities which predominate in, for example, apparel, toy making, shoe, and furniture (the south dimension). The application of the principle of interchangeability fosters precision machining and engineering and the capability to produce to continuously tighter tolerances. Applying the principle of *flow* opens up activities benefiting from scale economies. Raw material intensive processes, such as steel making, plastics and other petro-chemical based outputs, and food processing are examples (the east dimension). With the transition to capabilities dependent upon the principle of *multi-product flow*, companies and regions can achieve the throughput efficiency and quality performance standards required to compete in complex production processes. Bicycle, car, consumer electronics are examples (the west dimension). *Systems integration* is required to compete successfully across a range of 'knowledge intensive' production activities associated with industrial electronics, telecommunications, and information technologies (the north dimension).

The new principles themselves can be incorporated into a model of transformational growth. This involves a regional transition to new principles of production and corollary organisational capabilities. The critical factor for understanding growth is the regional capability to manage technology, a capability that has three dimensions: production, business model, and skill.

In Table 3.2, five technology management models are distinguished: each explores the *interface* of production principles, technology management, business organisation, and skill formation.[34] Each represents a discontinuity in performance standards and either a breakthrough innovation in production principles or a major extension in a production principle to create new production capabilities. The diffusion processes include the cluster growth dynamics of techno-diversification and integration. But the success stories also create role models for other enterprises and competitive pressures for organisational change.

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34 The table was first presented in Best (1998). It is summary statement from ongoing research on principles of production and organization. The method for discovering the principles is to examine historical shifts in industrial leadership.

Table 3. 2 Five Models of Technology Management

	Case	Production Principle	Application	Generic Skills/ Capabilities	Performance Breakthrough
TM 1	Armory	Inter-changability	Replace hand-fitters	Product engineering, specialist machines and tooling	Product performance
TM 2	Ford	Flow	Single Product	Process engineering, synchronization	Cost
TM 3	Toyota	Flow	Multiple Products	GT, cellular manufacturing, kaizen	Cost, Quality, Lead Time
TM 4	Canon	Flow	Rapid new product dev., technology and production integration	Applied R&D, technology fusion	Product innovation, Rapid NPD cycle time
TM 5	Intel	Systems Integration	Design Modularization, Design rule improvement, Custom design	Software and systems engineering, technology and science integration	Rapid innovation, smart products, technology transitions

The composition of activities in Figure 3.2 do not map one to one between refinement in the development of production principles and type of production activity intensity (low-skill, labour intensive, scale and raw material intensive, complex production intensive, and knowledge intensive). Regional competitive advantage combines generic production and technology management capabilities with technological know-how and skills that are regionally specific. Consequently, low-tech industrial districts can persist in high wage regions because of a combination of unique and generic capabilities, on the one hand, and a critical mass of entrepreneurial firms that can periodically trigger anew a cluster dynamic.

3.2 Principles of Production

Interchangeability. For Adam Smith, mechanisation, technical change, and invention were all parts of the process of increasing specialisation. His descriptions of how increasing specialisation leads to the simplification of production activities and, in turn, the search for improvements and innovation in methods and machines is a model of increasing returns and organisational productivity. The production principle of interchangeability illuminates the complementary technical aspects of the process of increasing specialisation.

Converting the principle of interchangeability into enterprise and regional production capability lays the foundation for major advances in growth potential. It is not easy; it requires reorganising industrial enterprises from top to bottom for consistency with interchangeability. Manufacturing methods and organisation, engineering practices, and skill development programs must all be advanced and made consistent with one another. The reward is a leap ahead in organisational productivity: it creates a technical infrastructure to institutionalise Smith's increasing specialisation growth dynamic.

Designing a production system around the principle of interchangeability is the first step in developing technology management capabilities. Specialist machines have to be designed and built to apply the principle. The 'accumulation of capital' means building networking relationships between users and makers of machines. A pure market relationship between machine maker and user does not build indigenous technology management capabilities. It can enable 'turnkey plants'. Application of the principles means the emergence of product engineering as a set of standard procedures, an organisational capability, and an occupational category to specify, identify, design, make, set-up, modify, adopt, refine, and operate efficiently the requisite machines.

Historically, the rudiments of process engineering also appeared with the application of the principle of interchangeability as methods were established to lay out, inter-face, standardise, measure, operate, and trouble-shoot machining activities along a production line. The elements of a production management system become subject to searches for improvement. Technology management is no longer a one-off affair in which a machine with superior performance capacity is introduced; instead, it becomes an ongoing organisational capability of industrial enterprises.

America's rapid early industrialisation was driven in major part by the application and diffusion of the principle of interchangeability in the form of a dynamic machine tool industry initially centred at the Springfield Armory along the Connecticut River Valley in Massachusetts. Across New England, an inter-firm technology management dynamic was set in motion between specialist machine users and makers. Incremental and radical innovations in the machine tool industry were both induced by machine users and fed back to increase productivity in production.[35]

Skill formation is integral to the process of applying and diffusing the principle and thereby fostering a regional growth dynamic. While the makers and users of the specialist machines are independent firms, co-location can fuel a regional innovation process which, in turn, is anchored in a community of workers and practical engineers skilled in the development, use, and improvement of the new principle and specific technological applications.

While the application of the principle of interchangeability may not always mean that product engineering is formalised into standard operating procedures, a machine making sector will not flourish without the emergence of a set of tools and skills associated with blueprint reading, metallurgy, geometry and trigonometry. This means that the regional technology management capability is limited and can not drive a regional growth dynamic. This will depend upon the management of technology becoming an organisational capability.

Like the organisational principle of increasing specialisation, the production principle of interchangeability, is enduring. Its manifestations vary. As we shall see next, interchangeability is a prerequisite to standardisation and the principle of flow; it also appears in the form of standards for establishing interface rules in open systems. But it remains as relevant to understanding the challenges and opportunities facing regions seeking to industrialise today as ever.

Flow. The principle of flow underlies a myriad of terms used today to describe the revolution in manufacturing led by the Japanese such as JIT, 'lean production', 'reengineering', advanced manufacturing, time-based competition, process integration, 'synchronised production'. Henry Ford's engineering team applied it to achieve an order of magnitude increase in throughput efficiency and an unprecedented jump in productivity and wages. It required the development of process engineering and the redesign of production around the concept of equalising cycle times. This organisational change was enabled by, and in turn drove, the integration of electric motors and machines.

Application of the principle of flow for Ford meant equalising cycle-times and the development of process engineering. Process engineering involves the redesign of plant layout, machining activities, and operator tasks according to the logic of the product (the sequence of activities required to make each requisite part). The unit of time became *cycle time* as the metronome governing every activity; it replaced *labour time*, the unit of pre-flow production systems. Co-ordination was achieved by the self-organisation of thousands of production activities each producing according to the logic of cycle-time,

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35 For examples of both types of innovation and references to original sources see Best and Forrant, 1996.

not by the scheduling instructions of the planning department. Cycle time required to achieve throughput efficiency replaced labour time, the time unit of 'scientific management', and revolutionised work organisation.[36]

The breakthrough in production performance demanded that Ford's engineers focus their attention on *technology management* and measures of throughput efficiency, not on *labour management* and measures of labour time and labour productivity. An example is the concurrent development of machines powered by attached electric motors and Ford's production line. Both were the result of simultaneously redesigning production system and the elements in it to capture the full advantage of technical change in the electric power delivery system.

The limits of Ford can be seen in the same terms. Instead of the institutionalisation of innovation, both incremental and radical, into the organisation Ford saw it as a one-off activity focused at the time of development of new plant.[37] To make the transition to the permanent integration of technology management and production would have required a greater revolution in work organisation and labour skills. But Ford set the stage by revealing the power of the principle of flow. It took others to extend it, first to multiple product systems, then to new product development, and finally to technology integration. Ironically, the practice only became a principle with the development of the Toyota Production System that, in fact, was a major extension of the principle of flow from single to multiple products. This extension, however, requires a deep change in production organisation.

Multi-product flow. The principle of flow applied to multiple products is the secret to achieving high throughput efficiency in 'lean production' or the Toyota production system. It is an extension of the principle of flow but depended upon prior or simultaneous changes in work organisation associated with cellular manufacturing methods including the associated practices of JIT, quick changeover machines, *kanban* (visual co-ordination of production activities), self-directed work teams, and *kaizen* (Japanese for continuous improvement methods). Application of the principle of multi-product flow established comprehensive performance standards involving cost, quality and time that can not be matched with other high volume production systems.

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36 Achieving Ford's order of magnitude increase in productivity not only required the co-development of technology, plant and work organization. It also depended upon the co-development of a labor force with the skills to achieve and maintain economies of time in material flow; conventional wisdom to the contrary, the requisite skills are not those elaborated in 'scientific management' manuals. Such manuals were not informed by Ford's challenge: revamping production and work to achieve high throughput efficiency. Managers, engineers, and workers trained and skilled in Taylor's terms defined production efficiency in terms of designing pay incentives maximize labor effort; the result was local optimization, a violation of the concept of flow.

37 Ford plants were not static, but subject to serial revamping in search of bottlenecks by engineers.

The application of multi-product flow at Toyota meant the corresponding development of a plant layout and the range of skills to do cellular manufacturing. The new production system required multi-skilled workers capable of operating and setting up a range of machines, departments organised by process and not similarity of machine or activity, and work organised into teams inclusive of the various skills and range of activities required to carry out the process from beginning to end. Flexible production means worker educated in blueprint reading, in the range of problem solving tools that constitute quality management including statistical process control, and in the communication skills required to work in teams.

The conducting of experiments and the discovery of new knowledge is no longer the preserve of engineers but spread to work teams. The business challenge becomes to build the discovery process into every ongoing activity of the organisation. In practice this meant the establishment of *kaizen*, or continuous improvement work organisation, a foundation for incremental and collective innovation and for the pursuit of product-led competition. Extending cycle time competition from production to 'time to market' of new product designs meant integrating design into the manufacturing process. Workers become part of the technology adaptation process.

The plan-do-check-act methodology, team-centred work organisation, and inclusion principle of 'total quality management' are a set of skills and practices that constitute the organisational counterpart to multi-product flow; skills, organisation, and material conversion technique are three aspects of the same, flexible production system. The comprehensive performance standards of cheaper, better, and faster can by achieve only if the triad of production principle, business model and skill formation is in synch.

The skill level undergoes another change with the integration of the new product development process and manufacturing to compete on the basis of short product cycle times. The rapid introduction of new products means the incorporation of technical change as an ongoing activity in the production system. This means combining incremental innovation and the systematic introduction of new technologies. As new technologies are pulled into the production system to achieve new product development goals, rather than being pushed in from outside as a consequence of science-driven innovations. The organisational capability to manage 'technology transitions' means that system integration related skills are required of shop-floor workers.

The principle of flow applied to new product development involves a major advance in technology management capabilities. It is the secret behind the Canon production system.

Systems integration. The system integration challenge is not unique to the new model of technology management. Henry Ford and his chief engineer, Charles Sorensen, would have understood the challenge, and rewards, of system integration.[38] Applying the principle of system entails redesigning the product from inside-out and outside-in to enhance flow. Popularly known as concurrent engineering, new products (inside) are designed simultaneously with production (outside).[39]

But system integration alone does not capture the full growth and innovative potential of the principle. System integration is a static concept with respect to *component design rules*; it does not imply openness to innovation or technological change. In fact, the challenge of system integration exerts pressure to freeze technological change. Kaizen, or continuous improvement management, pursues experimentation and technological improvement but *holds basic technology design rules constant.*

The organisational challenge is to manage manufacturing processes along a technology trajectory in which productivity is advancing 50% every 18 months. This involves integrating and reintegrating technologies themselves being independently redefined. Systems integration is the response. It is about building the organisational capability to incorporate rapid technological change in components into complex products. Design modularization is an enabling methodology that integrates two sets of design rules: those at the level of individual technologies or sub-systems and those that integrate sub-systems into a single system. The process of integrating sub-systems is not an additive one, particularly when sub-systems have independent design and development dynamics. Interactions amongst subsystems have dynamic feedback effects.

An advantage of design modularization is the potential to mobilise resources from outside the company for component design and to meet the challenge of rapid technological change. Unlike Ford's business model, an Intel depends upon, and reinforces, a network of affiliated companies constituted by multiple design nodes. Intel not only partners with a vast array of specialist producers and research institutions; Intel draws upon an extended industrial high tech region with an extraordinary capacity to conduct experiments, carry out innovations, and conduct research.

Versions of design modularity existed in earlier industrial orders but the emergence of new information and communication technologies have fostered new and more

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38 Ford was acutely aware of the opportunities offered by redesigning a whole system to fit the requirements of a seemingly independent technological innovation. Ford redesigned the production system to take advantage of new electric power technologies, particularly distributed or fractionated power designed into each machine (Best 1997). Technology management for both Henry Ford and Intel involves a double redesign challenge: redesign of technologies to fit production and redesign of production to fit the new technologies and technology combinations. Ford's engineers revamped machines to fit the cycle time standard by adjusting, for example, tooling, material, and machine speeds. Ford and Intel do not simply add new technologies to the existing system, the idea is to redesign the system to take full advantage of the new technology to make a leap in production performance.

39 For details see Best (1998).

comprehensive applications. Systems integration flourishes with entirely new resonance in the age of product-led competition. It creates new opportunities for business strategies based on the integration of design and production. Following *interchangeability* and *flow*, *system integration* is both a fundamental principle of production and a business-organising concept.

The new competitive advantage derives from the application and diffusion of the principle of systems integration. Systems integration involves the modularization and decentralisation of design in conjunction with shared inter-face design rules and, simultaneously, the replacement the business model of vertical integration with one of horizontal integration across networked groups of companies. Systems integration often entails the fusion of two or more technologies each of which is anchored in different scientific disciplines and associated language communities, and which operate according to different design protocols; hence the organisational imperative of teamwork across scientific backgrounds. The most evident case of systems integration is the integration of hardware and software that, with advances in information technology, have created the opportunity to continuously rethink product concept across most industries.

Information technology has played a double role: enabler of systems integration and open systems in both technology design and industrial organisation. In fact, the microprocessor is to the knowledge-driven economy what the machine tool industry was to the diffusion of the principle of interchangeability and unit-drive electricity was to the diffusion of the principle of flow, which ushered in the age of mass production (Best 1998). In each case a new principle of production was associated with the development of a new business model capable of achieving a breakthrough in performance standards which redefined the basis of industrial leadership. Like the emergence of the machine tool industry and fractionated electric power, information technology has fostered an entirely new approach to product architecture, production organisation, and business model that in turn have redefined industry boundaries.

The open system, networking model of industrial organisation both fosters and is fostered by systems integration at the enterprise level. As the case of Intel illustrated, rapid new product development entailed the integration of manufacturing and R&D, which, in turn, fostered design modularization at the inter-firm level. Design modularization requires networking, a dynamic mutual adjustment process in which the capabilities (Marshall's enterprise and labour specialisation conditions) of each firm undergo change. The process does not stop here. The response to the new challenge leads to new tensions between each company's core capabilities (defences in depth) and its emerging capabilities. New firms are created out of this tension.

The resurgence of both Silicon Valley and Route 128 has been driven by a mutually reinforcing combination of information technology innovations and open system industrial districts. The refinement of computer aided design has enabled shortening of the NPD cycle and a substantiation of systems integration. This has brought to centre stage in companies the continuous refinement and redefinition of product concept, often the starting point of innovation. The pursuit of innovation means both networking with companies specialising in complementary technologies and systems integration internally.

Innovation networks are enhanced in an open system district over a vertically integrated enterprise. This is because barriers from bureaucratic inertia are lowered and companies can integrate, dis-integrate, and re-integrate with other companies as technologies change. Thus the cluster fosters a dynamic involving networking, systems integration, and diversity. Information technology, by fostering new capabilities in systems integration has worked hand in glove in reinventing the industrial district as a model of industrial organisation.

This process of combining, reconstituting, and spinning off of both technologies and companies is a perpetual process in open-system networks. It offers an explanation of high value-added associated with integration and packaging capabilities.[40] The trick is to know when to pursue each as the objects of both bundling and unbundling are perpetually being redefined in the process. The combination of systems integration and vertical disintegration operate side by side, they are sped up in an open-system that fosters networking, techno-diversification, and industry speciation.

Digital technologies can assist firm seeking to become entrepreneurial firms by facilitating a transition in business models organized in terms of value chains to value networks. The value chain metaphor derived from assembly line concepts suited for long product life cycles in which communication across functional departments was routine (not consultative). Digital technologies assist real-time coordination across functions in the form of value networks that blur departmental boundaries, reduce middle management functions, and compress cycle times for new product development. Robust value networks, internally and externally, increase the responsiveness of companies to market opportunities and technology changes.

It has always been the case that firms can become entrepreneurial by integrating technologies into unique technological capabilities.[41] Moving from single to multi-technology capability can help the transition of a company into seemingly unrelated markets.[42] A common is IT and machining technology, or of software and hardware, but

40 The concept of integrate and package is used to explain Hong Kong's regional advantage in Enright, Scott, Dodwell (1997). For an application in the context of the Malaysian peninsula see Chapter 4).

41 Cam A lot, for example, made glue dispensing machines for the footwear industry (See Appendix). Today, it makes glue dispensing machines for the semiconductor packaging industry but it has moved smartly down the critical size dimension scale to the micro meter range.

42 IT speeds up the NPD process. CAD and related technologies make simulation and experimentation possible, which greatly reduces the time and enhances the experiments.

infinite varieties are possible.[43] But the integration of information technology and hardware assists firms in making the transition to the open-systems models of innovation and business organization even in companies noted for innovation.

Sony, for example, is seeking to move to an open-systems capability in innovation by developing the skill base to integrate software and hardware and create a business model to drive it. Sony's competitive advantage was in manufacturing audiovisual, consumer products. Physicists and materials specialists led its technical skill formation. Its innovation did not extend to computers and information technology. Sony defines its future as 'open system' networking. But to make the transition Sony has invested heavily in the Sony Computer Science Laboratory which is 'completely unlike most Japanese industrial labs' (TR, p. 77). The new model integrates basic research into product concept development and systems integration. The changes are required to position Sony into the new world of 'convergence' where the PC and home audiovisual appliances merge (TR, p. 74).

Sony is not a special case. The principle of systems integration is as important to competitive success in today's world as the application of the principle of flow was in Henry Ford's day. Firms big and small, old and new, can all benefit from integrating software and hardware. Information technology is to the age of rapid new product development what the machine tool was to the age of interchangeability. It is a general-purpose technology that can have a leveraged impact on growth because of its diffusion potential.

3.3 Technology Management as a Growth Roadmap

The history of the evolution of models of technology management is also a high growth roadmap for technological followers. The roadmap is of a terrain that alternates between hills representing the transition to new principles of production and organisation associated with higher levels of technology management and plateaux where the new principles and capabilities are diffused across firms and industries. The speed of the vehicle, representing the rate of growth, inevitably slows for the transitions but, if the hills are climbed and the new principles are established, the vehicle can again enjoy a long spell of steady speed (industrial growth) before a new hill is eventually encountered.

Here is a major criterion for identifying a pool of potential EFs. However, firms without IT skills, and without IT built into the organization, will not be successful EFs.

[43] IT combined with traditional business models will not enhance competitiveness. The challenge for public policy making is not to seek to diffuse IT into firms that are organized in terms of, or who have made the transition to, an integrated business model. Otherwise IT will be bottled up in IT people and departments.

The roadmap, however, allows the latecomers to traversed the terrain more rapidly because it is also clarifies and simplifies the industrial growth process by identifying the fundamental principles of production and organisation. Some of the principles turned into management and production practices with later TM models in the technological leaders have applicability for the latecomers at earlier stages. Early introduction will enhance growth and ease the barriers to transitions to higher levels of TM. For this reason much can be learned by examining the leading TM models.

The East Asian economies that have achieved high rates of growth have a critical mass of industrial enterprises with the capability to adopt, adapt, and diffuse technologies that originated in the most technologically advanced nations. Japan, South Korea, and Taiwan-China have developed the capability to develop new products and processes based on refining, fusing and advancing generic technologies. Together these are attributes of a national system of production and technology management.[44]

Making such transitions is not easy. The rapid pace of introduction of technologies in the success stories is a consequence of the prior or simultaneous development of a specific set of production capabilities. The high performers started with the idea of cutting edge technologies, not of a rapid pace of absorption of technologies. The latter was a consequence of driving down cycle times first in production and second in new product development. Other East Asian nations have followed Japan, particularly in driving down production throughput times. But making the transition to multi-product flow requires development of corollary organisational capabilities variously named kaizen, continuous improvement, high performance work organisation, total quality management, self-directed work teams, and plan-do-check-act. This means considerable investment in human capital to achieve the requisite performance standards.

Articulating a technology management strategy is central to economic policy making for a developmental state. Distinctive technology management strategies in each of the high growth East Asian countries can be identified. In fact, the idea of national technology management is to the theory of the developmental state what demand management was to Keynesian economics or money supply management is to monetarism. Different East Asian models of national technology management are presented in Appendix 4, which also includes case studies of transitions.

[44] Slow growth followers, on the other hand, lack the capabilities to tap the world's pool of technologies. This is not surprising. Successful technology management itself requires the development of three distinct but interrelated capabilities: strategic, organizational, and production. Successful technology management, like the establishment of price for Alfred Marshall, depends upon both blades of a pair of scissors; supply must be matched by effective demand. While demand in price theory is mediated by income, demand in technology management is mediated by production capabilities.

4. Skill Formation Processes

The links between technological change, industrial innovation, and regional economic growth go beyond the introduction of new technologies.[45] The technology development and diffusion process depends upon the growth and proliferation of business enterprises with the requisite technology management capabilities and a labor force with the requisite engineering skills.

The development and diffusion of a new technology depends upon a ramping up of the engineering and related skills to sustain the inter-firm or regional growth dynamics (see Figure 3.1). While some of the skill development will be internal to the firm much of the education embodied in science and engineering graduates is not.

The rapid growth in technical skill levels that has accompanied the high growth rates in the East Asian 'miracles' are shown in Table 3.3.

Table 3.3 Growth in engineering and science graduates 1975-1995

First university degrees awarded in science, engineering, and mathematics and computer sciences 1975 and 1995.

	1975 NS&E	1975 M&CS	1995 NS&E	1995 M&CS
Ireland	706	NA	5456	NA
Singapore	702	NA	2965	NA
South Korea	10266	Nil	47277	12351
Taiwan	6700	1200	15170	2818

Source: National Science Board, *Science and Engineering Indicators—1998*. Washington DC: U.S. Government Printing Office, Washington DC 20402, Appendix Table 2-2 and, for the Republic of Ireland, *Twenty-Second Report, 1995*, National Council for Educational Awards.

Singapore, South Korea, and Taiwan all followed Japan in investing heavily in engineering, natural science, math and computer science education to make technology-driven growth happen. The Republic of Ireland, the fastest growing region of Europe in the 1990s, is the same story. Government led the growth with large investments in regional technology colleges. In all cases, without the investments and growth would have been choked. Instead, a virtuous cycle emerged that funded the advances in education by rapidly growing national income.

[45] Bob's example of CNC and MIT.

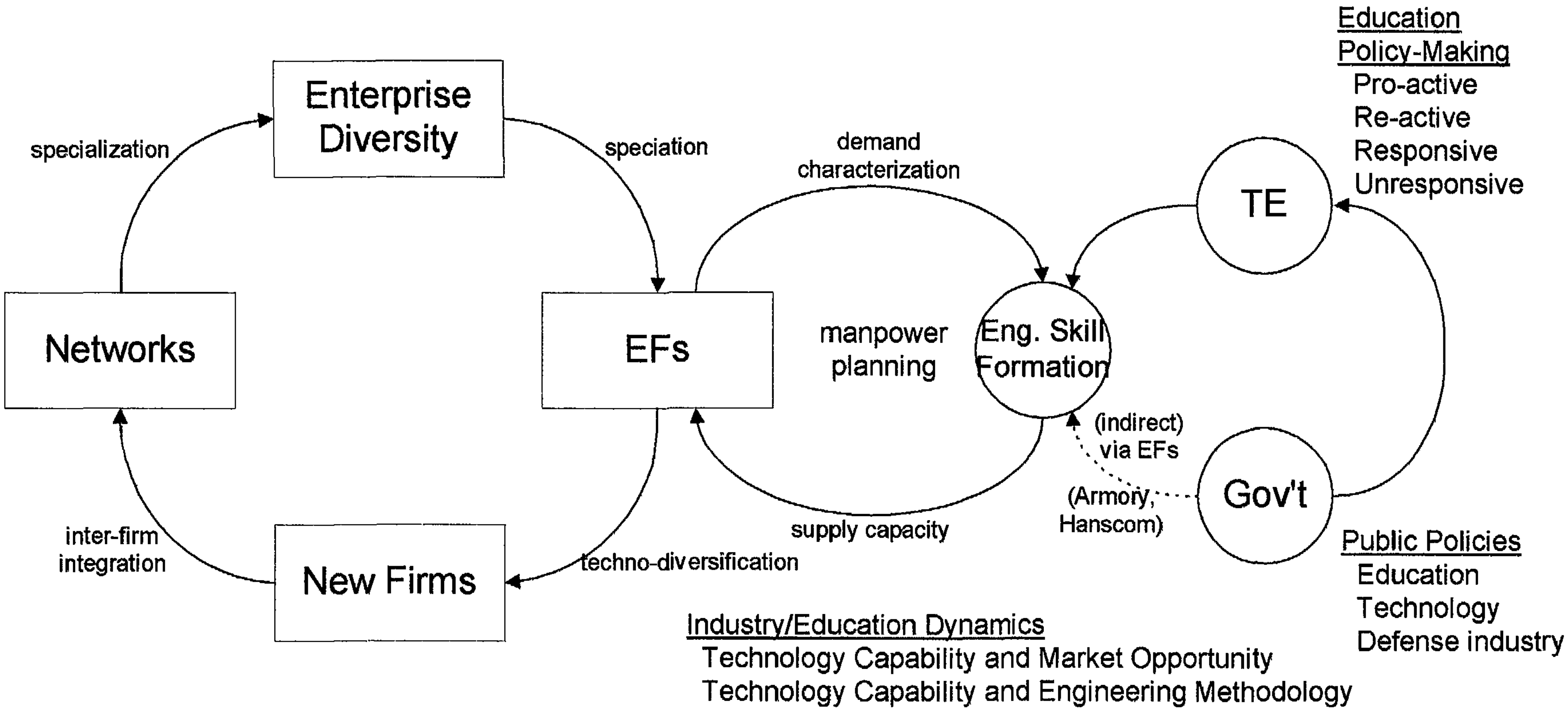
The figure titled Regional Growth Dynamics and Skill Formation (Figure 3.3) indicates linkages between regional growth and engineering education institutions. Matching supply of and demand for technical skills is a long term, mutual adjustment process requiring institutional coordination. Regional growth, represented by the growth dynamics on the left side of the figure, will be choked if the requisite numbers and types of graduate engineers are not produced by the education system, represented by the demand for and supply of technical graduates on the right side of the figure. Two conditions must be met for success. The first involves characterization of the demand for specific technological skills. The second involves investment in technical education.

Figure 3.3 Regional Growth Dynamics and Skill Formation

(See next page)

Regional Growth and Skill Formation Dynamics

Open-System Business Model | **Engineering Education Process**



EF = Entrepreneurial Firms
TE = Tertiary Education

4.1 Technology Change and Engineering Curriculum

The challenge of engineering education is exacerbated by technological change. The link between entrepreneurial firms and engineering graduates is mediated by engineering curriculum. During normal times updating the engineering curriculum does not present a challenge. But at times of technology paradigm or domain shift, such as from the age of mechanical to electrical technologies, the issue of curriculum becomes paramount. Firms seeking to advance their technological capabilities in opto-electronics, for example, seek graduates educated in photonics as well as electronics. This means that the challenge for educational institutions is not simply to increase the number of graduates but to increase graduates educated in a curriculum that includes emerging technological methodologies.

The mutual adjustment process between technology-driven enterprises and university curriculum is critical to an understanding of both Silicon Valley and Route 128. Silicon Valley and Stanford, in the words of Leslie and Kargon,:

> ...had grown up together, gradually adjusting to each other and to their common competitive environment. Each helped the other discover and exploit new niches in science and technology...In the proliferation of new technical fields and new companies that characterized the early evolutionary stages of these industries, the right kind of university could make a real difference in fostering horizontal integration and collective learning throughout the region (p. 470).

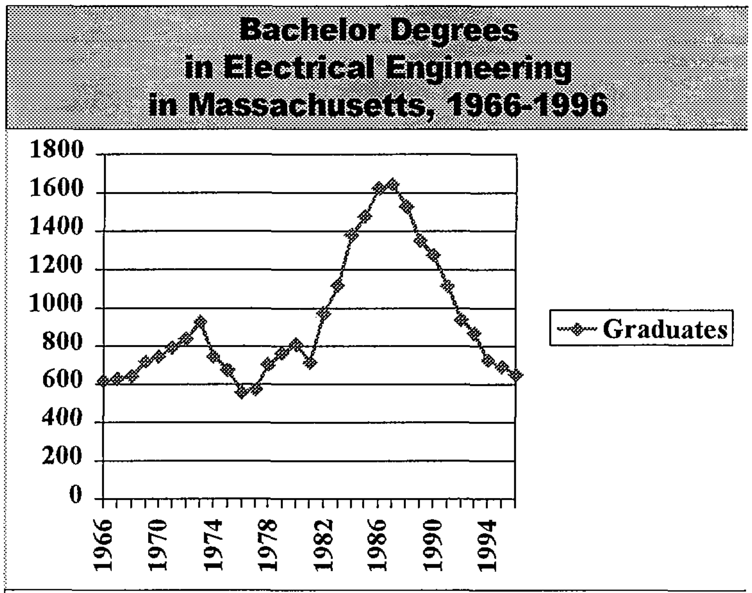
But the development of appropriate engineering methodologies within education institutions is not sufficient for regional industrial growth. The supply of engineering graduates must be in synch both in skill and quantity with the demand from technology driven firms. The supply response depends both on the appropriate curriculum and the ramp up capacity of the region's education institutions.

4.2 Investment in Engineering Education

The remarkable feature of the Massachusetts Miracle years (1978 to 1986/7) was the responsiveness of the education system to the skill needs of the rapidly growing firms. The result was a step increase in both engineering graduates and the technical skill base of the region. Entrepreneurial firms, educational institutions, and government funding partnered to provide the skill base required to fuel the growth and development of America's first high tech regional concentration.

Figure 3.4 reveals the extra-ordinary supply response to the technology capabilities being developed during the Massachusetts Miracle. The number of BA degrees in electrical engineering conferred by Massachusetts' universities and colleges increased from a low of 561 in 1976 to 1648 in 1988. The expansion in a region's 'production' of engineers is a costly process (also potentially high productive).

Figure 3.4 Bachelor Degrees in Electrical Engineering in Massachusetts, 1966-1996



Source: M. Best, "Technology Integration and the Resurgence of Route 128," UMass Lowell, 1999.

An expansion in graduates by 1000 requires an increase of 4000 students in four-year electrical engineering degree programs which, in turn, requires an expansion in faculty positions of roughly 270 (given a 15 to 1 student to faculty ratio) in electrical engineering plus a corresponding investment in facilities.

In the age of product-led competition, the skill formation process is not simply at the university level, important as this is. A feature of regional growth is that skill formation processes are instituted at both the high and mid technological levels. Otherwise, the growth potential of research investment will be lost. Often times, the critical factor is mid-level skills. This has been the case in the transition from electronic, circuit switched networks to ones based on optical, packet switched technology.

In the case of optical networking equipment, it is estimated that a single graduate engineer can support 5 to 6 associate engineers. Combined with a *kaizen* or HPWS capability in operations, these combined skills can compress the times for new product introduction and production processes. In the words of a Lucent executive:

> Success in the Optical Networking marketplace is dependent upon rapid introduction of new technology. Reduction of the interval from research through commercial product is an imperative. If our workforce is not equipped with the necessary skill level to manufacture advanced products, production capability will not adequately support the volume levels needed to meet customer demand. If this occurs, profitable gain from our research investment will be lost.

Investment in skill formation is costly. To get a high return of the investment, it is important to match the demand for skills from technology advancing firms with the supply from education institutions. The tripling in electrical engineering graduates during the 1976 to 1986 period involved, as noted above, partnering across three institutions: technology driven firms, education, and government. Only the government has both the funds and legitimacy to make educational restructuring and investments on the scale involved. Nevertheless, the state government was not the leader but a third partner in the implementation of an informal manpower development plan. The rapidly growing, technology driven firms were the active partners.

5. Conclusion: Productivity Triad

Exploring the links between technology development and growth focuses attention on the most important contribution that policymakers can make to rapid growth: manpower development planning for skill formation. Making the transition to more advanced models of technology management or into more precise technology domains will be blocked without the requisite skill base. Thus each transition involves newly instituted processes in three mutually interactive domains: principle of production, business model, and skill formation/technical labor pool and methodology. In this, each model represents a new *productivity triad*.

The concept of *productivity triad*, at enterprise and regional level captures the systemic dimension of organisational change: to make order of magnitude improvements in performance (last column of Table 3.2), institutional change has to be co-ordinated to address three elements simultaneously: production capabilities, the business model, and skill formation. At the level of the firm this means to move to multi-product flow (JIT or lean production), a company must simultaneously replace batch with flow production principles, supervisor with team-centred work organisation, and educate workers and managers in problem-solving practices and their new roles. At the level of the region it means that to jump to higher productivity and per capita income economic performance change has to be co-ordinated at the level of technology management, business and industrial organisation, and educational system.

The idea of productivity triad also offers a vision for achieving rapid growth. Success, however, depends upon corresponding changes in production, business and industrial organisation and skills. The principle of systems integration is also a principle of organisational change. Changes in any one of the three dimensions are not sufficient to drive the transition to a new technology management model. For example, the transition to multi-product flow (also known as just-in-time, lean production or agile manufacturing) depends upon complementary changes in bottom-up organisational principles common to kaizen, continuous improvement, total quality management, and cellular manufacturing. It also requires the move to process integration along the supply chain that commonly involves networking replacing market relations amongst firms.

Chapter 4: Cluster Dynamics

1. Introduction

The previous chapters identified Malaysia's critical impasse, the government's response to it as well as analysis of models of regional and international cluster successes. The framework utilised for clusterisation and the transition of industry to higher technology management capabilities is based on the Industrial Innovation and Cluster Dynamics Paradigm. This chapter will analyse MNC-driven and local capabilities using the paradigm, noting briefly the distinct development trajectories of each region in Malaysia and in detail Penang, the Klang Valley, Negeri Sembilan and Melaka, and Johor. The chapter evaluates the extent of capabilities developed in these locations through MNC activities, and local and indigenous firms, and support networks.

Most local and indigenous electronics firms started as SMIs and a number of them have graduated to become larger companies. Many of such companies have managed to retain their benefits and incentives as SMIs by creating smaller subsidiary companies, several operating as contract manufacturers, customised manufacturers, or simply as independent suppliers of parts or components. Some have also managed to break out to the export sector and internationalise their production by starting subsidiaries abroad. Several firms have also attained the capability of OEM (original equipment manufacturer), ODM (own-design manufacturer), and/or OBM (own-brand manufacture). However, most local and indigenous firms operations are confined to contract or customised activities, locked into the demands of MNC purchasers. Most of them operate with less than 150 full-time workers and realise less than RM25 million in annual turnover, and are therefore companies in the SMI category.

This chapter examines the extent of clusterisation and innovation capabilities achieved in the electronics industry in the major locations in Malaysia. Given the dominance of MNCs in Malaysia, it will examine MNC-driven development of local and indigenous suppliers, and development of complementary supporting institutions to stimulate movement of MNCs in the technology trajectory. Central to the investigation is the extent to which MNC-driven capabilities have diffused and become propellants of local and indigenous enterprise growth.

2. Malaysian Electronics: MNC-driven

While Japan, South Korea and Taiwan developed their electronics industries through the promotion of local enterprises Malaysia has very much pursued the Singapore model of stimulating foreign direct investment. Even when all foreign ownership restrictions were removed completely from Japanese manufacturing in 1971, no industry in Japan enjoyed more than 20% foreign ownership. However, unlike Singapore, which is a city-country that enjoys coordination superiority over most sites in the world, Malaysia has a large rural base and inferior coordination capabilities in sites outside Penang and the Kelang Valley. While foreign MNCs are not known to create the conditions for effective capability building as the political and economic basis for such developments tend to be located in their own nation states, their superior productive capabilities generate considerable synergies that can act as catalysts for stimulating further expansion.

It is on this basis that Porter's (1990) observation that the development of ancillary services and supporting industries tied to MNCs as being traditionally important in the advanced and industrialised countries is useful here. MNCs offer room for the development of supplier networks, though they are unlikely to actively promote it. However, the extent of deepening and technological sophistication that will take place in MNCs will *inter alia* depend on the availability of globally competitive suppliers and networks. The latter depends on a whole myriad of factors crystallised cogently in Best's (see chapter 3) argument on the industrial innovation and cluster dynamics paradigm.

This section presents the nature of electronics industries in the main conurbations in Malaysia.

2.1. Penang and the Northern Region

Penang is the top manufacturer of electronics products in Malaysia. It has built up a high reputation in the assembly and testing of semiconductors and components, computers and peripherals, machine tool support, as well as consumer electronics. A list of the world's "Who's Who" in electronics manufacturing have set up their offshore plants in Penang, including;

- Semiconductor and Components:

Advanced Micro Devices, Hewlett Packard, Integrated Device Technology, Hitachi, Intel, Fairchild and Siemens

- Communication Components and Products:

Alcatel, Northern Telecom and Motorola

- Computers and Peripherals:

Acer, Dell, Applied Magnetics, Iomega, Komag, Kobe, Seagate, and Quantum.

- Consumer Electronics:

Bosch, Sanyo, Sony, Toshiba.

Penang contributed around one-fourth of electronics production to the national total. Its value added was around one-third. Its share in the number of factories, value added and employment was 20.7, 30.3 and 27.2% respectively in 1993.[46]

The first phase of Penang's industrialisation process (1970-1986) was largely based on the abundant pool of cheap and trainable labour as well as the availability of pioneer status incentives. However, from the late 1980s, utilisation of robotics and automation increased. The 1990s saw the emergence of the computers and peripherals segment in Penang.

Penang's electronics industry has also created spillover effects for Kedah. The establishment of Kulim Hi-Tech Park (KHTP) in Kedah which is expected to house corporate, academic, and government tenants specialising in R&D activities related to electronics, is an example. Pioneering tenants at the KHTP include Intel Products (US), Akashic Kubota Technology (recently acquired by Stormedia), Empak, AIC, Maxmedia, Fuji Electric, MEMC Electronics Materials (US-Germany), Hitachi (Japan) and Celestica (US).

As one of the earliest regions involved in the electronics industry, Penang has the critical mass of firms for clusterization. The State Government of Penang and the Penang Development Corporation have successfully developed horizontal information sharing. Public and private partnership in skill formation and monitoring through the Penang Development Corporation is also evident. There are also signs of entrepreneurial firms emerging in Penang, utilising its skill base for maximum effect. A detailed analysis is presented later in the chapter.

2.2. The Central Region: Selangor, Federal Territory, Negeri Sembilan and Melaka

The Klang Valley (Federal Territory and the nucleus of Selangor state) received the first electric/electronics firm in Malaysia, i.e., Matsushita Electric which started operations in 1965. As with Penang, the first big inflow of electronics MNCs located in the Klang Valley from the early 1970s. Melaka and Negeri Sembilan received electronics investment from the late 1970s and early 1980s. Unlike Penang, however, the Klang Valley, Negeri Sembilan and Melaka did not receive tangible investment in computer and related assemblies. Some of the MNCs include:

- Electronics Components and Wafers

Motorola (Petaling Jaya), Motorola (Seremban), Texas Instruments, Intersil, MEMC, NEC, Fujitsu, Siemens and SEH

[46] Computed using data from the statistics department.

- Telecommunication Components and Equipment

Ericsson, Western Digital and Uniphone

- Consumer Electronics

Matsushita, Toshiba, Nippon Denso, Sony, Chungwa Picture Tubes, JVC, Samsung and Hitachi (Bangi)

The central zone of the Klang Valley, Negeri Sembilan and Melaka is likely to become a very important area for the electronics industry. The Bukit Jalil High Tech Park, the Multimedia Super Corridor (MSC), and Cyberjaya have been attracting high-tech and R&D based IT and electronics companies.

2.3 Johor

The electronics industry forms an important component of Johor's industrial sector although its strengths are more obvious in the shipbuilding and petrochemical industries. Most of the electric and electronics establishments in Johor fall under the electrical sector. More recently, electronics factories have also been set up in Johor. US based Seagate Technology has recently set up its printed circuit boards (PCB) plant in Senai as well as Hitachi Electronic Corporation.

Johor has the benefit of obtaining spillover firms from the Klang Valley as well as Singapore. However, the number of firms in the electronics industry is still small with a weak skills base, few entrepreneurial firms, and little public and private partnership. Computer and peripheral assemblies in Johore include Seagate, Wearne Electronics and Solectron. A significant amount of PCB assembly firms service Singaporean and foreign MNC contractors located in Singapore. The SIJORI growth triangle seems to have emerged with Johor as low end and ECM supplier base to regional MNC operations in Singapore.

Some of the main MNC firms located in Johor include:

- Electronics Components

SM Semiconductor, Eltech Electronics Technology, Hokuden, Fujitsu Components and Hitachi

- Computer and Peripherals

Wearne Electronic, Eastool, Deen Electronics, Eltech Electronics, Gautronic, Asahi, CMKS, Datadunia, Unique Existence, Tru-Tech, GG Circuits, Flextronics, MMI, Multi-Unify, Pintarmas, Rem Electronic, NCAB, Joman, Technocom, Sonitech, TacPrecision, Time-Carlee, WISRS, Technotronic, Compo, Solectron

- Consumer Electronics

Aiwa Electronics, Sharp-Roxy, Santronics, Dai Hwa Electronics, Hitec, Maker Electronics, Pioneer Technology, Raham Cony, Quamac, Okida, Tanashin, Skyline Frontier

Unlike Penang and the central states, the electronics industry emerged in Johor much later. Also, labour and space exhaustion in Singapore have been critical in the extension of a number of product chains into Johor. Hence, much of the electronics assembly activities support MNCs in Singapore.

2.4 East Malaysia: Sarawak and Sabah

Both Sabah and Sarawak are late starters in the electronics industry. The earliest firms came in the 1990s following efforts by the government to encourage through PS and ITA incentives labour-intensive firms facing rising labour and land costs to move out operations to the Eastern corridor and East Malaysia. Most of the electronics establishments that have set up operations in Sabah and Sarawak are labour-intensive. Komag of USA has set up its plant in Sama Jaya FIZ Kuching, Sarawak. Komag's suppliers who are already in operation in Malaysia, especially Penang, are expected to set up their factories. Other electronics MNCs in Sarawak include Taiyo Yuden and Hardco.

One major development suggests the possibility of Sarawak gaining a unique market niche in electronics production. The setting up of the first wafer fabrication plant at Sama Jaya FIZ in Sarawak by 1st Silicon if harnessed effectively could garner a snowballing effect into attracting other wafer fabricators into the state. This joint venture between the State government of Sarawak and the Khazanah is expected to use the latest technology to fabricate wafers. With semiconductor companies increasingly becoming fabless,[47] the potential for expansion at host-sites is growing. Sarawak's prime competitor is Taiwan which already has successful furnace wafer fabricating companies. United Microelectronics is one example. 1st Silicon could act as a catalyst to remove the risks

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[47] See Mazurek (1999), Making Microchips: Policy, Globalization and Economic Restructuring in the Semiconductor Industry, Cambridge: MIT Press; Mazurek (1999) "How Fabulous Fablessness: Environmental Challenges of Economic Restructuring in the U.S. Semiconductor Industry", paper presented at the conference, "Global Networks, Innovation and Regional Development", Santa Cruz, 11-13 November, 1999.

associated with maiden operations in underdeveloped sites. Its success if carefully planned can bring the requisite critical mass of firms for the development of a viable wafer fabrication base in Sarawak. However, considerable infrastructural investment outlays and development of related supplier base is essential if the government is to seriously attract a critical mass of wafer fabrication activities in Sarawak.[48]

3. Regional Manufacturing Dynamics

Chapter one identified the limitations faced by Malaysian electronics. Using Best's framework of cluster dynamics and industrial innovations paradigm advanced in chapter three, this section dissects the causes of these limitations. Four critical instruments are used to audit the clusters in Malaysia, viz.,

- Extent of differentiation and specialisation
- Extent and role of entrepreneurial and development firms
- Extent of technological variation
- Horizontal integration and reintegration

As noted in the preceding section, MNCs dominate electronics operations in Malaysia. Hence, strategies to develop the industry further cannot overlook their integral role. While MNCs seldom actively promote clusterization and innovations, a number of developments offer considerable clusterization potential in host sites. The potential for clusterisation has increased because of:

- Increasing globalisation of production to access resources and markets globally. The solid supply of basic infrastructure and knowledge-based human resource has made Malaysia an ideal base for expansion.
- The growing tendency of MNCs to integrate production activities related to particular product lines in a few regional centres. Dell reported its location in Penang as having been primarily driven by the need to integrate around its product chain as well as strategically customise product development to meet the Asia Pacific market.
- The need to minimise production and product cycle-time. The movement of computer assemblers to Penang has attracted disk drive makers such as Seagate, Quantum and Komag, and other peripheral contract manufacturers such as Solectron there.
- Increasing tendencies of MNCs to subcontract out operations to contract manufacturers. Intel, AMD, Motorola and Fairchild have increasingly

[48] As discussed in a past meeting, the consultants recommended a separate detailed study of wafer fabrication in Malaysia.

subcontracted out a number of their production lines to contract manufacturers such as Solectron, Globetronics, Unisem and Carsem in Malaysia

While the potential is growing, the successful promotion of clusters require the simultaneous development of several requisite support institutions. This section attempts an audit of firms capabilities and support institutions and their coordination mechanisms to locate the location of Malaysian electronics from the cluster dynamics required for it to move to the technology frontier.

Three definable bases can be identified in Malaysian electronics. Penang and the Kelang Valley function as the nucleus of the electronics operations in the Northern and Central regions respectively. Kulim and Perak function as outer rings in the Penang cluster, though, the federal government has successfully attracted high tech operations in the former. The siting of Siltera and effective policies to attract wafer fabrication plants in Kulim could integrate the Northern cluster further. Negeri Sembilan and Melaka function as the outer ring of the loosely formed Kelang Valley cluster. Johor functions as a satellite of the Singapore cluster.

While the locally based foreign MNCs continue to expand, the local and indigenous sector has evolved differently in the three main regions in Malaysia. MNCs in Penang tend to enjoy greater linkages with local and indigenous firms and better co-ordination with support institutions. A number of the MNCs and local firms have moved to attain critical aspects of TM3 status. Its linkages has spread to Kulim in Kedah and Northern Perak. MNCs in the Klang Valley have tended to evolve truncatedly (e.g. Texas Instruments and Motorola), some substituting supplier requirements with own subsidiaries (e.g. Chungwa Picture Tubes). MNCs in Johore tend to have evolved as offshoots of higher operations in Singapore, and to a small extent use the proximity to Singapore as a gateway to export markets. Successful local and indigenous firms in Penang enjoy strong links with MNCs in the state. Local and indigenous firms in the Kelang Valley and Johor do not enjoy strong production links with MNCs. MNCs in Negeri Sembilan and Melaka show patterns similar to the Klang Valley. Apart from flexible production systems used in assembly and test operations, MNCs and local firms in Kelang Valley, Negeri Sembilan, Melaka and Johor demonstrate largely TM2 operations.

Malaysian electronics industry is a composite of three micro-regional agglomerations with Penang being the largest in terms of firms' numbers, employment and value added, followed by the central states of Selangor, Federal Territory, Negeri Sembilan and Melaka, and Johor. Kulim has more electronics firms than Melaka, but functions primarily as an auxiliary support base to Penang, though, the national government has planned to develop as a high-tech base. Kulim, Negeri Sembilan and Melaka developed later as spillover effects took place in Penang and the Klang Valley. East Malaysia is a region that is just developing its electronics industry.

Penang has the largest concentration with over 90,000 employed, followed by the Klang Valley with 85,000 and Johor with nearly 80,000.[49] While all three districts are variants of the Singapore model, in that they are driven by MNCs, the linkages to corporate headquarters follow different patterns and consequently, the regional dynamics within and across firms are different as well.

3.1 Penang: An Emerging Cluster

Penang was suffering in the late 1960s. Its historic trading role virtually disappeared with the political turmoil and national realignments and unemployment reached nearly 15%.[50] In 1969 the state government established the Penang Development Corporation to "undertake and promote socio-economic development of Penang".[51] The PDC developed programs in industrialisation, urbanisation, urban renewal, tourism promotion and human resource development. In the next 25 years Penang's manufacturing share in GDP increased from 13% to 50%.[52] Penang has developed the resemblance of an industrial cluster but for it to be converted into a driver of the productivity-driven strategy the production and organisational capabilities of industrial enterprises must be upgraded and the skill formation processes must be substantially upgraded.

3.1.1 Specialisation (micro-diversity)

The Penang region has built a high volume production capability in electronic components which spread to hard disk drives and, more recently, to myriad elements of the PC supply chain (DCT, 1998). While many of these parts and components are elements in global production networks which are co-ordinated at the headquarters of MNCs and do not cross penetrate, since the 1980s it has witnessed a transition to a regional supply base with a growing degree of local horizontal integration. In Penang, Globetronics and Trans Capital supply MNCs while MNCs such as Intel and Motorola have created spin offs of their own. Intel has assisted and established Altera and AIC, while Motorola has done the same for BCM. This has been accompanied by the emergence of a locally owned supplier base with increasing capabilities in technology management (refer to Case Studies in Appendix 7).

A number of studies attest to the superior performance of the Penang region amongst the three regional concentrations of electronics firms in Malaysia. For example, two major

[49] Industrial Master Plan II, p. 38
[50] Koh Tsu Koon, 1995, p. 2
[51] PDC, 1994, p. 4
[52] Koh Tsu Koon, 1995, p. 2-3

studies and interviews by the consultant team show that most supplier firms in Penang have passed through the third and fourth stages of technology absorption and diffusion.[53]

The high level of technology diffusion in Penang compared to other states in Malaysia is due to a much higher proportion of local outsourcing by MNCs and local firms. Increased differentiation and division of labour has been made possible by greater local sourcing. Local supporting firms in Penang sourced 46 percent of their inputs locally.[54] Detailed studies of the linkages between seven electronics companies and nine indigenous machine tool firms in Penang, showed that the latter fostered the growth of second and third tier suppliers.[55]

> The first-tier vendors (those who had the first links with the electronics sector firms) have, in time, chosen to specialise in certain functions, and passed on some of their previous tasks to second-tier machine tool firms whom they now nurture. These second-tier firms have gone on to spawn their own third-tier subcontracting firms, giving them simply tasks likes parts fabrications which are no longer profitable for the former. In this way, not only has the number of machine tool firms increased but there has been a greater degree of specialisation among them. These findings suggest a wider diffusion of technology through the agency of first-tier firms to smaller firms servicing them. The findings of this study have been corroborated by other observers as well (for example Lim, 1992 (sic); Teh, 1989).[56]

When the MNCs first entered Penang, linkage with the local industry was almost non-existent as the MNCs brought in their own overseas vendors. Despite the lack of supplier companies and capabilities to support their needs, some of the pioneering MNCs tried to spawn local suppliers. Intel managed to support the modernisation of companies such as LKT, Metfab, Prodelcon, Rapid Synergy, SEM and Eng Teknologi and its staff founded Shintel, Samatech, Unico, Globetronics and Shinca. Motorola was instrumental in the modernisation of Wong Engineering.

Local sourcing by Penang's electronics industry rose from RM1.8 billion in 1995 to RM1.9 billion in 1997 after a fall to RM1.5 billion in 1996, which was caused by a slowdown in the industry. [57] The average per-firm local sourcing figures show a rise from RM56.1 million in 1995 to RM57.9 million in 1997. The breakdown using 10 major companies in the respective categories for local sourcing of total purchases in 1998 were 40-50% for consumer electronics, 4-10% for semiconductor components, 20-40% for other electronics components and communication equipment and 13-60% for computers

[53] Narayanan, Suresh (1997), p. 22; Rasiah, Rajah (1993); (1996); (1999)
[54] Narayanan, Suresh (1997), p. 23
[55] Rasiah (1994)
[56] Rasiah (1997), p. 25
[57]Based on 32 electronics companies that responded to the PDC Industrial Surveys for three consecutive years.

and peripherals in 1998.[58] Value added recorded by Penang's electronics supporting and ancillary firms rose from RM257.6 million in 1990 to RM736.2 million in 1996. Their contribution to Penang's overall manufacturing value added rose from 6.6% in 1990 to 6.7% in 1996. The value added per input of this industry rose from 0.56 in 1990 to 1.03 in 1996 when that of overall manufacturing in these years only rose from 0.32 to 0.33 respectively.[59]

The developments above show that the supporting and ancillary industries in Penang are productive and of high value added activities. However, human resource development in this sector, particularly in the plastics, software and fabricated metal industries is still lacking. MNCs have claimed that they would like to increase their local sourcing but are unable to find suitable local suppliers that meet their requirements. Some of the major components with a high share in the production cost are simply not available locally. Examples of such components include wafers, TFT-LCD, STN-TFT, aluminum and lead frames (refer Appendix 9 for MNCs' efforts to link with local companies).

Also, while a range of sub-industries have evolved with time, Penang's main electronics firms continue to be transplants from abroad. Hence, from semiconductors in the early 1970s, the sub-industries added from abroad include telecommunication component and equipment, audio, video equipment from the mid and late 1970s, integration of semiconductor testing from late 1970s and early 1980s, disk drives and computer assemblies from the early 1990s. They were relocated from abroad. Penang could achieve a new cluster dimension if entire new firms and sub-industries engaged in new products begin emanating from the state. This is the critical dynamics of speciation which has evolved in the Silicon Valley. Penang has to develop the capacity to stimulate such speciation to move towards the technology frontier.

The differentiation and the range of industries has stimulated greater specialisation in Penang as firms such as Intel, Fairchild, AMD, Motorola, Hewlett Packard, Seagate, Dell and Northern Telecoms have subcontracted out considerable amounts of dissimilar activities (e.g. machine tools, parts and components manufactures etc). However, the lack of suppliers in specific industries such as high quality plastics and wafer fabrication has continued to attract considerable imports. For an integrated manufacturing complex to evolve, these missing links must be addressed. In addition, an integrated manufacturing complex can only function competitively if it has the capacity to create new products often with new firms and sub-industries. This critical aspect of speciation is important to establish a strategic position at the technology frontier.

3.1.2 Entrepreneurial and Developmental Firms

PDC sought out a list of leading electronics firms that they visited personally to relocate operations in Penang. Among these firms were some of the world's most entrepreneurial

[58] Derived from PDC surveys.
[59] Derived from PDC surveys.

electronics firms, many of which fit what Intel's Grove describes as the 'new horizontal computer industry.'[60] Leading examples include Intel, Fairchild, Motorola, Hewlett Packard, AMD and later Dell. These firms operate using quick turnaround JIT and rapid ramp up capabilities. The latest products are shipped out from their plants and production can be stepped up and down quickly to meet fluctuations in demand.

Penang's electronics industry has advanced with the development of these companies. Intel's progressive moves from assembly to continuous improvement capabilities made it possible for its headquarters to transfer technology to Penang and for the local plant to move to more complex higher value-added activities[61] (refer to Case Studies in Appendix 7). The dynamics of flexibility in process technology transformation in Intel was achieved under totally Malaysian run operations in the 1980s. JIT and the shift towards TM3 took place from late 1984.[62] It is this flexibility that enabled semiconductor firms in Penang to avoid massive capacity restructuring whenever a downswing struck.

Motorola is a similar story.[63] The R&D centre, which started with four engineers, has nearly 120 in 1998. Motorola Penang enjoys the design leadership in Asia for the CT2 cordless telephone. The Centre does new product design, product-process interfacing and advanced manufacturing processes (refer to Case Studies in Appendix 7).[64] Penang already had a pool of requisite labour to achieve Dell's objectives.

Dell's Asian headquarters are in Penang. Dell is an industrial innovator; it is the leading example of the opportunity that the internet has created to build a mass customisation business model. Dell's "produce to order" business model combines the Toyota production system (cellular manufacturing, JIT, Kanban, quick changeover, continuous improvement, self-directed work teams) with internet to integrate production and distribution into a single high-throughput process. Dell's factory responds directly to the final customer; all intermediary distribution links are eliminated. The era of mass customisation, in which each product was assembled to meet a specific customer's specifications, has been promised for a decade but Dell's organisation plus the internet made it possible (refer to case studies in Appendix 2). The Managing Director of Dell's Penang operations reported that Penang stood out not only because of the smooth coordinating approach of the state government and PDC, but also because of its cultural mix that offered regional customisation potential for much of Asia.[65]

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[60] Andrew Grove (1996), p. 42; Also known as TM 5, a business model associated with horizontal integration, collective learning, and community institutions.
[61] Lim (1991)
[62] See Rajah Rasiah (1993) *The International Division of Labour: The Semiconductor Industry in Penang*, Kuala Lumpur: Malaysian Social Science Association Press.
[63] see Ngoh (1994)
[64] See also Rasiah (1996)
[65] Interview by Rasiah, Rajah (1995)

The implications are potentially as profound as other major technological innovations such as Ford's redesign of factory architecture to use the arrival of fractional horsepower, unit drive electric motors to achieve, for the first time, synchronised or mass production. To achieve the opportunities of the new model, Dell has developed ramp-up capabilities that are the exception even for Penang.

Furthermore, Dell pursues a simultaneous launch strategy. This means that the products made in Penang are first generation products, the same products made in Dell's home office plants. This increases the challenge and opportunities for local suppliers to Dell to be on the cutting edge of new product and technological developments.

The development of entrepreneurial skills in MNCs has created a large pool of potentially successful managers who could easily start new firms to stimulate further differentiation and horizontal integration in Penang. Local firms such as Globetronics, Shinca, Prodelcon, Metfab and Rapid Synergy were started by entrepreneurs who build up their experience working in MNCs in Penang. New MNCs such as Komag, Quantum and Solectron also benefited from absorbing managers from the earlier MNCs. Human capital deepening in local divisions of MNCs fostering technology transfer, particularly via skilled personnel moving to local firms has occurred.[66]

> Intel, AMD, Fairchild (National Semiconductor), Siemens, Hewlett Packard, Micro Components Technology and Motorola Malaysia reported that former personnel...had started up new firms, and have offered substantial technical support to local firms.[67]

This is not surprising as these companies are developmental firms and have long spin-off histories in the United States. Fairchild's subsidiary plants in Penang, Dynacraft and Micro Components Technology, trained many of the region's key personnel in precision engineering and metal working which now run successful local firms, including Prodelcon, Metfab and Rapid Synergy. Motorola encouraged its engineers and managers to join BCM during its initial development stage. Two of Intel's personnel left for AMD's NVD design centre in Penang. Two of Motorola's staff also joined the R&D division of Sapura in Ulu Klang.

The development of supplier firms in metalworking, machining and tooling, and plastics is critical to maintaining the competitive advantage of electronics in Penang. But, at the same time, the number of Malaysian-owned entrepreneurial firms (firms with design and new product development capabilities) in electronics is limited. Outstanding examples in Penang are Eng Teknologi, UNICO, and Globetronics[68] (refer Appendices 2 and 7 for further discussion).

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[66] Rasiah (1995) chpts. 6-7,

[67] Rasiah (1998) p. 10

[68] Each has been profiled by Lim Kah Hooi (1997).

Intel, Motorola, and, potentially, Dell are exceptional in their commitment to local innovation and opportunities for driving cluster dynamics. They are developmental firms within the Penang context, which have enhanced the skill and entrepreneurial base of the region (technical and managerial skills), a prerequisite for speciation to occur and to making the transition to systems-integrated manufacturing.

The spread of the synergies generated by the developmental firms in Penang to local firms could not have reached high levels without the active role played by PDC and the Penang government, which initially directly coordinated, and subsequently transformed the support infrastructure to include coordination and deliberation councils from 1990. Such a role stimulated considerable matching of potentially capable local firms with the developmental firms. Also collective action problems such as scale and scope involving training were resolved by PDC, which translated MNC demand into the formation of the Penang Skills development Centre (PSDC) in 1989 and in the 1990s the Penang Design Centre. The PDC and Penang government also actively promoted the growth of local innovation. Trans Capital, UNICO and Globetronics are examples that have benefited from such thrusts. Its critical role was also instrumental in attracting capitalisation of Globetronics from Malaysian Technology Development Corporation (MTDC).

3.1.3 Technological Variation

MNCs do 'product proliferation' rather than product design and new product development in Penang. But the diversification into product proliferation has enabled technological variation in the region. The earlier developments of precision engineering and machining and later to disk drives and computers are examples of new sub-sectors to the region that have enhanced the potential for technological diversity. However, these sub-sectors are not new to the universe. They merely expanded with the demands exerted by changes in the production dynamics of electronics MNCs operating in Penang.

The emergence of Altera, the first design studio, signals a new, critically important development in Penang's transition. The skills needed for "front-end" operations like chip design, systems integration, and applications engineering are in short supply in Penang. What does exist is bottled up in the R&D facilities of a handful of MNCs. Intel's Design Centre is a microcosm, internal to Intel, of the kinds of design capabilities that must become part of the wider cluster capabilities for Penang to make the transition to a more powerful cluster dynamics. Similarly, Motorola Penang has developed a design centre in its own premises for telecommunication products. The CT cordless phone was designed in that centre. The Penang Design Centre accounts for 3 phases in the development of design capabilities and tools across the following disciplines: mechanical engineering, electrical engineering, software engineering, media and communications, industrial design, and manufacturing.[69] Nineteen different software tools are involved; the Penang Design Centre has at least one trainer for each tool.

The importance of local skill development cannot be over emphasised. As one CEO put it, "If the changes outside the organisation is happening faster than the changes inside, then the end is near".[70] While the PDC and the Penang government have recognised the size of this problem and thus have been trying to diversify their training activities vertically as well as horizontally, interviews show growing shortfalls in the supply of skilled and technical labour to enable the broadening of design activities in Penang. Managing Directors of Intel, AMD and Motorola reported looking out for such Malaysian expertise in universities – both locally and abroad – for hiring.

3.1.4 Horizontal Integration and Reintegration

Companies such as Intel, Motorola, and HP have attracted world-class first-tier suppliers including contract manufacturers such as Solectron which, in turn, have filled in the PC supplier base making the region attractive to innovative PC assemblers such as Dell. As noted, Dell's strategy of combining the Toyota production system with the internet distribution channel has revolutionised the PC industry; a second feature of Dell's strategy, simultaneous product launches worldwide has created pressures in the Penang supplier base to operate at the frontier of production capabilities with first generation technologies.

Today Penang offers capabilities for state-of-the-art manufacturing and rapid ramp-up to high performance standards to market-led or design-led companies from anywhere in the world. Xircom, for example, is a fast growing telecommunications company that "started the mobile computing revolution" with small, inexpensive, adapters that make it possible for notebook PC users to access their corporate networks. The Xircom adapter turns notebooks into desktop PCs in terms of connectivity to local area networks but without sacrificing the mobility of the notebook. Xircom's products are made in Penang only. The local managing director was chosen because of his networks in Penang. He was able to build a management team; assemble the operations personnel; identify, set-up and equip a plant; and get it running to high performance in a time span that may be the fastest in the world. Making the plant operational has involved ongoing interaction with Automated Technology, a process automation supplier literally across the street. Automated Technology personnel work inside Xircom's plant.

[69] The Penang Design Center seeks to develop state-of-the-art design and manufacturing capabilities to transform product concepts into viable products. Advances in software, and modularization, have driven down the design cycle time. The design process has five phases: product definition, functional design, logic design, circuit design, and layout design.

[70] Lim (1997), p. 4

In addition, rapid process and product upgrades achieved by local suppliers such as TransCapital, LKT and Eng Hardware have also offered MNCs in Penang world class supplies. Especially disk drive and computer assembly firms in Penang have strong supplier base. To a large extent Porter's emphasis on ensuring the establishment of a world class supply chain has been evolving strongly in Penang in some component niches. However, MNCs in Penang lack requisite supplies of critical components such as fabricated wafers and high volume high precision machinery for semiconductor manufacturing. A new set of supplier firms must emerge to ameliorate this problem. Also, supporting firms in Penang must move towards greater R&D activities so that they function as world class suppliers.

3.2 Klang Valley, Negeri Sembilan and Melaka: Uncoordinated Loose Cluster

Klang Valley was better endowed than Penang when the first influx of electronics MNCs located in Malaysia in the early 1970s. The administrative capital, the promotional agency of MIDA, and federal support were strongest in the Klang Valley. Negeri Sembilan and Melaka benefited from the spillover effects from expansion in the Klang Valley. A number of MNCs seeking sites with cheaper land and lower wage costs from the late 1970s and early 1980s relocated in Negeri Sembilan and Melaka.[71] Hence, the Klang Valley, Negeri Sembilan and Melaka have become industrialised, albeit their share of electronics production is not comparable to Penang.

3.2.1 Higher Intra-firm Division of Labour

The Klang Valley, Negeri Sembilan and Melaka region has built a high volume production capability in consumer electronics, which spread to television sets, video and audio equipment and, more recently, to picture tubes and other components. However, many of these parts and components have remained as elements in global production networks which are co-ordinated at the headquarters of MNCs and do not cross penetrate much in Malaysia. Unlike Penang, local and indigenous firms such as Sapura and OYL electronics have not been able to penetrate significantly intermediate MNC markets in the Klang Valley, Negeri Sembilan and Melaka. Japanese, Taiwanese and South Korean firms generally supply the critical components sourced domestically by their mother firms.

MNCs have supplanted supply requirements by attracting either foreign suppliers or their own subsidiaries. For example, Taiwanese owned Chungwa Picture Tubes has a range of suppliers of its own in Shah Alam. Similarly, Samsung in Negeri Sembilan also sources considerably from its own plants. Even here, a number of high value added components

[71] Interviews by Rasiah, Rajah in 1995 and 1999.

such as LCD displays and TFT screens are imported from their subsidiaries or suppliers located in their home economies.

A limited number of local and indigenous suppliers in the same region supply MNCs, but all confined to non-core components. Procurement officers in four Japanese firms involved in the assembly of videos, CTVs and car air-conditioners in Bangi reported sourcing core components from either other Japanese suppliers or from their own sister subsidiaries.[72] Capannelli reports a similar finding:

Although the strategy of intra-group sourcing varied among the assemblers, as a general rule, the parts involving core technologies were often procured from sister companies of the same group. In contrast, the lower-end technology parts were mainly supplied by "Malaysian" firms. In several cases these input makers were joint ventures with third country firms from Singapore and Taiwan.... Finally another category of suppliers consisted of firms whose ownership was entirely non-Malaysian ... Such firms included American, European, South Korean and Taiwanese...[73]

Capannelli's[74] research also showed that only about a fourth of Japanese consumer electronics firms sourcing in Kuala Lumpur and Johore were from Malaysian firms. Japanese suppliers accounted for 60% of the supplies. Japanese firms in the Klang Valley also considered that local sourcing extended either to the whole of East and Southeast Asia or just Southeast Asia so long as they were sourced from outside Japan irrespective of ownership.

A further two major studies report weaker linkages between MNCs and local and indigenous firms in the Klang Valley, Negeri Sembilan and Melaka.[75] Supplier firms in these areas have hardly passed the first stage of transfer (adoption). Hence, local and indigenous supplier firms in these states have not progressed to the second stage of absorption. Instead of local firms creating synergies from an extensive division of labour – both horizontally and vertically – as in Penang, MNCs source minimally and directly from end-suppliers. The lack of micro-diversity among supplier firms in this region has restricted the development of world class suppliers.

American and European firms source far less locally in the Klang Valley, Melaka and Negeri Sembilan than in Penang. Motorola, Texas Instruments, Western Digital and Intersil reported sourcing between 2-20% of their purchases locally. Swedish owned Ericsson reported sourcing around 45% of its purchases from domestic firms, primarily from other foreign MNCs. Japanese, Taiwanese and South Korean firms source most of their supplies from firms of their own nationalities. Given the weak technological capabilities of local and indigenous suppliers, American and European firms either

[72] This finding is corroborated by Capannelli, Giovanni (1999)
[73] Capannelli, Giovanni (1999) p. 213.
[74] Capennelli, Giovanni (1999) p. 213.
[75] Rasiah, Rajah (1996); (1999); Narayanan, Suresh (1997)

source directly from the foreign East Asian firms, including Singaporean, or import their inputs. Some firms, including Motorola in Sungai Way and Intersil in Ulu Klang reported sourcing higher value added supplies from local firms located in Penang.[76]

The lower level of technology diffusion in the Klang Valley, Negeri Sembilan and Melaka is linked to a much lower proportion of local outsourcing by local firms. In Penang, MNCs – especially Intel and Motorola - have actively developed local firms to meet their qualitative and quantitative requirements. Eng Teknologi, LKT, Prodelcon, Metfab and SEM among the several firms who have directly benefited from such active developmental role of MNCs. No MNC in the Klang Valley reported developing local firms, stating that state institutions have not stimulated such activities. Local supporting firms in the Klang Valley accounted for less than 13% of MNC purchases.[77] A detailed study of the linkages between four electronics companies and four local and indigenous suppliers in the Klang Valley found that the latter has evolved little over the years.[78]

> The first-tier local vendors (those who had the first links with the electronics sector firms) still perform low-end activities outsourced by MNCs. Few second tier firms exist. When they do exist, the first-tier firms are either owned by Japanese firms, or both the first and second tiers are owned by Taiwanese, Singaporean and South Korean firms. Hence the division of labour between firms is very low, while within firms high.[79]

JVC, Toshiba, Soney, NEC, Fujitsu and Hitachi reported attempting to increase local sourcing following promotional efforts by the government under the subcontract exchange programme (SEP) and the vendor development programme (VDP) instituted in the late 1980s. Each MNC has attempted to use three to four suppliers for low-end inputs, including plastic injection moulding. As with the general pattern in the central region, local and indigenous firms enjoying supply relationships with MNCs do not have a division of labour vertically below them. Suppliers reported obtaining low margins due to competition created between them by the MNC clients. MNCs reported that local firms were undermining their competitiveness because of high costs and poor quality supplies offered by them. Such cutthroat business strategies have undermined integration potential.

Unlike in Penang, no state development corporations in the central states have estimated local sourcing achieved in the electronics industry. Interviews with 16 firms in the central states in 1999 suggest that MNC electronics component firms source between 2-10% of their inputs locally.[80] The commensurate figures for MNC consumer, and MNC computer

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[76] See also Rasiah, Rajah (1996)
[77] Narayanan, Suresh (1997), p. 23
[78] Rasiah (1999)
[79] Interviews conducted by Rasiah, Rajah in 1999.
[80] Interviews conducted by Rasiah, Rajah and Chang, Colin in 1999.

peripherals firms operating in the central states ranged between 40-60% and 20-70% respectively. These figures included inputs from foreign suppliers operating in Malaysia.

In the absence of a coordinating body to stimulate the initial solutions related to information flow, connectivity and identification of latent capabilities has left MNCs in the central states operating essentially truncatedly with little linkages domestically. As a senior officer of Motorola put it,

> The problems of failure is just too high. Private firms generally do not individually search and canvass for greater inter-firm collaboration and sourcing when known suppliers do not exist. It was possible in Penang because of the dynamic role of PDC, which created deliberation councils and took on a proactive role of promoting and matching firms. We will be glad to assist if some reliable organization assumes such a role here. We are aware of these developments from the operations of our telecommunications components and products subsidiary in Penang.[81]

Hence, while MNCs are increasingly outsourcing their manufacturing activities, including becoming fabless, institutions in the central states have assisted effectively the strengthening of inter-firm relations and their own links with firms to harness such potential domestically. With firms generally sourcing either from abroad or through integrating production of dissimilar activities, the intra-firm division of labour in the central region has been high, while that between firms low. If in Penang the vertical division of labour involving supplier firms evolved to four levels by 1990, similar firms in the central region show the most two levels. The lack of differentiation has reduced the capabilities firms could engender through greater specialization. The situation has led to substantial dissipation of synergies created in the central region. Also, the central region shows little signs of speciation capabilities.

3.2.2 Entrepreneurial and Developmental Firms

Developmental firms such as Motorola have their biggest operations in Petaling Jaya, but unlike Penang, as with linkages reported in the preceding section, the synergies generated in the central region has not been directed effectively to develop local and indigenous entrepreneurial firms. Intermediary organisations such as the state development corporations of the three related states hardly play a proactive role to gather and disseminate information, build bridges between firms and appraise economic performance in such detailed areas as technology and skills development, R&D, linkages and clusterisation. The PDC has been instrumental in developing and co-ordinating these activities in Penang. The SEDCs of Selangor, Melaka and Negeri Sembilan have not played such a role in the central region.[82]

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[81] Interview by Rasiah, Rajah, 1999.

[82] Interviews by Rajah Rasiah in 1990 and 1999.

While a number of development firms in the Klang Valley, Negeri Sembilan and Melaka have incorporated incremental engineering capabilities in-house, weak supplier support and requisite firm-level skills development and technical professionals has restricted headquarters ability to transfer sophisticated technologies to the central states. Where such transfers have occurred, it is confined largely to in-house developments as with Motorola (Seremban) and Matsushita Air-conditioners. Nevertheless, the emphasis on redesigning older technologies in Klang Valley firms does demonstrate the potential for higher technological synergies in the central region despite the lack of inter-firm linkages.[83] However, the lack of systemic relations between firms and support institutions and the community has restricted the movement of entrepreneurs developed in the MNCs to start new firms in the region. Three managers reported interest in starting their own firms after detecting considerable market potential for dissimilar activities, but the lack of institutional support and the environment has prevented them from leaving their MNCs.[84]

Although the scale of transfer of managers and entrepreneurs to local firms from MNCs have been limited, some firms did report some cases. Human capital deepening has occurred in local divisions of MNCs fostering technology transfer, particularly via skilled personnel moving to local firms.[85]

> Motorola, Texas Instruments, Intersil, Hitachi, Sony and Matsushita Electric reported that former personnel were hired by local firms such as Unisem, Carsem and OYL Electronics.[86]

Also, the extent of inter-firm support involving MNC assistance to local firms has been quite limited. Where it exists, much of it comes through the support of business councils representing the different foreign nationalities. Examples include JETRO and JACTIM and American Business Council. Because much of the drive has revolved around effective business-government relations to safeguard their own firms activities, little active drive has gone beyond their own national interests. The Japanese, German and French have promoted their own training centres in the Kelang Valley, which lack cross-national coordination. Japanese cooperation has included training of tool and die makers, and the Germans on precision engineering. Japanese participation in the development of supplier firms involved in moulds, tools, dies, jigs and fixtures in the Klang Valley have been important. However, much of the support has involved low-end supplier activities. Much of the high-end supplies are sourced from Japanese suppliers located in Malaysia and abroad.[87]

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[83] Interviews by Rasiah, Rajah (1999)
[84] Interviews by Rajah Rasiah (1999)
[85] Rasiah (1995) chpts. 6-7,
[86] Interviews by Rasiah, Rajah (1999)
[87] Interviews by Rasiah, Rajah and Chang, Colin (1999)

MNCs in the Klang Valley, Negeri Sembilan and Melaka concentrate more on process developments. R&D is confined primarily to adaptations and minor extensions. A few MNC exceptions include the development of split level air-conditioners developed by Matsushita air-conditioners in Shah Alam. The latter emerged from a well-defined R&D department that focuses on product adaptation and development. Matsushita operates using a flexible production model, approximating the Toyota multi-flow system. Matsushita's marketing division is quite developed to handle customisation.[88] However, its involvement on R&D is still generally underdeveloped. The Malaysian executive director of the firm reported that their product enhancement activities would be strongly magnified if more qualified R&D personnel were made available in the country. Serious shortfalls in the supply of technical and R&D personnel was reported as a major constraint in their efforts to expand innovative activities in the central region.

3.2.3 Little Technological Variation

While considerable technological and product diversity has emerged in the central region, most firms do not show strong levels of connections between each other. The disconnected operations of firms has seriously restricted the establishment of integrated clusters. The bigger and more successful local and indigenous firms tend to operate without production links with MNCs. Where such links exist they are confined to technology tie-ups as between Sapura and Nokia and OYL and York.

The emergence of Sapura and OYL Electronics benefited little from sourcing links with MNCs in the Klang Valley, though MNC-trained local personnel have been instrumental in their growth. Sapura and OYL have R&D capabilities and export extensively telecommunication products and air-conditioners respectively.
Yet 8 MNCs interviewed in the Klang Valley, Negeri Sembilan and Melaka contend that their operations will be enhanced if local suppliers develop to substitute imports. As the Managing Director of Motorola noted in 1995:

> We are for greater sourcing as that would raise our productive flexibility and lower costs. Our official contacts with government bodies has always been with MIDA and MITI. These two bodies only encourage local sourcing through formal investment guidelines but do not actively participate in building relationships. We don't see any other institutions even approaching us to stimulate local sourcing. We are still watching SMIDEC.[89]

The statement by the Motorola chief reflects the general opinion of MNCs in the Klang Valley, Negeri Sembilan and Melaka. Driven by similar capabilities market structures as with the semiconductor and consumer electronics MNCs in Penang, MNCs in the Klang

[88] Interviews by Rasiah, Rajah (1999)
[89] Rasiah, Rajah (1999), p. 14.

Valley, Melaka and Negeri Sembilan reported having interest in assisting the development of local suppliers if the requisite co-ordinating framework is put in place. In fact it is the development of these synergies that drew the early computer and peripherals assembly firms of Dell, Maxtor, Connel Peripherals, read-rite, Komag, Quantum and Seagate to Penang. Only Acer reported looking for low wages as an important stimulant for locating in Penang.

3.2.4 Horizontal Integration and Reintegration

A significant element of the success achieved by firms embedded in integrated systems such as the Silicon Valley is the transformation of production so that firms increasingly specialise horizontally (see chapter 3). Such processes continue to involve reintegration as the dynamics of production changes with the constant emergence of new process and product technologies. The vertical integration model envisaged in the Japanese Zaibatsu's and Korean Chaebols amplify the problems of control and coordination. The shift away to horizontal integration and vertical differentiation require that firms enjoy sufficient critical mass of internal and external support.

Companies such as Texas Instruments, Intersil, Matsushita, Sony and Toshiba have not attracted world-class first-tier suppliers including contract manufacturers, which has seriously affected effective clusterisation. Most MNCs use JIT, MRP2 and TQM practices in-house, but continue to retain in-house a number of even dissimilar activities such as machine tool support. Where specialised components are needed, such as microchips and lead frames, they are primarily bought from firms in Penang, Singapore, Taiwan, South Korea and Japan. The lack of a developed computer and peripherals sub-sector in these states has restricted the purchase of microchips from semiconductor firms. The latter's sales in Malaysia primarily go to Penang firms. The limited needs of the Klang Valley and Southern states are primarily purchased from Singapore. Meanwhile in addition to purchasing major machinery from abroad, Texas Instruments sources its machinery supplies from its subsidiary in Singapore.

Despite these limitations, firms in the central region offer capabilities for state-of-the-art manufacturing and rapid ramp-up to high performance standards. However, unlike Penang, the Klang Valley firms do not offer strong market-led or design-led start up opportunities. Unisem, a chip assembly located in Perak was started in record time of less than a year after its construction following the hiring of personnel from existing MNCs. The vast pool of managers developed in MNCs "invisible" colleges have offered the potential for starting firms quickly. As with most of the areas located outside Penang, it does not have design and market prospecting capabilities.

However, unlike the Kelang Valley semiconductor firms which have since the experience of the mid-1980s, successfully developed the capability to step up and step down production quickly when demand changes, those in the central region have yet to develop such capabilities effectively. Retrenchments did occur in when a cyclical industry-wide trough hit the region in the period 1995-98. The lack of effective cluster development has restricted firms in the central region to develop sufficiently their lean production process technologies, preferring to integrate vertically as a consequence compared to the outsourcing practices adopted in Penang.

A number of Japanese and Taiwanese firms act as anchor firms, creating a range of supplier links. In the Klang Valley, anchor firms include Matsushita group of air-conditioner companies, Sony Group of TV/Video companies, Motorola, Tamura Electronics, Chunghwa Picture Tube Component, Formosa Prosonic Technics and Quality Technologies Opto. Examples of local-entrepreneur-led anchors in the Klang Valley include Sapura, OYL, MEC, M-SMM Electronics and Jasa Kita. They usually license their technology from the market. These firms have been largely started by entrepreneurs with state support. The anchors offer markets and technological support for foreign and some local firms. However, interviews show that most local and indigenous suppliers are limited to low value-added non-core activities. Hence, the extensive localisation of air-conditioner, television, video and refrigerator component supplies has largely been confined to low value-added activities. Key technologies such as LCD are still imported from Japan, South Korea and Taiwan. All development work on audio and video equipment, including Discman and Internet music players is done at headquarters abroad. OYL, MEC and Sapura are exceptions in that they have R&D operations. Firms such as MEC have also entered production by building their knowledge of the domestic consumer market.

The success of PSDC in Penang led to the modeling of the Selangor Skills Development Centre (SSDC) in the Kelang Valley. However, unlike the effective coordination between firms and institutions achieved through the exemplar intermediary role of PDC, the SSDC has not gained much success. There is also a lack of institutional coordination and cooperation to strengthen relationships between firms. The state developed corporations have not assumed such a role in the central region.

In short, despite the long history and presence of a critical mass of developmental firms, the central region lacks clusterisation effects. Little inter-firm connections exist. Apart from uncoordinated assistance from intra-national organizations such as ABC, JACTIM, Jetro and GMI, the extent of inter-firm cooperation is limited. Participation of MNCs in deliberation councils have also be passive rather than active. According to one Managing Director, the state development corporations in Selangor, Melaka and Negeri Sembilan generally avoid resolving problems confronted by them, and also participate little in building relationships between them and firms, and between firms. Clearly there is little intermediary role played by institutions in the central region to enhance inter-firm links and resolve collective action problems associated with actions related to scale, scope and learning externalities such as training and R&D.

3.3 Johor: Outer Ring

Johor did not figure when the first early inflow of electronics MNCs located in Malaysia in the early 1970s. Johor attracted more textile firms in the 1960s and 1970s. Johor enjoys proximity with Singapore, but the latter city country absorbed even labour-intensive firms in the early 1970s. The prime motivation for relocating in Johor was driven by the need to shift out labour-intensive production stages out of Singapore from the late 1970s. MNCs seeking sites with cheaper land and lower wage costs from the late 1970s and early 1980s relocated in Johor.[90] The move was further strengthened following the launching of the Singapore, Johor-Riau (SIJORI) growth triangle.[91]

3.3.1 Specialisation in Low Value Added Activities

The Johor region built a high volume production capability particularly in computer peripheral and consumer electronics assemblies, which has spread to PCBs, disk drives, television sets, video and audio equipment and, more recently, to capacitors, resistors and other components. Many of these parts and components have remained as elements in global production networks that are co-ordinated regionally from Singapore. Suppliers unrelated directly to purchasers' equity holders, have also located strongly in Johor.

MNCs and suppliers operate primarily as suppliers or electronic contract manufacturers (ECMs) for MNCs located in Singapore. For example, Wearne Electronics, Solectron, PNE, Aiwa and Asahi send much of their output to MNCs located in Singapore. Exceptions include SM Semiconductor, which both export to Singapore for regional markets as well as export to the major markets.

A limited number of local and indigenous suppliers in the same region supply MNCs, but all are confined to non-core components. Six foreign PCB assemblers reported sourcing only non-core components from local and indigenous firms. However, over 90% of their inputs come from MNCs in Malaysia and Singapore.[92] A managing director reported that:

Most PCB assemblies in Johor cater for firms located in Singapore. Our inputs come primarily from Singapore, Penang and Selangor from a wide range of MNCs. A few of us use OEM facilities to supply PCBs. Most of us assemble PCBs using specifications given by our clients...It is difficult to compete with Singapore as it has much better facilities and government support for computer assemblies and regional design.[93]

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[90] Interviews by Rasiah, Rajah in 1995 and 1999.
[91] See Parsonage, James (1996), "Trans-state Developments in South-East Asia: Subregional Growth Zones", Rodan, Garry, Hewison, Kevin and Robison, Richard (eds), *The Political Economy of South-East Asia*, Melbourne: Oxford University Press.
[92] This finding is corroborated by Capannelli, Giovanni (1999)
[93] Interviews with a Singapore owned PCB assembly firm conducted in 1999.

Johor's Japanese consumer electronics assemblies also figured in Capannelli's[94] findings that along with the Klang Valley showed that MNCs only source 25% from local and indigenous firms.

Supplier firms in Johor have hardly passed the first stage of transfer (adoption). Hence, local and indigenous supplier firms in these states have not progressed to the second stage of absorption. Instead of local firms creating synergies from an extensive division of labour, both horizontally and vertically, MNCs source minimally and directly from end-suppliers. The lack of micro-diversity among supplier firms in Johor has restricted the development of world class local and indigenous suppliers. The world class ECM supplier firms such as Solectron and Asahi are foreign owned, and are only involved in component and peripherals assembly.

Sourcing patterns of American and European firms in Johor are similar to those in the central states. Unlike Japanese, Taiwanese and South Korean firms who source most of their supplies from firms of their own nationalities, similar national suppliers are sparse in Johor. Given the weak technological capabilities of local and indigenous suppliers, American and European firms either source directly from the foreign East Asian firms, including Singaporean, or import their inputs.

The lower level of technology diffusion in Johor is linked to a much lower proportion of local outsourcing by local firms. Interviews with 6 local supporting firms showed that less than 15% of MNC purchases in Johor came from local and indigenous firms.[95] As with the central states, the extent of differentiation and division of labour between local suppliers have remained low. Rasiah notes the following:

> The 6 local suppliers interviewed showed that they were horizontally unlinked in the production chain with other local firms. None showed more than one tier supply links. These firms either exported directly to firms in Singapore, or supplied foreign suppliers operating in Johor. The latter than mainly export to firms in Singapore. The lack of division of labour between supplier firms in Johor has stunted the capacity of firms to specialise horizontally.

PNE, Wearne Electronic, Fujitsu and Hitachi reported attempting to increase local sourcing following promotional efforts by the government under the subcontract exchange programme (SEP) and the vendor development programme (VDP) from the late 1980s. However, MNCs have not done much to use local suppliers for low-end inputs. Most MNCs have their own suppliers in Johor. Local and indigenous firms enjoying supply relationships with MNCs do not have a division of labour vertically below them. Solectron's ECM facilities, however, use large amount of inputs from MNCs operating in Malaysia.

[94] Capennelli, Giovanni (1999) p. 213.
[95] Interviews by Rasiah, Rajah (1999)

Johor firms are generally entrenched at the root of the electronics value added chain, though they have increasingly become automated due to rising wage costs. The lack of differentiation and division of labour and without much movement up the technology ladder, its shows little signs of horizontal integration. The entrepreneurial firms of Solectron and Seagate just opened production and with SM Semiconductor aside, have produced little first class entrepreneurs. The lack of institutional support has restricted the flow of even the experienced managers from the few entrepreneurial firms to start new firms.

The Johor state development corporation has not estimated local sourcing achieved in the electronics industry. Interviews with 1 semiconductor, 9 PCB assemblers and 8 consumer electronics firms in Johor in 1999 show that MNC electronics component firms source between 2-5% of their inputs locally. The commensurate figures for MNC consumer, and MNC computer peripherals firms ranged between 40-50% and 40-90% respectively.[96] These figures included supplies from foreign suppliers operating in Malaysia.

3.3.2 Entrepreneurial and Developmental Firms

Most electronics firms located in Johor appear to be fairly closed in their networking relationships with other firms located in the state. Interviews did not generate the presence of strong developmental firms in Johor. Not much seems to have been done to tap the synergies generated from Singapore to develop local and indigenous entrepreneurial firms. Intermediary organisations such as the state development corporation hardly play a proactive role to gather and disseminate information, build bridges between firms and appraise economic performance in such detailed areas as technology and skills development, R&D, linkages and clusterisation. The exemplar role of the PDC is hardly seen in Johor. An official from the Johor state development corporation reported:

> We rely considerably on Singapore's promotional efforts. Singapore spends heavily on promotion, while we absorb some of the synergies because of our close location and to the division of labour that has emerged in the industry. Our activities do not stretch to co-ordinating firms' activities. We only do that when we have equity participation in the firms. As for others, we see it as getting too involved in activities outside our area. If firms establish strong linkages in Johor, that is good for us. But it should come from firms' own initiatives.[97]

Consumer firms such as Sharp-Roxy, demonstrate stronger local supplier links. Most firms, however, do not operate as development firms in Johor due to the confinement of supply chains within subsidiaries and the lack of institutional support facilities to stimulate innovative activities in local firms. SM Semiconductor is a slight exception as

[96] Conducted by Rasiah, Rajah and Chang, Colin (1999)
[97] Interviews by Rasiah, Rajah in 1999.

it emphasises improvements in cycle time, quality and efficiency and therefore more than 60% of its 3,700 staff have engineering and technical backgrounds. The firm also has a process R&D department. This firm reported relying more on MITI from Kuala Lumpur for much of its infrastructural and incentive support. Also, weak supplier support and requisite firm-level skills development and technical professionals have restricted headquarters ability to transfer sophisticated technologies to the central states. Where such transfers have occurred, it is confined largely to start-ups of low value added supplier activities.

Johor seems to show a lower professional staff turnover to support the opening of new dynamic local firms. Broad-based and continuous human capital deepening in local divisions of MNCs is very important only in some firms such as SM Semiconductor and Solectron.[98] Others also reported emphasis on training to sustain production competitiveness. Unless effective support and coordination mechanisms are developed, Johor firms are unlikely to break out of their specialisation in low value added activities. Only a few MNCs, such as SM Semiconductor which rely more on federal support would should cutting edge process manufacturing activities.

Japanese participation in the development of supplier firms involved in moulds, tools, dies, jigs and fixtures in Johor have been important. However, much of the support has involved low-end supplier activities. Much of the high-end supplies are sourced from Japanese suppliers located in Malaysia and abroad.

MNCs in Johor concentrate more on process development. None of the firms interviewed engaged in formal product R&D activities. Minor adaptations and process improvements were reported as the most sophisticated activities. Firms show largely TM2 status and some aspects of TM3 due to the use of flexible production methods. However, Johor firms hardly involve in integrating customisation activities with flexible production methods.

With low level of technological deepening and focussed primarily on supporting entrepreneurial activities in Singapore, Johor electronics MNCs firms generate low levels of entrepreneurship turnovers for the Malaysian economy. Even where such staff are developed, the better ones are often attracted to Singapore thereby causing entrepreneurial leakage. Efforts to reverse the brain drain – which is critical to stimulate movement up the value chain, horizontal integration and strengthen the Johor cluster - will surely require a more proactive policy framework to attract parts of the apex of the division of labour from Singapore to Johor.

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[98] Solectron might be one of the exceptions due to the experience its MD gained while working for Intel. This firm recently started operations in Johor, assembling components.

3.3.3 Little Technological Variation

Johor firms are largely confined to computer peripherals, and consumer electronics assemblies. Johore has only one microchip firm and no computer assemblies. While a considerable number of firms have emerged in Johor, most firms do not show strong levels of connections between each other which has seriously restricted the establishment of integrated clusters. Instead if the current passive role, the Johor State Economic Development Corporation (JSEDC) should actively attract entrepreneurs and a range of higher value added firms from Singapore to establish sufficient technological variation. The bigger successful local and indigenous firms tend to operate without production links with MNCs.

Local and indigenous electronics firms in Johor have not developed R&D and OBM facilities. Suppliers in Johor operate as supply organisations in the conduit where most regional innovations, marketing and development are handled in Singapore. Over-specialisation vertically at the bottom in low value added activities has reduced the potential for differentiation and the evolution of and absorption of cluster synergy in Johor. Unless these problems are ameliorated, Johor's electronics rings will only remain a servicing base for the nucleus in Singapore.

3.3.4 Horizontal Integration and Reintegration

Companies in Johor such as Hitachi, Matsushita and Asahi have not attracted world-class first-tier suppliers including contract manufacturers, which has seriously affected effective clusterisation. World class contract manufacturers such as Solectron and intermediate item manufacturers such as Seagate have located in Johor to supply Singapore firms (as well as foreign markets). It is the MNCs in Singapore that have attracted these companies to locate in Johor. Yet, most MNCs in Johor use JIT, MRP2 and TQM practices in-house. Where specialised components are needed, such as microchips and lead frames, they are primarily bought from firms in Penang, Singapore, Taiwan, South Korea and Japan. The lack of a developed computer and peripherals sub-sector in these states has restricted the purchases of microchips from semiconductor firms. The vast numbers of PCB-assembly firms cater for Singapore's computer assemblers.

Anchor companies – involving their local own suppliers – have also evolved in Johor, though their incidence is relatively low. The anchors for Johor firms are largely located in Singapore. Dai Hwa Electronics, Flextronics, MMI Industries, Hokuden and Wearnes Electronic are some of the few foreign MNCs that function as anchor firms in Johor. Local firms, such as Setron, which supports anchor activities, are rare in Johor. Local entrepreneur performing supplier activities include Akijaya, Strong Tex and Multi-Unify. The audio equipment supply network is virtually domesticated, though foreign suppliers located in Johor, Melaka and Negeri Sembilan supply the core components. While the

VDP was cited by three firms as important, the high levels of anchor-firm based sourcing from Malaysia and Southeast Asia was reported as being primarily driven by the need to keep costs low and the need for production flexibility.[99]

Johor's capacity to use state-of-the-art manufacturing and rapid ramp-up activities is largely possible because of the capabilities it draws from Penang, Singapore and the Klang Valley. For example, an employee from its subsidiary in Penang, who made his name working for Intel Penang, manages Solectron. The lack of generation of substantial local capabilities in the state, and the hopping effect to Singapore, has also constrained the capacity of firms in Johor to engage in market-led or design-led start up opportunities. Hence, the capabilities for rapid ramp up and diffusion of flexible production process technologies have evolved only in a few MNCs. Rapid ramp up demand in Johor is often met through the hiring of experienced personnel developed in especially Penang.

Preoccupation with supplying firms in Singapore, and taking advantage of the lower labour costs in Johor, and the lack of effective intermediary role by governance mechanisms in the state has restricted technological transformation. With the exception of a few firms such as SM Semiconductor, few firms demonstrate strategies to integrate horizontally. Horizontal integration is essential if Johor firms are to raise their value added and engage in continued differentiation and speciation. Increasing generation and supply of entrepreneurs from existing firms is a pre-requisite for enhancing further differentiation, specialisation and speciation.

As pointed out earlier, firms in Johor lack intermediary support from institutions. The Johor Development Corporation does not produce a list of suppliers, attempt matching them with MNCs, and co-ordinate its Skills Development Centre to reflect industry needs effectively. Interviews show that the corporation does not perform *ex post* appraisal activities to improve its support services. The lack of such co-ordination efforts has prevented the establishment of information and co-ordination networks between firms and institutions. Hence, the extent of network synergy generated in Johor is significantly short of Penang. For firms in Johor to make the transition from TM2 to TM3, TM4 and TM5, PDC's role should be replicated taking cognizance of local conditions. The right policy framework can create the conditions necessary to attract MNCs from Singapore and local firms to emerge alongside so that the core in the cluster can be extended to Johor. Johor's land space, water resources, power supply and population access can assist the state to compete effectively with Singapore.

[99] Interviews by Chang, Colin and Rasiah, Rajah (1999).

4. Cluster and Innovation Strengths and Gaps in Malaysian Electronics

Looked at from the perspective of enterprise development indicators, Malaysian electronics does not seem to be progressing fast enough towards a cluster-based, productivity-driven strategy. There are quite clearly three major clusters in Malaysia, and they differ considerably in their strengths and weaknesses. Penang is the most promising location where cluster synergies have been utilised most demonstrating the potential for firms to make the transition from TM2 and TM3 to TM4 and TM5. The lack of inter-firm connections, differentiation and specialisation, technological variation, adequate growth of new firms from the operations of entrepreneurial and developmental firms, horizontal integration and institutional support seriously restricts the capacity of firms to move up the value-added chain. None have shown the capability for speciation. These are the intricate causes of the impasses facing Malaysian electronics. The IMP2 identified four related findings to that effect, *viz.*,

- **MNC-driven**: the traditional competitive advantage based on low cost labour is being eroded but local firms are ill-equipped to take up the new high-tech challenge because of the limited development of indigenous capabilities; including technology absorption capacity, and local inter and intra-industry linkages.
- **High import content**: imports add up to 74.2% of exports because of the limited development of local companies and high import quotient of intermediate and capital goods. The lack of an integrated supplier chain identified in the preceding section account for such high levels of porousness.
- **Low value added**: MNCs tend to concentrate assembly operations in Malaysia with minimal design, product development, marketing, and R&D activities. The lack of adequate numbers of entrepreneurial firms and movement towards to horizontal integration has restricted the capacity of domestic chains to move up the technology ladder.
- **Few SMIs**: since the establishment of the first semiconductor plant in Selangor in 1965, the industry has grown from 19 in 1972 to over 850 companies in 1995. If we compare this figure to that of Taiwan electronics, which has an industry with roughly the same number of total employees, it has over 3,300 firms.[100] The lack of differentiation the without speciation capabilities, the number of firms have remained too small to magnify synergy levels comparable to Taiwan.

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[100] Carl Dahlman, (1993), *Developing the Electronics Industry,* World Bank Symposium, p. 257

While the IMP2 identified some of the more salient flaws, it did not highlight the critical nuts and bolts problems that require addressing for any concerted effort to inject cluster dynamism in Malaysian electronics. The preceding section broached these problems and coordination discontinuities, and determined the specific differences confronting the three major electronics locations in Malaysia. For Malaysian electronics to establish effective clusterisation, the critical capabilities of continued differentiation, specialisation, horizontal integration and reintegration, speciation and increasing creation of entrepreneurial firms is necessary.

Nevertheless, the three conurbations enjoy certain strengths that continue to make them attractive for certain operations. These operations can be transformed into dynamic clusters if their weaknesses are resolved. A brief assessment of their strengths and weaknesses are advanced in this section. Recommendations to resolve them are presented in chapter six.

4.1 Strengths

Despite the impasse facing the industry, Malaysia enjoys certain endowments that continue to make it an attractive site for MNCs. Penang has quite clearly become more attractive than the other states. The central region comes second followed by Johor.

4.1.1 Penang: Strong Manufacturing, Linkages and Networks

Penang's electronic industry is an emerging dynamic cluster with deficits in engineering skills, the extent and density of value networks, and the amount of entrepreneurial firms. At the same time Penang has manufacturing capabilities which could serve as a platform for making the transition to a cluster dynamics that can foster industrial innovation. We look first at an optimistic reading of the transition potential based on Penang's strengths.

Penang enjoys ten important strengths that offer the northwestern region the potential to retain strong manufacturing activities, *viz.*,

First, MNCs continue to locate in Penang because it offers them a powerful production platform. At present this production platform has much to offer that is not available anywhere else, though the emergence of China, India, Thailand and the Philippines is eroding this strength.

Second, in order to stay competitive, MNCs have developed world class manufacturing capabilities in Penang at TM 2 levels, that is mass production including JIT and TQM systems with a number of examples of TM 3. These production practices enable participating companies to achieve world class performance standards in cost, quality, and time, though they lack new product development or innovation.

Third, American MNCs located in Penang tend to follow the Silicon Valley business model, which stresses horizontal integration, collective learning, and community identity. Many features of Silicon Valley have been transplanted simply because Penang has developed considerable communal networking identity.

Fourth, the range of companies, services and division of labour in Penang constitute an "open system" industrial district in which virtually all of the activities required to rapidly set-up and ramp up high volume production on a JIT basis are virtually co-located.

Fifth, PDC has been an exemplary intermediary organisation in identifying and acting on collective needs and facilitating local enterprises to seize development opportunities created by the presence of MNCs. An outstanding example is the Penang Skills Development Centre (refer Appendix 6).

Sixth, the PSDC in Penang has functioned as an exemplar training centre demonstrating effective private-public co-ordination to meet industry's external skills demands required during work. It has successfully reduced collective action problems faced by firms' to meet continuous training needs.

Seventh, the Penang electronics industry, as an industrial district constituted primarily by MNCs but with increasing local participation, is being driven by a set of dynamic forces that are built into product-based competition. These forces can be utilised to create local capabilities if the right policies are developed.

Eighth, the "invisible college" of company skill formation is considerable in Penang. Many of the large American and Japanese companies invest sizeable amounts, individually and collectively, in shop-floor training. An audit of the quantity and quality of "invisible college" graduates from these programs would reveal a considerable regional asset or social capital, which has been accumulated over 25 years.

Ninth, a few firms from the supplier chains – e.g., Trans Capital – have developed to enhance horizontal integration though the incidence is still low. The capability for rapid horizontal integration and reintegration to supply new products takes time to develop, is not easily imitated, and is problematic in high wage regions. It offers a competitive advantage platform upon which Penang can advance to higher technology management capabilities. Obvious steps are the transition to computer integrated manufacturing (CIM) for smaller volume and higher mix outputs. This has analogies, in terms of production and organisational capabilities, to the transition from TM2 to TM3. A second step is to move to a regional contract manufacturing capability that can also supply technology related services including design services, test engineering and equipment design, component qualification, failure analysis, value analysis/value engineering and prototyping.[101]

[101] Kimmel (1993), p. 156

Tenth, Penang has built considerable networking relationships through strong social ties. Indeed, inter-firm cooperation in Penang reveals some level of the features characteristic of the industrial districts of Italy. These ties are as important as other factors in the development of supplier firms in Penang.[102]

4.1.2 Central Region: Strong Manufacturing

The central region's electronic industry has evolved as a loose cluster with limited inter-firm connections and institutional networks. Electronics firms suffer from strong production chain leakage and growing deficits in engineering skills, the extent and density of value networks, and the amount of entrepreneurial firms. At the same time Klang Valley firms have manufacturing capabilities which could serve as a platform for making the transition from TM2 to TM3, which are prerequisites to a later transition to TM4 and TM5. With the right policy framework this transformation can be made a reality.

Despite the generally inferior development of networks in the central states, five major reasons continue to make them attractive for electronics MNCs, *viz.*,

First, MNCs continue to locate in the central region because it offers them a powerful production platform. The good infrastructure, political stability, over 30 years of electronics production experience has made the Klang Valley suitable for assembly and test operations. Negeri Sembilan and Melaka have an experience of over 20 years.

Second, in order to stay competitive, MNCs have developed world class in-house manufacturing capabilities in the central states at TM 2 levels, that is mass production including JIT and TQM systems. These production practices enable participating companies to achieve world class performance standards in cost, quality, and time, though rising costs has made China, India, Thailand and Philippines more attractive in the 1990s. The rising supply of professional and skilled IT labour has made India are real threat in the years to come.

Third, the in-house skill formation is considerable in the central region. Many of the large American and Japanese companies invest sizeable amounts, individually and collectively, in shop-floor skills. Although the region lacks institutional support which has restricted the outflow of entrepreneurs from MNCs to new firms, the potential created can be utilised to spawn a critical mass of entrepreneurial firms if the right policy is adopted.
Fourth, MNCs enjoy quick turnaround capabilities in the Klang Valley, Negeri Sembilan and Melaka. Also, the federal administrative authorities deal with requests quickly and favourably, though it is limited to basic infrastructural and legal services. These functions could be expanded by the three SEDCs in the region to include intermediary roles to match firms, strengthen coordination for increasing inter-firm networking and resolving collective

[102] See Rasiah, Rajah (1994).

action problems where scale, scope and learning effects are involved – e.g. training, R&D and university-firm collaboration.

Fifth, a few local and indigenous firms in the Klang Valley firms have built high volume production capabilities, such as in air-conditioning technology (OYL), telephone equipment (Sapura), and audio and video consumer electronics (e.g., MEC) (refer Appendix 7). The emergence of these locally owned firms with increasing R&D, technology acquisition, and capabilities in technology management has resulted in some large local firms, though, technology absorption and diffusion are still at the first stage.[103]

4.1.3 Johor: Support Services for Singapore Firms

Johor's electronics industry has evolved as a loose cluster largely servicing MNCs in Singapore. Electronics firms suffer from strong production chain leakage and growing deficits in engineering skills, the extent and density of value networks, and the amount of entrepreneurial firms. Despite being entrenched at the foot of the vertical division of labour originating from Singapore, firms in Johor show manufacturing capabilities which could serve as a platform for making the transition from TM2 to TM3. Solectron, Seagate and SM Semiconductor are some firms that generate considerable synergies that could be harnessed to drive the evolution of local and indigenous firms.

Despite the generally inferior development of networks in Johor, a number of reasons continue to make the state attractive for electronics MNCs, *viz.*,

First, MNCs continue to locate in Johor because it offers them a powerful production platform. The good infrastructure, political stability, over 20 years of electronics production experience has made the area suitable for assembly and test operations.

Second, a few MNCs have developed world class manufacturing capabilities. Firms like SM Semiconductor and Solectron have established mass production and process improvement capabilities, including JIT and TQM systems. These production practices enable participating companies to achieve world class performance standards in cost, quality, and time, though, rising costs has begun to undermine its attractiveness.

Third, Johor forms perform the role of a satellite location for Singapore MNCs. MNCs have been able to upgrade to process and regional product design customisation in Singapore, shifting out lower value added labour-intensive activities primarily to Johor.

Fourth, MNCs enjoy quick turnaround capabilities in Johor. With the exception of the customs checkpoint problems that surfaced and boiled over at the height of the financial crisis in 1997-98, bureaucratic co-ordination between Johor and Singapore has been smooth. Satellite manufacturers in Johor orbit around anchor manufacturers in Singapore. Johor benefits from its proximity to Singaporean anchor manufacturers. The IMS-GT's

[103] Narayanan, Suresh (1997), p. 22

potential for synergies between Johor, Singapore and the Indonesian island of Riau are constrained by the lack of a customs union. Moving components back and forth for finishing within IMS-GT is difficult to coordinate and manage at present, especially with customs declarations, and tariff. Trade liberalization as proposed in AFTA-CEPT would promote investment in the region, especially in Growth Triangle regions, where comparative advantages between the countries are exploited for different components and activities within an industry cluster.

Fifth, Johor also acts as a cheap production base for MNCs that use Singapore as a gateway to regional and global markets. A few companies act as anchors to ship out a range of finished goods through Singapore.

Sixth, Johor has a labour force developed over 20 years, though it suffers from turnovers caused by staff job-hopping to Singapore firms. Yet officials from Johor State Economic Development Corporation (JSEDC) that a substantial number of Johoreans commute to work everyday from Johor to work in Singapore everyday.[104] With the right policy framework the apex of the regional division of labour could be stretched to extend from Singapore to Johor, which would then reverse back the flow of Johor's skilled and professional labour.

4.2 Weaknesses

Despite two to three decades of operations, the electronics industry in Malaysia is still affected by a lack of innovation, low levels of differentiation and division of labour, lack of horizontal integration and virtual absence of speciation capabilities. In addition, sites outside Penang also suffer from a serious lack of linkages and networking. Johor firms also seriously lack technological diversity to support an effective cluster.

4.2.1 Penang: Weak Human Capital and Innovation

Five main problems threatens to stall Penang's efforts to achieve effective clusterisation, *viz.*,

First, the growing deficit of vocational, technical and engineering personnel has restricted the growth of firms. While poaching has generally fallen since business networks in the state helped co-ordinate salary scales and staff hiring involving professional and engineering staff in the 1990s along industry-lines, the lack of skill and technical manpower supply has constrained the expansion of firms critical for greater division of labour and differentiation in the industry.

[104] Interviews by Rasiah, Rajah (1999).

Second, the continuous widening of supply-demand gap involving innovations has limited electronics firms in Penang to redesigning activities. The most sophisticated firms such as Intel and Motorola engage in redesigning of older technologies. Local firms lack staff even to pursue such activities despite the successful development of innovative firms like Trans Capital. Penang lacks an adequate stream of innovators –individuals, firms and institutions – to generate the rapid innovations necessary to move to TM4 and TM5. Some firms use Universiti Sains Malaysia (USM) staff to undertake process development activities. However, despite the success of USM's innovation centre, the amount of such collaboration with electronics firms is highly limited, and unrelated to product development.

Third, the institutional set up in Penang still lacks the capacity to generate adequate supplies of manpower for the effective technological evolution of the cluster. These shortfalls have been identified by the Penang and Federal governments.[105] Unless an adequate framework is designed the growing skills deficit will undermine Penang's efforts to move up the technology ladder.

Fourth, there is a lack of horizontal integration involving firms in Penang due to a lack of product development in local firms. Unless supplier firms become world class process and product innovators, Penang will not be able to achieve the extent of differentiation and speciation achieved in Taiwan, though, it has done very well on the former. Trans Capital and Globetronics are poised to achieve horizontal integration, but the amount of participation in gearing product development to meet requirements of major markets is still limited. Hence, most firms limit themselves to ECM activities.

Fifth, Penang still lacks mechanisms to attract new entrepreneurs due to a lack of venture capital to underwrite risks. The role of venture capital in spawning SMIs and new entrepreneurs in the United States is now well documented. Silicon Valley is the biggest recipient of venture capital, which grew from less than US$5 billion in 1995 to around US$25 billion in 1999.[106] The San Francisco Bay area recorded a venture capital investment of US18.3 billion in the period 1995-99 when the next highest Boston area only achieved US$6.3 billion in the same period.[107] Given the importance of personal ties in the success of venture capital, Penang open system with strong networking relationships can make this viable. Penang has used its social capital far better than the other locations in Malaysia and that is part of the reason why it has managed to spawn substantially more local firms than elsewhere in the country. However, these numbers are far smaller than the success achieved by Taiwan and the Silicon Valley. The internet revolution has made such networking easier and more economic. A broader supply of

[105] See Lim (1997) and World Bank/MOSTE (1996)
[106] See Zook, Matthew (1999), Regional Systems of Financing: The Impact of Venture Capital on the Emerging Internet Content and Commerce Industry in the United States", Figure 1. See also Saxenian, AnnaLee (1994), *The Regional Advantage*, Cambridge Harvard University Press.
[107]Zook, Matthew (1999) Map 1.

entrepreneurs made possible by venture capital is essential to initiative speciation involving new products, firms and sub-industries.[108]

4.2.2 Central Region: Weak Linkages and Networks, Human Capital and Innovation

Electronics firms in the central region are faced with even more problems than Penang firms to make the transition to effective clusterisation. Eleven major weaknesses can be seen in these states, *viz.*,

First, the institutional mechanisms in the region has not stimulated American MNCs to follow the Silicon Valley business model, which stresses horizontal integration, collective learning, and community identity. Little inter-firm links and systemic networks exists between firms and institutions demonstrating a fairly unconnected operations and lack of development of synergy building open system networks.

Second, the extent of differentiation and division of labour generated in the central region is considerably less than even Penang. Within suppliers, the vertical chain does not stretch beyond two firms when compared to four in Penang. While a few large local firms exist (e.g. Sapura, OYL and MEC), no local firm linked in supply relationships with MNCs have achieved horizontal integration in the region.

Third, while a number of entrepreneurial MNCs have developed experienced managers, the lack of institutional support in the region has restricted the flow of such personnel into the formation of new firms. Hence, while the central states enjoy the capacity for rapid set-up and ramp up high volume production on a JIT basis, much of expertise created continue to remain in old firms. Only if mechanisms exist to stimulate managers from established to gradually start new firms to expand the division of labour can cluster dynamics be strengthened.

Fourth, the state development corporations of Selangor, Negeri Sembilan have not played a proactive role to identify and act on collective needs of firms to seize development opportunities created by the presence of MNCs. The lack of such a critical intermediary role has restricted inter-firm links and cooperation.

Fifth, initiatives to start the skills development centres in each of these states have not generated the depth of participation necessary to meet industry-level skills training. Hence, firms still lack adequate industry- and firm-based skills training demands.

Sixth, the electronics industry in the central states constitutes a loose configuration of firms that show little supply networks with MNCs. The competition created by MNCs to

[108] The innovative development of the virus buster by Dr Looi in Penang can be magnified through such support mechanisms.

keep prices low and raise quality has not translated into world class supply capabilities in Kelang Valley, Negeri Sembilan and Melaka. While the opportunities are emerging from MNC and local firms' activities, local and indigenous suppliers are not effectively harnessing them.

Seventh, there is no example of local firms achieving horizontal integration from supplier operations in the central region. The division of labour has remained vertical with suppliers heavily dependent on the MNCs. Penang already has several firms that have graduated to achieve horizontal integration with MNCs. Suppliers to anchor firms have remained under cut-throat relationships with them. Anchor manufacturers in the Klang Valley include those centered around air-conditioning technology, including motors, compressors and heat exchangers; television technology, including cathode ray tubes, chassis; and telephone equipment. However, while the Klang Valley has large semiconductor assembly and packaging plants, the firms are distributed without many connections.

Eighth, the central region faces a deficit in vocational, technical and engineering personnel. It is extremely important for the supply institutions to generate the requisite manpower ranging from basic skilled labour to engineers for firms to upgrade to more efficient and innovative work. The Human Resource Fund (HRDF) and other complementary institutional support incentives have been important in stimulating training. However, most firms complained of processing problems such as assessment of approved programs and the availability of required external training. The Human Resource Ministry's CIAST was also reported by firms to lack effective program selection and co-ordination. The SSDC should learn from the operations of the PSDC.

Ninth, the Klang Valley has most of the universities in the country, but few of them generate electronics industry-driven R&D. Much of the small amount of contract research activities involving university staff is limited to process development activities. With the exception of two local firms, none of the remaining firms interviewed reported performing product development research using university staff. Also electronics research undertaken by IRPA researchers hardly involve electronics firms directly.

Tenth, there is a rising need to participate in market prospecting and market development research to make the switch to TM3, TM4 and TM5. While Sapura, MEC and OYL have performed well in market promotion, they lack the R&D manpower and infrastructure to participate in market research. While these firms participate in OEM, ODM and OBM activities, most local and indigenous firms have not gone beyond OEM activities.

Eleventh, local and indigenous firms in the central region seriously lack networking skills and access to venture capital. Interviews showed several managers from MNCs keen on moving out to start their own firms, but have not made the move due to a lack of funding and the lack of network help.

4.2.3 Johor: Weak Linkages and Networks, Human Capital and Innovation

Electronics firms in Johor confront considerable problems that need addressing if they are to evolve into a dynamic cluster. Eleven major weaknesses can be seen in Johor, *viz.*,

First, very few entrepreneurial MNCs are located in Johor, and inter-firm networks have hardly evolved. Firms in Johor show relatively little collective learning, and community identity. Little inter-firm links and systemic networks exist between firms and institutions suggesting fairly unconnected operations and lack of synergy building typical of open system networks. Links between business networks and firms in these states have evolved superficially due to meetings called by the JSEDC.

Second, most firms are entrenched at the bottom of the division of labour, which emanates from Singapore with little differentiation and horizontal integration. With the exception of a few firms (e.g. SM Semiconductor), Johor lacks a critical mass of entrepreneurial firms to engender a dynamic cluster.

Third, the Johor state development corporation has not played a proactive role to identify and act on collective needs of firms to seize development opportunities created by the presence of MNCs. The lack of a dynamic intermediary role by institutions in Johor has restricted the productive absorption of even the few entrepreneurial capabilities developed in the state. Unless conditions are created in Johor, most entrepreneurs nurtured in Johor will continue to seek jobs in Singapore and elsewhere.

Fourth, the business-government coordinating and deliberation council have functioned passively in the state. Hence, the extent of private participation in government planning has been limited. For example, while the Johor skills development centre began operating in the mid-1990s, firms reported that it has not generated the depth of participation necessary to meet industry-level skills training. The Human Resource Fund (HRDF) and other complementary institutional support incentives have been important in stimulating training. However, most firms complained of processing problems such as assessment of approved programs and the availability of required external training. Hence, firms still lack adequate industry- and firm-based skills training demands. Local skill development is an important issue to world class firms such as SM Semiconductor, Matsushita, Solectron, Seagate and Hitachi. These firms have training departments and employ a high percentage of skilled and highly educated staff. They have also instituted quality control circles and provide rewards and other forms of recognition to employees who have generated new ideas, developments, and innovation. Johor's Industrial Manpower Training Center (Puspatri) offers training programs but co-ordination and response has been disappointing. Involvement from especially SMIs has been low. This situation stands in sharp contrast to what has been achieved by the PDC in Penang.

Fifth, the local and indigenous electronics firms in Johor have not evolved much. Inter-firm differentiation and the extent of technological variation between firms have been low. The vertical division of labour between local firms generally does not exist, though some show two levels. Being new and under-equipped and faced with a lack of requisite human resource, local and indigenous firms have not been able to meet the rising precision demands of MNCs.

Sixth, as a supplier base, Johor has merely been augmenting Singapore's needs primarily. Singapore has functioned as the base to plug to for Johor firms. For firms in Johor to become part of a dynamic cluster, a critical mass of firms and broader clusterisation mechanisms are necessary. Because a number of anchor manufacturers in Johor are Japanese, their risk of new location is reduced by the willingness of keiretsu partners, and other established suppliers (including Taiwanese SMIs) to co-ordinate their investment. An 'instant' value chain can be established in this manner. There is a well established cluster of speaker, PCB, motor and cabinet manufacturers stretching from Johor to Melaka and Negeri Sembilan. These anchor manufacturers see Johor as their main base, and have indeed invested in manufacturing R&D in *situ*. However, unless local initiatives are undertaken to support the development of local suppliers, foreign MNCs will continue to supplant their operations without adequate development of the Johor cluster.

Seventh, Johor faces a deficit in vocational, technical and engineering personnel. It is extremely important for the supply institutions to generate the requisite manpower ranging from basic skilled labour to engineers for firms to upgrade to more efficient and innovative work. The higher salary offered by Singapore has caused a steady brain drain out of the state. Johor must reposition itself to ensure that it catches up with the value added heights of Singapore firms' production activities. However, one firm reported having attracted back Johoreans, which suggests that the right policy framework and the upgrading of firms can shift considerable synergies from Singapore. However, that is a tall order for now as Singapore enjoys a massive lead over Johor on packaging and designing capabilities.

Eighth, Johor has only one university, i.e. Universiti Teknologi Malaysia, but the number of electronics industry-driven R&D generated by this university is still limited. Much of the small amount of contract research activities involving university staff is limited to process development activities. With the exception of two local firms, i.e. Sapura and Syarikat Telekom Malaysia, none of the universities perform product development research involving university staff. Also electronics research undertaken by IRPA researchers in the university have not involved MNCs.[109]

Ninth, local and indigenous firms' involvement in market prospecting and market development research capabilities are far more underdeveloped in Johor than in Penang and the Klang Valley. Horizontal integration and greater differentiation require strong market know-how. Specialisation in narrow supplier activities has constrained such developments.

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[109] Interview by Samion Abdullah (1995),.

Tenth, no local and indigenous firm has achieved horizontal integration in Johor. Unless such developments occur Johor will not have the capabilities to initiate speciation.

Eleventh, local and indigenous firms in Johor seriously lack networking skills and access to venture capital. It is important for the local government to stimulate the use of venture capital, which can be either privately or publicly administered, but with strong government-business coordination, to promote the growth of SMIs in the state.

5. Conclusions

This chapter dissected the dynamics of electronics manufacture in Malaysia, identifying three major conurbations of operations, i.e., Penang, the central region and Johor. All three locations face limitations. An audit of the three locations showed that none have adequately achieved the momentum for increasing differentiation, specialisation, horizontal integration, the capacity to spawn sufficient numbers of new entrepreneurial firms and speciation of new products, firms and sub-industries. Nevertheless, Penang has developed considerable cluster synergies. Penang is the only location which has a semblance of a dynamic cluster. The chapter showed that the problems inhibiting Malaysian electronics in some cases is common to all three locations, but generally tend to be unique to each of them. Hence, efforts to relieve the impasse will require treating them quite differently, though Penang can offer lessons for the other two.

Nevertheless, firms in Penang have established stronger linkages and with the inspirational role of PDC, have established good co-ordination relationships between firms and institutions. A number of collective action problems, such as the use of PSDC for industry-oriented skills development and a designing centre for specialised tool designing, have been stimulated by its intermediary role. The emerging cluster in Penang is fairly open with a diverse range of firms across the industry. However, for Penang to establish effective cluster dynamics, it needs substantial development of human capital, R&D especially involving local and indigenous firms. Only a handful of local and indigenous firms have successfully broken out from OEM facilities to ODM and OBM activities. While the potential for expansion exists, a more potent policy is necessary to generate the systems capabilities required to bridge the deficits required to establish effective systems integration.

MNCs in the central region of Klang, Negeri Sembilan and Melaka enjoy world class manufacturing capabilities, but in addition to the weaknesses afflicting Penang firms, also suffer from weak inter-firm links and network development. Negeri Sembilan and Melaka firms tend to service Klang Valley firms, but a few also service Johor firms. Institutions hardly play effective intermediary roles to strengthen inter-firm links in these states. Efforts to develop inter-firm links and business networks must be open. The Central region has much to learn from the role played by PDC, but the dynamism achieved in Penang requires adapting to meet the specificities of the Central states. These problems need to be ironed out, and deficits in human capital, innovations and market prospecting and research bridged for firms in the central states to make the transition from TM2 to TM3, TM4 and TM5.

Electronics firms in Johor operate primarily as suppliers of labour-intensive and low value added services for firms operating in Singapore. Most firms in Johor assemble PCBs, audio and video equipment and peripherals and other components. Johor firms also operate without significant inter-firm and network relationships, seriously restricting the potential for appropriating synergies. The Johor SEDC also does not play an effective intermediary role to build inter-firm links and business networks. As with the other states, Johor has much to learn from PDC to achieve the network dynamics achieved in Penang. The different local conditions in Johor require the adaptation of the PDC model to suit Johor. Along with efforts to overcome the deficits involving human capital and innovations, inter-firm links and business networks should be developed to assist firms to develop effective clusterisation. Such efforts will also help Johor attract much of the higher value added in Singapore.

Policy efforts must go beyond incentives to achieve the above goals. While incentives can be useful to start activities, especially risky and uncertain ventures, the success of a comprehensive policy for building long-term competitiveness requires emphasis on technology development and education. The focus should be on generating the requisite human capital, R&D and inter-firm links. At the firm level, the TM3 framework of Toyota incorporated all three for effective R&D, production and customisation. The whole industrial district must be tapped and be involved to create a system of continuous human resource development, innovation, creation of new firms and integration and reintegration in the cluster. Chapter 6 focuses recommendations to achieve this after reviewing prevailing incentives in Chapter 5.

Chapter 5: Review of Incentives and Promotional Instruments

1. Introduction

This chapter reviews the incentives and instruments used by the government to promote investment, exports, R&D, linkages and training, which have a bearing on industrial innovation and competitiveness in the electronics industry. Despite the critical importance of these mechanisms, which are necessary to build the overall science and technology infrastructure for industrial structural change, they have had little impact on effective clusterisation, which explains the impasse in the industry. Efforts to integrate clusterisation principles into the policy framework in the country are undertaken in chapter 6.

Incentives are directed at manufacturing without specific reference to particular industries, though, some are meant for high technology and strategic industries such as electronics. The government has continuously used incentives as a necessary instrument to boost electronics investment, and since the late 1980s to stimulate structural upgrading. The prime incentives used include R&D, promotion of supplier networks, marketing and branding support, technology transfer, promotion of indigenous firms, human capital formation, and incentives for the Multimedia Super Corridor (MSC). Appendix 9 lists the current incentives provided under the Promotions of Investment Act, 1986 and the income Tax Act, 1967. As noted in the introduction, the chapter will not review incentives related to the MSC.

Particularly in less developed economies, incentives form an important initiator and complement of technology management that is necessary to solve market failure problems to spur new investment in innovative activities and raise the pulse of inter-firm relationships involving a diverse network of firms. However, incentives must address the fundamental factors of industrial competitiveness in order to be effective. While the institutional support instruments can be independently conceived, an effective policy framework requires inter-links and co-ordination between the different support instruments and policies. Financial incentives alone cannot spur effective clusterisation. Policy planning is important, which must be carried out taking cognisance of the single goal of enhancing firms, and subsequently the industries, long-term competitiveness. Also important is the need to create and maintain the right infrastructure networks that enable individuals to innovate as well as direct it effectively to users.

This chapter presents a critical review of the incentives and key instruments used in the country, with specific reference to the electronics industry. While the principal mechanisms have been comprehensive, their effectiveness can be improved further with some fine-tuning.

2. Financial Incentives

Financial incentives have been among the fulcrum of electronics promotion in Malaysia. From efforts to attract labour-intensive and large-scale investment from the late 1960s and early 1970s, the emphasis on wooing electronics investment shifted to industrial upgrading and integrated manufacturing from the late 1980s. A string of financial incentives still remain.

2.1 Pioneer Status and Investment Tax Allowance

Pioneer Status (PS) and the Investment Tax Allowance (ITA) are some of the most attractive incentives offered by the Malaysian government. Under the PS incentive, an approved company can obtain tax exemption from 70% of is statutory income for a period of 5 years, commencing from the date of production. However, for companies located in the states of Kelantan, Pahang, Terengganu, Sabah and Sarawak, an exemption from 85% of their statutory income is permitted for a similar period.

Under the ITA, an allowance of 60% of qualifying capital expenditure incurred within 5 years from the date of approved of incentives, is allowed. The ITA can be utilised to offset 70% against statutory income in the year of assessment. However, companies located in Sabah and Sarawak can qualify for an allowance of 80% and the allowance can be utilised to offset against 85% of statutory income.

Both PS and ITA are given to projects that fall under the "promoted product" or "promoted activity" as determined by MITI.

The objective of the government is to encourage dispersal of industrial development into the less industrial areas, especially the Eastern Corridor states and Sabah and Sarawak. However, the slight regional differentials in the percentages of exemptions involving the PS and ITA incentives have not been attractive enough to entice firms to the relatively less developed areas of the country. Most still prefer to be located in the traditional and popular industrial sites in Penang, Kedah, Selangor, Negeri Sembilan and Melaka in the Western Corridor in Peninsular Malaysia.

Owing to industrial land becoming scarce and consequently, more expensive, in the more popular states, some electronic firms have opted to invest in the Eastern Corridor states and Sabah and Sarawak. Sabah and Sarawak have been active in promoting FDI, and have managed to attract some electronics firms to their newly created Free Industrial Zones (FIZs).

The appraisal mechanisms used since 1986 has transformed the application of PS and ITA to reasonable levels. From a total tax holiday offered to electronics firms generating high levels of employment and investment in the 1970s until the mid -1980s, the emphasis shifted to strategic and high technology industries from the late 1980s. Subsequent efforts have been taken to scale down the percentage of exemptions from 100%, depending on foreign equity participation and domestic market shares of sales. Since the 1990s, total tax holidays have only been given to high technology and strategic industries. While the incentives should be continued, it is also extremely important to refine it to only include specific target groups. Also, the time has come for even strategic and high technology industries to be imposed with a low amount of tax if the rival sites such as Singapore place a higher tax rate. For example, it should be all right to offer a 90% tax exemption under the PS for high technology and strategic industries than the current total exemption.

2.2 Reinvestment Allowance

Reinvestment allowance (RA) is granted to manufacturing companies which incur qualifying capital expenditure for the expansion of production capacity, modernising and upgrading of plant and machinery and diversification into related products. It is provided in the form of an allowance of 60% of capital expenditure incurred by the companies. This allowance is utilised to offset against 70% of the statutory income in the year of assessment. Additionally, companies that reinvest and significantly increase their productivity will obtain a 100% deduction against the statutory income but such companies must show increases in productivity.

This incentive is important to the electronics industry because of its characteristics of rapidly changing technologies and processes, shortening product cycles, rapid changes arising from innovations and R&D and intense global competition. All these would necessitate reinvestments to keep in line with global changes in technologies processes designs, products, competitions, etc.

An assessment of the extent of take up of RA is important to determine the quantum of allowance that is necessary to attract and encourage existing manufacturing companies to reinvest. Is the quantum of RA sufficient to stimulate reinvestment by existing manufacturing companies, considering industrial promotion by the neighbouring countries like China, India and Philippines?

In light of IMP2 strategies to promote the electronics industry through clusterisation, the need to reinvest in many of the existing electronics companies has become crucial. In particular, the government aimed the RA to encourage reinvestment in high productivity sectors through automation, extension into new product lines and labour saving devices. The local electronics industry is now poised to undergo drastic changes and the RA incentive would be important to meet these challenges.

However, as with incentives in general, the government does not have mechanisms to monitor the introduction of automation and labour-saving devices in firms. Such monitoring is critical to ensure that the incentive meets its objective. Also, since it is the overall returns in a deregulating environment that drives ultimate productivity and competitiveness of firms, the RA should emphasise reduction in input use as well as shifts to environment-friendly production methods.

2.3 High Technology Industries

Specific incentives are targeted to stimulate investment in high tech industries. Companies engaged in high technology industries are eligible for the following incentives:

- Pioneer Status with full tax exemption at statutory income level for a period of five years; or
- Investment Tax Allowance of 60% on qualifying capital expenditure incurred within a period of five years. This allowance can be used to offset against the statutory income for each assessment year without any restriction.

High-tech companies must meet the following conditions in order to qualify for the above incentives:

- Local R&D expenditure to gross sales should be at least 1% on an annual basis and companies are allowed a period of 3 years from date of operation to comply with this requirement
- The percentage of science and technical graduates to total work force should be at least 7%.

Most promoted activities and products are in the electronics and associated sectors. Given the industry specificity of electronics, knowledge creation and use, and as its complementary characteristics, supporting industries should be considered for promotion as well.

Incentives to stimulate high-tech activities are extremely important, as innovation is the critical determinant of competitiveness in the electronics industry. There is of course some subjectivity in the application of incentives for this purpose. The 1% criterion for local R&D expenditure to gross sales is subjective as sales vary from time to time. Also, the 7% condition for sciences and technical graduates does not explain much on the contribution to high-tech. Perhaps, the criteria for such incentives need to be reconsidered and more clear cut criteria to directly induce high-tech investment could be more effective.

In addition to ameliorating the above problems, the government should also consider imposing a 90% tax exemption on high technology firms when awarding PS. As is noted below incentives involving high tech industries overlap heavily with strategic industries, suggesting a need for integration.

2.4 Strategic Projects

Incentives are also awarded to strategic projects, including pioneer status and investment tax allowance for manufacturing companies that are involved in strategic projects of national importance. Manufacturing companies that are involved in strategic projects of national importance are granted the following incentives:

- Pioneer Status with full tax exemption at statutory income for a period of ten years; or
- Investment Tax Allowance of 100% in qualifying capital expenditure incurred within a period of five years. The allowance can be utilised to offset against the statutory income assessment year within any restriction.

Strategic projects are those with heavy capital investment and high technology which can generate extensive linkages and have significant impact on the Malaysian economy. The criteria to qualify for such incentives are for projects with:

- Investment of more than RM100 million
- Integrated manufacturing activities
- Backward and forward linkages
- High-tech products
- Incorporation of approved R&D facilities

However, the approval body seems to show a bias towards large companies. Most local companies are not eligible. It may be useful to take a closer look at these criteria so as to include SMIs in the strategic list. Perhaps, certain SMIs producing strategic products and acting as critical suppliers to MNCs should be favourably considered. The electronics industry is an industry most suitable for supplier-MNC relationships and such incentives would be important to nurture critical SMI companies to strategic status. Intel itself began as a small company in the United States with less than 200 employees. The continuous breeding of innovative SMIs will form the springboard to drive the progression of firms in the production chain from TM2 to TM3, TM4 and TM5.

Also, the application procedure involving incentives for strategic projects is subjective and difficult. The question of "high-tech" and "strategic importance to the nation" is difficult to quantify and is, therefore subject to abuse. An industry may be high-tech but not strategic and a project may be strategic but not high-tech. For example, how would a computer OBM project be identified - as a “missing link” in the IMP 2? Is it only high-tech or only strategic or both and, therefore, where would it qualify for incentives? Besides, given the emphasis on high tech industries within strategic projects, it is better to integrate 2.3 with 2.4.

In addition to resolving the above problems, the government should also consider imposing a small amount of tax on strategic firms as stated under the PS and ITA section.

2.5 R&D

Various incentives are given specifically to promote R&D. However, regulations involving R&D incentives tend to be biased towards large companies, often working unfairly against SMIs. SMI supplier companies in the electronics sector can benefit a great deal from having their own R&D if incentives stimulate their progression to OEM, ODM and OBM activities. Many supplier companies have the potential to engage in R&D, even if not related to high-budget R&D. Several small suppliers in the United States, Germany, Japan, South Korea and Taiwan have their own R&D. A number of these firms have progressed to really high-tech OEM, ODM and OBM operations. The indigenous companies can be nurtured to this status, given the right incentives and support by the government. Indeed, small teams of innovative individuals – from without affiliations, universities, firms and other organisations – have become increasingly important innovators in the Silicon Valley and Route 128.

In this respect, the Malaysian government offers grants for 3 major types of R&D activities, *viz.*,

- **Contract R&D company** i.e. a company that provides R&D services in Malaysia to companies other than its related associates;
- **R&D company** i.e. a company that provides R&D services in Malaysia to other companies;
- **In-House R&D** i.e. R&D activities within a company for the purpose of its own business.

In Malaysia, in the electronics sector the first 2 types of R&D activities are almost non-existent but some MNCs in the local electronics sector have initiated mild forms of in–house R&D though not of the high-budget type. Most of the existing R&D undertaken by the electronics companies are confined to designs, packaging and processes but little, if any, on technologies and even new product development. Most of the locally based MNCs undertake their new product development and technology R&D in their home bases overseas. As noted in chapters 1 and 2, MNCs generally do not undertake R&D in host-countries. Incentives should thus focus on assisting R&D, especially product-based, in local firms.

Part of the problems inhibiting R&D activities in Malaysia, especially involving local firms, can be overcome with existing incentives. The government should simplify the applications procedures and disseminate better such information more effectively. These incentives can also stimulate R&D activities by innovative individuals, firms and institutions, including universities.

- ITA of 50% on qualifying capital expenditure incurred within 10 years. The abatement is limited to 70% of the statutory income
- Double deduction is allowed on revenue expenditure incurred by a person on research directly undertaken by him or on his behalf
- Double deduction on payment for the use of services of approved research institutes, R&D companies or contract R&D companies, as well as cash contribution research institutes
- Buildings used for purpose of approved R&D
- Capital allowance on capital expenditure incurred in the provision of plan and machinery used for R&D
- Machinery/equipment, materials, raw materials/component parts and samples used for exemption from the duty/tax.

Applications for R&D have to be submitted before the R&D takes place. In most cases, manufacturing plants, especially those that belong to the local companies do not have an "official" R&D department. A lot of product and process innovations currently carried out do not qualify for R&D incentives because of definitional problems. Some firms find the procedures too unclear and subjective. A number of firms interviewed reported that applications for such incentives are too time consuming and require the supply of confidential information to the government.

In addition, Malaysians lack R&D skills especially in product technology. As such, most MNCs operating in Malaysia have even their designing capabilities in their home country, near to their headquarters. Some MNCs also reported opening designing centres in India. Some Malaysian industrialists reported considering locating similar facilities in the Silicon Valley and India.

When offering incentives, there is a need to recognise the relative comparative advantage of institutions and firms in stimulating R&D. While universities do not have a monopoly over knowledge creation and its dissemination, they form the cornerstone of basic blue sky research. Firms hardly participate in basic research because of its uncertain returns. Yet, basic blue-sky research – enabling a steady flow of new knowledge – is important to drive development research.

Design centres, with ownership share by both private and public interests, should undertake development research. MIMOS should specialise more on development research. Large firms too participate considerably on development research. Since MNCs retain such activities abroad, local and indigenous firms should be encouraged to undertake development research. Both intermediary organisations such as MIMOS and local and indigenous firms can also support particular development research as well as basic research in universities through contracts. The boundaries on research emphasis should overlap. Universities should enjoy relative specialisation in basic research, and firms and intermediary organisations on development research.

- Research grants for basic blue-sky research should be directed primarily to universities. The current emphasis on commercialisation should be handled through intermediary organisations such as MIMOS and privatised research wings of universities. Of the RM1 billion allocated for R&D, 25% of the amount should be earmarked to support basic research
- R&D grants involving universities, including contained under IRPA, in Malaysia should increase emphasis on supporting research by electronics engineering, physics and related scientists and technologists. Complementary hiring and expansion of such faculties in universities is pertinent
- IRPA grants to universities should emphasise basic research as much as development research. IRPA grants to intermediary organisations should emphasise more development research
- The initial lack of R&D scientists and technologists reported in chapters 1 and 4 should be met through imports from abroad, especially India. While local experts should be the ultimate aim, the industry cannot wait for them to be produced
- MIMOS, privatised university research centres and other related organisations should be earmarked for development research. Of the RM1 billion earmarked for R&D, 75% should go to such organisations which perform scaling up and commercialisation operations
- R&D centres should obtain an additional incentive of an equal subsidy from the government for every Ringgit invested on R&D building, equipment and personnel. The double deduction incentives should be maintained for firms engaging on product and process R&D
- Contract research undertaken by firms and institutions with foreign individuals, organisations and universities should enjoy the same double deductions
- Given that knowledge and innovations are not confined to firms and institutions, the R&D grants should be made available to individuals validated by the requisite authorities

2.6 Training and Skills Development

The government provides 5 different types of training incentives. The most widely used since 1993 is the Human Resource Development Fund (HRDF). The HRDF, which is co-ordinated by the Human Resource Development Council (HRDC) requires manufacturing firms with an employment size of 50 and more to contribute 1% of their payroll, which they can then reclaim using approved expenses. This mechanism actually penalises firms that doe not train their employees.

A similar, but using both the stick and carrot, approach was tabled for gazzeting for SMIs. If approved, SMIs with less than 50 to a minimum of 10 employees and with a paid-up capital of not more than RM 2.5 million, can avail themselves of the assistance grants under the HRDF. A 1% of payroll contribution will qualify them for claims twice as much. The other training incentives are:

- Double deduction for expenses incurred for approved training (employment size less than 50 employees)
- A single deduction given for contribution in cash to a non-profit technical or vocational training institution
- Exemption from import duties, sales tax and excise duties for imported machinery's, equipment's and materials used for training personnel
- ITA for new investment to upgrade training equipment or expansion of training capacities.

The inclusion of SMIs in the HRDF is an important especially for the indigenous electronics companies as it rewards them for training. For larger firms, the 1% payroll penalty forces them to increase training. A number of MNCs have also established training programs. In addition to the training requirements required by the move towards flexible production systems, the DDTI (from 1988) and late the HRDF (1992) were reported as instrumental in pushing MNCs such as Intel and Motorola to start their own training centres as well as supporting the formation of PSDC (1989). The surplus achieved from the difference between collections and claims goes to maintain the administration as well as subsidise training in SMIs. Human Resource Development Council (HRDC). This mechanism actually supports MNCs indirectly as SMIs form the supplier bed for the former. Such efforts enable the movement of SMIs to become globally competitive, meeting the need to create world class production chains by stimulating them to make the transition to TM3, TM4 and TM5.

Contributions to the HRDC were temporarily suspended in 1997-99 due to the financial crisis. Nevertheless, many locally based MNCs are beginning to establish their own in-house training programs for their staff. The indigenous electronics firms, however, still lack far behind in this respect. The incentive for training, in particular, should try to reach the indigenous companies to get them to be more conscious of the benefits of HRD. Their take up of DDTI has been low, suggesting a clear need for considering a stick similar to the 1% contribution of payroll required under the HRDF, which they can then claim twice from HRDC.
Training incentives, despite their complexities were also reported as instrumental in assisting the formation of some training centres. While the demand for external training was central, subsidies directed at training centres played an important role in the snowballing of participants in the PSDC. The PDC played a critical intermediary role in

resolving information and bureaucratic problems to make it a success. The absence of such co-ordination role is arguably the most important reason for its failure in the other states.

2.7 Industrial Linkages and SMIs

As indicated earlier, linkages between the indigenous companies and MNCs in the electronics sector have not been progressing fast enough. This incentive is, therefore, important to expedite the process and would be very helpful, especially, for the indigenous electronics sector.

To promote linkages between large companies - both foreign and local - and local SMIs, the government recently granted incentives to large companies in the form of a deduction in the computation of income tax to stimulate large companies to establish and expand industrial linkages. Under the industrial linkage scheme, expenditure incurred on the training of employees, product development and testing and factory auditing to ensure quality of vendor's products can be deducted from the statutory income.

Vendors including SMIs, which produce intermediate goods in an approved scheme, will be granted pioneer status for five years with 100% exemption on the statutory income. Vendors in approved scheme who are capable of achieving world class standard in terms of price, quality and capacity are granted pioneer status for 10 years with 100% exemption on their statutory income.

The 1998 Budget also proposed a fund of RM1 billion to be allocated to SMIs. This fund is for the purpose of providing financial assistance with attractive rates in order to encourage productive investments. The indigenous electronics firms should be encouraged to benefit from this fund.

In addition, it is important for new entrants demonstrating innovative potential but lacking in collateral to be offered preferential access to this pool. The Credit Guarantee Scheme should be widened to guarantee such risky but innovative ventures.

To stimulate greater industrial linkages locally, the government should also integrate the FIZs and LMWs with the principal customs areas. This will remove the indirect subsidy from tariff-free trade enjoyed by firms located in such preferential zones. Promoted products and component production should initially enjoy a tariff rate of 5%, making it compatible with both AFTA, APEC and WTO requirements. Prices of items produced in Malaysia will then be assisted by scale opportunities offered by the domestic market less 5% tariff barrier, and the markets of neighbouring economies.

2.8 International Procurement Centres

International Procurement Centres (IPC) refer to locally incorporated companies, whether local or foreign-owned, which carry out business in Malaysia to undertake procurement and sale of raw materials, components and finished products to its group of related and unrelated companies in Malaysia and abroad. These firms are especially pertinent to the electronics industry that sources about 70-75% of its components and only about 25-30% from local suppliers.

To encourage the establishment of IPCs and make Malaysia a distribution centre, the government offers the following incentives:

- Approval of the number of expatriate posts will be based on the requirement of IPCs
- IPCs will be allowed to open one or more foreign currency accounts with any licensed commercial bank to retain their export proceeds without any limit imposed
- IPCs will be allowed to enter into foreign exchange forward contracts with any licensed commercial bank to sell forward export proceeds based on projected sales
- IPCs will be exempted from the requirements of the Ministry of Domestic Trade and Consumer Affairs guidelines on foreign equity ownership on wholesale and retail trade
- IPCs will be allowed to bring in raw materials, components, or finished products without any payment of custom duties into FIZ or LMW for repackaging, cargo consolidation and integration before distribution to the final consumers.

The criteria to qualify for the IPC incentives include the following:

- Locally incorporated company under the Companies Act 1965 with a minimum paid-up capital of RM 0.5 million
- A minimum total business spending of RM 1.5 million per annum
- A minimum annual business turnover of RM 100 million
- Goods are to be handled directly through Malaysian ports and airports

As sourcing for components and parts is an important aspect of the electronics industry, incentives to promote IPCs are especially useful. Besides the above, various other incentives and schemes are also available not only to the electronics industry but also to other industries as well. These incentives, however, are basically for the promotion of investment. Only of late, more and more incentives are being introduced to selectively promote or re-orientate investments to capital-intensive and/or high-tech industries. Many of these incentives require refinement to make them more effective.

2.9 Promotion of Exports and Industrial Upgrading

A range of other incentives is also available for the promotion of manufacturing export activities in Malaysia. A number of these incentives are also used to promote training, use of environment-friendly technologies and technological – product and process - deepening in firms. The most important of these incentives are listed below:

- Export Credit Refinancing;
- Double Deduction for Promotion of Exports;
- Double Deduction of Export Credit Insurance Premium;
- Industrial Building Allowance;
- Incentive for Industrial Adjustment;
- Incentive for small-scale companies;
- Incentives for Computers and Information Technology Assets;
- Incentive for the Storage, Treatment and Disposal of Toxic and Hazardous Waste;
- Tariff Protection;
- Exemption from Import Duty on Direct Raw Materials/Components;
- Exemption from Import Duty and sales Tax on Machinery and equipment;
- Drawback of Excise Duty on Parts, Ingredients or Packaging Materials;
- Drawback of sale Tax on Materials used in Manufacturing; and
- Drawback of import Duty

Despite the cumbersome mechanisms associated with customs management of duty drawbacks, credit refinancing, warehouse use for export activities, claims on excise and import duties, and controls on imports involving strategically promoted import-substituting industries such as plastics and chemicals, these incentives were fairly successfully managed in Malaysia. However, a number of these incentives will have to be gradually removed to meet WTO and AFTA conditions. All subsidies that can be construed to balance trade will contravene the provisions contained under the Trade Related Investment Measures (TRIM) regime. Hence, export subsidies, including on insurance and credit will have to be gradually scaled down.

Meanwhile, the government can maintain tariffs on specific items under the WTO arrangement, but if similar treatment is given to all firms irrespective of ownership. Since the electronics products tariffs are actively liberalised – begun even before AFTA's CEPT fast track schedules were started in 1995 – protection is not an issue here. Hence, the real concern with incentives involving the electronics is to shift promotional emphasis where necessary to SMIs and indirect incentives such as training, R&D and environmental support.

3. Support Instruments

In addition, the government to stimulate exports, R&D, training, linkages and development of local and indigenous firms, use a number of instruments. These programs also need review.

3.1 Marketing and Branding

Commercialisation and markets constitute a critical building block of the new competition. As with basic product and process R&D, MNCs are unlikely use Malaysia strongly for global marketing strategies and market development. The most developed marketing operations in Malaysia are limited to regional customisation. Malaysian has been quite successful in market promotion. However, for Malaysian firms to move up the value-added chain, there is a strong need integrate more operations to include market prospecting and development. Incentives alone to support such activities are not enough.

The Malaysia External Trade Development Corporation (MATRADE)[110] was established on March 1, 1993, as the external trade promotion arm of Malaysia's Ministry of International Trade and Industry (MITI). MATRADE functions as a focal point for Malaysian exporters and foreign importers to source for trade-related information. By providing market intelligence and relevant advice, MATRADE assists Malaysian exporters to better position their products and services in the highly competitive global markets. This guidance facilitates smoother and more efficient international trade. A joint co-operation between Malaysia's public and private sectors, MATRADE also plans and implements various trade promotion activities locally and abroad.

MATRADE's mission is to:

- Promote export of Malaysian manufactured and semi- manufactured goods and services
- Improve marketing skills of Malaysian exporters in the international economic environment
- Provide comprehensive and up to date market information system and effective marketing strategies for the development of trade.

Government support to prospect and open markets for private ventures is initially helpful as developing economies' firms initially lack the infrastructure and financial muscle to break into foreign markets. Japan, South Korea and Taiwan benefited enormously from state support initially. However, the involvement of the government in this section also has its drawbacks. Private sector firms should form the basis for such activities, in conjunction with MATRADE or other government bodies.

110 http://www.matrade.gov.my/matcorp.html, viewed on 29 September, 1999.

Since export incentives are prohibited under WTO rules on grounds of preventing trade balancing within TRIMs, incentives should be directed at market prospecting and market promotion, including customer research. Incentives should be geared towards individual firms using marketing tools such as research and development of their products and customers as well as promotional activities. However, to prevent the dissipation of scarce resources, incentives should be strongly monitored to ensure that they are being successfully applied.

Local and indigenous firms should be encouraged and supported to extend their activities to cover market prospecting and market development. Customer markets often require development - symbiotically complementing their needs with firms' productive capabilities.

- MATRADE should use the support of MIGHT to stimulate greater involvement in market research in key markets
- MATRADE should expand its databank on foreign markets, which should be made easily accessible to local and indigenous firms
- R&D incentives should extend provisions to include institutions involved in supporting market research and prospecting
- SMIDEC should co-ordinate the activities of market research institutions to reach SMIs
- Local and indigenous firms should be encouraged to hire foreign staff or contract out market research on promoted markets. Local and indigenous firms should be offered incentives even when such research involves using foreign personnel abroad

3.2 Technology Parks

Technology parks have been successful abroad in attracting a blend of essential support services and the location of high technology firms to create the synergy necessary to support frontier R&D operations, as with the Hsinchu Science Park and the Cambridge Science Park. Such parks should be governed effectively to ensure that innovation-related activities are attracted.

The Kulim and the Bukit Jalil Technology Parks have been around for too short a time for serious assessment. Firm's assessment study suggests that they have been strongly technology-led rather than based on achieving potentially competitive high technology industries.[111] The two prime problems cited were one, that bureaucrats without serious consultation with the private sector have determined the targeted industries. Second, the co-ordinators of these parks themselves do not have a proven record in the private sector.

111 Rasiah's (1996)

Hence, many high technology initiatives such as wafer fabrication initially started as technology led ventures rather than technology managed such as locating industries considered really strategic for development based on Malaysia's latent capabilities. Only in Penang, with strong private-public co-ordination, have firms reported strong technology management trends.

There is a serious need to gear technology parks to the achievement of comparative advantage in viable industries. In addition to directors with strong private sector experience, technology parks must be promoted to attract industries seen as capable of taking the country to the technology frontier so as to eventually shape it. The national co-ordination council should be accessed strongly to line up the industries - not as contained in the Action Plan for Industrial Technology Development (APITD) - but as viewed as achievable based on currently endowed resources and potentially achievable. University experts should also be encouraged to locate research units in the parks to complement high technology firms activities.

Technology parks and technology transfer agreements are some key instruments used to increase the rate of technology transfer to local firms. Besides these government assisted technological transfer initiatives, in the private sector, human capital transfers from transnationals to local firms also occurred.

3.3 Promotion of Local and Indigenous Firms

The successful growth of the Northeast Asian economies has relied extensively on the promotion of local firms. Within the electronics industry in Malaysia, a range of local and indigenous firms has emerged. Despite the emphasis on attracting foreign investment, development objectives in Malaysia have consistently argued for the need to stimulate the growth of local firms. Among incentives provided are export incentives - export credit refinancing scheme, subsidised insurance schemes for exports (including use of warehouse), incentives for indirect support such as training, R&D incentives, controls on environmental pollution, and double deduction exemptions for exports. Given the policy emphasis, it is worth examining their prevailing productive capabilities and the mechanisms by which they could be supported to higher levels of competitiveness and move up the technology ladder.

A number of programs exist to stimulate the development of SMIs in the country. As noted in chapters 1, 2 and 3, SMIs form the critical connections in the development of competitive production chains. Given the significance of local firms in ensuring effective SMI development, the government offers six programs to assist SMIs, *viz.*,

- **Industrial Linkage Program (ILP) under SMIDEC**

The ILP is to promote and nurture the indigenous companies especially SMIs into becoming reliable manufacturers and suppliers of critical components and services to the larger companies and MNCs, which are involved in core manufacturing activities within a particular cluster, as well as across other clusters. The groups comprise electronics and electrical, transportation equipment and machinery and engineering companies.

- **Industrial Technical Assistance Fund (ITAF)**

ITAF was established in 1990 to enhance the development of SMIs into cost efficient and competitive industry sector. There are four schemes under ITAF.

- Consultancy Services Scheme (ITAF 1);
- Product Development and Design Scheme (ITAF 2)
- Quality and Productivity Improvement Scheme (ITAF 3); and
- Market Development Scheme (ITAF 4)

- **Modernisation and Automation Scheme for SMIs**

This Scheme is aimed at promoting the modernisation and automation of SMIs through the utilisation and application of modern technology. The scheme is in the form of soft loans to assist acquisition of new machinery and equipment capable of automating manufacturing operations. Electronics companies, especially those of the SMI category, could well benefit from this scheme.

- **Technology Development Program**

This program is formulated to develop and strengthen the capacity and capability of potential indigenous firms especially those of the SMIs category to adopt best manufacturing and management practices, to inculcate total quality management and R&D culture, to identify weaknesses within SMIs manufacturing processes and management as well as to enhance the competitiveness of SMIs. Indigenous sector has naturally been a target group of this program.

- **Export Development Program**

This program is to develop and nurture export-oriented SMIs to become world class manufacturers. The program includes the establishment of SMI-Link (Showcase), exhibition/EXPO, SMI Infornet and Resource Centres. It is unfortunate that even while firms are aware of the program, the participation rate of indigenous electronics companies in this program is low.

- **Infrastructure Development Program**

This Program is to assist SMIs in purchasing or leasing affordable factories at the industrial sites and also to facilitate the provision of assistance by the government to the SMIs.

The common eligibility criteria for the incentives includes the following:

- Incorporated under the Companies Act
- Shareholders' fund of less than RM 2.5 million
- Shareholders' fund of not less than RM 250,000
- At least 70% Malaysia equality

These incentives are pertinent to the development of the indigenous electronics sector where most of the firms are relatively small compared to the MNCs. It is extremely important for MITI and SMIDEC to gather and disseminate as widely as possible information on the missing links in the electronics production chain, market prices of inputs and output in the chain, man the available incentives and support mechanisms. The government should install a rigorous mechanism to appraise *ex post*, the effectiveness of SMI incentive packages and support programs.

Assessment mechanisms will benefit considerably from a careful audit of suppliers. In the absence of a detailed audit, it is important that a follow up study be undertaken to locate the technical and competitive topography of local indigenous firms. Of the firms undertaking product R&D only Sapura is clearly controlled by indigenous capital. The overall ranking of local firms generally places them in the category of simple and OEM activities within the technology trajectory. Few local firms are involved in ODM and OBM activities. Where firms operate as subcontract houses to multinationals such as the micro-chip assemblers, the dependence on government assistance has not been strong, but their evolution up the technology ladder has also been modest (see chapter 4). Carsem, Unisem and Globetronics have not gone beyond assembly and test of microchips. Designing, R&D and marketing are still controlled by the multinationals with operations abroad. These MNCs enjoy double deductions from taxable income on exports. Local firms enjoying strong government assistance such as Sapura, initially grew strongly through the control of domestic markets. Sapura's telecommunications division has subsequently dwindled due to the entry of other firms and falling support from the government, suggesting that the firm has not used the initial incentives to develop a leading competitive advantage.

Given the relevance of clusterisation explained earlier in the report and the role local firms have to play in becoming an integral part of it, the institutional framework should go beyond merely expanding links with multinational operations. If local firms only act as suppliers to MNCs without developing their own ODM and OBM processes this will create a serious deficit in net factor income from abroad thereby draining resources from the country. In addition the initial imbalances created from transnational relocations can only be used productively if they result in the development of local productive capabilities.

Malaysia has continued to offer a variety of incentives to encourage the development of the electronics industry but current WTO and AFTA agreements will influence this. As noted earlier, Malaysia will have to abandon trade-balancing incentives by 2003. As a consequence, the government must phase out incentives gradually so that export incentives - both the export credit refinancing scheme, subsidised insurance schemes for exports (including use of warehouse) and double deduction exemptions for exports, will be removed by the year 2003. It will also have to avoid reintroducing tariffs exceeding 5 percent after 2003. Additionally the WTO does not allow privileged treatment of local and indigenous firms over foreign owned firms in the provision of sales tenders, offer of indirect incentives such as R&D, and allocation of infrastructure support services. Ownership conditions will have to be deregulated in manufacturing after 2003.

Government instruments that are allowed include incentives for indirect support, such as training and R&D incentives and controls on environmental pollution. Such provisions cannot discriminate foreign firms over local firms. To prevent the sale of local firms to foreign interests that may work against the interest of the country, the WTO allows for legislation regarding the operations of firms. The WTO conditions allow for government capitalisation of firms, which can be an important channel for local and indigenous firms to access scarce capital. While AFTA is WTO-consistent, it also allows for countries to slowdown or temporarily suspends deregulation initiatives when faced with an economic crisis. Since the WTO is more important, it is critical that Malaysia co-ordinate its operations taking cognisance of this broader trade body.

Government assistance to local and indigenous firms should gradually be shifted to subsidise indirect support mechanisms such as in training, R&D, marketing, and finance. Small and medium firms can enjoy additional support through the preferential treatment accorded to them in several countries. The present efforts by MITI, MARTRADE, MTDC, MIMOS, SMIDEC, BCIC, business chambers and MIGHT are useful but they require effective co-ordination. Where local firms are involved a team comprised of the executive, representatives of the electronics firms, academics engaged in electronics research and civil servants should rigorously review the allocation of subsidies and to monitor and appraise results on an ongoing basis. All *ex post* appraisal results should be pooled to assist future screening. The national co-ordination council should subject the team itself for review. To prevent collusion, the members in the two councils should be different. Such a result-based evaluation is extremely important to remove failures quickly so that resources are not wasted.

The government should pursue strategic alliances similar to the Taiwanese system as a useful way of complementing and quickening local firm's movement towards the technology frontier and gain market access abroad. OYL Electronics has established strong alliance with multinationals and is now a billion Ringgit firm (see chapter 4).

MITI should assist in establishing alliances through incentives so as to strike agreements beneficial to local partners.

3.4 R&D Funding

With regards to funding for R&D, Malaysia through the Seventh Malaysia Plan has allocated sum of RM1 billion under the Intensification of Research in Priority Areas (IRPA) Programs. Other Financial schemes are:

- The Technology Acquisition Fund (TAF) to assist Malaysian industries to obtain strategic technology from foreign sources;
- The industry R&D Grant Scheme (IGS) to encourage Malaysian companies to be more innovative in using and adapting existing technologies and creating new technologies, products and processes which will benefit the national economy; and
- The Commercialisation of R&D Fund (CRDF) to enhance competitiveness and capability of the Malaysian industrial sector by promoting the commercialisation of indigenous technology.

These are moves in the right direction but, unfortunately, these are not much publicised. These should be more publicity here so that this could result in fostering greater awareness and collaboration between the public sector, private sector and academia with the hope that this amalgamation of minds would prove volatile enough to spawn exciting new multimedia, electronic and IT technologies. In particular, promoting indigenous electronics firms should be targeted for assistance.

Industry initiated R&D should be encouraged but should be screened carefully before approval. Funds for this could be accessed through the MSC R&D Grant Scheme where RM 20 millions have been provided out of the RM 1 billion allocation.

3.5 Human Capital Formation Institutions

Several institutions exist to support the development of human capital. Four of the existing levels of human resource development need scrutiny. The first deals with schools - both technical and vocational, and normal - generating basic human resource. The second deals with professional and engineering qualifications. The third addresses the supply of scientists and technologists necessary to undertake R&D operations. R&D teams of comprise members from all three levels. Finally, the rapid obsolesce of skills due to technical change necessitates in-house and out-house skills training.

The Penang Skills Development Centre (PSDC) offers the northern region world-class strategic industrial co-ordination and skills development capabilities involving the last level of human resource development requirement. The state and federal governments have been working on uplifting the standards of the institutions generating the remaining three aspects of human capital development. However, Penang still seriously lacks supply of personnel in categories two and three. For firms to make the transition to TM3, TM4 and TM5, this problem must be resolved. Meanwhile, firms in the Kelang Valley, Kedah, Johore, Negeri Sembilan and Melaka also face severe constraints on meeting level four training requirements despite the formation of skills development centres there. A separate study of the problems inhibiting the evolution of skills training in their skills development centres is urgently necessary. Sarawak and Sabah lack adequate skills supply in all four categories.

Human resource development is the most critical requirement for the growth of the industry. Normally there is a time lag between when students recognise an up-and-coming industry and when they start enrolling in related courses. When students have realised the trend, it may take them a few years to enrol in the relevant courses and a few more years to graduate. Also, student's decisions to pursue particular disciplines are also influenced by ease of completion, fees, and the prospects of gaining promotion. It is therefore necessary for systematic planning in anticipation of future human resource demands.

As indicated in the analysis of Penang in chapters 1 and 4, Malaysia is facing a serious shortage of skilled personnel to support the development of the electronics industry. It is estimated that in Penang alone 3,000 additional scientists and engineers are required on a yearly basis just to reach Singapore's or Hong Kong's current levels by the year 2002. Presently Malaysia lacks sufficient institutions of higher learning in order to be optimistic about the goal of reaching this significant increase in skilled personnel. The supply of engineers and R&D scientists and technologists must increase many folds for Malaysia to enable its electronics firms to make the transition from TM2 and TM3 to TM4 and TM5. Importing personnel from countries such as India can only be a short-term strategy. A long-term strategy would require the opening of more technical universities, including *Fachhochschulen.*

The use of human resource development techniques has provided Malaysia a significant source of capability enhancement for firms, underpinning their efforts in product, process and incremental innovation. Thirteen firms in that study stated enhancement effects following the opening of the Penang Skills Development Centre (PSDC) which was started by firms with state support in 1989. The PSDC emerged as a result of skilled labour shortages when electronics firms - especially foreign owned - began upgrading production activities to higher skilled and innovative activities. Serious pitfalls in institutional support and rising production from the late 1980s led to the development of the Penang Development Corporation (PDC). Its function was to resolve demand-supply gaps and help firms continue their transition to higher skilled operations. The PDC offered highly subsidised rent and brought together firms to use the PSDC to facilitate the realisation of scale economies associated with training. To ensure effective state-market co-ordination, officials from firms and the local state were elected to lead the PSDC.

Interviews show that firms' experiences with the federal state's human resource development efforts, was mixed. Foreign electronics MNCs were the prime beneficiaries of the DDTI that was in existence in the period 1988-92. The DDTI has failed to generate sufficient participation from small firms even after 1993.

Consumer electronics and local firms, especially, have introduced more organised training programs. Given the small incidence of external training involving small firms and their limited resources, the surplus generated from the bigger firms alongside government subsidies could be used to stimulate training in smaller firms. Since small firms often lack the ability to release staff, small-firm friendly methods should be employed to overcome such market failure problems.

Since 1993 component and telecommunications firms reported that they have already been training their employees and incurred higher than the 1 percent of payroll expenditure required by the HRD Act. These firms reported continuous training and retraining as having been carried out since the mid-1980s. Firms located in Penang regarded the PSDC as fairly well equipped to meet state of the art training requirements - but not in providing sufficient supply to meet demand. Firms located in other states reported a lack of quality training institutions to quicken their learning capacity. Continued weaknesses in existing training institutions to support technical transformation in other local states led the federal state to encourage the formation of specialised skills development centres in the fashion of the PSDC. These institutions have not achieved the kind of success enjoyed by the PSDC.

Efforts to start the modular approach of the PSDC in other states such as Selangor have not met with similar success despite advice sought from PSDC's management. Interviews suggest that the problem appears not so much due to differences in firms needs, in others parts of the Western corridor but due to a lack of effective co-ordination. The poor outcomes in other places appear to result primarily from a serious lack of participation by the respective partners. The PICC and the past intermediary role of the Penang Development Corporation (PDC) and the state government, which drew support from the firms, chambers of commerce and infrastructure organisations have not been reproduced, in other states. Such systemic relations, which have been so critical in PSDC's operations, are seriously lacking in other states. Skill development centres *a la* the PSDC is critical for firms to make the transition from TM2 to TM3.

The PSDC should also include in its armoury, when co-ordinating in the National Co-ordinating Council, the need to constantly review the private sectors demands on training content. Industries demand requirements on training processes and content have changed considerably making a number of training institutions obsolete. While efforts by the HRM, HRDC, EPU TI has brought some changes to a number of them, including IKIM, MIT, Vocational Schools, ITIs and Polytechnics, systematic co-ordination or flow and feedback of such demand requirements is still weak. For example TQM elements such as

TPM, JIT, QCCS, SPC, MRP11 that encourage efficient and flexible process techniques to raise efficiency and flexibility are not available from all training institutions.

The PSDC should take the lead in the formation of a co-ordination body on external industry-specific training that would include representations from the various vocational and technical institutes in the country. The collaborative bilateral training institutes should involve the technical and engineering divisions of universities in Malaysia and foreign-Malaysian initiatives such as German-Malaysia Institute (GMI), the French-Malaysia Institute (FMI) and the Japanese Malaysia Institute (JMI). The co-ordination body would represent industry-oriented training concerns. The success of this body will be measured by its ability to check shortfalls in skills and know-how requirement in the manufacturing sector. In addition to electronic manufacturing firms, the network of suppliers, buyer firms and institutions must be represented to ensure effective industry co-ordination.

- Make prevailing state-level Government-Business committees in the above states dynamic. Let the State Development Corporations co-ordinate its activities.
- The management and specialisation of training involving all skills development centres should be determined by the Government-Business co-ordination committees
- Skills training in the training centres should also include new skills (including designing) enterprises in the states aim to utilise
- Gazette Human Resource Ministry's efforts to extend the HRDF to firms of size less than 50 but to all sizes to reach everyone. Firms with size less than 50 should be allowed to claim 200% of their approved training expenses. Contributions of SMIs must be processed quickly. An endowment of RM200 million should be advanced to support such SMI training subsidies.
- The HRDF must define approved expenses clearly so that all firms will be entitled to receive 100% of their contributions
- Quicken processing of tax exemptions offered to firms contributing machinery and endowments to the Skills Development Centres
- Concentrate of Skills Development Centres in Penang, Selangor, Negeri Sembilan, Kedah, Melaka, Pahang, Sarawak and Johore. The prime focus of centres in Penang, Selangor, Negeri Sembilan and Melaka should be on electronics skills training.
- Where necessary recommend state officials administrating the above issues to be seconded to PDC for six months to acquire the required management and co-ordination qualities
- The Human Resource Ministry, Ministry of Education, MIGHT, FMM and representatives of local and indigenous firms associations should form a body to co-ordinate the activities of skills development centres nationally

In addition, the government seriously needs to review its efforts to expand the supply of R&D Scientists and Technologists. While knowledge generation is not confined to any category of humans, scientists and technologists form a critical component for stimulating firm's participation in R&D activities. It was identified in chapters 1 and 4 that R&D staff is seriously lacking in the country. For firms to engage in rapid innovations necessary to switch to TM4 and TM5, the supply of R&D scientists and technologists must be expanded.

Efforts must be taken to step up the supply of R&D scientists in technologists, with electronics being a key component.

- Universities should be encouraged to expand the faculties and enrolment of students entering electronics engineering and physics disciplines.
- The current emphasis on raising enrolment of post-graduate students in universities should be complemented with a wider availability of scholarships to increase enrolment
- To attract greater emphasis on graduate studies in electronics engineering and physics, fees should be subsidised so that they are not more than that for business and arts studies
- Applications by firms to hire foreign R&D scientists and technologists should be considered favourably
- University staff should be encouraged to take sabbaticals in firms to undertake R&D work. Staff undergoing sabbaticals should be rewarded when their work yields innovations
- To reward innovators, salary schemes should be revised so that outstanding scientists and technologists in civil service or universities can earn higher than their directors. The salary scales for innovative achievements should be raised so that the relative prices between innovations and administration, is tilted towards the former.

3.6 Technology Transfer Unit

The Technology Transfer Unit (TTU), which came into existence within the arm of MIDA in 1975, has documented technology transfer agreements since. In Japan, MITI has played an aggressive and dynamic role to screen, monitor, and appraise *ex post* technology transfer in the country. Indeed, any management of technology transfer would require effective governance.

Malaysia's TTU under MITI/MIDA began screening investments from the late 1980s. However, it has not gone beyond *ex ante* screening to use instruments that filter firms strategically to complement technology development and clusterisation in the electronics industry. Second, storing of data is essential to ensure that firms accessing incentives are in fact transferring technologies. Firms not complying should be removed from incentive schemes. Where local obstacles external to the firms are the cause of such weaknesses, efforts must be taken to solve them. An ex post appraisal is necessary to improve the governance mechanism so that it eventually becomes efficient and effective. The private sector through the national co-ordination council should be a major participant in such appraisals. The TTU should also assist local licensees draw better bargains from foreign licensors. In addition to seeking the right foreign licensor, the TTU should also screen to select viable local licensees for matching.

Technology governance is an important means to assist firms catch up with the moving technological frontier. Despite initiatives to improve government-business co-ordination arguably only a few committees can be considered to have functioned effectively, i.e. the Penang Industrial Co-ordinating Council (PICC). A number of similar councils have suffered from a lack of dynamic participation from partners. As a consequence, such committees have not been effective in forging strong co-ordination. The outcomes have been a lack of supplier networks, R&D co-operation, the streaming of demand-driven training, technology development and market building.

To ameliorate such a problem, Malaysia's MITI must revitalise the technology transfer screening committee so as to emulate the dynamic features of its counterpart in Japan. The unit will not only have to vet ex ante, monitor closely the process and appraise ex post the agreements, it will also have to involve experts from the private sector and universities with industry, market and technical know how to enable rigorous assessments. As in Japan, there must be a genuine effort to cheapen and deepen transfer or relevant technologies to Malaysian firms. The continued emphasis on such a role will help refine its capacity to support technology governance. The incentives associated with such agreements should be conditional to specific milestones jointly agreed by the firms and the unit.

The Technology Transfer Unit (TTU) in MITI/MIDA, which began screening investments in 1990s, needs to include *ex ante* assessment instruments that filter firms strategic to complement technology development and clusterisation in the electronics industry. Second, storing is essential to ensure that firms accessing incentives are in fact transferring technologies. Firms not complying should be removed from incentive schemes. Where local obstacles external to the firms are the cause of such weaknesses, efforts must be taken to solve them. An ex post appraisal is necessary to improve the governance mechanism so that it eventually becomes efficient and effective. The private sector through the national co-ordination council should be a major participant in such appraisals. The TTU should also assist local licensees draw better bargains from foreign licensors. In addition to seeking the right foreign licensor, the TTU should also screen to select viable local licensees for matching. Transparency and accountability is also necessary to reduce the incidence of collusion.

Incentives to promote linkages, international procurement, location of IT firms in the Multimedia Super Corridor (MSC) and in less industrialised areas of East Peninsular Malaysia and East Malaysia have also been important. The linkages and procurement initiatives have not generated a significant expansion of value added chain in Malaysia.

The relative success of Penang in the country suggests that systemic weaknesses have hampered its growth in other locations.

The electronics industry in Malaysia has a number of support institutions, created to attract and assist their operations, i.e. incentives for stimulating high technology operations, technology transfer agreements to register and govern inflows of foreign technology and, technology and industrial parks to support industrial and high technology activities. While a number of these institutions, especially the FTZs offered considerable support, co-ordination failures have restricted their effectiveness. FTZs have in particular successfully attracted foreign electronics firms, but their operations have generated little spin-offs outside Penang. There is still a lot of room for deeper spin-offs in Penang.

Chapter 4 reported cases of human capital deepening in local divisions of MNCs fostering technology transfer, particularly via skilled personnel moving to local firms. Malaysia must identify techno-entrepreneurs who are currently working overseas and attract them back to contribute their expertise to local industries especially in R&D, new product development.

4. Stimulating Growth of Local and Indigenous Entrepreneurial firms

The report established the limitations of merely relying on MNCs, which given the nature of their operations will generally be confined to assembly and testing activities. Even the significant spin-offs achieved in Penang reflect substantial initiatives to co-ordinate start-ups and links with local firms. However, given the excessive reliance on MNCs, Penang's have not gone beyond TM3 operations. One clear building block required assisting the industry make the transition to TM4 and TM5 is to stimulate the growth of local and indigenous innovators and entrepreneurs. Three recommendations are advanced to achieve this:

4.1 Financing Prospective Innovators and Entrepreneurs

There is a clear need to install mechanisms that attract potential innovators and entrepreneurs among individuals and firms into the electronics value added chain. Talent untapped and ungroomed will be wasted opportunities.

For the electronics industrial structure in Malaysia to make the transition to the dynamic open system networks, there must be a critical mass of innovative and entrepreneurial firms. The compass and pillars offered by the MNCs should make it easier for indigenous and local firms to hook on to relatively more easily into the network than in normal circumstances. The existing mechanisms to strengthen industrial linkages should be complemented by instruments that offer capital and opportunities to all prospective innovators and entrepreneurs. The current framework helps existing entrepreneurs and innovators. It does not attract potential innovators and entrepreneurs as they generally lack collateral. To ameliorate this problem, the government should widen the reach of venture capital to attract all potential innovators and entrepreneurs. Its application should be complemented by promotional mechanisms that both offer information and confidence to attract strong participation. Given that trade organisations continue to spare SMIs from subsidy-deregulation, preferential loans to SMIs can be maintained even after 2003.

- Promote venture capital companies and expand its access to potential entrepreneurs and innovators
- Widen Credit Guarantee Corporation's (CGC) guarantee to include individuals (including students, employees in firms and institutions) and small firms
- Collateral should be replaced with innovative and entrepreneurial potential to underwrite risk
- To ensure that the CGCs net is cast to cover only potential entrepreneurs and innovators, it should also carry out validations to undertake rigorous screening
- The CGC must be required to monitor and appraise *ex post* the effectiveness of screening and performance of the scheme, using the review to improve future screening and support

4.2 Stringent Screening Mechanisms

As in Taiwan, the government must enforce good management practices, including the use of the General Accrual Based Accounting Procedures (GAAP) to manage disbursements and recovery involving older firms accessing subsidised loans. Performance measures such as rising exports or efficiencies will be necessary to prevent the dissipation of rents. Financial instruments must be made transparent and accessible to all indigenous and local firms. Firms seeking such loans should also be screened rigorously to minimise misallocation of scarce capital. All preferential loan recipient firms must be subjected to close monitoring and supervision, and a penalty or threat of inefficient firms being removed from the scheme to prevent the diversion of scarce resources into unproductive ventures. While close co-operation is needed between firms, subsidy allocations and the supervisors, there must also be legally separated from recipients to ensure independence and to prevent collusion.

- Subject all loan-subsidy recipients to stringent monitoring and appraisal *ex post*
- Impose penalty or remove recipients if performance is deemed unsatisfactory by the validation organisation
- Use appraisal results to improve screening and monitoring mechanisms
- CGC should undertake the reviewing and screening.

Chapter 6: Towards Dynamic Cluster Development

1. Introduction

The policy incentives and instruments reviewed in the previous chapter are necessary for building the overall science and technology infrastructure to support industrialisation. While many of these instruments are necessary, they do not support effective clusterisation, which is why not much cluster dynamics has evolved in Malaysian electronics, especially in the central region and Johor. Clusterisation requires a different set of instruments.

The focus of recommendations in this chapter is on injecting cluster dynamism into Malaysian electronics using the regional growth dynamics and technology management frameworks advanced in chapter 3. Their central purpose is to create the conditions for increasing continuous differentiation, specialisation and horizontal integration of technological capabilities. To achieve this, the mechanisms must address continuous supply of entrepreneurial firms and speciation capabilities to stimulate new products, firms and sub-industries.[112]

The pivot of system dynamics is the network synergies it generates, replenishing the needs of component firms and at the same time enabling renewal and reinvention in existing firms and assisting the creation of new firms. Competition and cooperation between the coordinating members is critical. Differentiation and the intensification of the division of labour expand synergies exponentially. Since each effective link generates synergies greater than the sum of firms, the greater the division of labour in the network, the greater the synergies. Because social ties are critical in institutionalising risks and building experiential knowledge, regional dynamics, which make contacts easier, become critical. Local networks have been critical in building relationships in the Silicon Valley.[113] The internet has facilitated the expansion of these regional networks to wider physical spaces.

The current critical impasse in the Malaysian Electronics industry necessitates some changes in government policies. The government through the IMP2 has recognised the importance of developing clusters within the industry to assist organisations to move up the value added technology capabilities spectrum. What the IMP2 clearly missed addressing is the significance of regional dynamics and systemic relations that require promotion if effective clusterisation is to evolve.

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[112] The speciation of new industries in the Silicon Valley saw the semiconductor sub-industry leading the transition to a sequence of new sub-industries - telecommunications, computers, software and internet.

[113] See Florida, Richard and Smith, Donald (1993), "Venture Capital Formation, Investment and Regional Industrialization, *Annals of the Association of American Geographers,* 83(3): 434-51.

As the Silicon Valley example shows, neither tax incentives nor price relationships form the basis of strong clusterisation. In a survey involving 464 venture capitalists over the period 1967-82, Timmons and Bygrave found that entrepreneurs are primarily interested in establishing relationships with reliable entrepreneurs, who could recruit managers with the contacts and strategies.[114] This approach calls for active management to promote clusterisation and innovations through the creation and co-ordination of support institutions and systemic relations between individuals, firms and institutions. The electronics industry in Malaysia has a number of support institutions created to attract and assist their operations, i.e. incentives for stimulating high technology operations, technology transfer agreements to register and govern inflows of foreign technology and, technology and industrial parks to support industrial and high technology activities.

Second, the critical barrier to achieving the goal of value-adding rapid growth for electronics is articulated. Third, we examine five high growth challenges facing Malaysian electronics and draw out policy implications and offer recommendations. We then examine the three Malaysian regional electronics clusters. Following this we present case studies of skill deficits, skill formation policies, and regulatory regimes. Finally, we outline some of the types of indicators required to measure the success of Malaysian policymaking in addressing the critical impasse.

This chapter examines the four challenges to achieving the goals of high value-added growth in Malaysian electronics. The challenges, in turn, focus attention on those areas in which policy can be most effective and suggest policy guidelines. We then draw policy implications for three Malaysian electronics clusters. In the appendices we present case studies which offer examples for many of the policy challenges. Appendix 8, Case Studies in Skill Formation includes examples of skill diffusion agencies; Appendix 9, Dynamic Regulation in East Asia provides case studies of regulation and technology policy associated with making the transition to product-led competition; and Appendix 10 suggests a range of indicators of technology management capability. We begin with a brief restatement of the concept of the productivity triad (exposed in chapter 3) and the critical impasse facing the industry.

2. The Capabilities and Innovation Perspective

The capabilities and innovation perspective advanced in chapter 3 offered an explanation of sustained high growth. The agents of rapid, technology-led growth are entrepreneurial firms, defined in terms of the technology capability and market opportunity dynamic.[115]

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[114] Timmons and Bygrave (1986) "Venture Capital's Role in Financing Innovation for Economic Growth", *Journal of Business of Venturing*, 1: 161-76.

[115] See chapter 3. The primary growth dynamic in all three scenarios is an entrepreneurial firm driven interactive process between advances in productive (usually technological)

The source of growth is an increase in production and organisational capabilities. Three conceptual frameworks linking capability development and diffusion to growth have been elaborated. The crystallisation of (1) regional growth dynamics, (2) models of innovation and (3) technology management models form the foundation of the new competition and hence the direction Malaysian electronics must pursue.

A major implication of the technology management framework is that rapid productivity-led growth does not come from marginal or piecemeal changes. It is the result of the development and institution of new processes often driven by new firms. In fact, it involves synchronised step-changes in technology management, business model, and skill formation. This is the concept of the *productivity triad*.

The public policy challenge and the opportunity are that skill formation dynamics must work in synch with technology management and business model advances and with the regional diffusion of new technologies. This requires step-changes in public investments. These processes underlie the 'knowledge-intensive' industries. Skill formation processes can be found in all successful industries.

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capability and market opportunity. The first scenario involves entrepreneurial firms that pursue a business strategy of vertical integration, a technology strategy of integral architecture, and an organizational structure of functional departmentalization. The result is a closed-system product architecture with design concentrated in within the R&D department of a single firm. The open-system product architecture with internally decentralized and externally diffused design fosters the regional growth dynamics that drive today's most successful electronics clusters.

3. The Critical Impasse

The Malaysian electronics industry has been a major driver of growth for nearly three decades. However, the very success of the industry has created new challenges, as have new developments elsewhere. In fact, the electronics industry is being redefined as a consequence of innovation and the emergence of whole new technology and product domains. What will it take for electronics to continue to be a source of rapid growth in Malaysia for the next decade and more? The first requirement is a definition of the problem. The capabilities and innovation perspective defines the problem as growth with limited innovation. This is not because Malaysia lacks clusters.

Malaysia has electronics clusters. Ironically, it lacks cluster dynamics. The three regional electronics clusters in Malaysia are all lead by multinational companies. To date, however, these firms (with a few exceptions) do not pursue the technology capability and market opportunity dynamic that defines the entrepreneurial firm *in their Malaysian operations*. They invest in plant and equipment and human resource development to run world class manufacturing platforms. This has generated extensive growth. But without entrepreneurial firm activities, the dynamic processes that drive regional growth dynamics are missing. The missing dynamics processes include techno-diversification, interfirm networking, industrial speciation, and regional innovation (see Figure 3.1).

The Malaysian electronics clusters are *externally integrated*. Operational units even within each of the three regional clusters are not networked. In most cases they are production units within a vertically integrated value chain coordinated in the home country of the multinational. Thus the Malaysian electronics clusters do not generate the productivity gains associated with specialization and integration. They are clusters that are highly cross-penetrated by vertical value chains *without overlap*.

Malaysia has world class electronics manufacturing capabilities *for a given product design*. It lacks the technology management capabilities to engage in the higher value-adding activities associated with new product design and development.

To achieve the goals of IMP2 the Malaysian electronics industry must make a transition from clusters to cluster dynamics and extend its world class production capabilities to new product development. Making these transitions will require a step change in the annual output of science and engineering graduates.

Electronics manufacturing is engineering intensive if a country seeks to engage in new product development. The reason is clear. New product development requires a whole range of engineering activities including:

product concept
- conceptual design
- product architecture
- technology search and analysis
- target market

product planning
- model building
- structural testing
- technology design viability testing
- technology R&D and integration
- investment/financial projections

product/process engineering
- detailed design of product
- tooling/equipment design and specification
- building/testing prototypes
- master technology and engineering interfaces
- setting standards
- supplier tie-ins

pilot project/scale-up
- initial production runs
- establish work skills and activities
- volume production tests

production
- factory start-up
- volume ramp-up
- establish performance standards (cost, quality, time)
- maintain standards
- master engineering and work team interfaces for continuous improvement

Electronics enterprises in Malaysia have specialised on production activities in which most of the engineering has been done outside the country. This has been sufficient to get growth in output, but the value adding activities are conducted elsewhere.

Rapid growth in electronics, which involves new product development and technological transitions, is associated with a step change in the output of technical skills. At present Malaysia suffers from a huge skills deficit. The magnitude is captured in Table 6.1.

Table 6.1 Scientists and Engineers/Population

Country	Year	Per 10,000 Population	% 24-yr-olds with NS&E degree
Japan	1993	43	6.4
United States	1991	38	5.4
Norway	1992	32	4.4
West Germany	1989	28	5.8
Taiwan	1993	26	6.4
Singapore	1992	23	7.6
Denmark	1991	23	6.5
France	1991	23	5.0
United Kingdom	1992	22	NA
South Korea	1993	22	7.6
Italy	1991	13	2.5
Mexico	1990	7	NA
China	1993	3	1.3
Malaysia	1994	2.3	0.8

The year refers to the column with the number of scientists and engineers engaged in R&D per 10,000 population. The United Kingdom figure is not included, as it was not comparable. The last column refers to the number of 24-year-olds with natural science and engineering degrees. The years vary.
Source: National Science Board, *Science and Engineering Indicators—1996* and *1998*. Washington DC: U.S. Government Printing Office, Washington DC 20402, p.3-25, 1996, Appendix Table 2.1, 1998: *1994 National Survey of Research and Development*, MASTIC, Table 3-19.

Taiwan, South Korea, and Singapore, for example, have more than 20 scientists/engineers per 10,000 population. Malaysia has 2.3. A similar tenfold skill gap with Taiwan, Singapore, and South Korea is also indicated by statistics on the number of 24-year-olds with natural science and engineering degrees is shown in the same table.

To achieve the goal to become an advanced industrialized nation by the year 2020, Malaysia will have to increase the proportion of scientists and engineers per 10,000 population by nearly 10 times.

4. The Cluster Dynamics Vision

The cluster-based approach of IMP2 is a good starting point. However, meeting the growth objectives calls for extending the vision to integrate cluster dynamics with skill formation or production capabilities with knowledge management. The IMP2 seeks a shift in electronics from a focus on manufacturing alone to manufacturing ++. The activities that make up the ++ are knowledge intensive. As we have seen, capability development and skill formation are part of the same growth process.

Figure 3.3 captures the mutual facilitating roles of cluster dynamics and skill formation. To increase the supply of scientific/engineering graduates is a facilitating process. It can fuel the driver. The driver will be entrepreneurial firms tapping into the world's pool of technologies in creative ways. If the cluster dynamics do not get underway, investment in scientific/engineering graduates alone will not drive the growth process.

The links between cluster dynamics and education suggest a shift in vision from one that emphasizes capital accumulation to one that targets skill formation. For this reason we recommend expanding the cluster-based vision to a cluster dynamics vision which integrates technology management and skill formation. Cluster dynamics can lead to regional growth dynamics through a range of dynamic processes (entrepreneurial firms, techno-diversification, networking, speciation) but sustaining the growth impulses depends upon complementary skill formation dynamics as shown in Figure 3.3.

The cluster dynamics vision focuses attention on five fundamental but inter-related challenges to its realization.

- Entrepreneurial firms
- Networking capabilities
- Technology management
- Technology transition
- Skill formation

The growth barrier can be defined in terms of any one of the five challenges: lack of entrepreneurial firms, of technical skills, of technology management capabilities, or of cluster dynamics. But movement on anyone will not be sufficient as each facilitates the other. The challenge is to generate a cluster growth dynamic that mutual adjusts one to the other in a high growth path. This is the impasse and the opportunity.

We turn next to the five challenge areas. Each of these challenges must be addressed if Malaysia's electronics industry is to make the transition to a globally competitive, knowledge based industry. But they must be addressed jointly. Regional policymakers are key players. They are best situated to develop strategies that integrate skill formation into regional growth dynamics.

5. High Growth Challenges

5.1 Create Entrepreneurial Firms

The entrepreneurial firm is the agent of industrial change. The technology capability and market opportunity dynamic of the entrepreneurial firms is the driver of high productivity growth. The first challenge of industrial policy is to institute processes of entrepreneurial firm creation. Why entrepreneurial firms? Because entrepreneurial firms are learning and teaching firms that contribute to technological advance and to skill formation. Equally important, the need is to seize market opportunities and to be able to do so a firm needs technological capabilities. Firms which lack technological capabilities also lack the capacity to anticipate emerging market opportunities.

As mentioned in Chapter 3, the entrepreneurial firm start-up system is particularly strong in the Silicon Valley and Route 128 high tech regions in the United States and in the design-led and the fashion industries of the 'third Italy'. Taiwan, Ireland, and Israel have all established variants if on a smaller scale. Most attention has been focused on financial markets as the enablers of entrepreneurial firm emergence and development. Venture capital and IPO capability are certainly contributors to the high new firm creation rates in both Silicon Valley and Route 128/495. As important as financial commitment is, the driving force must be the technological and market opportunities for establishing a firm with the profitability to make an attractive return to suppliers of finance.

A business strategy of focus and network (focus on a core capability and partner for complementary capabilities) can trigger complementary regional growth dynamics illustrated in chapter 3. The resulting open-systems business model is a business system that expands opportunities for yet more entrepreneurial firms. Collectively the open-systems business model sets higher performance standards in rapid new product development and disruptive innovation (as distinct from continuous improvement or incremental innovation). It is a driver of growth.

The industrial policy lesson is that vibrant regional growth dynamics provide an incomparable infrastructure for the creation of entrepreneurial firm. Once the inter-firm dynamics are underway, new firm creation is built into the process. Rapid growth and new firm creation feed on one another. Fast growing, technologically driven firms provide the managerial experience critical to its reproduction in yet new firms.

Lacking regional growth dynamics, the biggest policy challenge is to trigger the processes by fostering the first entrepreneurial firms. This is a big challenge indeed. A recipe does not exist but different new-firm-creation processes have been successful.[116] The challenge is to *examine the process* and identify bottlenecks for the purpose of identifying policy leverage points. Taiwan has created new entrepreneurial firms and new industries via state-led science parks that have fostered such firms. Singapore and Ireland triggered the process by attracting FDI with higher TM capabilities. Israel has used the public and private venture capital funds plus the in-migration of highly skilled personnel from abroad, particularly from the ex-Soviet Union countries.

FDI can quick start the process by introducing new principles of production and organization to a region. International firms may or may not be entrepreneurial firms. The challenge is to identify firms well advanced on the production capabilities spectrum with technology management and networking capabilities and then to develop institutional means of fostering diffusion of the new practices and triggering the regional growth dynamics.

In Malaysia, the example of Intel and UNICO (see Appendices 2 and 7) is a case study in the emergence of a rapidly growing, locally owned entrepreneurial firm which could provide clues into fostering the new firm creation process. Converting any of these pilot projects into methodologies for diffusion agencies is a crucial industrial policy role. Successful diffusion requires partnering of industry, government and educational institutions.

5.2 Foster Networking Capabilities

As mentioned in Chapter 3, open-systems networking is a model of industrial organization that fosters specialization and innovation. Historically, open-systems prevailed in the design-led industrial districts of the Third Italy. More recently, the emergence of systems integration capabilities in technology has both fostered open-system networks and developed because of them. In both cases the business model of specialization and inter-firm networking form an internal/external dynamic that fosters innovation and growth.

As networking capabilities of a region become more robust, the more the region takes on the semblance of a collective entrepreneur. The virtual collective entrepreneurial firm is a self-organizing change agent composed of networked groups of mutually adjusting enterprises.[117] The collective entrepreneurial firm is a composite of networking firms that collectively administer the regional growth dynamic processes.

[116] See Gerschenkron (1962), *Backwardness in Historical Perspective*, Cambridge: Harvard University Press.
[117] See Best 1990, pps. 207-8.

Malaysia as a whole has considerable potential, enhanced by the internet, to develop a competitive advantage in flexible mass production in which one-piece flow is integrated with specialist design capability. This is the promise of real one-piece flow in which each piece is independently designed. Manufacturing to order, as presently practised by Dell in Penang, is a first step in this direction.

Dell has extended the principle of flow to the supply system via the internet. The internet drives down the supply chain cycle time to levels previously achieved only by closed networks with unchanging design specifications. This strength of the 'old' just-in-time and captive supplier network, however, did not involve design information. The open-systems protocol of the internet enables seamless integration of design information across virtually all computer systems and resource planning systems.[118] This is a second step in the use of the networking capability of the internet to enhance competitiveness.

The third step is the use of advanced information technologies such as CAD/CAM/CAE for collaborative product development processing. But for such product design tools to be effective, the various departments of the enterprise must be internally networked and aligned or process integrated. Otherwise, information technology gives rise to isolated islands of computerisation in which information is proprietary and communication is limited.[119]

Network capabilities also foster innovation. In chapter 3 we examine the role of techno-diversification in both new product development and industrial speciation, or the creation of new industrial sub-sectors. The protean character of technological capability, particularly evident in high tech sectors, is a feature of industrial change even in the oldest sectors. The electronics industry morphs into, for example, an information and communications sector. Furniture becomes interior design and furnishing. The process of industrial speciation can not be done within a single firm. In fact, the very success of a firm's pursuit of one technology trajectory can create obstacles to technological transition.[120] Hence the role of networks by which new entrants can focus on a technological capability and partner for the complementary capabilities. Regions with open-systems networks have low barriers to entry for new, specialist firms. This process drives down the time for technological change and the process of new sub-sector formation.

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[118] See 'Adaptec: Getting the slack out of cycle time', *Fortune*, Nov 8, 1999 for an example of a 'value network' involving internet facilitated partnering across multiple countries.

[119] Nanyang Polytechnic's Computer Integrated Manufacturing Centre offers a range of manpower development and information technology partnering arranges to Singaporean companies. Its website is www.technocim.edu.sg. This centre was established as part of Singapore Economic Development Board's Report of the Committee on Singapore's Competitiveness (CSC). The vision, short-term recommendations, and long term strategies are summarized at www.sedb.com.sg/vision/vi_cs.html.

[120] Christiansen, Utterback, etc.

As an easy plug-in system for specialist companies, the internet lubricates the internal/external dynamics that spawn entrepreneurial firms. But it can also be seen as a metaphor for networking in general and thereby a target for policymakers seeking to increase entrepreneurial firms.

5.3 Upgrade Technology Management Capabilities

Technology management capability is defined in terms of principles of production and organization. A history of changes in industrial leadership can be explained in terms of transitions to new models of technology management (a sequence of 'new competitions'). Regions with a critical mass of firms that pioneered the emergence of new model enjoy jumps in productivity and growth.

The history of the evolution of models of technology management is also a high growth roadmap for technological followers. The roadmap is of a terrain that alternates between hills representing the transition to new principles of production and organization associated with higher levels of technology management and plateaus where the new principles and capabilities are diffused across firms and industries. The speed of the vehicle, representing the rate of growth, inevitably slows for the transitions but, if the hills are climbed and the new principles are established, the vehicle can again enjoy a long spell of steady speed (industrial growth) before a new hill is eventually encountered.

At each point along the way growth for the technology followers occurs for as long as the ratio between wages and production capabilities is low compared to other countries. But the process of growth will advance wages until following nations make the transition to a new level of production capabilities and, enjoying a lower ratio between wages and production capabilities, undersell the market leaders. [121] Having achieved a new, higher

[121] Nakame Akumatsu, a Japanese proponent of a unique theory of industrial development, described a process common to development literature but added an interesting twist. Countries would move from imports to import substitution to exports as they learned from foreign technologies. He described the process in terms of three waves of flying geese for each product. Imports would be represented by the first gaggle of geese in flying formation: increase, peak and fall off; production the second gaggle: increase peak and decline; and exports the third gaggle again representing an inverted V pattern. He described these patterns are occurring first in 'crude' products and later in 'refined' products; in final goods and later capital goods. Where a country is at a point in time is determined by the balance of forces between the level of development and wage rates. Higher development led to higher wages and a loss in exports of easier to produce goods. The idea of a production capabilities spectrum combines the principles of production and organization described above with Akumatsu's notion of sectoral transitions. The production capabilities spectrum in suggests a criteria for locating a

level of production capabilities a region or country enjoys growth as the new practices and technologies are diffused to old and new products by old and new firms. However, in the process, wages rise and opportunities for further diffusion diminish and growth becomes threatened as imitating regions and nations develop the requisite production capabilities to move into the same markets but with lower wages.

To sustain growth, enterprises in such regions must make the transition to the next higher level of production capabilities. Once and if a critical mass make the transition, a new range of opportunities open up as the region or nation becomes competitive in more technically and organizationally advanced activities and products. Growth reasserts itself as the opportunities are taken up until, once again, the wage rate to the respective production capabilities ratio rises above that of competitors. If a region or country successfully makes the transitions along the production capabilities spectrum then growth rates will be high and sustained.[122]

The East Asian economies that have achieved high rates of growth have a critical mass of industrial enterprises with the capability to adopt, adapt, and diffuse technologies that originated in the most technologically advanced nations. Japan, South Korea, and Taiwan-China have developed the capability to develop new products and processes based on refining, fusing and advancing generic technologies. Together these are attributes of a national system of production and technology management.[123] Sustained high-growth rates depend upon making the transition along the technology management spectrum summarized in Table 3.2.

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country in the international production order and for identifying the challenges at any point in time.

[122] The dynamic process described starts with production capabilities moves to higher rates of investment, greater learning by doing, greater competitiveness and sustained high growth. Savings follows from high profits. In this story, high growth generates savings; the conventional view attributes high growth to high savings but does not satisfactorily explain the sudden surges in savings. The production capabilities perspective starts with the firm and thereby focuses explanation on organizational capabilities and competitiveness; the conventional view begins with the consumption and savings choice of individuals as the determinant of growth. Empirical evidence supports the production-oriented perspective (Singh, 1996).

[123] Slow growth followers, on the other hand, lack the capabilities to tap the world's pool of technologies. This is not surprising. Successful technology management itself requires the development of three distinct but interrelated capabilities: strategic, organizational, and production. Successful technology management, like the establishment of price for Alfred Marshall, depends upon both blades of a pair of scissors; supply must be matched by effective demand. While demand in price theory is mediated by income, demand in technology management is mediated by production capabilities.

Making such transitions is not easy. The rapid pace of introduction of technologies in the success stories is a consequence of the prior or simultaneous development of a specific set of production capabilities.

The transition to the open-systems business model and associated entrepreneurial firm start up system in 1990s United States was engendered by market pressure from the superior performance of the kaisha-led TM 4 production system. Firms were forced to restructure and downsize which, in turn, created opportunities to grow new enterprises organized according to the new principles of production and organization. At the same time the transition to self-directed work teams increased the integrative skills of the workforce which expanded the share of workers with managerial skills. Here downsizing pressures and multi-skilled, problem solving workers combined to foster the emergence and growth of small firms. Public policy contributed to this cause as across the country states pursued polices that made it easier to start and grow new business enterprises.[124]

Articulating a technology management strategy is central to economic policy making for a developmental state. The range of industrial policy instruments applied by Japan, Taiwan and Korea to foster sectoral transitions offer a range of possibilities.[125] However, distinctive technology management strategies in each of the high growth East Asian countries can be identified. In fact, the idea of national technology management is to the theory of the developmental state what demand management was to Keynesian economics or money supply management is to monetarism.

The mechanisms necessary for building dynamic networks that pushes continuously differentiation, specialisation, horizontal integration and reintegration with constant evolution of entrepreneurs, products, firms and sub-industries call for strengthening links between firms and institutions within regional locations. Policy framework should act as the enabler and stimulator of clusterisation.

Given the success of PDC, developmental institutions such as the State Economic Development Corporation (SEDC) should be the cornerstone of promoting systemic links within individual regional clusters. Where the cluster overlaps with the jurisdiction of two or more SEDCs as with the Kelang Valley, Negeri Sembilan and Melaka, Melaka, Negeri Sembilan and Northern Johor or Penang, Southern Kedah and Northern Perak, these institutions can coordinate to avoid duplication and synchronise their activities.

In addition to interaction between them, these organisations should actively gather information of electronics and supplier firms located in their respective regions, stimulate cooperation and matching through coordination councils. The PDC actively promoted inter-firm networks, though the spread has been confined to its reach. The PDC itself

[124] The MIT example is a case study of techno-entrepreneur creation in emerging technologies. Such unintentional industrial policy helped Massachusetts considerably.
[125] See Johnson (1982), Best 1990 (chapters 5-6), Magaziner. Range of modernization programs described in Best (1995).

could be encouraged to have more staff to spread its reach across its regional cluster, sharing some overlapping responsibilities with the Perak and Kedah SEDCs.

The SEDCs should also initiate through intermediary roles, the formation of specialised organisations or enterprises to resolve collective action problems. R&D, training and marketing often require separate organisations that require pooling of resources. The coordination councils – comprising all key agents of dynamic clusters - should collectively influence the location, depth and governance of the enterprises/organisations required to solve collective action problems. The PSDC and the Penang Design Centre emerged from such collaborative coordination between the PDC and the firms. However, these institutions cannot on their own generate the increasing and changing configuration of human capital required to assist clusters transform dynamically. It is pointless putting up the technology machinery in the firms and institutions if the human capital is not there to drive them. Human capital is the key Public investments in generating R&D technologists and engineering personnel is critical. The basic education of these segments of personnel must come from universities – both general broad-based and technical – examples include the *fachschulen* in Germany and the Indian Institute of Technology in India. Hence, the recommendations below will address human capital development within a techno-dynamic framework.

As the personification of inter-firm relations, at all levels, from forward-backward production relations to indirect relations with other firms and institutions, is important. The SEDCs can stimulate that through the coordination councils as well as supplying details of all of them through the internet.

For cluster diversity, the SEDCs should also identify missing links in the value added chain, as well as institutional support organisations, so that they could be attracted from abroad or promoted domestically for operations. The move to start wafer fabrication in Kulim and Sarawak in light of the trend towards fabless manufacturing by microchip firms is good as it could plug one missing segment in the semiconductor value added chain. However, from the one in Kulim and one in Sarawak, a critical mass of firms may be necessary to attract suppliers and institutional support. Foreign firms, including United Microelectronics from Taiwan could be approached to relocate in these clusters. The movement of lead contract wafer fabricators will also ensure that the demand-supply patterns can be reproduced in the clusters Malaysia.

As firms evolve and individuals in the system evolve, they often require new challenges to apply their ideas and experience. For the effective utilisation of these human resources, the SEDCs should also stimulate open networks and counselling outlets to direct them to productive destinations. The continuous movement of entrepreneurs developed from firms and the systems will not only create the room for the continuous maturation of personnel as new ones come in, but also offer the capabilities for the speciation of new firms. The proliferation and escalated movement of these human capital production factories – the 'invisible colleges' – will also offer the opportunities for increasing differentiation, specialisation, horizontal integration and reintegration and evolution of new products and sub-industries. Intel in Penang has been able to generate a continuous stream of entrepreneurs who have gone on to start new firms, *inter alia*, because of the close rapport and coordination of their initiatives with the business network which has been actively been promoted by PDC. As Timmons and Bygrave (1986)[126] noted in the Silicon Valley, identifying and establishing contacts with entrepreneurs rather than access to capital, which is the most important factor in the successful allocation of venture capital.

While entrepreneurs are central for cluster dynamism, the technical requirements of the electronics industry necessitate that a large pool of personnel need to be amassed to make it work. Malaysia currently seriously lacks an adequate supply of engineers, technicians and R&D scientists and technologists. Singapore, South Korea, and Taiwan had over 2000 R&D scientists and technologists per 10,000 people, Malaysian only less than 300 (see Table 6.1). Without a critical mass of human capital, the transition to TM4 and TM5 cannot be made. To inject dynamism into Malaysian electronics, the government must expand further its intake of engineers and scientists, especially with a background in engineering, physics and mathematics. The Education Ministry in the country did go a long way to ameliorate this problem. Inter alia, it tabled the Private Universities Bill in 1995 in Parliament that has opened the way for the introduction of private universities, and has expanded student intake in Malaysian universities. However, it must ensure that staff enrolment does not lag behind student expansion, as high student-staff ratios will affect creative teaching. To these developments, the government must also stimulate closer cooperation with electronics firms in the country so that industry-university links are strengthened.

It was also noted in chapters 4 and 5 that industry-university partnerships are still too thin in Malaysia, which in the Silicon Valley, Route 128, Japan and Taiwan, have become strong.

5.4 Anticipate Technological Transitions

A recommendation is to anticipate technology transition for the electronics industry. The Action Plan for Industrial Technology Development (APITD) of 1990 came up with the selection of strategic industries. Government sponsored R&D played a critical role in the development of virtually every major new technology the lie behind the knowledge intensive industries. Government funding has also been critical in the application of systems integration in the range of industries associated with information and communications technologies.

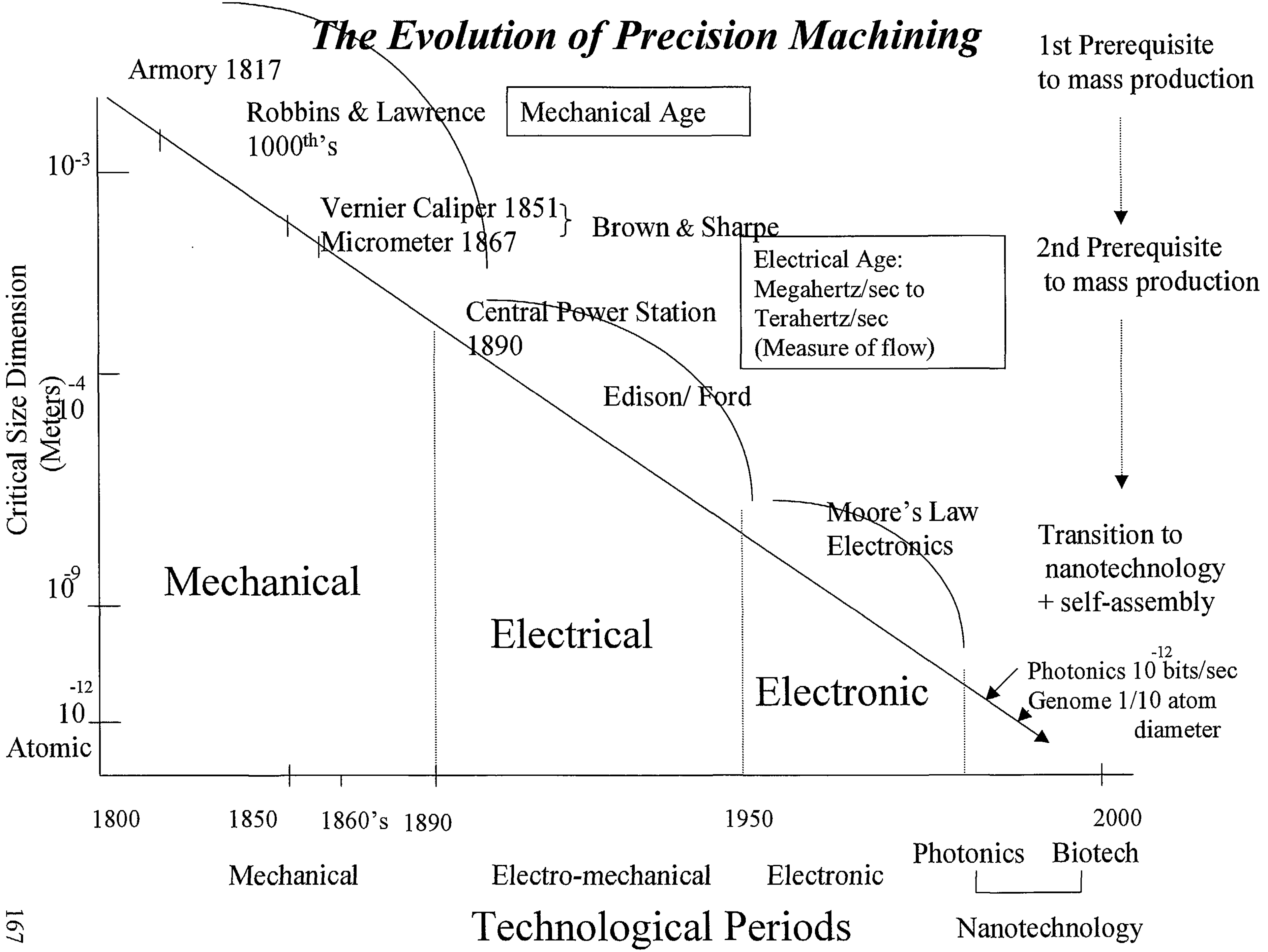
[126] Timmon and Bygrave, *op cit*.

Industrial policy has also been used to establish technology roadmaps to coordinate and mobilize investment decisions in key industries. Understanding technological trajectories has been an important input in making these policies successful.

While new technologies are highly uncertain, technological trajectories have a logical progression. Figure 6.1 is an example to illustrate both the change and continuity dimensions of technological change.

Figure 6.1 The Evolution of Precision Machining

(See next page)


The Evolution of Precision Machining
Armory 1817
Robbins & Lawrence
1000th's
Mechanical Age
1st Prerequisite
to mass production
Vernier Caliper 1851
Micrometer 1867
Brown & Sharpe
Electrical Age:
Megahertz/sec to
Terahertz/sec
(Measure of flow)
2nd Prerequisite
to mass production
Central Power Station
1890
Edison/ Ford
Moore's Law
Electronics
Transition to
nanotechnology
+ self-assembly
Critical Size Dimension
(Meters)
10^{-3}
10^{-4}
10^{-9}
10^{-12}
Atomic
Mechanical
Electrical
Electronic
Photonics 10^{-12} bits/sec
Genome 1/10 atom
diameter
1800
1850
1860's
1890
1950
2000
Photonics
Biotech
Mechanical
Electro-mechanical
Electronic
Technological Periods
Nanotechnology

This figure shows major transitions ushered in by the introduction and integration of new technological domains into production systems. One feature is constant: a sustained reduction in critical size dimensions cuts across technology transitions. As technologists and scientists drive down the size dimensions of critical devices new opportunities for technological change, new product development, new firm and new industry creation emerge.

The enduring evolution of precision machining toward ever smaller critical size dimensions illustrates a technology trajectory that will continue. As such it can be a powerful industrial policy lever even in the most technologically advanced companies and regions.

Moore's law is an application of the principle of decreasing device size in the age of micro-electronics. But Moore's 'law' is as much an industrial policy and business strategy as it is a scientific law. Intel, with the help of Sematech, played a role in turning Moore's Law into industrial reality. The predictability of the principle was used to great effect in governmental policies in the United States to resurrect the semiconductor industry.

Sematech was formed in 1987 to improve chip-manufacturing capability in US. Gordon Moore (p 172-3) describes its purpose:

> ...its founders organised a series of industry wide workshops to identify the technological advances required for U.S. semiconductor and supplier industries to catch up with Japanese industries. The outcome, in March 1988, was a timeline and the specifications for a sequence of technological generations that would lead to parity by 1994—a "road map for semiconductor technology". The timeline specifications required the demonstration of a 0.8 micron technology in SEMATECH's new wafer facility in 1989, with further advances to 0.5 micron technology in 1990, 0.35 micron technology in 1992, and 0.25 micron technology in 1994. (Moore p. 173)

The Semiconductor Industry Association, founded in the 1970s, coordinated the activities of the Semiconductor Research Consortium (established to organize and focus university research, see page 170) and SEMATECH. These agencies "...provided a road map for 15 years, pointing out key technology needs and the times at which those technologies would be required to keep the semiconductor industry on the historic productivity curve of a 30 percent reduction in cost per function per year" (Moore, p. 173).

The predictability of technological change can be used to great effect by partnerships between entrepreneurial firms and governmental research programs. It illustrates as well, the potential role networked groups of firms can play as collective entrepreneurs in shaping technological and industrial change. This example is played out everyday in every industry.

Industrial policy has considerable potential to shape the technological trajectory of a region's enterprises by coordinating research activities. It is critical, however, that Malaysia invests in science and technology human resources in order to advance national capabilities in anticipating technological trajectories.

5.5 Institute and Upgrade Skill Formation Processes

The second core recommendation involves the need to expand and deepen the supply of skills and technical professionals. Exploring the links between technology development and growth focuses attention on the most important contribution that policymakers can make to rapid growth: human capital development planning for skill formation. Making the transition to more advanced models of technology management or into more precise technology domains will be blocked without the requisite skill base. Thus each transition involves newly instituted processes in three mutually interactive domains: principle of production, business model, and skill formation/technical labor pool and methodology. In this, each model represents a new *productivity triad.*

The idea of the productivity triad is that the application of new principles of production (and technologies) involves investment in counterpart engineering methodologies. For example, application of the principle of interchangeability involves product engineering just as applying the principle of flow means knowledge of process engineering. Leaders in the development of the new principles are also leaders in the development and diffusion of methods for educating the counterpart skills. Innovation does not depend upon a large skill base, but innovation-induced industrial growth does.

The rapid growth in technical skill levels that has accompanied the high growth rates in the East Asian 'miracles' are shown in Table 3.3. Singapore, South Korea, and Taiwan all followed Japan in investing heavily in engineering, natural science, math and computer science education to make technology-driven growth happen.

The numbers speak for themselves. The output of engineers in Singapore increased *7 times* between 1975 and 1995.[127] The graduates of scientists/engineers in South Korea

[127] The success of Singapore suggests that the cause of Malaysia's skill gap is not due to heavy reliance on MNCs. Singapore, which has pursued a similar strategy attracting MNCs has, at the same time, developed indigenous production and technology management capabilities. Singapore, like Taiwan and South Korea, has major education programs to continuously upgrade their skill base. Unlike Singapore, Malaysia has yet to turn heavy reliance on technology imports into indigenous production capabilities. The critical factor is the development of a local skill base that can serve as a medium for absorbing and diffusing technology and technology management capabilities in local firms.

increased by nearly *5 times* over the same period. The Republic of Ireland,[128] the fastest growing region of Europe in the 1990s, is the same story.[129] Its output of scientists and engineers increased over *7 times* in the same two decades. These numbers all testify to the industry and education dynamics captured in Figure 3.3. In all cases, without the investments in skill formation, growth would have been choked. Instead, a virtuous cycle emerged that funded the advances in education by rapidly growing national income.

A region that can institute skill formation processes in anticipation of technology transitions has a competitive advantage against regions that lack such capability. Furthermore, realization of investment in R&D often depends upon mid-level skill formation. Otherwise, the growth potential of research investment will be lost. Often times, the critical factor is mid-level skills. This has been the case in the transition from electronic, circuit switched networks to ones based on optical, packet switched technology. In the words of a Lucent executive:

Success in the Optical Networking marketplace is dependent upon rapid introduction of new technology. Reduction of the interval from research through commercial product is an imperative. If our workforce is not equipped with the necessary skill level to manufacture advanced products, production capability will not adequately support the volume levels needed to meet customer demand. If this occurs, profitable gain from our research investment will be lost.

In the case of optical networking equipment, it is estimated that a single graduate engineer can support 5 to 6 associate engineers. Combined with a *kaizen* or HPWS capability in operations, these combined skills can compress the times for new product introduction and production processes.

Regions that fail to integrate skill formation and technology change will risk undermining the skill base required to sustain production of once successful industries. Investment in middle level skills is important for income distribution purposes, as well. The link between income distribution and technological change has been examined for decades. The research represents a "venerable and fruitful tradition extending back to Paul Douglas (1926) and Jan Tinbergen (1975) of viewing the evolution of the wage structure...as depending on a race between technological developments and educational advance" (Katz, 1999, p. 1). When technological change is low-skill labor saving it means that the only way that technology-driven growth in productivity can be shared is through advances in education at the lower levels.

Each of these challenges requires policy responses. While the challenges are imposing at the same time they also impress upon us the significance of past accomplishments. They are certainly no more imposing than the challenges that policymakers successful

[128] Government led the growth with large investments in regional technology colleges.
[129] See Figure 5.4 for a similar explosion in output of engineers accompanying the Massachusetts 'Miracle'.

addressed in the process of initiating the electronics industry in the early 1970s. We turn next to recommendations targeted at each of the three regional electronics clusters in Malaysia.

6. Towards Three Dynamic Clusters

This section presents recommendations for the three clusters identified in chapter 4 to have the potential for strategic development. A subsequent study is recommended for jump starting an additional cluster in Sarawak, which could not be undertaken here due to its absence in the original report and the short time given to the current team. Penang should be the initial apex of the Northern region, though the stimulation of horizontal integration should disperse the cluster horizontally. The techno-dynamic dispersal required in cluster dynamics differs fundamentally from the vertical division of labour envisaged in the growth triangles recommended by the government. The former makes every firm in the chain world class innovators and equally powerful in the value chain, while the apex enjoys greater power and higher value added activities in the latter.

6.1 Northern Cluster: Penang-Kedah-Perak-Perlis[130]

Penang forms the nucleus of Northern Malaysia's electronics industry. It hosts the biggest mass of firms with fairly good inter-firm links. It has undergone structural transformation with the sequence of industries moving from semiconductors to telecommunication components and products and consumer electronics to computers and computer peripherals, and internet support firms such as Xircom. What it lacks is broad based inter-firm links and horizontal integration and reintegration, and speciation capabilities. Penang also enjoys the superlative roles of PDC, PSDC and the Penang Design Centre, and several sub-electronics business groups, which represent machine tool firms, plastic firms and electronics firms. Universiti Sains Malaysia is the only university located here.

The Kulim area in Southern Kedah initially evolved as an offshoot supporting Penang and later as a base attracting labour-intensive firms that moved out of Penang due to rising wage and infrastructure costs. It was subsequently earmarked by the federal government for high-tech development, and hence a high-tech park was created. Several Penang MNCs have begun design centres there and one of Malaysia's wafer fabrication plants, Silterra is currently being built there. The Kulim region could form a potentially important link to service Penang firms. Universiti Utara Malaysia is located in Kedah, though in the Northern town of Jitra. Kedah's SEDC is located in Alor Star. With effective development, the Northern cluster could encapsulate the whole of Penang, Kedah, Perlis and Perak.

[130] See chapter 4 for an expanded case study of Penang.

Perak currently houses a range of electronics firms from contract assembly and test of semiconductors (Carsem and Unisem) and telephone receivers to computer monitor assembly (Acer). This region does not have many firms and is still relatively new, but with tremendous potential as large areas of industrial land have already been developed along the Ipoh-Lumut highway for electronics operations. The North-South Highway makes transport relatively easy. The Perak SEDC is located in Ipoh. Universiti Petronas Malaysia is also located along the Ipoh-Lumut highway. With further development, the Northern cluster could stretch into Southern Perak. Southern Perak could be engulfed in both the Northern cluster and the central cluster – overlapping to service both clusters.

For the Northern cluster to achieve a dynamic transition to broad-based TM3, and towards TM4 and TM5, the following problems must be resolved:-

Recommendations

- First, the entire valued added chain in Penang still lacks product innovation capabilities. To make the transition to effective clusterisation all firms in the value added chain must operate at the technology frontier innovating new products. Given MNCs focus on keeping much of their key R&D activities in developed sites housing their parent plants, the focus must be on developing local innovation capabilities.
- Second, the growing deficit of vocational, technical and engineering personnel has restricted the growth of firms. The key human power segment requiring a drastic rise in supply is engineering and R&D personnel. The Northern region also requires more technical and vocational staff. Government policy must step up the supply of human capital matching the demands required in the technology roadmaps.
- Third, there must be greater industry-university linkages so that more basic and contract research involving electronics and complementary activities can be undertaken in the Northern region. Universiti Sains Malaysia and Universiti Utara Malaysia must figure more in these relationships
- Fourth, the PSDC's reach must be expanded to the entire Northern cluster, particularly through the creation of subsidiary organisations in Kedah, Perak and Perlis. This way a network of organisations can service collective action problems involving training across the Northern cluster to enable high precision.
- Fifth, the Penang Design Centre's reach should be expanded to cover the whole Northern cluster to enable high precision designing capabilities among supplier firms.
- Sixth, the SEDCs of Penang, Kedah, Perak and Perlis should coordinate more and use cooperation as a vehicle for promoting clusterisation in the Northern region. The PDC should be the role model to use here. The deliberation councils should follow the PICC model used in Penang where active relationships have injected dynamism into planning and matching potential and prevailing production capabilities with demand.
- Seventh, all the state SEDCs should collect data on human resource and firms in their locations. This role should be expanded to the publication of these data, including the

productive capabilities of firms in their states. Matching and promotion of inter-firm links start with the dissemination of such vital statistics. As with the PDC, the SEDCs in the Northern cluster should play an active intermediary role to promote business networks, inter-firm a firm-institution links.

- Eighth, private venture capital's role should be expanded with a review of its management. The Northern region still lacks mechanisms to promote inter-firm links. Reliability and trust is often important in establishing strong inter-firm links. Penang's open system with strong networking relationships can be expanded across the Northern region. Penang has used its social capital far better than the other locations in Malaysia and that is part of the reason why it has managed to spawn substantially more local firms than elsewhere in the country. However, these numbers need to be expanded even more if the region is to emulate the success achieved by Taiwan and the Silicon Valley. The internet could be a good vehicle to stimulate this further. Effective inter-firm links across the whole Northern cluster could offer the social capital to stimulate speciation as managers gain confidence to leave old firms to spin off new firms and sub-industries. Dr Looi's innovation of the virus buster and his subsequent establishment of his own web-based firm in Penang is an example.
- The value added chain in the Northern region still requires other sub-industries to bring integrated manufacturing operations. The government should promote the relocation of MNC wafer fabricators alongside local firms in Kulim to establish a critical mass of firms for effective clusterisation. The government should also stimulate the speciation of local firms into cutting edge electronics machinery firms to support existing and higher value added operations in the Northern cluster.

6.2 Central Region: Federal Territory-Selangor-Negeri Sembilan-Melaka-Perak

The Kelang Valley forms the nucleus of the central region's electronics industry. It hosts the second biggest mass of firms in the country. Its sub-industries include semiconductors, telecommunication components and products, consumer electronics and auto-electronics firms. However, it seriously lacks inter-firm links and horizontal integration and reintegration, and speciation capabilities. The central region has the promotional and governance ministries of Human Resource Ministry, MITI and Ministry of Science, Technology and Environment. The Kelang Valley also has the SEDC of Selangor, several vocational and technical schools and colleges, business groups, including the FMM's headquarters, the high tech park of Bukit Jalil and the Multimedia Supercorridor (MSC). It also has several universities, Universiti Malaya, Universiti Kebangsaan Malaysia, Universiti Putra Malaysia, Universiti Islam Antarabangsa, UNITEN and UNITEL.

Negeri Sembilan and Melaka initially evolved as an offshoot supporting Kelang Valley and later as a base attracting labour-intensive firms that moved out of the Kelang Valley due to rising wage and infrastructure costs. Although most firms function as supplier firms, these states also have semiconductor and consumer electronics firms. Negeri

Sembilan and Melaka form an important link servicing Kelang Valley firms. Negeri Sembilan and Melaka are serviced very well by the North-South Highway and are close to the Sepang International Airport. These states are also serviced by the SEDCs of Negeri Sembilan and Melaka. The states also overlap within the Southern cluster.

Recommendations

As shown in chapter 4, electronics firms in the central region are faced with even more problems than Penang firms to make the transition to effective clusterisation. To make the shift to TM3, TM4 and TM5, the following recommendations are advanced here:

- First, the severe engineering and technical human power deficit generated in the central region can only be ameliorated through an expansion in the production of engineering, physics and mathematics graduates from Malaysia universities. The additional two universities, the increase in student enrolment across the country and the upgrading of the private colleges could solve this problem, but projections are necessary to avoid shortfalls.
- Second, the central region, especially the Kelang Valley is crowded with firms, institutions and universities, but little links exist between them. Serious efforts must be taken to build effective links between firms, firms and institutions and universities.
- Third, the Kelang Valley region suffers from greater value added leakage than Penang, which can only be resolved by stronger domestic sourcing. With greater speciation, the potential for continuous differentiation can be enhanced. There is a clear need to stimulate technological upgrading in local firms, without which horizontal integration cannot be achieved. The technology roadmaps noted earlier can go a long way to achieve this.
- Fourth, institutional coordination in the region need improvement to offer managers maturing in established firms – both MNCs and local - and new ones emerging from the environment to easily extract opportunities from the system to start new firms. These entrepreneurial synergies must find a conduit for realisation. It will not only help expand the supply of entrepreneurial firms, but also assist incumbent firms to continuously develop their personnel. Otherwise potentially capable entrepreneurs will remain in incumbent firms thereby losing the potential for expanding the cluster.
- Fifth, the SEDCs in the region must play a more active intermediary role to strengthen inter-firm links through proactive deliberation councils and resolving collective action problems through supporting public investment in training and R&D. These SEDCs should use the PDC and PICC as role models to achieve this in the region. The expansion of the division of labour would strengthen cluster development.
- Sixth, the SSDC in the Kelang Valley participation could be enhanced considerably to resolve training deficits in the region if the intermediary role of the PDC and the PICC is copied. Subsidiary training organisations are required in Negeri Sembilan and Melaka.

- Seventh, local and indigenous suppliers in the region must be assisted to become more independent and horizontally integrated to prevent cut-throat competition and over-exploitation by MNCs and other anchor companies. The VDP and SEP should go beyond their current roles to assist these suppliers upgrade their technologies and to diversify their markets.
- Ninth, the government should encourage through contacts and proactive deliberation councils, university-industry and industry-institution R&D in the region. Contract research, sabbaticals by scientists in firms should be promoted through these councils. Also, the IRPA could be better harnessed if representatives from firms are included in the review committees. The government should also promote designing centres in the central region which can specialise on product and process development research.
- Tenth, Martrade should assist more in supporting local and indigenous firms' efforts to undertake market research.
- Eleventh, the deliberation council, modelled around the PICC should stretch to cover the whole central cluster, and it should seriously promote networking, which is seriously lacking in the region.

6.3 Southern Region- Johor-Melaka-Negeri Sembilan

Singapore currently forms the nucleus of the Southern electronics cluster. Despite being a supplier base, Johor hosts the third biggest mass of firms in Malaysia. Its range of electronics industries include PCB assemblies, audio video and computer peripherals. Located in the region is the JSEDC, Johor's Skills Development Centre, and north of it is the SEDCs of Melaka and Negeri Sembilan. The latter two states function as support base for both the central and Southern clusters. All three states are serviced by the North-South Highway. The Technology University is located in Scudai, Johor. Considerable efforts are needed to push Johor and the Southern region as a dynamic cluster horizontally linked to Singapore rather than its current position at the foot of the division of labour with the latter at the top.

As noted earlier, Negeri Sembilan and Melaka also house a number of electronics firms. These two states can overlap in the central and southern clusters. Unlike the growth triangle concept, firms in Melaka and Negeri Sembilan should be developed to participate horizontally rather than vertically in the division of labour with Johor and Singapore.

Recommendations

The Southern cluster is the least developed of the three. The following recommendations are pertinent to push firms to make the transition to TM3, TM4 and TM5.

- First, the Southern cluster seriously lacks the engineering and technical human power to stimulate support industrial upgrading. The supply of engineering, IT, physics and mathematics graduates, and technical vocational staff must be expanded to offer the critical mass of staff necessary for continuous differentiation and intensification of division of labour in the cluster. Efforts from 1995 by the federal government to expand student enrolment in universities and technical and vocational institutes are a good move. However, effective projections of human capital needs and supply is necessary if the objectives are to be met, though several reports on the matter have already been produced.[131]
- Second, there is a need to stimulate the relocation of more entrepreneurial MNCs and local firms in the Southern cluster. Because of the importance of contacts and social capital in the forging of strong inter-firm relations, supplier firms, financiers and other supporting institutions such as training and R&D services must also be located with good coordination links in the region.
- Third, the technological capabilities of firms in the Southern region must be upgraded so that they could be horizontally integrated in the division of labour with Singapore.
- Fourth, the Johor state economic development corporation (JSEDC) has not played a proactive role to identify and act on collective needs of firms to seize development opportunities created by the presence of MNCs. The lack of a dynamic intermediary role by institutions in Johor has restricted the productive absorption of even the few entrepreneurial capabilities developed in the state. Unless conditions are created in Johor, most entrepreneurs nurtured in Johor will continue to seek jobs in Singapore and elsewhere. The JSEDC should take the initiative to play an enabling role, leaving the actual business activities to private entrepreneurs. The PDC is a good role model to learn from.
- Fifth, the business-government coordinating and deliberation councils in the region must become proactive. The PICC and PSDC are good role models to emulate. Johor's Puspatri and subsidiary organisations in Negeri Sembilan and Melaka should develop training programs a la PSDC to supply training for firms in the cluster. The SEDCs should assist the initiation of business links to stimulate participation from the firms operating in the Southern cluster.
- Sixth, the local and indigenous electronics firms in the Southern cluster must be developed further to establish horizontal integration and integrated manufacturing operations. The coordinating and deliberation councils should become the platform for strengthening. The SEDCs intermediary role can also help greater participation of these firms in SMIDEC, MARTRADE, SEP, VDP and ITAF activities.
- Seventh, the Southern cluster must shed its triangle concept development program so that it can develop a horizontal link with Singapore. The state should now aggressively stimulate the relocation of world class electronics and supplier firms instead of awaiting auxiliary synergies from Singapore's promotion efforts. The existing anchors and supplier firms should be encouraged to upgrade and work

[131] For example, the Review of the APITD by World Bank/MOSTE submitted in 1996 is an example.

towards the technology frontier so that the value added chain in the Southern cluster will constitute world class firms through out the chain. The technology roadmaps will be critical for effective planning.

- Eight, the SEDCs should promote university-industry collaboration between firms and Universiti Teknologi Malaysia, and private design centres should be encouraged to support innovation in the cluster. University-industry-institution links through proactive coordination and deliberation councils should include contract research, staff sabbaticals in firms, and firms' representatives participating in IRPA review committees. In addition, the SEDCs should also promote the formation of design centres to undertake product and process development research and application in firms through the deliberation councils.
- Ninth, MARTRADE's role should actively disseminate market research information to firms in the Southern cluster especially using internet support.
- Tenth, the SEDCs in the region should stimulate the relocation of missing firms in the cluster such as computer assembly, TFT and LCD screens.
- Eleventh, the SEDCs of the Southern states must use their deliberation councils to stimulate greater networking between firms and support institutions. R&D support, training institutions and venture capitalists rely considerably on the record of entrepreneurs and social ties due to the high risks involve. Hence, networking can help build bridges and establish strong social capital in the cluster.

LIST OF FIGURES AND TABLES

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Appendices

Appendix 1: Analysis of Applications Received and Approved for the Establishment of Manufacturing Projects in the Electrical and Electronics Sector

Table 1.1: Applications Received for the Establishment of Manufacturing Projects in the Electrical and Electronics Sector

Year	94	95	96	97	98
By # of Applications					
E&E Sector	307	315	251	186	186
Percentage of Total	30%	28%	27%	22%	26%
Total (all sectors)	1018	1116	929	849	726
By Potential Employment					
E&E Sector	68714	55443	42672	24826	30760
Percentage of Total	43%	41%	36%	30%	41%
Total (all sectors)	159141	135470	117552	83538	75950
By Capital Investment (RM mil)					
E&E Sector	6521.1	7012.2	10132.7	6032.6	5886.4
Percentage of Total	27%	26%	24%	18%	31%
Total (all sectors)	24363.2	26870	42100.5	34177	18914.3

Table 1.2: Applications Approved for the Establishment of Manufacturing Projects in the Electrical and Electronics Sector

Year	94	95	96	97	98
By # of Applications					
E&E Sector	268	194	215	190	194
Percentage of Total	31%	22%	27%	25%	23%
Total (all sectors)	870	898	782	759	844
By Potential Employment					
E&E Sector	62994	39821	37865	24738	27147
Percentage of Total	46%	34%	41%	34%	33%
Total (all sectors)	136487	117607	91891	73421	83241
By Capital Investment (RM mil)					
E&E Sector	6339.5	3151.8	13061.9	6222.7	2412.1
Percentage of Total	28%	15%	38%	24%	9%
Total (all sectors)	22951.3	20869.1	34257.6	25820.6	26352.4

Table 1.3: Progress in the Implementation of Approved Projects (1991 – 1997) as of 30/6/98.

	# Projects Approved	In-production	Machinery Install'n/ Factory Constr'n	Initial Stage of Implem'n	Not Implemented
E&E Sector	1536	1098	30	296	112
Percentage of total	26%	29%	17%	21%	21%
Total (all sectors)	5842	3736	175	1391	540

Table 1.4: Capital Investment in the Projects Approved in 1998 – by E&E Sector (RM mil)

State	Capital Investment
Sabah	<0.1
Kelantan	6.8
Perlis	7.5
Negeri Sembilan	11.2
Kuala Lumpur	20
Perak	34.2
Kedah	76.9
Pahang	125
Melaka	133.4
Johor	215.3
Selangor	483.4
Sarawak	622
Penang	674.5
Total	2410.2

Source: MIDA

Table 1.5: Foreign Capital by Source – 31/12/99 – E&E Sector (in RM'000)

	Paid-up Capital	Fixed Assets
Arab countries	$ 2,100.00	$ 1,718.00
Australia	$ 23,619.00	$ 20,438.00
Belgium	$ 1,036.00	$ 3,044.00
Canada	$ 11,654.00	$ 34,735.00
China	$ 1,000.00	$ 428.00
Denmark	$ 2,400.00	$ 976.00
Finland	$ 2,000.00	$ 2,054.00
France	$ 45,967.00	$ 31,624.00
Germany	$ 38,280.00	$ 480,282.00
Hong Kong	$ 75,125.00	$ 603,576.00
Indonesia	$ 2,756.00	$ 944.00
Italy	$ 1,500.00	$ 1,020.00
Japan	$3,678,075.00	$ 5,307,724.00
Korea, Rep of	$ 99,481.00	$ 126,730.00
Netherlands	$ 123,546.00	$ 114,994.00
Panama	$ 17,089.00	$ 7,413.00
Singapore	$ 811,460.00	$ 1,584,120.00
Sweden	$ 2,000.00	$ 6,933.00
Switzerland	$ 1,257.00	$ 196,702.00
Taiwan	$1,022,644.00	$ 953,096.00
UK	$ 34,539.00	$ 73,763.00
USA	$ 576,388.00	$ 2,933,146.00
Others	$ 112,345.00	$ 133,927.00
Total	$6,686,261.00	$12,619,387.00

Appendix 2: Summary of Penang Case Studies

Table 2.1 Unico Technology

1. **COMPANY: UNICO TECHNOLOGY**			
Structure	Production/Spin- Offs	Linkages/Supply Relationships	Other
1. Initial shareholder was Intel Cooperative 2. Subsequently totally divested by Intel and assumed name of Unico Holdings 3. Investment arm of Chinese Chamber of Commerce 4. Joint venture: With Italian and Taiwanese. Discussions with UK and Canadian companies in order to diversity products base. 5. Within the next 4 years- hopes to achieve total sales of RM 1 billion	1. Spin-off from Intel. Supplies mother boards (PCBA) and audio products for Intel 2. With Italian Company to produce modems, with Taiwanese company-to produce CD-Rom drive. Proposal with UK Company to produce Digital Enhanced Cordless Telephones. With Canadian Company to produce 900 MHz cordless transmitting phones. 3. Already achieved status of ODM 4. PCBA main products – mother boards, sound cards, multimedia cards. Also OEM for desk top computers.	1. Supply relationship with Intel 2. Production linkages with Italian, Taiwanese and possibly UK and Canadian companies 3. Sourcing of components – through synergistic linkages: PCB from Taiwan, components from other international sources and metal parts locally.	1. Has achieved vendor breakthrough to supply to MNC's especially Intel. 2. Has successfully achieved new product diversification 3. Has developed fairly good international connections. 4. Has little R & D though it is attempting to develop R&D expertise. 5. Complains of lack of entrepreneurial spirit in Malaysia. Malaysians more interested in working for MNCs rather than investing in start-up operations 6. Company is a good example of a successful local company linked closely to MNCs.

Table 2.2 Globetronics Technology

2. **COMPANY : GLOBETRONICS**			
Structure	Production/Spin-Offs	Linkages/Supply Relationships	Other
1. 100% locally owned and has 6 plants in Penang – some with subsidiary status. 2. Some of these subsidiaries have foreign partners e.g. Sumitomo. 3. Received ISO 9002 certification. 4. Expected sales revenue of RM70 million in 1997.	1. A subcontract manufacturer 2. Supply relationship with Intel for PCBA products 3. Also produces advanced pig-grid arrays (PGAs), plastic lead chip carries (PLCCs), quad flat backs (QFB), ceramics, packages, etc.	1. Has some linkage relationships with Intel for PCBA products 2. Carries out co-designing with Sumitomo 3. Carries out some subcontracting for Intel. Intel sometimes supplies raw materials on consignment. 4. Carries out company reliability tests as well as failure analysis.	1. Company has been performing well in subcontracting and has links with MNCs and other companies. 2. Intel used to be its anchor company but now the company does not rely on Intel alone. It has successfully diversified. 3. Still maintains its core business in subcontracting 4. Cites job-hopping and poor labor discipline as major problems. 5. It has growing upstream activities, it is active in substrate and provides testing services. It is a successfully, and expanding, local SME 6. Company is an example of a successful local company developing good supply and subcontracting linkages.

Table 2.3 Bakti Comintel Manufacturing

3. COMPANY : BAKTI COMINTEL MANUFACTURING

Structure	Production/Spin- Offs	Linkages/Supply Relationships	Other
1. Relatively new company – incorporated in 1993. 2. Company started through an agreement between Motorola and the Malaysian government as part of an initiative in technology transfer. 3. Company is 100% Malaysian owned. 4. Has a work force of over 400 workers.	1. Its product spin-offs include multitask adapters, hands-off walkie talkies, mobile, radios, microphones for walkie talkies, mother boards for mobile radios, PCBA, charges, cordless telephones, headphones for CD - ROM, CD Players. 2. It has achieved OEM status and is now an ODM as well. 3. 60% of its material and requirements are sourced locally. The 40% imported include cables, high-end electronics/engineering plastics, rubber, gaskets.	1. Works closely with Motorola – it has a vendor arrangement with Motorola. Motorola supplies Bakti approved vendor list. 2. Has supply linkages with companies in Taiwan and Singapore.	1. Uses a high degree of local content, which includes plastic molds, parts, tapes and reels, resistors, capacitors. However some of these parts are sourced from locally based foreign companies. 2. Company is a good example of how government assistance and targeting of MNCs can help vendor development programs. 3. Company is also an example of active local sourcing to promote the use of more local content and how an MNC can actively assist in vendor development and local content development.

Table 2.4 Eng Technologi

4. COMPANY : ENG TEKNOLOGI			
Structure	Production/Spin- Offs	Linkages/Supply Relationships	Other
1. Eng is a relatively new company incorporated in 1992. 2. It was a hardware company 3. 4 locations in Penang (2 sites), China & the Philippines. It has expanded internationally. 4. Initially started as a hardware company and then diversified into engineering, and recently into computer lines.	1. In the computer sector, Eng is principally engaged in manufacturing computer hard disk drivers. 2. Its main products include manufacturing actuators/E-blocks, assembly of hard disk drives, peripheral components and automation system designs and production assembly. 3. It also undertakes contract OEM, precision machining, batching, machining and other engineering works like plating services	1. Eng has built up good supply networks with MNCs. 2. Maxtor and Eng developed good links for supplying Maxtor as well as Fujisashi. 3. Eng's other customer-supplier linkages were with Maxtor, Micropolis, Seagate, Corner, Quantum MIKE, Dec and Fujitsu. 4. Fujitsu is Eng's key customer now.	1. Eng is a local company which has successfully built close relationship with suppliers and buyers 2. As an OEM manufacturer it produces a range of electronic based products for supply to MNCs. Its most active line is hard disk drives. 3. Eng is an example of a local company that has succeeded in Malaysia's push for more local content. 4. Its success is also an example for other local SMEs on how to venture into the vendor sector. 5. Eng is an example of a local company that has successfully engaged in R & D. Eng's R & D outfit uses CAD/CAM work stations, FA and test equipment.

Table 2.5 P.K. Electronics

5. COMPANY : P.K ELECTRONICS			
Structure	Production/Spin- Offs	Linkages/Supply Relationships	Others
1. PK is an indigenous company. It started operation in 1982 2. Company has 400 employees and sales turnover of about RM30 million 3. Has won a number of awards including the world Intellectual Property Organization Gold Award & the Investors Award in Geneva.	1. PK specializes in manufacturing uninterrupted power supply systems (UPS) and speed controllers, collectively referred to as power electronics. 2. PK also carries out its own innovations and some R & D to upgrade its products. 3. PK is looking into its other strategic sectors to order to improve its performance, as well as to developing its production activities.	1. 50% of its products are for the local market and 50% for export, chiefly to regional markets. It has recently stepped up promotion activities overseas 2. PK has built up good connections and developed a market niche in the speed controller market and in power electronics. 3. It is in the process of building up international linkages	1. PK is a successful local company that has developed its own products. 2. It has managed to move its speed controller production from OEM to ODM 3. It is an indigenous company that has successfully made inroads into the local as well as international markets. Exports are expected to reach 80% of output. 4. PK's main strengths are in its personnel, finance, market development and good management practices. 5. It has plans to expand but is aware of the need for supply support through intermediates institutional support, technical services, HRD support, R & D and is still limited by its small output base (PK requires larger scale economies in production) 6. PK is an example of a company, which has been able to development quality products. It is a good example of a local content manufacturer.

Table 2.6 Dell

6. **COMPANY : DELL**			
Structure	Production/Spin-Offs	Linkages/Supply Relationships	Others
1. Dell was established in 1995 in Penang 2. Dell obtained its ISO 9002 within 8 months. 3. The Penang site is the HQ for all Dell investment in the Asia Pacific region. 4. Dell's employs approx. 560 workers. 5. It is a foreign MNC and has operation in Europe, Asia and US.	1. Dell's strength is its ability to customize its orders 2. Its main activities in Penang include assembly and testing, marketing and distribution 3. Dell can install software according to the requirements of buyers (all in an package) 4. Its new market strategy is to localize its products for the Korean, Chinese, Taiwanese and Thai markets. 5. It exports about 80% of output overseas.	1. In respect to linkages and supply relationships, Dell works according to its approved vendor list. 2. Dell's main supply links are overseas including Sony, IBM, Sharp, Hitachi, Sanyo, Samsung, Alps, Complement, Chichony, and Intel. It also sources locally from foreign owned MNCs including Intel Malaysia, Texas Instruments, Solectron, Western Digital, Micron, Samsung and Liteon. 3. The only indigenous Company that Dell acquires supplies, such as plastic components/casings, is Teik See. 4. About 50% of its parts and components requirements are sourced locally. Dell hopes to increase these to 70%.	1. Dell is an example of an MNC that works closely with its specialized suppliers in a relationship that resembles a strategic alliance. 2. However, its vendor are generally based overseas or are highly specialized locally based MNCs. 3. Its closest local Vendor Partner Teik See. It has developed a vendor development program with Teik See. 4. Dell is a good example of how success can be achieved through competing on the basis of delivery, quality, and customer satisfaction. 5. Dell has some reservations concerning the Malaysia business environment – it believes that Malaysia, unlike Singapore, does not have an environment conducive to spawning entrepreneurs in electronics. 6. Dell is a highly successful customized manufacturer which Malaysia can learn from.

Appendix 3: The Production Capabilities Spectrum, Changing Competitive Advantage and Industrial Growth

Several East Asian Countries have growth at 8-10 percent per year for periods ranging from 1 to 3 decades. Prevailing economic theory has no satisfactory explanation of this explosive and sustained growth. It is suggested that policymakers in the rapidly growing East Asian countries have developed new approaches to industrial policymaking that focuses on production modernization, technology application and skill upgrading. They have traded in order to upgrade their production capabilities. In short, they have developed regional and national systems of production and innovation that adopt, adapt, apply and diffuse, not only foreign technologies, but also foreign production capabilities more rapidly and thoroughly than anywhere else.

However, dynamic national or regional systems of production and innovation (NSPI) do not just happen; they must be socially and politically negotiated. This is what turns these 'miracles' into national achievements. Western economic theories, whether free market, Keynesian or planing perspectives, lack conceptual space for the concept of a NSPI. Yet it is the key factor that explains whether trade will be the 'god or the devil' in terms of its impact on local productions capabilities, business opportunities in production, and industrial growth.

Sustained industrial growth involves developing the organizational capabilities necessary for a nation to make the transition across sectors along the production chain (shown in Figure 3.2), and up the production capabilities spectrum. Economic growth is, in part, a consequence of making the transition along this spectrum or of pushing the diamond upward over time. While Japanese policy makers used a variant of this Figure in the early 1970s, the idea is grounded in a conceptual framework developed in the mid-1930s at roughly the same time as the Keynesian demand management approach was being developed.

Nakame Akumatsu, a Japan proponent of a unique theory of industrial development described a process from imports to import substitution and then to exports as firms learned from foreign technologies. He described the process in terms of three waves of flying geese. Imports would be represented by the gaggle of geese in flying formation: imports would increase, peak and then fall off; production, the second gaggle, would increase, peak, and decline; and exports, the third gaggle, would again represent this inverted V pattern. He described these patterns as occurring first in 'crude' products and later in 'refined' products; in final goods and later capital goods. Where a country is at any point in time is determined by the balance of forces between the level of development and wage rates. Higher development leads to higher wages and a loss in exports of easier to produce goods.

The idea of a production capability spectrum combines the principles of production and organization described above, with Akumatsu's notion of sectoral transitions. The production capability spectrum suggests criteria underlying an organization's location in a country in the international production order and for identifying the challenges at any point in time.

Table 3.1: Production Capabilities Spectrum.

1. *Pre-flow, pre-interchangeability: traditional craft production*: This means, for example, that each drawer in a dresser is a unique fit. Craft production, by itself, offers no basis for flow. The task is to develop product engineering skills; Pre-TM1.
2. *Interchangeability without flow*: Production that involves product engineering but lacks integration engineering, hence low inventory turnover and working capital productivity. TM1.
3. *Single product flow*: These plants enjoy economics of speed but are dedicated to a single product or range of products with dedicated lines. Workers are not trained in continuous improvement, rapid changeover, or blueprint skills. TM2.
4. *Single product flow with process innovation*: labor force includes maintenance and process control technicians who can identify and fix electronics problems in machinery. The next step is programming technicians and associate engineers that can identify and solve bottlenecks. This may involve reconfiguring design parameters at main office. Singapore in the mid-1980s, Malaysia in early 1990s. Redesigned TM 2.
5. *Multi -product flow*: The Toyota system that has spread from small and medium sized suppliers to MNC throughout East Asia. Kanban, JIT and SMED are introduced in large plants. High throughput and flexibility are combined. TM 3.
6. *Multi-product flow with continuous improvement*: This involves plan-Do-Check- Act or TQM at shop floor level and self-directed work teams. TM 3.
7. *Multi-product flow and new product development*: Japan and Taiwan both excel at concurrent engineering and design for manufacturability. TM 4.
8. *New product development and technology management*: Japan's Toshiba and Canon are leaders in linking development to operations and linking research in generic technologies to product development. Core technologies are developed, often via fusion in generic technology labs. Technology management involves world-wide sourcing of the existing technology base in pursuit of novel applications. TM 4.
9. *New product development and fundamental research*: 3M, HP and Motorola have developed networking systems to identify new technology drivers for product development. Radical breakthroughs are pursed, but within an organizational context of process integration. These Companies are learning firms with knowledge workers and education at all levels. Motorola has achieved phase 7 in self-directed team development and supplier development programs that emphasize partnering. TM 5.

At each point along the production capabilities spectrum, when the ratio between wages and production capabilities is low compared to other countries, growth will advance wages until following nations make the transition to a new level of production capabilities. Following countries will take over when lead countries wages rise for that type of production, as they enjoy a lower ratio between wages and production capabilities and can therefore undersell the market leaders. Having achieved a new higher level of production capabilities a region or country enjoys growth as the new practices and technologies are diffused to old and new products by firms. However, in the process wages and opportunities for further diffusion diminish and growth become threatened as imitating regions and nations develop the requisite production capabilities to move into the same markets with lower wages.

To sustain growth, enterprises in a region must make the transition to the next higher level of production capability. Once a critical mass of firms make the transition, a new range of opportunities open up and the region or nation becomes competitive in more technically and organizationally advanced activities and products. Growth reasserts itself as the opportunities are taken up until, once again, the wages rate to the respective production capabilities ratio rises above that of competitors. If a region or country continues to successful make the transitions along the production capabilities spectrum then growth rates will be high and sustained.

The dynamic process described starts with; production capabilities moving to higher rates of investment, greater learning by doing, greater competitiveness and sustained high growth. Savings follows from high profits. In this scenario, high growth generates savings; the conventional view attributes high growth to high savings but does not satisfactorily explain the sudden surges in savings. The production capabilities perspective starts with the firms and thereby focuses explanations on organizational capabilities and competitiveness; the conventional view begins with the consumption and savings choice of individuals as the determinant of growth. Empirical evidence supports the production-oriented perspective.[1]

The goals of a development state are to pursue industrial growth by facilitating and negotiating industrial transition by addressing the challenges indicated by the production capability spectrum. This involves acting as a catalyst to advance indigenous production, innovation, and technological development capabilities. The means are to partner with entrepreneurial firms that are themselves the seeds and drivers of transitions, the promoters of creative destruction. The challenge for the development state is not one of initiating, but of shaping, responding to, enhancing and complimenting the entrepreneurial drivers, with the requisite infrastructure including transportation, energy, regulations and education.

[1] Singh (1996)

Appendix 4: Technology Management and Management Systems:

Five Models of Technology Management

1. Introduction: The Idea of Technology Management

Technology does not fit easily into economic theory. Growth theory and trade theory, for example, do not control for technology.[2] Technological change is central in explaining industrial leadership and technology-follower nations can achieve much faster growth rates than the technology trailblazers by tapping the world's existing pool of technology.[3]

Government "technology policy, both planned and inadvertent, has impacted technological development. Historically, technological breakthroughs have been bound up with wars, both hot and cold. The United States government's R&D funding and defense procurement during the Cold War were catalysts for a range of new technologies and industries important to American growth and trade.[4] More recently, high-tech "hot spots" in the United States have engendered regional growth and become models for policy makers around the world. Governments in the rapidly growing East Asian economies have pursued active technology governance policies. Their goal has been to move up the export production ladder to more technologically advanced products.

Technological leadership has long been an object of business strategy as well. Decades ago AT&T, DuPont, GE, and IBM established in-house laboratories to conduct fundamental scientific research in order to identify future technologies and engender marketplace success. At the same time, the relationship between scientific research, industrial innovation, and competitiveness has remained controversial. Noting the cutbacks in federal funding for research and corporate long-range fundamental research, pessimists argue that America is failing to maintain the research foundation that has supported America's competitive advantage in new technologies and high-tech industries. However optimists hold that America's industrial resurgence is due, in part, to the emergence of new models of technology management enabled by, and reinforcing, new models of business and industrial organization.

Economics has little to offer these important concerns. The disjuncture between technology and economic theory is caused, in part, by the failure of economics to get

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[2] For a survey see G.N von Tunzelmann, *Technology and Industrial Progress: The Foundations of Economic Growth*, Edward Elgar, Brookfield , Vermont, 1995.

[3] The transfer of technology has not been so simple. At the same time, high growth East Asian success that rapid rates of growth are associated with high rates of technology adoption and diffusion. This is not inconsistent with either neoclassical or new growth theory. In Robert Solow's 1957 article, roughly 80 percent of US growth was explained by "technology"("Technical Change and the Aggregate Production function", Review of Economics and Statistics 39, pp. 312-20) However, technology was neither defined nor made endogenous to the growth model and innovation. The New Theory is equally sympathetic to "technology" in the form of new ideas. Recent studies in international trade have, likewise, brought in technology and organization and through the backdoor to explain high rates of unemployment (Paul Krugman and Robert Z. Lawrence, "Trade, Jobs and Wages", Scientific American, April 1994, pp. 22-27).

[4] In this sense America had an inadvertent industrial policy

a grip on production and business organization. A linear process has been taken for granted across autonomous spheres of science, and economic growth. The beauty of the model is its simplicity for policy prescription: growth can be enhanced by funding science, which leads to technological breakthroughs followed by new products. The model ignores the overlap of, and space between, science and technology, technology and product development, product development and production. The associated range of mediating activities, institutions, capabilities and purpose are ignored but at the cost of understanding how economies actually function. To the extent then, that technology is import to understanding economies, it should have a place in economies.

The technology-economic growth process can be divided into two sub-processes. The first puts fundamental scientific research and technological innovation in centre stage. Government technology policy and economic research on technological change tend to focus here. The second targets relations among production, new product development, technology choice, and applied R&D within and across business enterprises. This is the domain of technology management and the concern of this paper.

Five heuristic case studies are presented to explore the idea of technology management from a production perspective. The cases highlight the interfaces of production and technology. The method is to explore management from the context of major innovations in production and associated organizational capabilities.

The central claim is that technology management is a powerful tool for the growth of firms, regions, and nations at every level of industrial development. Success, however, depends upon certain key principles of production and organization being in place. Otherwise, no amount of investment in R&D, technology transfer, or commitment to technology policy, will impact growth.

The challenge of technology management in leading industrial enterprises today is to develop the organizational capability to combine and recombine new existing technologies with production in the pursuit of rapid new product development. The challenge to technology-follower firms and regions is to develop technology management capabilities that enhance competitive advantages specific to time and place. This does not mean a one-off introduction of a new technology or "turnkey" plants. Nor does it mean that a company or country can continue to thrive on the basics of a specific technology management capability. The five case studies suggest that sustained industrial growth depends upon making a series of transitions to more advanced technology management capabilities. These transitions, however, depend upon the requisite production principles and organizational capabilities being in place.

2. TM 1: The American System and Interchangeability

Surprisingly, the timeless principles of mass production became a hallmark of industrialization. The American System of Manufactures, as the British labeled it, was based on interchangeability. Applied first at the Springfield Armory in Springfield, Massachusetts in 1817, interchangeability revolutionized production. The concept of interchangeability is as relevant today as ever. Before interchangeability each drawer in a desk was hand-fit, each firing pin on a rifle was hand-fed. Without interchangeability armies would still need to include a regiment of hand-fitters repair arms, furniture manufacturers and a department of hand-sanders to individually fit every piece. The idea is simple but it is rarely deployed in Third-world factories today.

Designing a production system around the principle of interchangeability was, at the same time, the origin of technology management. A range of specialist machines had to be designed and built to convert the principle into practice. Product engineering emerged as a set of standard procedures, an organizational capability, and an occupational category to specify, design, make, setup modify, adopt, refine, and operate efficiently the requisite machines. The rudiments of engineering as methods were established to lay out, inter-face, standardize, measure, operate, and trouble-shoot machining activities along a production line. The elements of production management system were taking shape. Technology management was no longer a one-off affair in which a machine with superior performance capacity was introduced; instead, it was becoming an ongoing organizational capability of industrial enterprises.

Product engineering means first, deconstructing a product into its constituent pieces. Second, reorganizing the flow of material according to the logical sequence of operational activities for manufacturing the piece. Third, analyzing each for simplification by identifying, modifying, and designing machinery. Fourth, networkings with machine tool companies to make, modify, and maintain machines, tools and streamline processes.[5]

The stock of a gun at the Springfield Armory was subjected to a product engineering exercise. To eliminate hand-standing, and the need for craft-skilled woodworkers, a bank of 14 specialist lathes were designed, built and integrated into a production line. The performance of each machining operation, tended by a machine operator, was measured by precision gauges and compared with formal specifications. Failure meant adjustments to the machine and/or operator task.

In early industrial New England, an inter-firm technology management dynamic was set in motion between specialist machine users and makers. Incremental and radical innovations in the tool industry was induced by both machine users and back increase productivity in production.[6] The system was not centrally managed; it was self-organizing with a powerful boost from orders and services provided by the Springfield Armory.[7] Without the development of a set of (informal) management

[5] For examples see Michael Best and Robert Forrant," Production in Jamaica: Transforming Industrial Enterprises", in Patsy Lewis (ed.), *Preparing for the Twenty- First Century: Jamaica 30th Anniversary Symposium (* Kingston, Jamaica: Ian Randle Publishers, 1994) pp. 53 – 97.

[6] For examples of both types of innovation and references to original sources see Michael Best and Robert Forrant," *community-based Careers and Economic Virtue: Arming, Disarming, and Rearming the Springfield Armory," in Michael Arthur and Denise Rousseau, (Ed's)The Boundaryless Career, Oxford university Press, 1996, pp. 314-330*;and Robert Forrant, (1994) *Skill Was Never Enough: American Bosch. Local 206. And the Decline of Metalworking in Springfield Massachusetts 1900-1970.* University of Massachusetts Doctoral Dissertation, Amherst.

[7] The district model of industrial organization is associated with networking as distinct from pure market or hierarchy as a mode of coordination of economic activity (See Michael Best, *The New Competition*, Harvard University Press, 1990. Networking suggest long term, consultative relationships

practices known as product engineering for guiding the design and development of machines, it is likely the process would have been self-sustaining.

Inadvertently, New England became the site of a regional technology management capability. The world's first machine tool industry, created in the wake of applying interchangeability, facilitated the integration and mutual development of production and technology. It also diffused the new principle to the region and other parts of the country and by so doing, created a vehicle for transferring technology across sectors. [8]

While the makers of specialist machines were independent, they were fuelled by a regional innovation process, which in turn was anchored in a community of workers and practical engineering skilled in the development, use, and improvement of these new technologies. While the idea of product engineering was not always formalized into standard operating procedures, without the emergence of a set of tools and skills associated with blueprint reading, metallurgy, geometry and trigonometry the machine making sector would not have flourished. It did and with it the management of technology became an organizational capability. As often as not, technology management as a capability was embedded in the tacit knowledge and skills of those who learnt product engineering without ever knowing it. This organizational accomplishment introduced a whole new world of production potential over the craft predecessor.

The centrality of networking and technology diffusion to the growth process was also established in industrial New England. The practice of technology management was not found in textbooks or management training courses; instead it was embedded in the dynamic relationships between machine makers and users and in the skill of the labor force. The element of product engineering, a machine tool sector, and a skilled labor force, provided the method and means for the region to make the transition from an industry organized according to the principle of craft to one organized according to interhangeability.[9]

Application of the production principle of interchangeability led to the redefinition of a whole range of products and created new industrial sectors.[10] In its wake, New England enjoyed a rapid rate of industrial growth. It also demonstrated that an organizational capability can be the source of competitive advantage.

3. TM 2: Ford and Single Product Flow

Henry Ford wrote: "In mass production there are no fitters" (p.40). The implied emphasis on interchangeability does not describe what was novel about Ford's plants. Henry Ford's plants were organized according to the principle of flow. The point is

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which facilitate in design and R&D. The process involved technology policy by the Federal government.

[8] Nathan Rosenberg, *Perspectives on technology*, Cambridge University Press Cambridge, 1996, pp. 9-31.

[9] The lack of a craft tradition meant less resistance to the new principle of production than in gun making regions of England.

[10] See Best, *The New Competition*, Ch. 1

captured by one of Ford's most successful students, Taiichi Ohno, creator of the Toyota just-in- time system:[11]

> "By tracing the conception and devolution of work flow by Ford and his associates, I think their true intention was to extend a work flow from the final assembly line to all other processes...By setting up a flow connecting not only the final assembly line but all the processes, one reduces production lead time. Perhaps Ford envisioned such a situation when he used the word "synchronization" (p. 100).

Ohno identifies the single term that captures the revolution at Ford Motor Company even though it does not appear in Ford's published writings. It was not interchangeability, as stated by Ford, the moving assembly line or economies of size, but synchronization. It is captured in the words of Charles Sorensen, Ford's chief engineer: "It was...complete synchronization which accounted for the difference between an ordinary assembly line and a mass production one."[12]

Sorensen uses the term in a more expansive description of the model T where all the "links in the chain" were first connected at the Highland Park plant in August, 1913:

> "Each part was attached to the moving chassis in order, from axles at the beginning to bodies at the line. Some parts took longer to attach then others: so, to keep an even pull on the towrope, there must be different spaced intervals between the parts along the line. This called for patient timing and rearrangement until the flow of parts and the speed and intervals along the assembly line meshed into a perfectly synchronized operation throughout all stages of production (130-1 emphasis)

Sorensen finishes the paragraph with the phrase: "a new era in industry had begun". Few would deny this conclusion. Ironically, most explanations do not capture the fundamental challenge that ushered in the new vision of production and thereby the real difference between the old approach to production as articulated by Sorensen.

The production organizing concept of Ford and his engineering was timing. The challenge was to regulate material flows so that just the right amount of each part would arrive at just the right time. In fort's words:

> "The traffic and production departments must be close together to see that all the proper parts reach the branches at the same time – the shortage of a single kind, or both, would hold up the whole at a branch" (p11, my emphasis).[13]

Making one part too few slowed the flow; making one part too many produced waste in the form of inventory and Ford was Vigilant against the "danger of becoming overstocked (p.117)

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[11] *Toyota production System: Beyond Large-Scale Production*, (Productivity Press, Cambridge, MA, 1988)

[12] *Forty Years with Ford,* (Cape, London 1957).

[13] *Today and Tomorrow,* (Double Page and Company, 1926; reprinted by Productivity Press, Cambridge, MA. 1988).

Sorensen referred to this process as "progressive mechanical work" which reached its pinnacle with the introduction of the V-8 engine at the Rouge plant in 1932:

> "All materials entering a Ford plant went into operation and stayed there. They never came to rest until they had become part of a unit like an engine, an axle, or a body. Then they moved on to final assembly or into a freight car for branch assembly, and finally to the customer. It was a glorious period; a production man's dream come true (p231).

The vision of a flowline concentrated the attention of engineers on barriers to throughput. A barrier, or bottleneck, occurred wherever a machining operation could not process materials at the same pace as the previous operation. The bottleneck machine was the activity that constrained not only the throughput at that machine, but of the production system as a whole. Increasingly the pace of work of any other machining activity could not increase output, only inventory.

Henry Ford's assembly lines can be seen in this light. It was not the speed of the line that was revolutionary in concept,_it was the idea of synchronizing production activities so that bottleneck did not constrain the whole production system. Unfortunately, all too often the basis of mass production was mistakenly defined in terms of economies of size when it was really synchronized production that drove the rate of throughput up, and the per unit cost down.[14] Flow requires synchronized which, in turn, requires system integration.

Sorensen's assistant superintendent on the first line was Clarence Avery. Avery spent a total of 8 months working in every production department. In Sorensen's words: "Beginning at the bottom in each department, he did all the physical work necessary to understand its operations, then moved on to the next"(p130). Avery then moved into Sorensen's office and elaborated the whole system:

> "With firsthand familiarity with each step in each parts departments, Avery worked out the timing schedules necessary before installation of conveyor assembly systems to motors, fenders, magnetos and transmissions. One by one these operations were revamped and continuously moving conveyers delivered the assembled parts to the final assembly floor," (p130; my emphasis).

Linking up an assembly line was a final step and one that by itself, had no direct impact on throughput time.[15] A conveyor line is a physical linkages system that integrates all of the requisite machining and other operations required to convert material into finished product. Before it can be connected operations must be "revamped." One by one to equalize the cycle time for each constituent operation. A cycle time is the time it takes to complete a single operation, usually on a single piece-part. Ohno argues that Ford's engineers did not go the whole way: they did not

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[14] A prime example is Lenin's admiration of Henry and Frederick Taylor which, based on the mistaken view that mass production was about economics of size, figured in the identification of modernism with giant factories throughout the Soviet Union and Eastern Europe. Unpublished paper by Robin Murray, Sussex University.

[15] The pace of conveyor line did not determine the rate of material flow; rather the speed of the conveyer line was adjusted to the pace of material flow. The pace of material flow depends upon the slowest cycle time in the whole production process. Otherwise timing would be thrown off.

equalized cycle times for one-piece flows (see next section). However they did balance material flow so that the right parts would arrive at the right place at the right time.[16]

The principle of flow yields a simple rule, the need to concentrate the attention of engineers in equalizing cycle times. Optimally, every operation on each part would match the standardized cycle time, the regulator of the pace of production flow. Failure to synchronize appears as inventory buildup in front of the slower operation. Any activity that takes more time does not meet the condition and requires engineering attention. The way to increase the flow of material is not to speed the pace of the conveyor belt but to identify the bottleneck, or slowest cycle time, and develop an action plan to eliminate it.

Ford's assembly line, from the perspective of flow, was primarily a signaling device or a visual information system for continuous advance in throughput performance. It established a standard cycle time. The engineering task was to revamp each operation into conformity with the standard cycle time.[17] Every time a bottleneck was removed, productivity and throughput advanced.

The visual signaling feature of inventory in the system was not obvious or perhaps even understood before it was implemented. Ford attacked inventory because it was waste and waste added to costs, without a near-zero inventory system the signaling function of the conveyor line would be knocked out. With the near-zero inventory system, the work assignments of engineers were signaled by material build up on the line. They were prioritised without central direction. Ford approved; this meant less indirect labor that, for Ford, was another form of waste.

Scheduling too was decentralized in Ford's system. The idea that Ford's system could indeed operate without chaos would have seemed, understandably, far fetched. At an output rate of 8000 cars per day, production of the Model A, with 6000 distinct parts, involved 48 million parts in motion. A huge planning and scheduling department would seem to be necessary. Ford's plants were orderly. Schedules were met and orders were achieved by the application of the synchronization rule: equalized cycle times. Once the system was in sync, more cars could be produced, not by increasing the speed of the line, the operational efficiency of individual machines, or the intensity of work

Production rates could be increased in two ways: reduce the cycle time the slowest operation (successive elimination of bottlenecks) and drive down the standardized cycle time. To this day production mangers would not believe that the Ford system could work, if in the meantime, the Japanese had not demonstrated it. This is why it is know by the Japanese term: Kanban. A failure to understand Ford's assembly line as a visual-scheduling device, backed by standardized cycle times, is what led America volume producers to build huge, centralized planning and scheduling departments.

[16] Some of Ford's heavy machinery stamped in lot sizes of greater than 1. This meant that inventory crept into the system as piece-parts pulled into assembly 1 at a time. The output of all machines was regulated by the standard cycle time but cycle time was not equated for the fabrication of each piece-parts. In this, Ford's plants were single-products but nit single-piece flow.
[17] Equal cycle time does not mean machine is operating at the same pace but that just the right amount of parts for each car are made in each time-cycle.

Their efforts have demonstrated that no amount of information technology can avoid bottlenecks in such systems.[18]

Like interchangeability, the principle of flow is simple but implementation demanded a revolution in the organization of production and the management of technology. Ford simplified the organizational challenge, including co-ordination, by constraining the productions system to one product.[19] The technological challenge was considerable. Equalizing cycle time for even a single product was a monumental achievement. Equalizing cycle time for more than one product was inconceivable without organizational innovations that go well beyond Ford's system. In fact, the conveyor line itself precludes multi-product flows (see next section).

Synchronization and the equal cycle-time concept necessitate two technology management activities. First, adjustments are required in operational activities to meet the synchronization constraint. Ford could not simply purchase machines "in the market" even if a market existed for high volume machines. Achieving the narrow time and timing specifications required by the principle of flow involved Ford engineers in continuously "revamping", searching for new technologies, adjusting, regearing, retooling, fitting new jigs and fixtures, and redesigning machines and plan layout. This was the end process for Ford as for practitioners of the management philosophy of continuous improvement today.

Second, the pursuit of new technologies is to reduce the standard cycle time. Ford attacked the standard cycle time by addressing generic technologies that impacted on all machines. One example is power. Before Ford, most manufacturing plants were powered by centralized power systems and machines were linked to the source by lines and shafts.[20] The synchronization rule would have no meaning in such a system. Ford innovated. He substituted wires,[21] and he built his own power system.

The River Rouge plants was fueled by gasified coal which powered steam turbines designed and built by Ford and his team. Immediately obvious was the impressive 90% efficiency rate in conversion of heat to water. Thermal efficiencies of purchased electricity from centralized power stations were restricted by the Rankine (Carnot efficiency) barrier from surpassing 35%. Ford's generators included a number of innovations: they were a third less in size than other turbines then available, the first

[18] Ironically, the Ford production system was self-regulating much like a perfectly competitive market system in economics theory. Instead of prices the adjustment mechanism, surpluses and shortages of inventory et in motion corrective forces; instead of the "invisible hand" the reaction agent was the engineers re-establishing equal cycle-times.

[19] Ford seemed to worship his original product design. Sorensen writes. "In all the years with Model T no one worried or bothered Mr. Ford with design changes, and it was to be told he should adopt something else for Model A"(p.224). Ford adamantly refused to modify even the brakes when through the Model T was banned in Germany and at risk from merging state safety boards in the United States. See Karel Williams and Colin Haslam and John Williams, "What henry did, or the relevance of Highland Park" in Keith Cowling and Roger Sugden (Ed's), *Current Issues in Industrial Economics Strategy* (Manchester University Press) 1992 pp.90-105.

[20] See Warren D. Devine, Jr., "From Shafts to Wires: Historical Perspective on Electronics:, The Journal of Economic History , Volume XLIII, June 1983, Number 2, pp.347-372. I have drawn heavily on Devine's work in this section.

[21] Belts and shafts cluttered the factory and precluded machine layout according to the logic of the process. In theory, cycle times could be equalized in such a plant but the challenge of adjusting gearing rations and machine speeds would have created gridlock with the clutter of power transmission devices.

to use all-mica insulation, and relied upon a " radically" different system of ventilation.[22]

Why did Ford pursue innovation in electric power generation? Part of the answer is that the cost of power determined the location of plants.[23] More important, implementation of the principle of flow depends upon and was intertwined with technological innovations in electronic power. Flow, applied to car production, is impossible without the electric motor: the [unit drive] electric motor meant that plant layout and machine location could be freed from the dictate of a central power system and the associated shafts and belts. Power, for the first time, could be distributed to individual machines, and machinery could be arranged on the factory floor according to the to the logic of product engineering and the material conversion process.

Ford's innovation in electricity enabled his engineers to organize plants according to the logic of material flow; competitors departmentalized factories according to machining activity. For Ford, the independently power machines went to the material; for his competitors, material went to the machine and the machine was located by the power system was located.

Flow meant redesigning machines to incorporate unit drive motors. While electrical power had become commonplace in factories in the first decades of the twentieth century its delivery system was unchanged. A 1928 textbook indicates only "trends toward incorporating the motor as an integral part of the machine tool" even though the concept had been understood since the turn of the century.[24]

Why the slow growth in distributed electrical drive systems? Answer: The limited diffusion of the principle of flow. The fusion of the electric motor with machines offered enormous potential to expand productivity but only with a prior commitment to a radical reorganization of the factory. Ford systematically pursued innovations in processes, procedures, machines, and factory layout to exploit the productivity potential of the principle of low. The electric motor was a tool in the process.[25] Technological change in electric power awaited organizational change. Unit drive, in turn, created unforeseen opportunities in advancing productivity when integrated with production redesign.[26]

In short, technology management for Ford meant integrating technology and production in pursuit of the principle of single-product flow. While followers of Ford could take advantage of innovations developed by technological leaders, the synchronization requirement will always demand a technology management capability.

[22] Ford given an insight into an important secret an important secret to his success and a key aspect of technology management in reference to his coal gasification system. "The processes are well known- most of our processes are well known. It is the combination of processes that counts" .(p172)
[23] Ford, p116
[24] Devine, p. 369
[25] Ford's earlier experiences as chief of engineering at Detroit Illuminating served him well.
[26] See a more extensive treatment of the relationships between energy and manufacturing process see Michael Best and Denise Martucci, *Power to Compete*, Center for Industrial Competitiveness, 1997.

With hindsight, Ford from the perspective of technology management, is a story of both productivity leaps and limits. The challenge of high throughput forced Ford's engineers to integrate a range of technologies, apply new ones, and continuously adapt others to facilitates flow. At the same time the organizational practices associated with single-product flow place limits on other forms of technological advance and erect constraints on the introduction of new technologies. Toyota, not General Motors, exposed the limits of single-product flow.[27]

Like interchangeability, the concept of synchronization is simple but the implementation demanded a revolution in the organization of production and the management of technology. This was so even though Ford simplified the coordination problems by constraining the production system to one basic product and even though Ford's engineers did not go the whole way (the cycle times were not equalized for all fabrication activities).[28]

Ford's revolution was practical; the principle of flow was not conceptualized into a theory of production. Cycle time on the final assembly line regulated flow and established timing targets. However the Ford systems was not a pure JIT system for reasons explored in the next section.[29] The completion of Ford's system was limited by the failure to conceptualize the principle of flow.[30] Again, as in interchangeability, the refinement in both concept and application was a multi-decade affair. The concept of flow penetrated into management through practice in the early 1990s masquerading as "reengineering" and "lean production".

Ford, unlike America industrial followers, had no interest in measuring labor productivity, conducting time and motion studies, or devising piece rate systems. The rate of production depended on throughput efficiency and associated cycle times. Ford increasing the rate of production by technology management: bottleneck were eliminated and standardized cycle times were driven down. Unfortunately, these principle were not written into industrial engineering manuals, which instead adopted the scientific management paradigm. Less surprising was the complementary practice in economics research of focusing on capital and labor at the exclusion of production and organizational issues. Both obscured the source of productivity gains in America's the most celebrated production system for roughly a half century after

[27] General Motors moves from the organizing concept of materials flow, developed by Ford, to that of function departmentalization and the concept of" economics order quantity". In terms of throughput efficiency, GM was a step backwards; they did multiple products without multiple-product flow (see Best, *The New Competition*, p.151)

[28] Ford seemed to worship his original product design. Sorensen writes: "In all the years with Model T no one worried or bothered Mr. Ford with design changes, and it was hard to be told he should adopt something else for model A "(p.224). Ford adamantly refused to modify even the brake when though the Model T was banned in Germany and risk from emerging state safety boards in the United States. Five models, see Karel Willians.

[29] For example, some of Ford's machine processed more than 1 piece-part at a time that meant that inventory crept into the systems and all materials was no kept in motion. The point is not that such inventions were uneconomic, but they were not deemed a challenge to be addressed as in the Toyota Production System.

[30] Ford rules were to keep material in motion and to eliminate waste. These rules produce the effect of equal cycle times without the concept. The tendency of perfect markets to produce the allocative efficiency rule of P=MC is an analogy from neoclassical economic theory. Producer's actions are consistent with the rule even though their actions are guided by maximizing profits and not profits and not allocative efficiency.

Ford's engineers first applied the principle of flow. Toyota forced the issue back onto the manufacturing agenda by extending the principle of flow to multiple products. [31]

4. TM3: Toyota and Multi-product Flow

When Toyota developed JIT, engineers were not aware that they were triggering a sequence of organizational innovations is production that would create conditions for a new trajectory of industrial growth.[32] They were just in time.

Japan had wrung growth out of the early post-war trajectory driven by labor-intensive and raw material intensive products, processes and sectors. The high rate of the old trajectory had undermined its own preconditions: wages were driven up and imported raw materials inputs were constraining critical industries such as steel. Equally important, Japanese success was not lost on business enterprise in nearby nations with lower wages and indigenous raw material,s and aspirations to develop the same industries. Sustained growth, for Japan, depended upon the establishment of more complex-production products, processes and sectors.

The new productions system know either as just-in-time (JIT), the Toyota Production System and lean production, was not the consequence of large investment in capital. Nor was it about the introduction of new hardware-related technologies or lower cost production methods, but it was an organizational prerequisite to both. The new system was based on the development, application and diffusion of new principles of production and organizational capabilities that enabled Japanese manufacturing enterprises to compete on more comprehensive performance standards combining cost, quality, time and flexibility. The new performance standards put industrial enterprises and regions throughput the world on notice, much as Henry Ford had done a half century before: failure to adapt to, or counter, the new production system would lead to industrial decline.

The central organizing concept of Toyota can be described as multi-product flow. The major difference with Ford, and it's a major one, is that Toyota was not constrained to one product. Toyota applied the principle of flow to a range of products: different models go down the same line. For Henry Ford, this idea was an anathema: the timing task would have been overwhelming as the product range proliferated. It would have implied an unacceptable compromise to the production goals of minimal through time

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[31] As noted neither the principle of flow nor system were widely diffused in American business until the 1990s. Deming often stated that the what he look to Japan was the "theory of the system". He meant, in part, that much of American business enterprise was organized into profit centers and the associated logic of local optimization; the Japanese management system came to embody the idea of managing interrelationships or interfaces across business activities, hence the idea of process integration or global optimization.

[32] In section 7 links among technology platform, production capability and growth trajectory are suggested. The idea, in brief, is that for any set production capabilities the rate of growth depends upon the wage rate relative to other nations at the same level of development of production capabilities. Japan's rising wage rates were choking growth potential for low skilled, labor intensive products and processes. But, relative to countries with complex production process capabilities Japan enjoyed a cost and, equally important, quality advantage. Hence the idea of a new production capability platform and associated growth trajectory.

and of low inventory targets. Finally, it would have meant delinking the conveyor lines and all that this implied for labor discipline.

Nevertheless, Toyota, the JIT standard setter, achieved an inventory turn (ratio of sales divided by work-in-process) approaching 300. It is unlikely that Ford ever achieved above 200 and was probably considerably below. When General Motors began to measure work-in-progress turns the rate was in the neighborhood of 6 to 8. [33]

Toyota took Ford's challenge of synchronization two steps beyond Ford. The first step, as noted, was to introduce multi-product flow. The second was more fundamental:
Equalization of the cycle times for every part. Taiichi Ohno, who is to JIT what Ford was to mass production, describes the difference between Ford and Toyota in the following words:

> Where the Ford system sticks to the idea of making a quantity of the same items at one time, the Toyota Systems synchronization production of each unit...Even at the stage of making parts, productions is carried out one piece at a time"(1978, p96).

Thus Ford did not achieve complete synchronization.[34] This would require one piece flow, or transfer lot sizes of one, throughout the production system. But in certain fabrication stages, Ford's shops produced in large lot sizes. Lot sizes of more than one entail inventory if a single car absorbs less than the lot size. In these cases the process was fragmented into separated operations with the resulting interruption in flow and throughput inefficiencies.

The reason that Ford did not produce each of the 6000 distinct parts in the same cycle-time are not hard to understand. Engineers can direct the practice of equalizing cycle time but it is best accomplished by a management system in which workers take on a quasi-technology management role. This necessitated a revolution in management philosophy. Consideration of such a move was completely alien to Ford.

The wok organization ideally suited to the challenge of multi-product flow is cellular manufacturing. The idea harks to the concept of groups technology in which work "cells" are organized by the logic of the product. The reason? Multi-product flow requires equalizing cycle times and the flexibility to have different, but equal cycle times. This enables the product mix to be varied in response to demand shifts. While cycle times vary according to the products, they are the same for each individual product.

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[33] The inventory turn ratio for GM is because GM did not take on board the challenge of equalizing cycle times. Products flow was deeply congested by the mass batch system in which plant layout was organized by machine function. Instead of sequencing machine in the order dictated by the sequence of operations required to make a part, they were groups by machining function. Materials moved back and forth from department to department in large "optimized" batchs. Inventory adjustments were used in lieu of synchronization even at the final assembly line.

[34] As noted, Ford's engineers aggressively attacked inventory waste early saw it as an interruption to flow. But they did not make the nest step to equalize cycle time foe every single piece-part. S stamping machine, for example, may stamp 100 pieces at a time. This meant that all pieces would not be in motion; some would be waiting.

Flexibility comes from first, being able to adjust the number of workers in a cell, second, quick set-up changeover design of the machines and third, multi-skilled workers. Each worker must operate not one machine, but three or four machines, and also do set-ups (and maintenance activities) on the machines. What was revolutionary at Toyota was not just-in-time productions but the idea of single-minute-exchange-of die (SMED). To produce products on the same line it is necessary to make the machines capable of being programmable (mechanically or electronically) for different products. The challenge at Toyota was to go beyond multiple products on the same line, to the idea of multiple products on the same line batch sizes of one. This meant the workers had to be able to set-up the machine and, in certain circumstance, set up several machines.

By establishing cellular production, Toyota was able to achieve the same high performance standards in term of equal cycle time as Henry Ford, but with multiple products.[35] Machines, as on Ford's assembly line, are laid out and reconfigured according to the dictates of the routing sheet or flow chart in U-cells, without a conveyor line.[36]

The new management paradigm makes possible the organizational capability of continuous, incremental innovation in the form of an accumulation of thousands of tiny improvements and an unrivaled persistence to productions detail built into the organization of production. The plan-do-check-act management paradigm of W. Edwards Deming was an organizational corollary to the principle of, multi-product flow. While Deming's focus was not on innovation but on continuous improvement of product and process, his approach to integrating thinking and doing on the shop floor introduced a new dimension to the management of technology.

For Deming, the discovery of knowledge is not the preserve of science, just as thinking is not the preserve of management. The business challenge became to built the discovery process into every level and activity of the organization. For example, the workers involved can discover knowledge about the causes of product defects if the organization is property designed. The purpose of statistical process control was not only to distinguish systems from special causes of defects but also to focus attention on improvement of the organization as the means to advance quality and productivity. The idea was to design quality into the system, not inspect it into the products. This required innovation capability on the shop-floor. It created whole new

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[35] The benefit of the Toyota production system do not stop with shorter productions lead times. Mass batch production methods are extremely costly in finance because or low working capital productivity. JIT plants require much less inventory and indirect labor per Car. See Abegglen and Stalk, and Cusumano for comparative measure of indirect to direct labor and inventory per car.

[36] Group technology developed in England in the 1950s by, among others, John Burbidge was a forerunner of cellular manufacturing. Ironically, the concept was probably developed first in the Soviet in the 1930s even though it was never used in the Soviet Union achieve high throughput efficiency (probably because it wreaked of capital productivity, an oxymoron to Marxian ideology and Soviet thinking). Burbidge believes that group technology was applied successfully in at least 11 UK engineering plants in the 1950s and 1960s. Preliminary research, based primarily on conversations with Burbidge, suggest that the experiments were successful but did not survive the transition to finance dominated management and the merger activities of the 1970s. Burbidge himself, a brilliant engineer who has authored several books on productions, did not integrate the principles of production with those of organization. Here we have to wait for Taiichi Ohno and the Toyota Production System for the first Systematic treatment.

possibilities for decentralized technology management that will take us beyond Toyota.

Multi-products flow is the mirror image of a new organizational principle, which appears in a range of variants and goes under the popular names of continuous improvement, TQM (total quality management), Kaizen, small group activity, and self-directed work teams.[37] Deming considered each of these management practices to be aspects of the "theory of systems" which, for him, meant replacing the hierarchical, up/down, vertical information flows and functional departmentalized with cross-functional relations, and horizontal, interactive information flows of process integration.[38]

The new principle of production (multi-product flow) and corollary organizational capability (Kaizen) are interdependent and self-reinforcing; neither can one be successfully applied without the other. Successful implementation, however, depends upon a prior, or simultaneously development, of specific organizational capabilities and investments in the skills to apply and convert the new production principle into production capabilities and pursue the new technological opportunities.

Equalizing cycle times in production and driving down throughput times had an even more powerful induced, although unintentional, side effect: it created the possibility for driving down new product development cycle time and introduced a new form of product-led competition. It created yet another new model of technology management.

5. TM 4:Canon and New Product Development

Driving down manufacturing process times (increasing throughput efficiency) lowers costs, improves quality, and shortens delivery times, but the logic of reducing process times is not limited to the transformation of material in production. If can be extended to, and linked into, other business processes such as new product development (NPD). The implications for technology management are profound.

While the Toyota Production System laid the foundation, consumer electronics companies applied and extended it to develop a new dimension to technology management and a new source of competitive advantage. Canon, for example, uses the same multi-product flow platform to institutionalize dynamic feedback between production and R&D. The result gives new force to product-led competition. Technology is put in the service of continuous product redefinition as never before.

[37] Each of these management orientations are secondary to the fundamental principle of system integration.

[38] Deming inspired enterprises to focus on the management of interrelationships as well as the plan-do-check-act (PDCA) paradigm of total quality management. The idea of system or process integration spread from the material conversion process in the factory to the business enterprise which became understood, not as a collection of profit centers but as an integrated set of inter-related processes such as material flow, order fulfillment, new product development, instead of a collection of business units.

Reducing new product development process time means redesigning and integrating every activity in the product development process that includes:

Product concept
- Conceptual design
- Product architecture
- Technology search and analysis
- Target market

Product planning
- Model building
- Structural testing
- Technology design viability testing
- Technology R&D and integration

Product/process engineering
- Detailed design of product
- Tooling/equipment design and specification
- Building/testing prototypes
- Master technology and engineering interfaces
- Setting standards
- Supplier tie-ins

Pilot project/scale-up
- Initial production runs
- Establish work skills and activities
- Volume production tests

Production
- Factory start-up
- Volume ramp-up
- Establish performance standards (cost, quality, time)
- Maintain standards
- Master engineering and work team interfaces for continuous improvement

Shorter new product development cycles mean more product introductions. But it has a secondary, powerful benefit: integration of NPD and new technology instruction cycles. For any given product life-cycle, product and process architecture are locked into place. To change any part requires new tooling, supplier specifications, testing, work task definitions, etc. Each new product introduction, however, is an opportunity for the adoption of new technologies and technology ideas (Gomory, 1992).[39]

The Shorter the NPD cycle the grater the opportunity and organizational capability to introduce both discontinuous or radical technological innovation and new combinations of existing technologies into production. A company that is capable of

[39] Ralph Gomery makes this point in distinguishing "the cyclic process" from a "ladder" type of innovation. "ladder" refers to the step by step process by which an innovation descends from science downward "step by step" into practice. "The cyclic process" refers to "repeated' continuous, incremental improvement" built into a series of dynamic design/manufacturing cycles.

reducing the NPD cycle to one-half that of a competitor can introduce technological innovations at twice the rate. Being first to market with a new technology is important, but having the shortest NPD process time is also important in the technology adoption as adaptations can be introduces more rapidly.[40]

The potential for rapid technological introduction induced a complimentary organizational change: the shift of laboratory technicians from the laboratory onto the shopfloor. Laboratory technicians conducting research on the shopfloor can discover new technological knowledge. What can appear as the elimination of R&D may be the development of cross-functional product development teams integrated into the production process.

In another application of the organizational principle of systems integration, the Deming critique of the functional division of labor can be applied to the science-push model of innovation. The science-push model is one of central laboratories doing R&D and pushing it on to the design engineers department and on to the production manager. In the interactive model responsibility for discovering new technological knowledge is spread from the central corporate laboratory to functionally integrated production groups. The chain-linked metaphor technology innovation has been elaborated by Stephen Kline to capture the interaction and feedback loops common to many revolutionary new products and including, for example, the jet engine.[41]

The pull, interactive model seeks to permeate R&D throughout the organization in a way that draws the customer/user into definition the of the problem and the solution. The concept of customer here is not only the final customer, but the chain of customers in which each production unit links to the next link. Decentralizing technology management for purpose of NPD mirrors the displacement of the responsibility for quality control from a central department into the operating activities of work teams on the shopfloor.

Teruo Yamanouchi, an ex-Canon Direct of the Corporate Technical Planing and Operations Center, distinguishes a range of technology categories.[42] Discovery-driven knowledge and precompetitive knowledge are the basis of a technology pyramid and overlap with the domain of science. Yamanouchi argues that technology management in the Japanese business enterprise has not made contributions to these areas of Technology knowledge. Rather, the pool of science knowledge is rapped by Japanese enterprises for purpose of identifying the third layer of generic technologies to institutionalize a Schumpeterian innovation process. Here is where the Japanese technology management system has made significant contributions.

Technology management at Canon is not a linear process beginning with generic technology. The process begins with development research for the purpose of product innovation on technology categories near or at the top of the technology pyramid. The

[40] The engineering change orders and other changes required to implement rapid new product development are not conceivable under the Scientific Management paradigm.
[41] See S. Kline, "Innovation is not a Linear Process",*Research Management*, Volume 28, July-August, pp.36-45.; "Styles of Innovations and Their Cultural Basic", *Chem Tech*, Volume 21, No 8, pp.472-480.
[42] See T Yamanouchi, *A New Study of Technology Management*, (The Asian Productivity Canter, Tokyo, 1995; distributed in North America and Western by Quality Resources, New York).

research is conducted on or next to the shopfloor. Findings at this level feed into applied research in design centers or business level labs which, in turn, leads to modifications in core technologies; where applied research are not enough, fundamental research in corporate laboratories is conducted at the generic technology level. Contributions here lead to technological advance that can feed back into scientific knowledge. The Japanese technology management system has been particularly strong at recombining generic technologies and integrating these with process technologies. However, to date, most of the Japanese contributions to fundamental knowledge has been at the generic technology level as distinct from the more narrowly defined scientific knowledge at the bottom two layers on the pyramid.

The technology management model is consistent with Deming's underlying concept of system and, as in production, led to the replacement of the pull analogy.[43] However, such a small conceptual step represents a paradigm shift in the power relationship within an existing business enterprise. In the process of creating a knowledge-discovering business organization, the activities of work, management, and R&D are profoundly redefined.[44] The new business connects Deming's focus of continuous redesign of the product to Kline's chain-linked model of technological innovation.

The new model of the business enterprise, the "entrepreneurial firm", is one that not only achieves continuous innovation built on a Deming inspired organizational method, but one that combines continuous innovation with technology management and thereby develops the capability to manage technology transitions. Canon, for example, redefined the camera by rethinking the camera as a computer with a lens. The means was to combine the electronic and optical technology (generic technologies) with precision machinery technology and component assembly technology (engineering technologies).

Canon didn't simply combine generic technologies. It adopted, adapted, and refined generic technologies and combined them in unique ways. The result was the emergence of specialized, proprietary products technologies which were not easily imitated. Firms without the Deming type organizational capabilities could not meet the time and quality standards; companies without the expertise across the rage of technologies could not match the production performance standards.

Canon did not stop here. The emergent technological capabilities gave the company sophisticated resources to target technologically related areas. Canon moved first into the electronic office equipment business by developing electronic calculators which, in turn, led to the development of digital technology capabilities. The big hit came in the photocopier business in which Canon established its unique cartridge product technology by combined technology transfers from the camera office equipment

[43] Combining the concepts of chain-of-customers and interactive of chain-linked R&R result in a organization in which each production links is also a customer to central R&D units. The resulting NPD-pull is analogous to Kanban or pull-scheduling in which decisions to produce are governed not by a centralized scheduling department but by the demand of succeeding units.

[44] The Wagner Act was not set up to deal with quality, productivity, or innovation. The plan-do-check-act of work organization is a prerequisite as is the development of a quality system.

businesses with new technologies such as electrophotographic process technology, photosensitive materials technology and toner technology.[45]

Combining Deming and Schumpeter in the same business enterprise has led to the development of an organizational chart that is unique in that two organizations functions side by side within the same company: one accommodates the costs, quality, and delivery time performance standards associated with Deming; the other accommodates technological management to drive innovation and competitive strategies based on ever shorter products life cycle.[46]

The organizational structure is designed to establish layers in the R&D process to target product development at the business unit level the development of long term core technologies at the company level. The concept of the company is defined in term of the core technologies and associated organizational capabilities. Separating the operations enables the company to engage in both incremental and breakthrough innovation. The company has relatively open channels for internal technology transfer to new business units and core technologies are revitalized as new products units are developed.

To summarize: products-led competition has engendered new organizational capabilities that involve the redefinition and integration of four process:

1. Manufacturing. The cell is the building block of the edifice; without cellular manufacturing the rest of the business system can not drive product-led competition and continuous improvement.
2. Design/manufacturing cycle. Companies need to compete on the basic of rapid new product development or they will fall behind technology adoption.
3. Technology adoption. Technologies are pulled by the first two process as distinct from being pulled by autonomous R&D autonomous R&D activities.
4. Technology R&D. Increased technology knowledge is generated by developmental research, applied research, and generic technological research.

6. TM 5: Intel and Systems Integration :From VI to SI

America's semiconductor industry was suffering in 1990. Massachusetts, the home of Route 128, lost one-third of its manufacturing jobs between 1986 and 1992. This loss in industrial leadership was not expected in high tech industries and regions.

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45 The next technological transition was to combine laser-imaging technologies to what were now core and develop a laser printer business. In each of these transitions Canon existing proprietary (or at least uniquely adapted) product and engineering technologies with new generic technologies to establish innovative products. The technologies are embedded in organizational and personnel capabilities which must be transferred and recombined in many cases into new business units specially designed to fabricate the new range of products. For discontinuous innovations, Canon developed a process of internal technology transfer into new business units rather than developing the product technologies and products in plant that had been successful in preexisting technologies.

46 The chief technologist of each center or laboratory does not report along the business system chain of command: instead reports to a technology strategy committee with the vice president of R&D as chair. The central labs, in turn, are hubs which network with the product specific research centers doted line responsibility to their respective business groups.

Scientific research in the great industrial laboratories of AT&T, Du Pont, GE, IBM, and Xerox was not being converted into a stream of commercially successful products.[47] Many warned of a "hollowing out" of American industry given the capability of the Japanese model to engage in rapid new products development, absorb technologies, diffuse innovation and achieve new comprehensive production performance standards. Manufacturing firms that built American industry such as GE and Westinghouse were down-sizing and out-sourcing of manufacturing and diversification into financial services and the media ocurred. In 1987, America's Defense Science Board, a government advisory board of distinguished scientists, claimed that the U.S. was in the lead in only three of more than a dozen critical semiconductors technologies.[48]

However by 1996 the U.S. had established a dominant position in microprocessor chips (the most technologically complex semiconductor) and strong leadership positions in personal computers, telecommunications including Internet related activities, and software. Sales in information and communication technology (ICT) related industries grew from $340 billion in 1990 to $570 billion in 1995, a period during which Japanese ICT related industries grew less than one-quarter as much, from $450 billion to $500 billion.[49] Both Silicon Valley and Route 128 were booming again.

The resurgence can be explained by the development and diffusion of a new model of technology management. The new model reinvented production by integrating manufacturing continuous technological change within a business model of focus and networking. The old American Big Business model of technological change driven by standalone industrial laboratories, had come up short against Japanese competition. Instead of ossifying. America industry has been revitalized by a business model which extends the systems integration capabilities of the Japanese production systems in two ways; first, it incorporates fundamental research, not as a driver of new development but as an integral element in the production organization; and second, it fosters dynamic, networked groups of firms linked by design modularization. In fact, the application of the concept of modularity to design has fostered new regional-based industrial dynamics with the widely diffused design capabilities celebrated in internationally competitive light industries of the Third Italy.

Intel, a volume producer of ever-faster performing microprocessor chips, is an exemplar of TM 5. The historic productivity curve for chip production has followed Moore's Law of a 30 percent reduction in cost per function per year.[50] This involves combining fast changing technologies with high performance manufacturing. Thirty percent annual increases in product performance depend upon simultaneous advance in integrated circuit design tools, production technologies, and miniaturization capabilities.

[47] Seven Novel prize were awarded for sciences breakthroughs at Bell labs. Most of the major labs were associated with breakthrough innovation that has redefined whole industries such as the transistor at Bell labs or nylon at Du Pont. Nevertheless al have suffered loss of support.
[48] *Economist,* September 16, 1995, Survey, p4
[49] *Economics,* March 29, 1997
[50] For example, in 1960, the average selling price for a transistor was $5.oo;by 1985 an integrated circuit containing 500,00 transistor sold for $5.00(Dahman, IBRD, p32).

Just as the microprocessor is a driver of the American industrial resurgence, Intel is a symbol of America's manufacturing recovery. In fact, the micro-processor is a driver of American industrial growth in the information age of the turn of the century, like the machine tool was in the era of the the steam engine in the railroad age, the dynamo during electrification, and the car in the era of mass production.[51] Not surprisingly, as the leading microprocessor maker, Intel invested $10 billion in complex manufacturing plants in the first half of the nineteen-nineties. Chip-fabrication plants are among the most complex manufacturing plants in one of the most internationally competitive industries.[52]

Strikingly, Intel has never owned a stand-alone R&D laboratory.[53] This Company policy decision was based on lessons gained from experience in the semiconductor industry by Intel founders. Moore observed that the premier semiconductor firms that invested in central research laboratories suffered from two major barriers to successful technology transfer and commercialization. The result was slow "time to market", an issue of paramount importance to Intel. The first barrier was resistance by manufacturing. Ironically, the barrier became greater as companies with stand-alone laboratories upgraded their production organization. In Moore's words:

> "... the more technically competent a receiving organization [product and process divisions] becomes, the more difficult it is to transfer technology to it, As the production organization became more successful and began to recruit more technical people...technology transfer became more difficult. Production, it seemed, had to kill a technology and reinvent it in order to get it to manufacturing"(p.167)

The second barrier was resistance to technological change by companies with success in earlier generation technologies. In fact, an inherent disadvantage is built into their very success in past technological advances.[54] Again, in the words of Moore:

> "... because these companies are large, successful and established, they tend to have difficulty exploiting new ideas...Running with the ideas that big companies can not cope with has come to be the acknowledged role of spin-offs or start-ups" (p.171)

Does this mean that Intel does not engage in R&D? Quite the contrary. Intel's R&D budget exceeds $1 billion annually. Emphasizing the D in R&D, Intel opted for the co-location of development research and manufacturing: "development would be conducted in the manufacturing facility."[55]

Intel divides research into two types: research that "require[s] integrated manufacturing capabilities to examine," and "chunks" that do not require state of the

[51] Chris Freeman and Carlotta Perez
[52] One hundred sixty companies in the industry (Dahman, p32).
[53] Moore, p168
[54] Moore's argument is not that laboratories have not contributed to the dynamism of the semiconductor industry or been highly successful in developing new technologies. It is a free rider problem. "The large, central research laboratories of the premier semiconductor firms probably have contributed more to the common good than to their corporations"(p.171).
[55] Moore, p168

art semiconductor technology. Intel focuses on the former and networks with universities to get the latter. Moore notes that a number a processes in semiconductor manufacturing are "more of an art than a science", the plasma etching process, for example, is not well understood. Universities have supplied invaluable research in, for example, parallel processing as well as design automation software (p.172).

Intel's integrated-manufacturing focus requires the construction of full scale experimentation plants.[56] For Intel, new product development is simultaneously new process development. Experimentation is carried out under full scale manufacturing facilities under actual, not simulated, operating conditions. In the words of Moore:

> "with a product as complex as semiconductors, it is a tremendous advantage to have a production line that can be used as a base for perturbation, introducing bypasses, adding steps, and so forth. Locating development and manufacturing together allows Intel to explore variations of its existing technologies very efficiently."(p.128)

The experiment plants are enormously expensive. Instead of a "lean" production team driving high throughput, the experiment plants are plants operated by technology-integration teams. The teams do not conduct fundamental research but collectively team members are familiar with a whole range of technology domains each with deep roots in fundamental science.[57] The experiments may involve an entirely new chip in which case many of the technologies will be novel applications, some of which will have never been used before (Iansiti and West, p70). Or a team may be developing a new version of an existing chip. Intel, for example, produces 30 different kinds of the 486 chip (Economist, March 23, 1996, p 21). Here, too, experiments will be conducted on novel applications and combinations.

The experimentation activities address the challenge of integrating every advancing technology into full scale manufacturing plants as distinct from innovations in individual technologies. The systems integration challenge is not unique to the new model of technology management. In this Intel does not break with earlier models of technology management. Henry Ford and his chief engineer, Charles Sorensen, would have understood the challenge and rewards of system integration. Applying the principle of systems entails redesigning the products from inside out and outside in to enhance flow. Popularly known as concurrent engineering, new products (inside) are designed simultaneously with production (outside).[58]

System integration alone does not captures Intel's uniqueness. System integration is a static concept with respect to *component design rules;* it does not imply openness to innovation or technological change. In fact, the challenge of system integration exerts pressure to freeze technological change. Kaizen, or continuous improvement

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[56] For details on Intel's technological see Marco Iansiti and Jonathan West, "Technology Integration :Turning Great Research into Great Product", *Harvard Business Review*, May-June 1997, pp. 69-79. Other reference include" Silicon Valley: The Valley of Money's Delight", *Economist*, March 29, 1997 and[omit : on Intel's basic budget is a minuscule $10 million annually but Intel funds work at universities and national laboratories] (*Business Week*, May 26, 1997, p.170)

[57] Iansiti and West point out that a number of the technology-integration team members will be recent graduated who have done dissertations on fundamental science.

[58] Sorensen's description of Avery, a one off operation but later refined.

management experimentation and technological improvement *holds basic technology design rules constant.*

The domain of systems integration encompasses design rules: those at the level of individual technologies or sub-systems and those that integrate sub-systems into a single system. Systems integration pulls into the management or production organization the challenge of technology design rules at both levels. The challenge is to co-manage manufacturing processes with processes of integrating and reintegrating technologies themselves being independently redefined. Further, the process of integrating sub-systems is not an additive one, particularly when sub-systems have independent design and development dynamics. Interactions amongst subsystems have dynamic feedback effects.

Intel's concept of integrated manufacturing in which research experimentation and manufacturing are co-located is a response to the challenge of (complex) systems integration: change in individual components will have system altering effects some of which can not be identified or measured except in actual operating conditions.

Intel addresses complexity with the principle of design modularization and business strategies of open systems. Modularization in production goes back to interchangeability of parts, an early application of modularity. The implementation of interchangeability required precise measurement that was facilitated by the development of gauges, an original and integral feature of the "American System". Modularization in design is new. It enables systems integration and the incorporation of rapid technological change. Common interface platforms unleash design potential in every component supplier by enormously expanding the potential market size for the assembled product.

Instead of designing its own equipment or complimentary components for the various uses of microprocessors, Intel establishes and publically discloses parameters for makes of chip making equipment and for users of Intel chips *for the next generation of microprocessors.* Following the precepts of design modularization, equipment manufacturers build to performance requirements established by Intel. Equipment makers, in turn, independently and privately design machines that will be inserted into Intel's chip fabrication plants. The challenge is to meet interface design rules which themselves incorporate in Moore's law rates of performance improvement.

Why do equipment manufacturers play the game and invest heavily in design? In part, because Intel is the standard setter. Intel, along with Microsoft, establishes the technology platform for the PC. The computer makers, Microsoft's and applications software producers must design next year's products according to the performance parameters of the central processing unit. Similarly, the equipment manufacturers must fall in line. With open systems the U.S. PC industry has developed a model of industrial organization that has demonstrated unprecedented rate of technological innovation and diffusion.

Ford was acutely aware of the opportunities offered by redesigning a whole system to fit the requirements of a seemingly independent technological innovation. Ford, as noted above, redesigning the production system to take advantage of new electric power technologies, particularly, distributed or fractionated power designed into each machine. Technology management for both Henry Ford and Intel involves a double redesign challenge: redesign of technologies to fit the new technologies and technology combinations. Ford's engineers revamped machines to fit the cycle time standard by adjusting, for example, tooling, materials and machine speeds. Ford and Intel do not simply add new technologies to the existing system, the idea is to redesign the system to take full advantage of the new technology to make a leap in production performance. But Intel, unlike Ford, designed an organizational model geared to integrating new technologies on a continuous basic. Ford's system redesign was a one-off for all commitments. Thus the central role of cross-functions teams at Intel, a concept that would not have appealed to Henry Ford.

Unlike Ford, Intel depends upon, and reinforces, an industrial district constituted by multiple design nodes. Intel not only partners with a vast array of specialist producers and research institutions; Intel draws an extended industrial high tech district with an extraordinary capacity to conduct experiments, carry out innovations, and conduct research.

The semiconductors manufacturing industry in the U.S. has more than 1000 firms. In contrast, Japan's semiconductor manufacturing industry is highly concentrated with 12 companies accounting for 75 percent of sale.[59] Most of the Japanese semiconductors manufacturing companies are members of *keiretsu* supplier arrangements.

Turning to sales, distributors in America service a customer base of over 150,000 firms "which are generally small and medium-sized companies in the computer, telecommunications, aerospace, instrumentation, and defense industries".[60] A number of distribution firms differentiated themselves by establishing design centers. This has been associated with a dramatic increase in the application specific integrated circuit (ASIC) market. In contract, the five largest semiconductor producers in Japan (NEC, Toshiba, Hitachi, Fujitsu, and Mitsubishi Electric) have built-in customers in the form of consumer electronics, computer, and communication division.

Intel is also adept at TM in terms of defining research projects and networking to tap existing technology bases in the integrated process of pulling technologies into the production system. Moore describes Intel's transition in primary site for identifying relevant research:

> "In its early years, the company looked to Bell laboratories for basic materials and science related to semiconductor devices; it looked to RCA's Princeton labs for consumer-oriented product ideas; and it sought insights into basic materials problems and metallurgy from the laboratories of General Electronic. Over time, Intel found that most of the basic R&D relevant to its needs was being done by companies such as Fairchild and Texas Instruments, which had evolved to become the products leaders in semiconductors.
>
> Today, Intel looks to Universities for much of the basic research...the semiconductor Research Corporation (RSC) established in the early 1980s by

[59] Dahman, p.34-35
[60] Dahman, p 35

the semiconductors Industry Association (SIA)...taxes large numbers of firms and users and then deploys the monies [sic]raised to promote university research..."(p.170).

To summarize: For Ford and Toyota, the challenge was to synchronize by equalizing cycle times; for Canon the challenge was to reduce new product development cycle time which involved enhancing the introduction of established technologies new to Canon. For Intel the challenge is integrate all of the technologies required to make a chip along an emergency technology trajectory in which productivity is advancing 50% every 18 months. This is not simple, as many of the activities are rooted in distinct science-technology domains with unique science lineage and physical characteristics.[61] Intel alone of the three, built a business model based in the principle of design modularization. Canon and Toshiba have substantial systems integration capabilities. They, like Intel, integrate new product development with process reorganization. However the participants of TM4 have not redesigned their business systems to capture the innovation potential offered by the principle of design modularity. To do so would mean moving from a closed to an open systems model of supplier relations and industrial organizations.

Conclusion

The challenge of system integration in production is common to all five models of technology management. But TM4 and TM5 integrate production and new product development and thereby push design to center stage. For TM1, the concept of interchangeability acts as an interface design rule to ensure compatibility; for TM2 and 3, the concept of flow is achieved by the interface compatibility rule of equal cycle times. The interface design rules present a new challenge with the integration of production and new product development associated with both TM4 and 5. While machines in isolation are relatively well understood, the interactions that occur within systems that combine technologies or combine material information flows are less well known. In lieu of purely analytical theorems (formal algorithms) to capture the independent, systemic effects, high performance production systems depend upon the practical evolution of system integration design rules.

System integration in TM4 involves combination, fusion or, the once and for all integration, of technologies, such as the integration of electronics and mechanical technologies into mechatronics. TM 5 extends the challenge of system integration to designing interface rules for systems constituted by more than one sub-system each grounded in distinct technologies which operate according to different design rules. The systems integration can involve the integration of, amongst other, hardware and software, technology and organization or independently dynamic technologies.[62]

[61] In this conception of technology, Intel's application is closer to the Japanese tendency to conflate science and technology into the single term science-technology. Kline, Rosenberg and other offer many examples of technology assisting in the development of science. Astronomy, for example, depend upon advance in optical instruments.

[62] For example, material advance that alter the physical characteristics of the transistor will the design circuitry (a commination of hardware and software) and thereby the interactions between operating system software and the hardware which, in turn, will alter the material characteristics which, will

The management of system integration required interface rules that account for, or otherwise deal with, interactive system effects. Solutions to systems integration problems can not be solved by centralized interface design rules alone; solutions depend upon the capacity to integrate two sets of independently governed and dynamic design rules: overall system and sub-system. This is the domain of design modularization. Complexity here is defined in terms of dynamic interplay between system and sub-system design rules.

demand changes in software and alter the performance of the system. These change, in turn will impact power requirements and heat characteristics which, in turn, will effect information processing speed.

Appendix 5: Institutional Audit

Institutional Audit: Electronics and Electrical Sectors

Category	Institutions/Programs	Roles/Functions
FINANCIAL	Development Bank of Malaysia: 1. New Entrepreneurs Fund (NEF)	1. Promotes funding programs to Bumiputera enterprises under the Asean-Japan Development Fund scheme.
	Industrial Bank of Malaysia 1. Shipping Fund A. RM500 million shipping venture facility (SVF) B. RM300 million Ship Financing Facility (SFF)	A. To mobilize institutional funds in conjunction with the Government to raise private shipping capacity in the country. B. 1. Provides long term financial assistance as well as equity financing to all eligible shipping companies 2. RM65 million – domestic shipping 3. RM185 million – international shipping 4. RM50 million – equity financing 5. 1995 budget – additional allocation RM300 million to SFF – RM100 million will be allocated to finance domestic shipping while RM200 million is for shipyards in a move to promote the ship repair and shipbuilding industry in Malaysia.
INFRASTRUCTURE	Railway Services 1. KTM Berhad	1. transports several classifications of goods ranging from grains to machinery
	Industrial Estates	Provides basic infrastructure such as roads, water, and transportation
	Free Zones Bayan Lepas, Prai Prai Wharf Batu Berendam Tanjung Kling Sungai Way Ampang Hulu Klang Telok Panglima Karang Johor Port Therity Industrial Land Jelapang Kinta Muara Labuan	Specially designed for manufacturing organizations producing or assembling products for export in order to enable them to enjoy minimum control and formalities in their importation of raw materials, parts, machinery, and equipment as well in their exports of finished products.

	Licenced Manufacturing Warehouses (LMW)	In place of FZs if the latter are not practicable or desirable; encourages the. dispersal of industries and enables companies to establish factories for the manufacture of products mainly for the export market.
	Electricity supply TNB for Peninsular Malaysia SESCO for Sarawak SEB for Sabah	Provides electricity supplies throughout Malaysia, transmitting voltage of 275uv, 132v, 66v, 33 u & v, 22uv, 11uv, 6uv, & 15v three phase or 230v & single phase & systems frequency of 50HZ
	Water Supply Water Works Department	Provides the water supply
	Telecommunications service TNB Celcom Binacom Binariang Kilatcom Emartel Sapura	Provides a full range of domestic and international voice message services, and data communication facilities with international circuits and optic fiber systems
	Air-cargo facilities Subang - KL International Airport Penang International Airport Kota Kinabalu International Airport Kuching International Airport	
HRD	PSDC	PSDC offers 2 types of training; namely job-skills enhancement and career advancement programs in four major categories, i.e. computer, manufacturing, management, and technical courses.
	Human Resource Development Fund	Set up for the purpose of developing and promoting the upgrading of skills in the workforce
	Ministry of Youth & Sports	Responsible for planning, monitoring, and coordinating skills training
	Ministry of Public Enterprises	Provides industrial training courses
	German-Malaysia Institute	Produces highly skilled technicians in the field of production technology and industrial electronics
	Center for Instructors and advances (CIAST)	Offers courses and skill training for instructors, supervisors, and skilled workers with the objective of providing post employment training

	Industrial Training Institute (ITI)	Provides full time training for school leavers, skill enhancement training for industrial workers, and customized industrial courses. The 3 main categories of courses are; electrical, electronics, and mechanical.
	Japanese Malaysian Training Institute	Provide courses with foreign aided training
	French Malaysian Institute	Provide courses with foreign aided training
	SIRIM	Provides industrial management training programs for personnel and R&D training
	MIMOS	Provides industrial management training programs for personnel and R&D training
	A time sector privatization scheme under the Dept. of Manpower	Providing the private sector with facilities in industrial training and institutions to train workers.
	Ministry of Home Affairs	Monitors the approval of applications to engage foreign labor.
	Dept. of Industrial Relations	Provides advice to the Minister on all industrial relations matters and related legislation, and to employee/employers organization, workers trade union and others on industrial relations matters.
	Malaysian Trade Union Congress	Plays a vital role in matters affecting industrial relations as a whole. It performs a particularly valuable service in promoting industrial democracy, information technology exchange, and consultancy among members.
	Malaysian Commercial Banks Association	Upgrades manpower skills in banking
	States of Malaya Insurance Association	Upgrades manpower skills in the insurance industry
	Personal Links by Malaysian Technologist (MINDS)	A source of technology based companies in Malaysia, esp. scientist and engineers, licensing (IPR) works
	Malaysian Technology Consultants	Responsible for marketing the services of SIRIM and other related institutions; further strengthens the support available from the govt. and SMI's.
UNIVERSITIES	Universities	Advanced Skill Training & Research
	Universiti Kebangsaan Malaysia	Focuses strength is in the area of water treatment and management of environmental technology

	Universiti Malaya	Strong is in the areas of lasers and opto-electronics for industrial ecosystems as well as conservation and environment engineering research focusing on electromagnetic wave propagation, fault analysis, monolithic crystal design and separation processes.
	Universiti Sains Malaysia	Environment, computer aided translation, information technology, geographical information, distance education, and robotic visions.
	Universiti Putra Malaysia	Environment conservation and the sustained use of natural resources, increased use of automation
	Universiti Teknologi Mara	Product research in the area of technology, applied sciences, and communication. The 3 main research thrusts are: advanced manufacturing, processing materials and structure, analytical and graphical computerization Others area include; Consultancy Environmental analysis Engineering and design analysis, planning, simulation, software and product development.
REGULATORY ENVIRONMENT	SIRIM	Regulates several types of industries that are involved in issues pertaining to health and safety Provides a support role for industries in the setting of standards to serve as a guide in acceptable standards in the different areas of the manufacturing sector Representative of foreign regulatory agencies in the certification of products
	Labuan Municipal Council	Ensures and implements policies stipulated in the enactment and by-laws of the council on matters pertaining to the local authorities.
	Management Division - STEM	Governs the general administration, personnel management and training, finance, office security, implementation of development projects and coordination of various activities in the Ministry to achieve the goal of the Ministry.
	Department of Environment	Enhances and improves the quality of the environment to achieve a better quality of life, balanced goals of socio-economic development.

Appendix 6: Penang Skills Development Centre

The State Government of Penang and the Penang Development Corporation partnered with industry, particularly MNCs, to establish the first industry-led training institution in Malaysia.[63] At a seminar organised by the American Business Council in September 1987, the problem of skilled manpower shortages was highlighted. In the process of a series of meetings with CEOs of MNCs, the concept of a technical training centre in Penang was developed. In April of 1989, the concept of the Penang Skills Development Corporation became a reality with the election of a Management Council that in turn garnered the pledge of 24 companies to become Founder Members. The mission of the PSDC is as follows:

> "To be a Resource for the Promotion of the Shared Learning for Manufacturing & Service Industries by Providing Proactive HRD Initiatives to Strategically Support & Strengthen Business Requirements."[64]

Nine years after its opening the PSDC has 81 member companies employing over 75,000 workers.[65] The 21 member Management Council consists of 11 elected, 4 appointed, and 6 ex-officio members representing industry, government, and educational institutions. All companies are entitled to send members to the Training Committee, which is divided into two sub-committees which "...identify and recommend course work within a specific section (job enhancement and career advancement) of the overall training program". The training sub-committees are for defining training needs; they oversee an annual training needs analysis, prepare an annual training calendar, obtain feedback and evaluate the effectiveness of courses, encourage sharing of resources among member companies through the PSDC, and assist the Executive Director in funding efforts. [66]

The participation of industry in the management structure of the PSDC has fostered a matching of skill demand and supply. Virtually co-located with member companies, the PSDC is easily accessed. Nearly 40,000 have been enrolled in courses, which have grown from 32 courses offered in 1989-90 to 495 in 1997/8. [67]

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[63] Many argue that Japanese FDI In Malaysia tends to be involved in minimal technology transfer. It also appears that a division of Japanese companies in Malaysia relies on ex-patriot top management with little use of local managers. See Itagaki (1997).
[64] PSDC, 1998, p. 3
[65] PSDC, p. 1
[66] The material in this section is based on publications of the PSDC and an interview with its executive director Boonler Somchit.
[67] PSDC, p. 11

Appendix 7: Case Studies of Successful Electronics Companies in Malaysia

1. Motorola, Penang

1. Activities and operations

Motorola has five sites in Malaysia, two in Penang, two in Seremban and the other in Kuala Lumpur. Both the Seremban and KL plants produce semiconductor products.

Motorola Penang is involved in the land mobile products sector as well as the automotive, energy, and controls sectors. The Motorola Penang plant was established in 1974. It began to localize its management in 1989.

Motorola's land mobile products operations comprise of a hybrid/chip carrier factory, a portable radio factory, a mobile radio factory, an R&D design center, and a logistics/distribution center. The automotive energy component operations comprise a battery flex/battery factory.

2. Future Plans of Motorola

It is envisaged that by the year 2000, the Penang plant will have its own design resource center for Asia and be involved in applied research. It is anticipated that this design center will help spawn other Motorola design centers in Asia. In fact, this center has been supporting a number of regional initiatives with resources from Penang. Its counterpart in the US is even looking upon Penang to be the hub of their expansion in the region.

Today, Motorola Penang is highly automated and CIM (computer integrated manufacturing) is heavily used. However, the management does not foresee a true "lights out" (fully automated) scenario in the near future. The company has been working aggressively on improving productivity to gain more output with less human intervention. However, it is still too early to forecast the achievement of this effort as hefty investment is required to attain this goal.

For the year 2000 and beyond, Motorola Penang anticipates that they can develop towards AMT consultancy, where new technology research will be carried out. The Penang plant also anticipates that they will be capable of providing consultancy services to the other Motorola plants in the region.

3. What are Motorola's success factors

3.1. Growth in R&D

In the 1970s, there was a transfer of technology from the US to the Penang plant. Joint programmes were carried out and the Penang plant was involved in matrix pager and HT440/90 portable production. Motorola Penang began to carry out R&D in 1976.

By the 1980s, Motorola concentrated on building its capacity in software support. It was also involved in the envoy pager, Genesis and Jedi portables. Co-design was carried out in the 1980s between Malaysian and US engineers for products meant for the US market.

In the 1990s, the Asia Design Center was set up and reverse transfer of technology began to take place. Design works were fully carried out in Malaysia (from scratch). Other than localization of management, there was also localization of R&D, where the Penang plant designed and developed products for the Asian markets. There are more than 120 personnel attached to the R&D section and of this total, 95% of them are engineers. There are about 6 engineers per product group. However, the R&D efforts are still very much confined to development and design of products and processes with only a few applied research projects undertaken in collaboration with the University Science of Malaysia (USM). These products are meant for the global market.

3.2. Growth in Manufacturing Technology

In the 1970s the production process was basically manual assembly. The machinery used included hand placement, and pick & place machinery.

By the 1980s, automation set in and there was auto assembly of chips utilizing software control. At the time SMT (surface mount technology) machines were used in addition to vision robots as well as integrated auto-test equipment. Motorola Penang received its ISO 9002 in 1987 and was awarded ISO 14001 on September 23, 1999.

In the 1990s, Motorola Penang began to utilize advanced manufacturing technology (AMT). This includes utilization of CAM (computer aided manufacturing) systems, flexible manufacturing, applied research, as well as the setting up of a manufacturing resource center. In addition, automation is also viewed as important in design activities. Automation has helped to cut the amount of manpower required in design, by half.

3.3. Supplier Development

Motorola Penang spawned a local company called BCM, which has graduated to the ODM stage. Many of the managers and engineers were encouraged to cross over to BCM during the initial stage of the firm's development. Assembly and test operations were subcontracted out to BCM and another locally owned firm, Unico. Other suppliers include Wong Engineering, Datin Onn (a Bumiputra company located in Taiping doing PCB), and Actacorp.

3.4. Human Resource

Motorola's Penang plant today employs more than 2000 workers. Labor turnover is about 10% per annum and is higher, about 15%, for production workers. It does not employ foreign workers. The management team comprises Malaysians, and about 40% of its workforce comprise engineers and technical staff. Degree holders account for about 25% of the total headcount, out of which first degree holders account for 84%, Masters degree holders – 15% and PhD holders account for 1% of the total number of degree holders.

3.4.1 Human Resource Development

Motorola believes in training its workers. It is compulsory for each worker to go through at least 40 hours of training per annum. In actual fact, most of its workers receive up to 70 hours of training per annum. The Mutiara project implemented by Motorola is a classic example of the company's efforts in enhancing the skills level of its workers. Under this program, production workers are sent for training in order to upgrade their technical skills to enable them to carry out basic technical tasks.

In addition to this project, Motorola also sends its workers for various courses, which include the following:

- Masters in Industrial Management
- Masters in Electrical Engineering
- Masters in Mechanical Engineering
- Masters in Business Administration
- B. Sc. In Manufacturing Management
- Engineering Council
- Business & Technical Education Council Diploma
- Business & Technical Education Council Certificate
- Mechatronic Course for Supervisors
- City & Guilds 271 Telecommunications FTC
- City & Guilds 803 Electronics Engineering FTC

Although the management feels that the supply of labor force matches the company's demands, training is still required to ensure productive resources. Skill requirements are job specific and common sense as well as the appropriate attitude are important. The company recruits experienced people as well as fresh graduates and school leavers. It feels that it is easier to get the relevant skills in the US and therefore, conducts cross training with the US. What is required is product design knowledge, which is the key infrastructure element required for future growth.

Finally, Motorola Penang's plant has managed to train world-class managers and its managers are now attached to the following Motorola plants:

- 3 factory MDs in China
- 1 factory MD in India
- 3 VPs in Singapore
- 1 VP/Country Manager in Kuala Lumpur

3.5. Distribution & Marketing

Motorola set up its logistics/distribution center in Penang in January 1998. This center administers orders and distributes all walkie-talkie products, which are manufactured in Penang and from Motorola facilities in the region. This center also distributes parts and accessories for after sale service.

3.6. Remanufacture/Refurbishing

The latest trend in the industry is the remanufacture/refurbishing activity. Today, in addition to assembly, test, design, R&D, as well as logistics, Motorola Penang has begun to carry out the activity of remanufacturing/refurbishing. As in the case of design and R&D, the remanufacturing/refurbishing activity requires highly technical skills, as the personnel involved must have the capabilities of failure analysis, trouble shooting, as well as product repair.

4. The following lessons can be learnt from Motorola.

4.1. Emphasis on R&D

Motorola's emphasis on growth in R&D runs contrary to what is happening in indigenous firms. It's initial transfer of technology from the US to the Penang plant allowed for the Penang plant to develop a strong position. Co-designing efforts between Malaysian and US engineers, for products meant for the US market, strengthened the market position of Motorola. Motorola also noted the need for R&D for products specifically made for this region. The emphasis on R&D allowed for marketing orientated programs, and allowed Motorola to provide the required products to the market.

4.2. Improvement in Manufacturing Technology

The initial manual assembly in the 1970s was quickly changed to automation by the 1980's. By the 1990's Motorola Penang began to utilize advanced manufacturing technologies (AMT). This has reduced the amount of labor required while increasing productivity and efficiency. Indigenous firms would do well to emulate this strategy.

4.3. Supplier Development

Motorola Penang developed a local company (BCM) and encouraged it to become an ODM. The sharing of skills, by allowing managers to transfer to BCM, and further subcontracting to other local firms strengthened Motorola's position in the country. The transferring of skills built up local companies and provided a supplier ring that was able to provide quality products that meet the requirements of Motorola.

4.4 Human Resource Development

Motorola believes in training it workers. Its Mutiara project enhanced the skills level of its workers. Workers that have upgraded their technical skills are able to carry out technical tasks. This emphasis on training allows for the development and maintenance of skilled workers, thus helping the productivity and efficiency of the plant. This belief in training must be adopted by indigenous SMI's in order to better their workers and therefore the firm.

4.5. Distribution & Marketing

Motorola's logistics/distribution center in Penang administers orders and distributes all of Motorola's products to markets in the region. Such a concentration in distribution and marketing efforts allows for a quick reaction to customer demands. It also allows for market information to be gathered and distributed to management, allowing for modifications in the production process that better meet customer demands.

5. Conclusion

There is an emphasis by Motorola on R&D and the development of its own human resource as well as its suppliers. This is in order to develop an essential skill base as a forerunner to the firm's progression up the value added technology spectrum.

Motorola's emphasis on R&D, improving its manufacturing technology, developing its suppliers, developing its employees and an emphasis on distribution and marketing has provided it with a long term competitive advantage for the provision of telecommunication products. Indigenous firms must emulate these success factors in order to progress up the technology value added spectrum.

2. Intel Penang

1. Activities and Operations

Intel in Malaysia has 2 sites, the first is in Penang, which commenced operation in 1972, and the second at Kulim Hi-tech Park, which commenced operation in 1996. The company has 12 buildings in Malaysia, 2 of which are in the Kulim Hi-tech Park. Intel employs a total of approximately 8,000 employees. Presently, 29.29% of its 8,000 odd workers fall under the engineer & technical staff category. About 21.8% of its total workforce are degree holders. Bachelor degree holders account for 92.1% of the degree holders while Master degree and PhD holders account for 7.2% and 0.7% of the degree holders respectively. Intel's investments in 1998 totaled RM 1.6 billion, a 1,000 fold increase from its initial investment of RM 1.6 million in 1972.

Intel's products in Malaysia include microprocessors, microcontrollers, motherboards, chipsets, network chips, cartridges & mobile modules. Its current products include OLGA (organic LAN grid array) and FCPGA (flip chip pin grid array).

After TYTX, FA, QIP, and risk assessment, Intel Penang has begun to implement Packaging Design. The Penang plant started with ceramic packages, which were then followed by plastic packages. In late 1998, the Penang plant carried out design for organic packaging and recently the packaging for OLGA.

The design center emphasizes training and yield optimization during the 1990-1991 period. By 1992-1994, it was handling fab migrations projects, cost reduction projects and proliferation projects. Its first patent was awarded during this period. Between 1995 and 1997, the design center achieved its original design for the products (MCS251, K21, CPU, USB) and had 4 patents pending. Intel Penang participated in new chipset programmes and had its own new chipset project during the 1997-1998 period. During the same period, it had its 2nd patent awarded.

In 1993, the micro controller design center was established in Penang. The center is responsible for the design of the 8-bit controller and 16-bit controllers. Today, the 8-bit controller business is shrinking and Intel Penang has begun to sub-contract the assembly works out to ASE, a Taiwanese subcontractor in the semiconductor business. In addition to the 8- and 16-bit controllers, Intel Penang also designs the chipsets.

Intel Penang also ventured into the area of test tooling, the design of Test Interface Unit hardware, and design of software for the TIU. In addition to the TIU, Intel Penang plant is also capable of designing the burn-in boards for their own products. In 1999, Intel started to design motherboards in its Kulim Hi-Tech Park plant. Intel Penang is also producing the 5-layer metal FA. In addition Intel Penang personnel are now providing training on metal layer FA to staff in the US.

2. Future Plans of Intel

Intel has not completely utilized CIM equipment. Automation in this context refers to process automation and integration. The management of Intel does not think that they would go completely 'lights-out' (fully automated) as there is still a lot of work and improvement to be done before this can be accomplished. This will be carried out in the future.

Today, Intel is phasing out its last assembly and test plant in the US. Although Intel plans to have a fabrication plant in Asia, it is not necessarily going to be in Malaysia. Intel's manufacturing facilities are in Costa Rica, Penang, Shanghai (memory and flash), and Manila (flash). Today, most of the new technologies from the HQ come to Penang first.

Intel's next strategy is toward sub-USD 1,000 PCs. It also plans to set up a learning center for manufacturing technology. Although Penang is still a high volume production center, it is moving toward flexibility and product development as well as packaging development. To support the falling prices of PCs, cost reductions are pertinent and there is also a need to sustain the Internet economy.

Meanwhile, Intel has set up another plant at the Kulim Hi-Tech Park. Initially, it was supposed to do PCBA services for motherboards but has since sub-contracted the work out to Solectron and Unico Technology. The Kulim plant is now doing single edge cartridges for chipset as well as network & communication chips, and carrying out design for motherboards. Intel plans to expand its capabilities to chipset architecture, system validation, system level simulation, design automation and standard cells library work.

3. What are Intel's success factors?

3.1 Emphasis on R&D

Intel Penang's emphasis on R&D is shown through the various research and product development activities it has carried out. As an example, Intel Penang carried out Packaging Design, from the early stages of ceramic packages through plastic packages, organic packaging, to packaging for OLGA.

Intel obtained its first patent in the period 1992-1994. Between 1995 and 1997, Intel Penang achieved original design for the products MCS251, K21, CPU, USB and had 4 patents pending. Intel Penang obtained its second patent in the period 1997-1998.

3.2 From Assembly to Test

Intel Penang graduated from assembly work to testing and designing in six years. Initially Intel Penang took advantage of the availability of cheap and trainable labor in Penang. In 1978, Intel Penang advanced to test manufacturing.

Prior to 1978, testing operations were only carried out in the US. In order to carry out testing operations, Intel Penang employed only Masters degrees and PhD graduates. All the workers who were recruited for testing operation are Malaysians. Half of the workers were trained abroad, while the other half were trained locally.

3.3 Automation

Automation at Intel Penang commenced around 1978, and today Intel's production lines can be considered fully automated, although not completely 'lights-out' (utilizing CIM equipment).

3.4 Transfer of Responsibility

In 1985, Intel initiated the TYTX approach (transfer of responsibility from US to Penang). Engineers from the Penang plant were sent to the US for on-the-job training. The Penang engineers recorded what they learned and this was then documented into training manuals used in Penang. Through the TYTX approach, transfer of know-how and equipment was carried out.

The process of transferring responsibility was carried out in stages, first the engineering group and Q&R group, followed by FA, QIP and risk assessment. This synergistic program benefited Intel Penang, and it won an award at the International Reliability Technical Symposium in 1988.

3.5 Logistical Systems & Business Services

Between 1979 and 1980, the JIT concept was introduced and implemented in Intel's production floors. By 1982, Intel Penang started its Customer Support Group.

In 1994, Intel business services unit was transferred to Penang. The business services unit initially handled microprocessors and gradually increased its responsibility to other products such as embedded processors. Intel Penang increased the pre-tax profit from 5% to 16%. This is attributed to:

- integrated business planning in Penang
- better rapport between the distributors and Intel sales people
- reduced costs (Penang had 20 people compared to 60 in the US)
- good rapport with the wafer fabrication people
- close collaboration with the design team
- personnel trained in marketing skills

3.6 Human Resource Development

Intel human resource development starts even before a person joins the company. Intel provides scholarships to under-graduates who excel in their studies in order to be able to hire the best engineers that are available in the market. Those that obtain scholarships from Intel have to serve Intel for a specified period of time.

Intel Penang also offers in-house (local and overseas) training programs, job enhancement and workforce transformation. Production operators are trained to handle simple technical tasks that used to be carried out by technicians. Technicians on the other hand are trained to handle simple tasks carried out by engineers, such as testing. To do so, the technicians are sent for training in mechatronics for 2 to 4 years.

3.7 Supplier Development

Supplier development in Intel focuses on five major areas, namely:

- Development of engineering skills, process technology as well as automation
- Resources emphasizing capital equipment and human resources
- Training on manufacturing, product technology and management skills
- Safety encompassing the contracting safety program
- Quality control, which namely means 'do it right'

Intel's assisted in establishing and managing Altera and AIC, local joint venture firms, which carry out mask design. AIC has its own design team mainly in assembly and testing. Two of Intel's people left for AMD's NVD design center in Penang.

4. The following lesson's can be learnt from Intel Penang

4.1 Emphasis on R&D

Intel's emphasis of R&D runs contrary to what is occurring in indigenous firms. It's transfer of responsibility and technology from the US to the Penang plant allowed Intel Penang to develop. The various research and product development activities Intel Penang has carried out allowed it to provide products the market requires. Its emphasis on R&D also provided Intel with two patents and 4 patents are currently pending.

4.2 From Assembly to Test

Intel Penang graduated from assembly work to testing and designing in six years. This is in itself an achievement. This indicates that there is potential for firms currently involved in assembly processes to move up the technology value spectrum. This can be achieved in a relative short period of time given an emphasis on R&D and skill development.

4.3 Automation

There has been a drive towards automation, which has increased cost efficiencies. Though Intel may not have fully automated systems, the drive towards automation has reduced its reliance on low cost labor assembly processes and allowed personnel to develop their skills. Given the increase in labor costs in the local industry, automation is becoming an essential ingredient for the success of electronics firms. This increases the need for more technically competent personnel.

4.4 Logistical Systems

Intel introduced JIT to their Penang plant to provide them with logistical efficiencies. This increases the need for strong supplier links and sound managerial control and planning practices. Local firms can use this as well as other relevant models when analysing the requirements for their own systems.

4.5 Marketing

The marketing unit has allowed the company to recognize and take advantage of opportunities that exist in the market. The location of the unit at their production base provides knowledge of product feature adjustment demands to be incorporated into the production process.

4.6 Human Resource Development

Intel has recognized the need for highly specialized trained personnel in order to provide their organisation with a competitive edge. This focus on human resource upgrading has allowed them to continue to adjust their production systems to become more automated as well as flexible.

4.7 Supplier Development

Intel Penang emphasis on human resource upgrading goes beyond their organisation to include their supplier network. To control their logistical and supply needs Intel Penang has planned and implemented its own clusters. The management, through value chain analysis, has being able to provide an integrated approach to their production chain, from supplier to customer.

5. Conclusion

There has been an emphasis by Intel Penang on R&D, training, and technological development. This indicates that an essential skill base must be developed as a forerunner to the progression of local firms up the value added technology spectrum.

Intel Penang has also carried out marketing support and supplier development. This has allowed them to provide products to the market and develop systems that allow adaptability in the production process. The benefits of the firm developing its own clusters generate consistent supply, quality assurance, and flexibility. These benefits have been the true driving force behind Intel development of supplier networks rather than government incentive programs. A critical element therefore is the availability of technically competent human resources. These resources are as important in the areas of marketing as the are in R&D.

3. Matsushita Air-conditioning Group of Companies (MACG)

1. Activities and Operations

Matsushita Air Conditioning Group of Companies (MACG) consist of four companies: Matsushita Industrial Corp Sdn Bhd (MAICO), Matsushita Compressor and Motor Sdn Bhd (MCM), Matsushita Air-conditioning Corp Sdn Bhd (MACC), and Matsushita Air-conditioning R&D Center Sdn Bhd (MACRAD). MAICO was established in 1972. The paid up capital of the group stood at RM252.5 million in 1993. MACG parent company is the Air-conditioning Division of Matsushita Electric Industrial Co. Ltd (Japan) which has branches in Taiwan, the Philippines, Thailand, Indonesia, the United States, the Ivory Coast, and Malaysia. MACG exports to more than 120 countries world-wide, including Japan.

MAICO produces window type, room air-conditioners. Production has increased from the initial 100,000 units to more than a 1,000,000 units annually. MACTEC was set up in 1992 and produces dies and moulds as well as providing technical assistance to its suppliers increasing the level of local content. MCM was established in 1987 and produces compressors, motors, air conditioners for motors, vacuum cleaners blower motors, hermetic motors and toroidal motors. It has three factories that supplies MAICO, MACC, and it also exports worldwide. In 1990 MACC started producing split room air conditioners

Currently MACG employs 5,588 local employees and 52 Japanese. Out of the total work force, 5% are managers with the production department employing the most managers, refer Table 1. Table 2 depicts the educational backgrounds of the managers by level, 80% of senior management have engineering backgrounds.

Table 1: Number of Managers by level and function.

	Management Function					
Management Level	Finance	Marketing	R&D	Production	Personnel	Total
Senior	4	2	11	36	3	56
Middle	2	10	32	28	3	75
Junior	20	20	17	61	11	129
Total	26	32	60	125	17	260

Source: Ong Fon Sim and Md. Nor Othman (1999). Comparing Japanese and Malaysian Companies. In *Industrial Technology Development in Malaysia. Industry and Firm Studies*. Jomo, K.S, Felker, Greg, and Rasiah, Rajah. Routledge: UK. p 56.

Table 2: MACG: educational background of managers by level

Management Level	Engineering	Science	Comp. Science	Bus. Admin.	Arts / Soc. Sc.	Others	Total
Senior	40	-	-	-	5	6	51
Middle	18	1	-	3	-	25	47
Junior	54	11	5	7	4	53	134
Total	112	12	5	10	9	84	232

Source: Ong Fon Sim and Md. Nor Othman (1999). Comparing Japanese and Malaysian Companies. In *Industrial Technology Development in Malaysia. Industry and Firm Studies*. Jomo, K.S, Felker, Greg, and Rasiah, Rajah. Routledge: UK. p 56.

2. Future Plans of Matsushita

MAICO intends to become a comprehensive manufacturer of air-conditioners and air-conditioning equipment. It intends to service every aspect of the market. In order to achieve this MAICO has undergone, and will continue to undergo, a series of evolutions in product technology and design in order to keep up its development pace.

3. What are Matsushita's success factors?

3.1 Emphasis on R&D

MACRAD was established in 1992 to undertake R&D activities. It was part of the group's strategy to become a self-reliant production complex. MACRAD designs and develops new models for MAICO and MACC, for sale in Malaysia. MACRAD also provides assistance to its sister companies in ASEAN, and provides product engineering and quality assurance systems. MACRAD is working to enable localization of parts and components, and has begun to file patents in Malaysia and abroad. The R&D carried out by Matsushita is mostly applied research.

3.2 Product Innovation

Matsushita pays attention to two factors in its product innovation systems: 1. changes in customers' tastes and needs, and 2. technological seeds. Matsushita also consults with its parent company in Japan, especially for products for the export market, using their international experience, in order to provide products suited to international market demand.

3.3 Process Innovation

Matsushita believes in stringent quality inspections (carried out daily). The production process is inspected under actual conditions in order to improve productivity and reduce costs. Process innovation also runs concurrently with product development to swiftly transform market demands into products.

3.4 Human Resource Development

Matsushita policy states "We make people before we make products." MACG established an in-house training institute known as the Masters Institute of Technology (MIT). Matsushita provides both on-the-job and off-the-job training and overseas training (Japan). This policy has allowed Matsushita to have high levels of employee loyalty, which has translated into a more efficient and skilled workforce.

Matsushita has also instituted quality control circles (QCC) in order to further develop the skills of its employees. In-house competitions, monetary rewards, and other forms of recognition are also provided to employees who have generated new ideas, developments, and innovation.

3.5 Information Sharing System

MACG's parent company in Japan compiles and summarizes relevant and important information and disseminates it to MACG and other subsidiaries throughout the world. This arrangement allows MACG to be informed of current and developing technologies in the industry.

3.6 New Product development

Matsushita follows a systematic approach toward new product development and is intensely involved in providing new products. New product development is carefully planned and not left to chance. Continuous improvement in product quality, design, sizes, and durability are the core strategies for market competitiveness for Matsushita.

3.7 Automation

Matsushita's manufacturing system is highly automated, though it has not caught up with the parent company in Japan. This drive to automation has increased cost efficiencies and the ability to incorporate product innovations quickly into the manufacturing process.

3.8 Marketing Management

Matsushita practices geographical segmentation and uses multiple distribution channels. MAICO handles all domestic sales and the air-conditioning division of the parent company handles all export sales. Matsushita uses 'National Shops' that exclusively carry its products, and uses a range of dealers that carry a mix of brands. Matsushita aggressively sends its marketing personnel throughout the world in order to obtain orders.

4. The following lesson's can be learnt from Matsushita

4.1 Emphasis on R&D

Matsushita has set out to know what the customer wants and to create an atmosphere in the company that is conducive to idea generation, idea development, and innovation. Matsushita has obtained local and foreign patents and its R&D department has created products that are hard to match, even by its closest competitors. This emphasis has provided Matsushita with a competitive edge that goes beyond its current competitors and explains why it has 35% of the world market share in compressors and motors and a continuous increase of its production in air-conditioners.

4.2 Product and Process Innovation

Matsushita has tied in the two separate processes in order to generate both cost reductions, generated by process innovation, as well as leadership in products produced. This feat is difficult to pull off, but MACG has emphasized quality as well as unrelenting checks of the actual state of its production process. It is this merciless need for continuous improvement in product quality, design, sizes, and durability that makes Matsushita competitive and a leader in the market.

4.3 Human Resource Development

Matsushita has recognized the need for trained employees and an ambience of creativity and innovation among its personnel. This has provided the company with a competitive edge. Personnel are loyal, well trained, and take pride in their jobs and the company.

4.4 Information Sharing System and Marketing

The provision of information from Matsushita's parent company in Japan has provided it with extensive and 'in-time' knowledge of the market. This is then exploited by its salesforce. Matsushita marketing unit takes every advantage in the market, and co-ordinates with its production department to provide the right product on time. Demands for product features can be adjusted into the automated production process, while the product innovation process continues upgrading and creating new products.

5. Conclusion

MACG is a leader in its field because it has created an environment that is conducive to human resource development, emphasis on R&D and innovation, and an effective system of marketing management. All these factors work hand in hand with the production process in order to provide products that are demanded by the market.

This emphasis on R&D, personnel upgrading, and marketing has allowed Matsushita to provide products and process development that allow adaptability in the production process and reduces costs. A critical element in Matsushita's plan is the availability of technically competent human resources. These resources are as important in the areas of marketing as they are in R&D.

4. Trans Capital Holding (TCH)

1. Activities and operations

Despite the recent regional economic crisis TCH stands out as a sound example of what proactive planning can do to enhance a company's performance even during times of crisis. Trans Capital Holding (TCH), is a Penang-based contract-manufacturing firm and a manufacturer of disk drives, that has developed and introduced a new product during the recent economic recession. This successfully product launch has helped to put TCH into the revered inner circle of the disk-drive world. Among some of its buyers are MNCs, both local and foreign. Their focus on innovation and new product development has enabled TCH to clinch new contracts and new markets at a time of slow-down in the electronics sector.

The driving force behind TCh is Syed Iftikar, an Indian-born, and American-educated ,entrepreneur who has worked in Seagate Technology and Syquest Technology and was engaged by TCH both as a minority partner and employee. With a combination of his expertise, local capital and experience, TCH has developed an innovative product that commands good market prospects.

2. What are TCH's Success Factors

2.1 Selecting the right partner(s) in forming strategic alliances

TCH's ability to select the right partners in strategic alliances has resulted in success. TCH took a minority interest (5-10%) in Castlewood Systems, a company established by Iftikar in California. Castlewood Systems produces the Orb storage system and is active in R&D. By taking an equity interest in Castlewood Systems, TCH not only acquired a base in California, but also gained access to the Orb product as well as launching TCH's R&D capabilities.

2.2 Getting the right people with experience and expertise

The chief executive of TCH is an US-trained electrical engineer who has worked for a number of years for American-owned AT&T in Singapore and had helped Connor Peripherals set up its plant in Penang. Ho took over TCH in 1990 and transformed it into a manufacturer of components for many of the world's leading handphone, computer, and automobile companies. Iftikar, whom he engaged and teamed up with, is an US-trained entrepreneur who earlier helped found the US disk-drive giants Seagate Technology and Syquest Technology. Later he established his own company, Castlewood Systems, and when looking for a manufacturer established a strategic alliance with TCH. In Castlewood Systems, TCH found a good partner and was able to inject new innovative and R&D skills to its operations. Besides the CEO and Iftikar, the entire top management team of TCH are experienced personnel.

2.3 Timely Introduction of innovative products to the market

TCH has been able to successfully launch the new Orb Storage System. The Orb Storage System is a new high-speed, high-density disk-drive that industry watchers predict will dislodge traditional hard drives as the standard for personal computers. The 2.2 gigabyte Orb disks, that slip into the drive, store more data than most hard drives. Each can pack in 380,000 pages of text or one full hour of movie images and sound, stored in DVD format.

The Orb drive is the first to use the so-called magneto-resistive technology, which allows it to pack 2.2 gigabytes or 2,200 megabytes of data onto a disk the size of a regular floppy disk. Old-style floppies store a mere 1.44 megabytes. On top of that the Orb-drive transfers data at an impressive 12.2 megabits a second, making it capable of recording high-quality video, hitherto unheard of. According to industry experts, the Orb drive will revolutionize the hard-disk industry. The same disk can be used to store computer data or graphics, to play and edit movies, or to record sound and music.

2.4 Innovating new products at competitive costs

Besides the quality and versatility of its product, TCH will also be able to undercut its competitors. The drive is only promoted at about ¼ of the price and the disk is about 1/5 of what Iomega's 2-gigabyte Jaz-2 drive and disk cost. Moreover, although the Orb disk-drive is now enjoying good sales, TCH is already thinking ahead to get new products onto the market quickly in order to satisfy the ever-changing needs of the market-place. Owing to the quality and competitiveness of its products, TCH's forecast is that the demand for its products could be well over 10 million drives in the next 12 months. Its alliance with Castlewood Systems is expected to boost its total sales revenue to RM1 billion (US$327 million by the year 2000).

3. The following lessons can be learnt from GTB

3.1 The Development of Strategic Alliances

Succeed and compete internationally. For example, one advantage of TCH strategic alliance was that it enabled the company to move up the value-added chain. Its main product lines, until now, have been disk-drive components, scanners, and printers, but with the Orb storage system, it has moved up the value-added chain.

Success in innovation and R&D can be rapidly achieved if an indigenous company can carefully strike up a strategic alliance with a good partner. As many indigenous companies are lacking high-tech R&D expertise, one approach is to acquire these skills through joint ventures or strategic alliances.

3.2 An Emphasis on Innovation and Quality

Given ingenuity firms can quickly become world class in producing quality products that are competitive and internationally demanded, like TCH's high-speed, high-density disk drives. Indigenous firms can attract global attention of MNCs if they can produce innovative and quality products. For example, among TCH's international buyers are Sanyo and Aiwa of Japan, and a host of American companies.

4. Conclusion

Indigenous companies through proactive planning, ingenuity in innovation, and new product development can develop into world class manufacturers. Success in this fast moving industry requires innovation and the recruitment of top class experts and personnel to help a company forge ahead up the value-added chain.

5. Sapura

1. Activities and Operations

Sapura started operations in 1975. It has three main business areas: telecommunications, information technology, and metals based technology. Its core competence remains in telephone equipment. Sapura started its business with a contract to lay cables for JTM (Malaysian Telecommunications Department) in 1975. Sapura is also the sole agent for Macintosh personal computers, ancillaries and software, and NEC portable telephones and facsimiles. Sapura distributes Apple computers, peripherals and software's, integrated surveys of resources and environmental management. Sapura supplies PABX systems, sales and technical services for radio equipment and marketing and servicing heavy electrical engineering for substation projects. Sapura has also joined forces with Hewlett Packard, Nokia, Mitsui, and Fujitsu.

Between 1977 and 1979, Sapura won a contract to supply phones to JTM, which it later lost to a Taiwanese firm. However, after criticisms that resulted in government intervention, Sapura regained its contract in 1991. Sapura also obtained a contract for payphones from JTM. Sapura also operates a paging service. Sapura provides twelve critical component parts to Proton (brake disc, rear hub, water pump pulley, left and right rocker shaft assemblies, reverse shift hug, clutch, release fork shaft assembly, control shaft, stopper body, and three shift rail shaft assembly system). Refer to Table 1 for list of activities of Uniphone and Sapura Telecommunications 1995.

Sapura acquired a majority interest in Uniphone Telecommunications Bhd (UTB) in 1984. UTB is involved in the manufacture of copper rods and communication cables, cable network installation, the manufacture and supply of push button subscriber phones, and the manufacture, supply, and maintenance of public pay phones. Three subsidiaries specialize in digital services and pages, namely Komtel Sdn Bhd, Sija Sdn Bhd, and Komtel Farahat Sdn Bhd. Uniphone Fiber Optic Sdn Bhd provides fibber optic transmission system. Sapura Motors Bhd provides parts to Proton, Perodua, Mercedes Benz, Volvo, Ford, Suzuki, Mazda, and Timor. There are other subsidiaries provide manhole covers, mailboxes, and cast iron bars.

Table 1: Detailed activities of Uniphone and Sapura Telecommunications, 1995. (RM million)

Activities	Uniphone		Sapura	
	Turnover	Pre-Tax profits	Turnover	Pre-Tax profits
Manufacturing	113.2	10.4	-	-
Telecommunications	386.0	41.3	408.9	40.3
Investment	1.0	-0.3	-	0.3
Trading	45.0	-0.6	-	-
Property Investment	0.9	0.1	2.6	0.6

Source: Company Annual Reports

2. Future Plans of Sapura

The company has shifted its emphasis to the lucrative sub-sectors of automotive parts is due to the importance of this sector to the country. Pre-tax profits of this sector are continuously increasing and the rents are still protected. Sapura is also tapping into multimedia information technologies utilizing the multimedia super corridor incentive.

3. What are Sapura's success factors:

3.1 Emphasis on R&D

Sapura is well known as an indigenous company that emphasizes R&D. It has developed in-firm capacities to innovate products, involving extension and enhancement of existing products, such as the voice activated telephone. Among local firms, Sapura has the most developed product R&D facilities. Between 1977 and 1996 Sapura produced four different telephone models. The first homegrown Malaysian telephone, the S2000 series, used almost RM1 million in development funds. Sapura reported having a special research plant with 37 engineers and technicians. This firm absorbed two key R&D engineers from Motorola Malaysia in the late 1980's, highlighting the role of foreign firms as a training ground for expertise.

3.2 Good connections

Malaysia's new economic policy (NEP) was introduced in 1970 to promote Bumiputera involvement in business. Shamsuddin Abdul Kadir the founder of Sapura was among the earliest Bumiputeras' to capitalize on NEP. Shamsuddin served as the director of Permodalan Bersatu Berhad, the holding company of UMNO's co-operative Koperasi Usaha Bersatu (KUB). This connection and Bumiputera status helped Sapura to obtain contracts as well as to renew its telephone supply contract in 1991.

These connections have also allowed Sapura to enter less developed Asian countries like Bangladesh, India, Sri Lanka, Pakistan, Myanmar, Mauritius, Thailand, Indonesia, Vietnam, Cambodia, and Laos, due to inter-government agreements. Sapura also obtained special treatment from the government's business mission abroad. Sapura also had good connections with foreign corporations such as Sumitomo Corporation of Japan which helped it to obtain a contract in Bangladesh in 1989, El Salvador in the Philippines in 1996.

3.3 Economies of scale

Large contracts (telephones, pay phones and cable links) have contributed to Sapura's economies of scale, growth, and profits. The telephone market is large and has experienced substantial growth. Being the only supplier of telephone sets to JTM, the rapid expansion of demand for telephones has ensured rapid growth for Sapura. Sapura's growth has also been a result of contracts to lay cables. Sapura provided both local and overseas services for Lembaga Letrik Negara, with telephone contracts in Bangladesh, Thailand, Mauritius, and a license to manufacture telephones in Jordan.

3.4 Rent seeking

Sapura has more profitably utilized its rents than other Bumiputera firms. This is shown by its heavy investment in R&D, the manufacture of its own locally developed telephone set, foreign licenses (Siemens 1980, Bell 1983). By following the apprenticeship mode of technological acquisition, Sapura has maximized its rent seeking activities.

3.5 Innovation

Sapura telephones have won prizes both locally and world-wide. It is Sapura's aim to increase product technology, improve products and conducting research of new products for the future. However it is still weak in process innovation.

3.6 Localization

60% of Sapura's inputs are procured from local sources. Table 2 shows major components and raw materials supply for Sapura.

Table 2: Components and Raw Materials, 1995

Major components and raw materials	Supplied by		
	Import	In-house production	Local Manufacturer
PCBs	*	*	*
IC's/chips	*		
Test instruments	*		
Metals/plastics			*
Chassis/mould		*	*

Source: Interviews

3.7. Diversification

Sapura has diversified from its initial business, telecommunications, into IT, supply of automotive parts to Proton and other car manufacturers, PABX, and computers. This diversification has provided Sapura with some defense against increasing domestic competition and the liberalization of the telephone industry in Malaysia.

4. The following lesson's can be learnt from Sapura

4.1 Emphasis on R&D

Sapura's emphasis on R&D, even though it has not provided breakthrough materials, has propelled it ahead in the technology trajectory. It is ahead of local indigenous firms. This emphasis provides it with better products and greater potential for sales and innovation.

4.2 Good connections

Even though it may be difficult for a firm to totally depend on good connections, these connections should be developed over time. Sapura has built good connections with the government, local, and foreign firms. These connection have enabled it to enter markets that have been herewith closed. These connections (goodwill) can and must be built between firms, allowing for the dissemination of information and technology transfers.

4.3 Economies of scale

Sapura attained projects that enabled it to achieve economies of scale in a relatively short time. This must be the aim of every SMI in Malaysia, so that costs can be reduced and production efficiency increased. Economies of scale allow for higher growth rates and profitability, thus allowing a firm to continue to progress along the technology trajectory.

4.4 Rent Seeking

Sapura was aware that its position was that of a rent seeker. However, it was not passive, but aggressively pursued 'rents'. This aggressive pursuit enabled it to better itself and obtain better rents. Meanwhile, a side effect of improvements means that Sapura no longer depends on rents in order to survive. It has become a competitive player in the economy.

4.5 Innovation

Sapura may be weak in process technologies but it is innovative. It continues to upgrade its products and produce better versions of telephones and other services. This has increased its profitability.

5. Conclusion

Technological advancement in Sapura seems to be incremental, gradual, and achieved through small modifications rather than through major breakthroughs. Products or processes developed by Sapura may be new for Sapura but not new to the world. Production cost has not fallen even though Sapura has been involved in R&D.

Sapura initially depended upon its connections for survival. It has now outgrown that dependency and moved ahead. Its R&D, innovation and economies of scale have allowed it to move up the production ladder and technology capabilities spectrum. However, there are many more factors that require development in order to further increase Sapura's competitiveness, such as Human Resource Development, better production processes, automation, and management skills.

6. OYL Manufacturing Company Sdn. Bhd. (OYLMC)

1. Activities and Operations

OYL Manufacturing Company is the manufacturing arm of OYL Industries Bhd. It is a company that has built and acquired a significant presence in the global heating, ventilation, air-conditioning and refrigerating market (HVAC&R) in a relatively short period. OYL belongs to the Hong Leong Group of companies in Malaysia, industrial and financial conglomerate.

The main product group for OYL in is air-conditioners for industrial, commercial and consumer markets. It manufactures the products under the York and Mitsubishi labels, as well as its own Acson brand. It has also started to integrate product lines that it acquired under the AAF-McQuay label in its manufacturing facilities in Shah Alam. The key chronology to the activities of OYL is in Table 1 below.

Table 1 Key Dates in OYL's growth

Year	Activity:
1974	OYL Industries commenced operations – assembling GEC gas cookers and Glem Gas ovens.
1976	Joint-venture with Guthrie Malaysia to form OYL-Condair Industries – manufacture industrial air-conditioners, refrigeration equipment
1977	Entered agreement with Acma Ltd for technical assistance in manufacturing Acma refrigerators and air-conditioners
1978	Entered agreement with Borg Warner Corp. (USA) to manufacture York air-conditioning and refrigerating equipment
1982	Acquired 100% of Acma Electrical Industries (Malaysia), the distributors of Acma refrigerators and air-conditioners in Malaysia
1983	Entered long-term contract with Mitsubishi Electric Corporation (MELCO), Japan to assemble and package Mitsubishi air-conditioners, together with technical assistance from MELCO
1984	Launches Acson® brand range of air-conditioners and refrigerators
1985	Converted to public company
1986	Listed on the KLSE
1990	Became a member of Hong Leong Group, Malaysia
1993	Won ISO9002 accreditation from SIRIM
1994	Acquired from Snyder General (USA), McQuay International and American Air Filters (AAF) International, - leading manufacturers and designers of heating, ventilating and air-conditioning equipment (HVAC) and air filtration equipment
1996	Acquired J&E Hall Ltd (UK) a HVAC service integrator to spearhead design and specification of AAF-McQuay products in UK and Europe

The group's recent sales record is provided in Table 2.

Table 2 OYL Industries Bhd – Key Financial Figures

	31 Dec 98 MYR '000 (Half year)	30 Jun 98 MYR '000	30 Jun 97 MYR '000	30 Jun 96 MYR '000
Total revenue	2,172,406	4,433,431	3,145,613	2,929,103
Net income	67,722	76,466	120,669	120,011
Total assets		3,504,217	2,501,146	2,549,112
Total liabilities		2,734,069	1,766,058	1,774,023

Approximately 45 percent of OYL's products in 1998 were exported. The present capacity is about 180,000 residential units as well as 80,000 commercial units a year. OYL Industries presently employs approximately 8000 employees.

From its inception OYL has constantly developed into new areas of production in order to develop. Since starting out in the assembly of gas cookers, OYL through acquisitions and strategic alliances with such companies as Guthrie Holdings and Mitsubishi, has progressed into air conditioner and refrigeration units. This has allowed them to progress and develop their own brand of air conditioners, ACSON, with exports to 48 countries.

OYL has not neglected to invest in its own R&D. It presently employs fifty full-time technical personnel at its Sungai Buloh facility. Among its many tangible efforts include the patented built-in starter that has now found its way into many of OYL's products, and the coil units' thermal overload protection of sensitive components. The trend in the design of HVAC&R equipment appears to incorporate more microprocessors that use control algorithms based on fuzzy logic and neural networking. Such skills are still relatively rare in the country, and if they cannot be found in sufficient numbers and quality, OYL may have little choice but to build another R&D center.

2. Future Plans of OYL

OYL's management team has clearly defined the business they are involved in, that is the HVAC&R equipment market. They see the industrial, consumer and commercial sides of the business as complementary and symbiotic. On the consumer end, they plan to invest more to better define and build the Acson brand, to become a market leader, such as Carrier, Trane or Matsushita. The industrial end involves exacting solutions to their customers heating and cooling problems. OYL also very much in the market for new acquisitions if they can contribute strategically to OYL's plans to be a global front-runner.

3. What are TCH's Success Factors

3.1 *A strategic commitment to growth*

At no period has OYL rested on its laurels or even attempted to maintain the status quo. From its inception the management team was looking for growth. OYL has kept its principals happy through delivering quality product that meet specifications, and even suggests improvements. When OYL felt it needed to move along the value chain through marketing, it acquired its principal's marketing arm, and built its own brand. OYL has added new export markets in each year of the existence of the marketing arm. When it felt that it could not license new technology, OYL's management showed commitment in investing in international companies. Finally it expanded its knowledge generating functions in R&D, Sales & Service, and Marketing. Its view was that these functions cannot be isolated from manufacturing if manufacturing is to remain relevant and fresh.

3.2 A focus on its core businesses and competencies

Unlike many other entrepreneurial firms, OYL has kept its eye on essentially one business, that of manufacturing heat transfer equipment based on the compression and condensation cycle. These products incorporate many competencies and technologies, including temperature control mechanisms; reliable low-maintenance silent motors and the control of flow of volatile fluid in two phases. This focus allowed OYL opportunities to build a stable core team of knowledge workers.

3.3 An internally generated source of capital for expansion

It is debatable if another firm that did not belong to a conglomerate would pursue growth to the extent of taking on considerable risk in acquiring and managing firms outside of Malaysia. Individual entrepreneurs with limited resources are likely to be more risk adverse and pursue less aggressive growth strategies. Without aggressive growth, catch-up firms may never reach the technology frontier.

3.4 The ability to retain key management to ensure the execution and continuity of business plans

One absolute requirement for running a firm in active growth mode, is that the decision-making team has accumulated sufficient knowledge to be able to make quick decisions when the environment changes and new threats and opportunities arise. This luxury is not available to many Malaysian firms, as key personnel tend to serve short stints in each position of responsibility. The complexity of managing a modern technology-based firm is daunting. If the issues are not instinctively grasped, any decision-making is fraught with peril. OYL is fortunate in that some of the key management personnel have remained through crucial decision-making challenges.

4. Conclusion

Through a process of continuous improvement and partnering with the right partners OYL has developed into a leading world supplier of air conditioners. A focus on growth in its core business activities, strong financial backing and the ability to retain key personnel has allowed the company to succeed.

7. PNE PCB Bhd

1. Activities and Operations

PNE PCB is among a group of companies that manufacture printed circuit boards for electronics companies operating in Singapore and the Asia Pacific region. PNE started life as Print 'n' Etch, a partnership (essentially the Tan family of Singapore) that supplied printed circuit boards to electronics companies in the island in 1976. The rising costs of operations in Singapore prompted the move to a lower operating cost center, and the Tebrau industrial area in Johor Bahru was chosen. The move was made in 1988. Throughout the years, the customer list for PCBs grew, and they have added more printing lines. Presently, there are five fully automated lines, and one semi-automated line.

The pressures to invest in new lines, and in new technology prompted the company to turn public in 1994. It was listed on the Kuala Lumpur stock exchange in 1997.

PNE PCB's sales have continually increased over the years, although it has recently hit difficulties as a result of the economic slowdown in Asia. A breakdown of its customers is as follow: exports 80 percent; Japanese origin firms 40 percent, European origin firms 35 percent and American origin firms 10 percent. Its two biggest customers account for a third of its sales. They are Philips (20 percent) and Aiwa (15 percent). The other important customers include Apple computers, Matsushita, Pioneer, Sony and Thomson.

Table 1 Sales PNE PCB Bhd

Year (ending Sept 30)	Sales (RM '000)
1992	57,100
1993	58,000
1994	81,100
1995	97,800
1996	87,800
1997	85,600

Its main focus and product remain PCBs. The range of activities that the firm can now undertake include some design (in partnership with customer), engineering, artwork, silkscreen preparation, printing and etching, drilling, punching, electrical testing and finishing operations. Its range of products remain single sided and double-sided boards, incorporating carbon and silver through hole technology, although there is a committed objective to extend their capabilities to multi-layer boards in the near future.

2. Future Plans of PNE PCB

UK-based BPA Ltd, an electronics research house, estimates the PCB industry will be worth around US$20 billion by the year 2000. All electronic circuits of any complexity make use of PCBs, from the lowest end clocks and transistor radios to top-end computers, defense, avionics equipment, and telecommunications equipment. There is a vast gulf between the two levels. The top end puts a premium on ever smaller and complex circuits, operating on micro currents on the smallest piece of real estate, and yet maintain the same reliability and operating range as traditional boards.

The top end market is driven by huge R&D budgets, and expensive capital equipment. The barriers of entry are such that it is expected that the top ten global companies will account for 90 percent of output. Cost reduction drives all levels of the PCB market. Economies of scale and high yields are the principal determinants of cost. Because of their highly automated nature, low labor cost countries do not offer much of a competitive advantage, except in the associated PCB assembly (PCBA) sector. Environmental standards, and strict environmental enforcement in some developed countries may have some minor impact on the total cost structure.

As PCBs are a critical component in all electronic equipment, manufacturers of high-volume products normally source each of their PCB requirements from five or six manufacturers. The decision is invariably made to favor manufacturers offering low costs, high delivery reliability, and low defect rates. Large electronic companies have traditionally designed their own PCBs for internal use, and transfer the designs to their PCB suppliers. However, an increasing number of PCB firms have developed their library of PCB designs, to the extent that they can design more efficient, lower-cost PCBs than their customers. This capability provides certain manufacturers with a competitive advantage.

Smaller electronic firms that manufacture low volume products are also likely to value the design services of PCB manufacturers. PCB manufacturers who target low-volume business need to possess the capability of highly flexible lines, with good engineering turn-around capability. This market has reasonable margins, but is relatively small.

There have been several interesting developments in institutional support for the PCB/electronics market. The government in Taiwan maintains a PCB net, which matches firms with PCB manufacturing capabilities with firms that require PCB design and manufacturing services. This benefits all SMI's and electronic start-ups, whose prototypes and initial production volumes pose serious capital investment problems. PCB manufacturers also benefit, as it saves them on sales and marketing efforts required to source new business. Certain manufacturers also manage to save costs by concentrating on only certain types of designs that do not involve much modification. Other independent matching services have also appeared on the Internet that provide such services.

The future of PCBs lie in such technology as multiple layer boards, which basically extends board design and manufacture to three dimensions, the use of lasers with which even smaller holes and shapes can be formed with greater precision and new materials such as 'microvia' boards. PNE PCB faces enormous challenges in its quest for growth and technology upgrading in order to be able take advantage of the top level of the PCB market.

PNE PCB has a strong relationship with many multinationals operating in the region. This is a key their future. They need to build trust with its key customers in order to be looked upon as a design partner, as opposed to a purely contract manufacturer. To effectively achieve this level of closeness, PNE PCB has to first strengthen its in-house design ability. The ability to access designs through libraries is critical in making good, efficient designs. The longer a PCB firm has been in business, the larger their library and knowledge base.

This knowledge base comes down to the availability of human resources. The number of good electrical engineers available in Malaysia appears to have increased marginally since PNE PCB's operations began in 1988. However, the competition for them is intense. Staff turnover has been a problem in a business where retained knowledge is an asset. PNE PCB does not believe that its problem of retaining talent is particularly unique or due to any failing of its management team.

The amount of capital that needs to be continually invested is also high. Most equipment manufacturers are Japanese and European, and with the weak ringgit, investment costs have increased significantly. PNE has established some in-house capabilities in machinery maintenance and modifications, but they can only go so far. The next generation of PCBs, multiple layers for example requires a new set of equipment. PNE has really no choice but to invest, due to customer demand.

At present the price of boards is set largely by customers. This puts constraints on margins. As the industry moves up to the next generation technology, margins for the newer boards will also come down. The only option for growth and survival is a knowledgeable team that can run the lines with high throughput and few defects, with a customer support team that can ensure a full order book.

3. What are PNE PCB's Success Factors

3.1 A Good Delivery Track Record

Reputation is the greatest asset in doing business in Asia. Entrepreneurs and start-ups face the difficulty of having to prove themselves. PNE PCB was fortunate that its team was able to learn the business very quickly of PCB manufacturing, and was able to deliver on the contracts of its first few customers. From then, the relationship with customers needed to be nurtured through personal, and organisational contact. However, business is getting more competitive, and price seems to taking a more important role in customer decision making.

3.2 The Willingness to Invest in Capital Equipment

Having good bankers and investment bankers appears to be a necessary condition for the PCB industry. If PNE were to reinvest only from internally generated capital, then it would not be able to remain competitive and grow. PNE has been willing to seek investment support.

3.3 A Quick Learning and Adaptable Workforce

The PCB business, along with other technology-based industries requires a work-force that is constantly able to learn and relearn. The technology that was used five years ago no longer remains competitive today, and what they have today may not be used in two-years time. PNE PCB has been fortunate that its team of workers has managed to commission new lines and new processes in a relatively short time frame.

4. Conclusion

PNE PCB is a company that focuses on growth, but faces constraints in that it is still technologically dependent on customers and suppliers of equipment for next generation innovations. Presently, they have some competitive advantage due to relatively advanced equipment, a good work-force, and the weak ringgit.

8. Wearnes Electronics (M) Sdn Bhd (WEM)

1. Activities and Operations

Wearnes Electronics (M) Sdn Bhd is a subsidiary of Wearnes Technology (Pte) Limited (WT) - a multi-national corporation with its head-quarters in Singapore. WEM was set up as the contract manufacturing arm of WT, with its main facilities being in Pontian, and recently two more factories have been set up in Simpang Renggam and Kemaman in Terengganu. This has resulted in a production area of about 30,000 square meters fully equipped with modern machinery and equipment.

Shortly after the survey and interviews were conducted, the component store at the Pontian factory was completely destroyed by fire on September 20, 1999.

The three worksites have a total of 2,000 workers, of which 70 percent are skilled workers, experienced engineers, trained technicians, supervisors and production assistant. More than half of them are based at Pontian.

Financial Performance of WBL Corp. Technology and Manufacturing Businesses

Year	Sales S$ '000	Profits S$ '000
1997	326,295	29,052
1998	316,581	21,358

Among the products that are assembled at WEM are; telephones, computers, CD-ROM drives, car radios, deck mechanisms, flasher units and video CD players under OEM/ODM arrangements with top consumer brands such as Philips, Siemens, Heimann, Pioneer, Takara and others. More than 90 percent of its products are exported.

WEM has capabilities for PCB assembly (PCBA) that include Surface Mount Technology (SMT), Nitrogen Reflow Process, Auto-Insertion and the No Clean Process that significantly reduces volatile effluents. Beyond the assembly, WEM has acquired a full range of testing equipment, including; In-Circuit Testing, Functional Testing and Electrical and Environmental Stress or Burn-In. WEM has had ISO9002 certification since 1995.

WEM represents the relatively non-strategic part of its parent's business operations, which include divisions that develop integrated circuits, design and manufacture sensors, video conferencing systems, develop customized Internet access devices, and a producer of CD-ROM/CD-R drives. Another division produces remote access networking products. Together with these high value-add businesses, WT, the parent also own manufacturing facilities for precision connectors, flexible and rigid PCBs, die-casting and precision machining, and a miscellaneous industrial products group. Just about the only internal manufacturing that WEM performs for the group is in the CD-ROM product area.

Without much integration with the rest of the group's value-add chain, WEM stands in danger of disposal by the group, if the cash flow generation should slow, or if new investments requirements become too high. The PCBA and the general electronics assembly sector is extremely competitive. Where it is labor intensive, regions with lower unit labor costs holds greater competitive advantages, and where it is highly automated, regions that have access to capital and technology gain the competitive advantage.

At present, the level of linkages a contract manufacturer like WEM has developed within the Malaysian electronic cluster is significant, but limited in terms of technology. Components like PCBs, and optical read/write components in CD-ROM and VCD players are made in Malaysia by multinationals and Malaysian companies manufacturing under license. Most of the capital equipment in the assembler's work-shop, are imported. The percentage of Malaysian origin components that WEM exports lies between 50 and 95 percent. There is a thriving cluster of plastics moulders and extruder companies that supply casings and parts. The emergence of these usually SMI-based suppliers can trace their origins to some of the OEM/ODM contract manufacturers locating their operations in Malaysia.

The core product technologies still controlled by multinationals. The high value components are similarly owned and developed by firms already at the technology frontier. The main process technologies in assembly, like Surface Mount Technology and the Nitrogen Reflow Process, were also developed by OEM/ODM firms. However, WEM has claimed to have significantly modified the set-up of the machinery and process flows, with significant productivity gains.

To counter the competitive threat of countries with cheaper labor costs like China, Indonesia and the Philippines making in-roads into the PCBA market, WEM has made significant investments in Enterprise Resource Planning (ERP) software, training and organisational procedures. It is felt that through such investments in knowledge augmenting systems, that overheads like stocks, machinery turn-around time and rework/rejects can be minimized, and yields and on-time delivery maximized. A large percentage of productivity gains will have to come from the work-force in learning new process skills.

It is extremely difficult for a pure contract manufacturer to move up the value-chain towards the brand marketing and R&D end. The capital required to build a global consumer brand almost ensures that the current market-leaders are impregnable. It is only through a technological shift, and through new classes of substitute products, that new entrants can challenge the leaders. The contract manufacturer has a certain degree of input and control over the process technology, but almost no control over product technology. If WEM were to start from scratch in investing in product R&D, it would have to invest a large amount of effort and capital in developing expertise and proprietary knowledge that resides at the frontiers of technology.

Strategically, WEM believes it has a better chance of a positive return through investing in process R&D. Process modifications can bring small incremental returns, with a more modest scale of investment. An experienced contract manufacturer can be a significant contributor to the technological development of a cluster if it is allowed to input into product design. A well thought out product design can significantly reduce the cost and complexity of manufacture. If cluster-wide R&D consortiums can be organised, contract manufacturers who have invested in process improvement are definite assets to the cluster.

Good contract manufacturers are also diffusers of technology, from the OEM design to the community of SMI-type suppliers with their sub-components and sub-assemblies. Experienced contract manufacturers may enlist the expertise of their community of suppliers in facilitating technology and productivity gains.

2. Future Plans of WEM

WEM hopes to contribute significantly in designing manufacturing processes for the various electronic products that the other divisions of WT are developing. It hopes that it can win the confidence of the group in order to allow it to manufacture what are clearly high-technology high value products in Malaysia. Beyond winning new business from within the group, WEM is also working with present OEM/ODM partners in order to win the right to manufacture new electronic products that are presently in development. It looks forward to the support of a cluster of smaller suppliers in order to be able to rise to the challenge.

Meanwhile, it would continue looking for further productivity gains and cost reductions through training and process improvements.

3. What are WEM's success Factors

3.1 Constant Investment in New Machinery, Computers and Software.

Electronics contract manufacturing is an extremely competitive business. As the technology comes from the OEM owner, there are few barriers to entry. To remain ahead of potential entrants, a contract manufacturer has to keep upgrading his capabilities, or it risks erosion of its margins.

3.2 Constant investment in personnel training and human capital.

The workforce has to be willing to learn and change. To know what is required, the worker has to be familiar with products and equipment, and required procedures and standards. Without investment in training, investments in capital machinery would deliver sub-optimal returns.

3.3 Belonging to a strategic group of companies

The Wearnes group is a diversified conglomerate, with automotive, mining, as well as IT and electronics interests. This relationship gives WEM advantages when it comes to opportunities to develop new product groups and new products. As a conglomerate, Wearnes has the capital to invest in strategic businesses. However, WEM has not managed to leverage a telling advantage in the past, but hopes to be able to do better.

4. Conclusion

The key to WEM's current and future success is the ability to provide cost effective manufacturing facilities to MNC's. In order to keep manufacturing costs down investments in process improvement and personnel skills is essential. Equally important is WEM's ability to keep in touch with future contract demands in order to be able to deliver new products as the market develops.

9. Globetronics Technology Bhd (GTB)

1. Activities and operations

Globetronics Technology Bhd (GTB) is mainly involved in ceramic and plastic integrated circuit (IC) package assembly, dynamic burn-in (DBI), and visual check services for its major clients, Intel Technology Sdn Bhd (Intel) and Sumitomo Metal Electronics Devices (SMED) Inc., Japan. Sales to these two companies collectively contributed 95% to the Group turnover in 1996. Currently, the Group's equipment is on a consignment basis from Intel and SMED.

Yhe Group mainly assembles two types of integrated circuit (IC) packages:

i. Plastic based IC packages

ii. Ceramic based IC packages

In 1996, GTB had an annual IC assembly output of 71.5 million plastic IC packages and 14.3 million ceramic IC packages. The division contributed 49.3% and 48.9% respectively to the Group's 1996 turnover. The division also provides plating services for advanced opto-electronics devices. Its plating services contributed 4.1% and 5.3% respectively, to the Group's 1996 turnover.

Joint venture (JV) companies

GTB formed two JV companies with SMED, and they are SMCIs Globetronics Technology Sdn Bhd (SGT) in 1996 and SMCI Globetronics Technology Industries Sdn Bhd (SGTi) in 1997. SGT is involved in the manufacture of technical ceramic substrates (such as CX-Lids and C-Dips), which are used as a cover for IC ceramic packages. SGTi is involved in the manufacture of advanced co-fired laminated high pin-count Ceramic "Pin Grid Array" (PGA) packages used for high-end microprocessors. Additionally, SGTi has commenced production of the latest high technology and speed "Ball Grid Array" (BGA) packages in 3Q97.

1.2 Earnings review

The Group showed tremendous growth during the 1992-96 period with an average rate of 49.6% p.a., mainly driven by expansion in DBI and IC packaging capacity, and increases in demand from the global semiconductors industry. GTB enjoys relatively high margins as its raw materials and equipment are consigned from its customers, Intel and SMI. GTB's prospects depend on the world-wide demand for semiconductors.

Future Plans of GTB

In line with the policy of the GTB Group to effect strategic responses and adaptations to new developments in the domestic and international electronic components industry, it is presently considering the following plans:

(i) **Final High-End Testing** –Presently, GSB provides the full range of IC assembly services except for final testing services. It is the company's objective to also provide final high-end testing services so as to become a "one-stop" integrated center for IC assembly.

(ii) **Turnkey ICs/IC Packages Manufacturer** –To position GTB to be a world-class turnkey manufacturer of ICs/IC packages, with active implementation of several strategies including:-

- *Sub-contracting Migration* – To enhance its sub-contracting position from the current 19% dependence on consigned equipment and direct materials (level 1) to 65% dependence on consigned equipment and direct materials (level 2).

Ultimately, the Group aims to become a turnkey semiconductor assembler with its own equipment and raw materials (level 3). Presently the Group is at the transition level (level 2) and is steadily progressing toward the turnkey level (level3), expected by year 2000.

- *Horizontal Diversification* – To diversify both product and customer bases horizontally. This includes the following:

> Production of a wider range of ICs with different technologies for a broader base of applications for existing and new customers.

> Production of a wider base of packages, such as the latest high technology and speed "ball grid array" ("BGA") packages which the Group is actively planning to commence commercial production by the end of – 1997.

> Expanding the customer base for the existing products manufactured/services provided by the Group.

(iii) Downstream Diversification
To manufacture technology-based intermediate downstream products and end-products which incorporate ICs, such as computer peripherals by year 1998/1999, media-based products by year 1998/1999 and burn-in ovens for external sale by year 2000.

(iv) **Business Expansion/Diversification** – To expand the existing operations of the Group as well as pursue other joint ventures with strategic partners both in the domestic and global electrical and electronic products industry in a continuous move towards the production of technologically advanced components/products. This includes plans to set-up overseas manufacturing facilities as and when appropriate opportunities arise.

3. What are GTB's Success Factors

3.1 Developing Strategic Supplier – MNC Relationship

GTB has successfully developed a very good supplier – MNC relationship with Intel Technology Sdn Bhd (Intel) and Sumitomo Metal Electronics Devices Inc., Japan (SMED). It supplies ceramic and plastic integrated circuit (IC) packages, dynamic burn-in (DBI) and visual check services and some of its associated companies are involved in the manufacture and assembly of pin grid array (PGA) and ball grid array (BGA) packages which it also supplies to other MNCs. Currently, GTB group's equipment are mostly undertaken on a consignment basis on behalf of Intel and SMI which jointly account for 95% of GTB's turnover.

GTB's good relationship with Intel has developed gradually. The good relationship was enhanced by the fact that some of GTB's founder members were ex-Intel staff. Intel not only encouraged them to develop the supplier relationship, it also nurtured this relationship directly, helping GTB to develop its initial production processes.

3.2 Creating an Initial Niche Market to Kick-Start the Company

GTB started through its initial tie in with Intel. GTB supplied Intel with ceramic and plastic integrated circuit packages, dynamic burn-in and visual check services. Subsequently, when GTB started, it already had a number of core products and Intel provided it with a core market. This enabled it to operate profitably and prepare for future development.

3.3 Developing Quality and Customer Satisfaction

GTB is committed to Total Customers Satisfaction with zero defects as the goal. This is to be achieved through continuous quality improvement and partnerships with customers, vendors and employees. This commitment coupled with excellent teamwork and an in-depth grasp of quality principles won GTB ISO 9002 in 1994. On addition to developing good customer relationships, GTB has also worked to gain strong government support and strong business partners that have provided GTB the competitive edge. This synergistic co-operation has allowed GTB to further enhance its niche technologies in the semiconductor IC services, and in the field of technical services.

3.4 Establishing Sound Training and Human Resource Development (HRD) Programme

Employee training and HRD are taken very seriously by GTB. The result has been a well-trained workforce, which has enabled GTB to enhance its quality and productivity, acquire new technology, and adapt to business complexities. Various training methodologies such as on-the-job training, hands-on coaching, as well as experimental and instructional training are used to enhance employee skills and development.

3.5 Striving for Diversion, Joint Ventures, and Innovation

GTB undertakes continuous innovation and diversification to pursue viable new product development, by using its core competencies in IC assembly, test manufacturing, and its established organisational structure. These moves have resulted in highly successful joint venture projects with world class, high-tech companies, OEM, OBM, and ODM are being aggressively pursued resulting in GTB becoming a highly successful indigenous company.

4. The following lessons can be learnt from GTB

4.1 Strong MNC Support when Starting Up

An indigenous electronics company with close MNC connections and working very closely with the MNC can acquire a good start-up to operate profitably from the start. As shown, GTB is in a way a supplier to Intel after having nurtured it to supply Intel with certain niche products. Also, some of the founders of GTB have been employees of Intel. In this respect a very successful supplier – MNC foundation had already been put in place as GTB took off.

4.2 The Need for Quality Experienced Personnel

An indigenous company with a good and proactive management and organisation with experienced and professional personnel, can get the respect of MNCs to strike a good supplier-MNC relationship. This is crucial to develop core products and niche markets to ensure successful start-up and new product development. GTB has carefully developed these assets which are no doubt important factors in its success.

4.3 An Emphasis on Training and Human Resource Development

Training and HRD, which GTB has given very high priority, are no doubt part of its ingredients of success. Indigenous companies should learn from this and realize that good personnel are indeed one of the best assets to the success of a company. Any company that scringes on staff and is afraid to recruit good employees, because they are relatively more expensive, are definitely not proactive enough and lack foresight in its outlook.

4.4 An Aggressive Approach to Product Improvements

GTB has taken a very aggressive outlook in its product development, innovation, diversification, and future development plans which have kept its market with its MNC buyers not only intact but also expanding to new areas. In an industry where product-cycles are becoming even shorter, these are some strategies where other indigenous companies should well learn and adopt as a matter of survival over the long term.

5. Conclusion

This case shows that indigenous electronics companies can succeed well even in an environment of high-tech and highly connected MNCs given good planning, an initial market niche, innovative management, and good business and government relationships.

Appendix 8: Case Studies in Skill Formation

1. Science/Engineering Skills Deficit in Penang

Although Penang does benefit from cluster dynamics in electronics the limited number of firms, technological diversity, start-ups and spin-offs suggest that it is a weak cluster dynamics without the high-powered injections from either research institutes, as in Taiwan, or complementary service-sector intensity, as in Singapore.

From this perspective, Penang's institutional, physical and skill formation infrastructures orchestrated by the Penang Development Corporation were highly successful in guiding the transition to a high-volume manufacturing cluster. But a new transition is called for and will require an entirely different set of institutional and skill formation capabilities. Unfortunately, to date, a similar strategy or consensus has not been developed to begin to mobilize the resources.

The most crucial short-fall is in the skill formation required to foster entrepreneurial firms and industrial innovation. There are no short-cuts: innovation in electronics is engineering intensive. Penang's limited innovation related skills, given the considerable manufacturing capabilities, illustrates the limits of an electronics infrastructure that does not include strong skill formation capabilities in areas such as design engineering, computer science, systems analysis, and information technology generally.

The problem is understood in Penang. Koh Tsu Koon, the Chief Minister of Penang, indicates the numbers involved, if not the scale of investment in higher education required to address the challenge:

> It is estimated that there are now about 12,000 scientists and engineers with a Bachelor of Science degree or equivalent working in Penang. This works out to a ratio of 10,000 scientists and engineers per million population, which is lower than that of over 25,000 per million population in Singapore and Hong Kong. We must therefore aim to reach the ratio of 25,000 by year 2002...With Penang's population expected to reach 1.4 million people, we would need at least 35,000 scientists and engineers by then, which means that we must produce and recruit some 23,000 scientists and engineers within the next eight years, or about 3000 per year. This is a very tall order indeed. (1995, p. 12).

With a ratio of 10,000 scientists and engineers per million population, Penang more than quadruples the Malaysian national figure of 2,300 per million. This means that Penang will likely have to grow its own engineers and scientists. While individual firms can poach engineers from one another and can harvest the existing crop of students, the region as a whole must plant new seeds in the form of an expanding flow of students entering into engineering and information technology related programs.

Industry and state government has a history in Penang of responsive collaboration in skill formation at the technical skill level. Each year the PSDC offers courses to over 8000 students (see Sidebar 3). The collaboration has contributed to the targeting of curriculum and upgrading of shop-floor skills appropriate to high-volume manufacturing production.[68] Presently, the PSDC is moving into information technology with a series of pilot projects that, if scaled up, could make a big contribution to upgrading the IT capabilities of the manufacturing labor force. A Bangalore, India software training company has been contracted to teach computer programming skills.

Why the lack of a similar program at the engineering education level? Faced with a skill shortage of manufacturing and technician skills, industry and state government created the Penang Skill Development Center to expand skills.

The main answer is that, the world over, even big companies do not have the time horizon to engage in skill formation investments for engineers or computer scientists. It was a matter of months between the time the concept of the PSDC was established in May 1989 and courses were underway; within months companies were enjoying the benefits of training programs.

The first reason, then is time scale: it takes not months but years for the training of engineers, and software engineers and developers. The second reason is that the qualifications for teachers is much higher. In the case of technician and manufacturing skills, companies themselves run related training programs and could quickly upgrade the quality of teaching staff.

Therefore, the bottleneck constraint in engineering skill formation is qualified teachers. It takes 4 years to increase the output of new engineers or scientists at the bachelor of science degree level even if the supply of qualified university entrants is available. To increase the flow by 3,000 per year means 12,000 students in a four year program and, with a student to teacher ratio of 15:1, 800 additional faculty with the appropriate engineering and science qualifications. This is a tall order indeed.

Given the shortage of engineers and scientists in Penang, finding over 800 quality faculty with the requisite capabilities and experience will be difficult. The major pool of candidates would likely be from within the MNC companies and Malaysians working overseas. To attract faculty will require considerable attention to quality of life issues. But it would also involve considerable attention to a curriculum appropriate to building on the strengths and strategic opportunities for Malaysian electronics.

The benefits from building up university education programs in engineering are not only in skill formation of engineers. The development of both the Route 128 and Silicon Valley electronics clusters involved the simultaneous development of university departments, research institutes and curricula, on the one hand, and rapidly growing entrepreneurial enterprises, on the other. This dynamic is the hot-house environment that has nurtured techno-entrepreneurs, important drivers of cluster dynamics.[69]

This captures the challenge of making transitions: without adequate graduates, new graduates can not be produced. Nevertheless they must be. This is the case in Penang.

[68] Lim documents both the areas of strength and the missing areas (1997).
[69] The best Asian model for the development of techno-entrepreneurs is Taiwan.

It will require the development of a plan in which companies, universities, regional and national government all make substantial contributions.

There is another big reason to make the investment. Skills and schools are local, immobile resources. Graduates from regional colleges and technical schools around the world tend to remain in the region.

Meeting the "tall order" will require institution building which will, in turn, require a large commitment of government funding, local political leadership, and industry/education institution partnering to develop the skills required to make the transition. The range of incentives that attracted MNCs to Penang were successful but they are not appropriate for addressing the transition challenge. Incentives that mask economic fundamentals—incentives that if withdrawn, would not leave behind lasting economic activity in the region—must be avoided. Effective industrial policy is more about education policy and technology policy than about tax incentives.

2. Case Studies: Diffusion Agencies for Medium-level Skills

Many of the large American and Japanese companies invest continuously in shop-floor skills. In fact, the "invisible college" of company skill formation is considerable in Penang. An audit of the quantity and quality of "invisible college" graduates from these programs would reveal a considerable regional asset or "social capital" (Lim, 1998[70], offers a starting point for a skill survey). These skills represent a sizeable regional asset, which have been accumulated over 25 years.

The MNCs in Malaysia are representatives, or elements of, the national systems of innovation of their home base country. This means that each subsidiary organisation within Malaysia is an element of a knowledge-increasing production system even though the idea creation potential of the subsidiary has not been developed or exploited within the Malaysian context. Realisation of knowledge-creation potential depends upon networked, organic relationships with other elements in the respective national systems of innovation. Nevertheless, much can be learned from the local representation of each national system and functionally equivalent "infrastructures" or networks of complementary institutions can be developed to better exploit the repressed knowledge-creation capabilities.

Industrial transitions can be fostered by mission-driven intermediary institutions (neither business enterprises nor government agencies) which form integral parts of regional and national business systems. Ignored by much of the industrial organisation literature, these intermediary organisations can be established; by industrial policy makers, by groups of enterprises, or by professional associations. They are an example of how the most effective industrial policy can often be conducted in the name of education and labour policies.

Technology diffusion and skill-formation work hand-in-glove in industrial transitions. The technology diffusion process depends upon the level of skill formation in the work organisation of a region's enterprises. The pace is enhanced by a shared supplier base of SMEs that can achieve world-class performance standards in cost, quality, and

[70] Lim (1998)

time. In fact, every region that has made the transition to TM3 has simultaneously incorporated a variant of the *kaizen* or continuous improvement model of work organisation across a critical mass of SME supplier firms.

Looked at from a national or regional perspective, advancing shop-floor skills again raises the issue of the size of the teacher pool. The number of teachers and the appropriateness of the curriculum place limits on the pace of skill formation. Successful programs have a common feature: teacher training is designed into the program.

The MNCs with subsidiaries located in Penang often have world class programs and processes located in other regions that can be benchmarked and applied throughout Malaysia. Examples follow.

Hitachi and incremental innovation

One example is small group activity (SGA) which constitutes the work organisation of many Japanese companies. Hitachi, in Penang, uses the same continuous improvement, *kaizen* work system that made the company a world leader in a range of electronics sub-sectors. The operational performance of the Penang plant generates a high level of productivity at the shop-floor level within the constraints of the innovation infrastructure. Hitachi-Penang does not co-locate applied research and manufacturing operations and does not integrate, locally, applied and developmental research. Consequently, the productivity potential of the system is limited. At the same time, SGA is a prerequisite to making the transition from TM2 to TM3 (see Table 1 next page) because it provides the flexibility and shop-floor problem-solving capability required for mixed-product flow. Hence it is a building block for higher levels of industrial innovation. It is also a model that, if diffused, would enhance the skill formation of the region.

Motorola and supplier skill development programs

Motorola's United States supplier development program, a second example, is often benchmarked by other companies. Key features of the program are industrial co-operation and networking with junior colleges to develop curriculum and to train the trainers.

BCM is a beneficiary of Motorola's supplier development program in Penang. A systematic 5-year technology transfer methodology has been developed with two complementary activities: manufacturing systems know how and engineering know how.

Manufacturing know-how transfer involves the following sequence:

- back end manufacturing of accessory products (1993-4)
- front end build of accessory products (surface mount technology transfer, skill transfer) (1995)
- materials procurement, stockroom and storage management (planning, buying, vendor interface, minibank) (1996)
- turnkey management (materials sourcing, materials procurement) (1997)

Engineering know-how passes through the following steps:

- materials quality engineering (failure analysis, vendor development, vendor process characterisation) (1996)
- process/reverse engineering (internal process characterisation, root cause analysis and design of experiments, statistical process control methods, product enhancement, prototyping, pilot manufacturing) (1997)
- research and development procurement (phone systems, radio frequency technologies) (1998)

The Motorola case is particularly instructive as a potential methodology, already piloted within the Malaysian environment, which could become the basis for a broad-based skill development program.

Dell and IT awareness

Several of Dell's world class organizational capabilities as practiced in Penang are examined in Chapter 4. Elsewhere, Dell has teamed with a local council to foster IT training. Dell co-sponsored an "Executive Studio", a hands-on work experience and training facility for chief executives, with the West London Training and Enterprise Council (**Manchester Guardian, 1998**, p. xii[71]). The studio gives senior managers real experience of using IT. To quote from Phil Blackburn, chief executive of the West London TEC:

> IT demands a new generation of senior managers. E-commerce is coming toward us like a tidal wave and senior management must be able to ride the wave. So the studio is not about IT awareness—but rather giving chief executives the confidence and competency to use IT directly.

TWI: Transfer of a skill-formation diffusion methodology

We illustrate a powerful Japanese example of a shop-floor skill formation agency with a case studies of the JUSE[72] and the Japanese Human Relations Association[73] in

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[71] Manchester (1998)

[72] JUSE was established in 1947 to promulgate quality control, statistical process control and total quality management, administers two journals, and publishes numerous books. PDCA, for example, has been introduced into numerous enterprises. Kaoru Ishikawa, who invented the fishbone, was a long term president of JUSE. The JUSE as much as any other single organisation has provided Japanese enterprises with a continuous improvement approach to production and a participatory approach to industrial engineering (see Best, 1990).

[73] The JHRA specialises on continuous improvement methods. Kaizen tiean is a system for eliciting commitment from every worker to contribute to ongoing improvement. While the suggestion box system has long existed in America, it has become a powerful organisational tool in Japan, not for eliciting one big idea but for promoting participation. The ideas of participation is to involve everyone in a concept of work with the goal of productivity enhancement through the accumulation of numerous small improvements. A second key improvement in the suggestion box system has been to give authority for approval and implementation to the front lines. The idea is not to simply give a suggestion, but to implement a suggestion; this means

Appendix 4. Another outstanding model is the Training Within Industry (TWI) program.

TWI was developed in America but thoroughly refined in Japan. Some have argued that the most important export from America to Japan was the Training Within Industry program.[74] It deserves special attention as it illustrates both a successful shop-floor skill-formation diffusion program and successful institutional transfer.

The effectiveness of the TWI program was clearly demonstrated during the Second World War when the United States dramatically increased its production while at the same time deploying millions directly in the war effort. It did so by developing a training program for a new labour pool composed largely of women and recruits from non-manufacturing sectors. Undertaken by the Department of War and based on analysis of the most successful industrial training efforts around the nation, TWI broke down the training system to its basics. They made five important distinctions: knowledge of the work; knowledge responsibilities; job instructions (every supervisor has to be taught how to train other workers); job methods (every supervisor has to be taught the importance of methods, particularly the principle of flow); and job leadership training. The first two are company specific, the latter three are referred to as the 3 J's. The key to the program was the cascading effect by which the trained became trainers.

Post-war Japan understood it's value; particularly the Ministry of Labour who hired United States trainers laid off by the US Government. The Ministry continues to license a range of groups to teach the program in companies. Toyota has their system, they call it TTWI (Toyota Training Within Industry). In Canon, every single trainer is certified in TWI.

The Penang Skills Development Center

The Penang Skills Development Centre, an industry-led, company and state government partnership to enhance manufacturing and technician skills plays a similar role in Penang (see Appendix 3). Such an institution will continue to be critical in the context of a move to greater industrial innovation capabilities in Malaysia. Regional advantage will depend not only on innovation but on the diffusion, successful application and improvement of proven technologies. SMEs, the world over, depend on skill formation agencies such as the PSDC for best practice methodologies and the improvement of capabilities. Mr. Lim documents the areas of shop-floor strength and weaknesses in modern manufacturing practices in Penang plants. Clearly, the PSDC could play even a much wider role as SMEs begin the long process of manufacturing modernisation.[75]

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educating and empowering work teams to control the process. The contrasting implementation capability is indicated by the fact that while 0.2 ideas per worker per year are submitted in the US, 20 ideas per worker per year are submitted in Japan (JHRA, p. xiii).

[74]This section draw heavily from Robinson and Schroeder, 1992.

[75] For an assessment of America's Manufacturing Extension Partnership, a national network of technology and business service providers see Shapira (1998).

3. Skill Formation in Singapore

Singapore electronics industry has successfully negotiated two transitions: internal to MNCs from labour-intensive to automation, and from automation to integrated manufacturing and in the process from vertically integrated MNCs to a dynamic cluster. In the mid 1990s, the electronics industry remains Singapore's most important manufacturing industry, accounting for 36% of manufacturing value-added, 25% of the manufacturing workforce and contributing 12% of the island's gross domestic product (Pang Eng Fong, 1995, p. 122-3 [76]). The foreign equity share of Singapore's electronics industry was 88% in 1992. All of these numbers are similar for Malaysian electronics, but the similarities stop here.

One difference is the huge gap between income levels in Johor and Singapore that has persisted even though they are elements of a single integrated production system. The technology management and the cluster dynamics model provide a number of insights into Singapore's success. Each of the following characteristics exists in Singapore. They offer criteria for the assessment of the present position of Malaysia's electronic and electrical industry and provide insights on the transformation.

Entrepreneurial firms. A dynamic entrepreneurial base is critical for acquiring technologies and exploiting market opportunities. Singapore industrial policy recognised the crucial role of entrepreneurial firms and that entrepreneurial firms can be local, joint ventures, and/or foreign subsidiaries. Secondly Singaporean industrial policy recognised that indigenous entrepreneurial capability alone was insufficient. Finally Singapore industrial policy makers recognised that entrepreneurial firms are both learning firms and have voracious appetites for engineering capabilities.

The development strategy was based on synchronising skill formation with the progression of firms along the production capability spectrum. The strategy was not based on leapfrogging technologies but on incremental advances in production capabilities that facilitate transitions across the technology management models. The strategy was not R&D or design-led but based on upgrading manufacturing capabilities in synch with the development of the engineering and technical skill base.[77]

Engineering and technical skill formation. The role of skill formation deserves special attention. Siow Yue Chia, director of the Institute of Southeast Asia Studies in Singapore points out that

[76] Pang (1995)

[77] Mike Hobday presents a case study of Wearnes Hollingsworth Group, a Singaporan owned, entrepreneurial firm. Wearnes began as a sub-contractor of connectors and progressed to OEM, ODM, and OBM in personal computers and added software and R&D capabilities to basic manufacturing skills in electromechanics and precision engineering. Hobday notes that: "In the early 1990s, Wearnes still saw its main technological strengths in high quality engineering applied to electromechanical and electronic interfacing tasks, in connector manufacture, chip packaging, plastic molding and electroplating, rather than software or R&D" (1995, p.1183).

> ...since the 1960s, the educational system has been continually restructured—with emphasis on technical and vocational education below tertiary level to provide a growing pool of skilled workers and technicians; and rapid expansion of engineering, business and computer education at tertiary level. Forty percent of the graduates from polytechnics and universities are trained in engineering and technical areas. Formal education is supplemented by training in specialised industrial training institutes to produce qualified craftsmen and technicians. The establishment of the Skills Development Fund provides upgrading training for those already employed (1998, pp. 2-3 [78]).

Matching productive capabilities and productive opportunities. The heavy reliance on MNCs was a means of focusing on building manufacturing and technology management capabilities that matched with emerging market opportunities (productive opportunities in terms of the cluster dynamics model). With the development of design capabilities primarily manufacturing firms (or subsidiaries) took a big step toward becoming entrepreneurial firms. These firms are still some distance from having innovation capabilities, at least in the case of electronics. Breakthrough innovation is still concentrated within electronics clusters particularly in Silicon Valley and Route 128.

Competitive advantage in manufacturing and services associated with low-cost, high quality production engineering. Singapore did not seek to enter into competition with regions that have competitive advantages in software, or in software and hardware integration, but built a competitive advantage in the delivery of low-cost, high-quality production engineering services. This competitive advantage goes beyond manufacturing to "packaging and integration" capabilities that underpin Singapore's emergence as a regional headquarter for supplying manufacturing services.

Singapore as packager and integrator. The expression "packager and integrator" comes from Enright, Scott, and Dodwell (1997 [79]). It captures the idea that Singapore firms are not mere co-ordinators of regional activities but "instigators and initiators" of economic activity, matching demand and supply on local, regional and global levels. Such firms (or networked groups of firms) embody a complex of activities that enable them to add value in a number of ways including through their knowledge of source and destination markets, through their familiarity with production capabilities of literally thousands of factories scattered throughout Asia, through advanced capabilities in logistics, and through expertise in managing subcontractors. Rather than a 'middleman', the Singaporean firm becomes a complete business partner for the customer, co-ordinating and putting together, 'packaging and integrating' a range of activities often beyond the capabilities of the customer... They provide a complete headquarters for management, financing, technology, design, prototyping, quality control, marketing, and distribution service between dispersed assembly plants on the one hand, and retail buyers on the other (1997. p. 55).

The cluster that captures all of the firms involved in 'packager and integrator' activities breaks down any manufacturing/services dichotomy; more, it transcends the

[78] Siow (1998)
[79] Enright, Scott, and Dodwell (1997)

metaphor of value chain with that of value network. The idea of a value chain is derived from a linear, assembly line context; the idea of value network captures the idea of real-time co-ordination and design integration across activities. The IMP2 has looked into the value chain intensively and its purpose is to move the industry along the value chain or position it higher. The Singapore model looked into the value network in order to seize real-time co-ordination and design integration across activities of the cluster.

The left-hand box in the cluster dynamic circular flow captures the capability of a region to quickly form value networks. The network integrator in the dynamics paradigm replaces the roles of either the auctioneer or the middle manager in equilibrium economics. The network integration capability operates at the cluster level much as systems integration capability operates at the enterprise level. In both cases each unit is flexible and design-responsive and the whole is subject to redesign to address new challenges. Whereas systems integration depends upon technical interface rules, network integration depends upon trusted social interactions. Proximity is important to both; thus the metropolitan advantage.

The extent and type of specialisation in the top box of the cluster dynamic circular flow in a dynamic metropolitan cluster contains a whole range of service type activities. In the case of Singapore many of these are elements of a manufacturing-services cluster. Singapore can not be faulted for having ignored the role of "low technology" supplier firms to a flexible "high-technology" cluster. Singapore's skill formation system has supplied a steady stream of skilled labour to maintain a regional small- and medium-sized enterprise (SME) supply base composed of machine tooling, metal working, plastic processing, die and mould making, instrument making, and related specialist inputs into manufacturing.

Growth and high value-added in Singapore come from the development of cluster dynamics involving mutually reinforcing entrepreneurial firms, developing unique capabilities, spin-offs and start ups that are facilitated by skill formation and infrastructure, and a proliferation of specialist firms that can horizontally combine and recombine to rapidly carry out projects. There are a number of lessons Malaysia can take from this example.

Appendix 9. Dynamic Regulation in East Asian Countries

Three Regulatory Models

The term regulation is used in the sense of rules, regulations, and institutions by which enterprises are governed and co-ordinated. Governments play a role in shaping the rules of competition and cooperation which, in turn, impact on a region or country's industrial organisation. Industrial policy is about developing a strategy to shape industrial organisation including cluster formation. Regulatory institutions are central to such strategies.

Regulatory models of the past were based on fostering price-led competition. The goal of enhancing product-led competition calls for new regulatory models. They also create new policy opportunities for local or regional governmental agencies.

The new regulation is about establishing rules of inter-firm competition and cooperation to advance capabilities and innovation. Inter-firm adjustment processes include market processes and the dynamic processes that constitute regional growth dynamics. The goal of the new regulation is to foster mutual adjustment processes that advance a region's collective entrepreneurial capabilities. Collective entrepreneurial capabilities are not centralized but self-organizing or self-assembling. Product-led regulation is about regulation for new product development, new firm creation, skill formation, technological advance, and for industrial innovation, speciation and new industry creation. These are the processes that foster technology-led growth

Three rapid growth regulatory models have successfully driven a transition to more advanced electronics clusters in East Asia are described in Appendix 4. The first model is the Japanese and Korean model driven by large, domestically owned conglomerate-type business enterprises in close alliance with industrial policy strategies committed to developing indigenous technology management capabilities. The second is the Taiwan "industrial district" model based on a proliferation of small and medium sized firms some of which have become entrepreneurial firms and an industrial policy geared to developing techno-entrepreneurs. The final model is the Singapore model driven by local divisions of foreign owned multinational companies and a human resource oriented industrial policy designed to transfer capabilities from corporate headquarters to local divisions which, in turn, act as the hubs for regional production systems.

Malaysia has pursued a variant of the Singapore model in that the electronics industry is virtually entirely foreign owned. In the period 1984-89, Malaysia was the fifth largest recipient of inward FDI flows going to developed and Asian economies but became the second largest over the 1990-1994 period (Singh, 1998).[80] Given that Malaysia has followed a variant of the Singaporean model we explore it further. We are not proposing the Singapore model but recognizing that a product-led regulatory

[80] Over the 1984-89 period, Singapore led with 28.3% followed by Hong Kong with 12.2%, the United Kingdom with 11.5%, the Netherlands with 9.9% and Malaysia with 8.8%; Taiwan received 3.3%, China 1.8%, Indonesia 1.6%, Korea 1.4% and India 0.2%. Over the 1990-1994 period Singapore remained the leader at 28.4%, followed by Malaysia at 22.4%, the Netherlands at 12.2%, China at 11.6% and the UK at 10.5% (Singh and Zammit, 1998).

model for Malaysian electronics must begin with the strengths that the region has and these involve a 'flexible mass production' (TM 3) manufacturing platform closely tied to multinationals.

Case One. Big National Firm Networks: Japan and South Korea

Japan: The Japanese licensed cutting edge technologies as a means of building indigenous TM capabilities. The Japanese pioneered new TM concepts (and instruments) such as interactive (or production pull), as distinct from science-push models of technology demand articulation, technology fusion, and assessing of technology diffusion. In addition, financial institutions and corporate governance were all designed to provide long term funding for investing in technological advances. The Japanese model of TM gives the country a competitive advantage in integrating volume production, new product development, and pace of technology introduction. The organizational model applies system thinking and emphasizes the management of interrelationships.

Lead manufacturers as part of the development of JIT production systems drove diffusion in Japan. They needed to upgrade the capabilities and performance standards of suppliers; so they found willing collaborators in both specialist intermediary agencies and strategic industrial policy initiatives. The result was the development of a dynamic domestic production system composed of lead manufacturers integrating and interacting with a broad base of small and medium-sized enterprises (SMEs). While the contributions of the big enterprises are widely know, the SME base is less familiar. For example, the Keihin region outside of Tokyo and home to 200,000 SMEs employing 1.7 million people is the heartland of the Japanese electronics industry.

South Korea: Followed Japan in pursing rapid growth by focusing on the importation, refinement and diffusing of diffusion strategic, cutting edge technologies. Both encouraged the development of giant corporations which made technology management endogenous and led to indigenous technology development capabilities. It is estimated that the 10 largest Chaebol's are responsible for roughly half of industrial output.

Both have developed new models of corporate organization which emphasize applied technological R&D capabilities. Both countries are on the cutting edge of technological change in certain industries, but Japan in many more. In comparison to Silicon Valley and Route 128 in the United States, both countries are relatively weak in entrepreneurial activity in small but fast growing firms. These firms have been particularly successful in design-related areas from the integration of software within chips to the use of software engineering to redefine and redesign product areas.

Slow growth followers, on the other hand, lack the capabilities to tap the world's pool of technologies. This is not surprising. Successful technology management itself requires the development of the three distinct but interrelated capabilities: strategic, organization, and production. Successful technology management, like the establishment of price for Alfred Marshall, depends upon both blades of a pair of scissors; supply must be matched by effective demand. Demand in price theory is mediated by income, demand in technology management is mediated by production capabilities.

The rapid pace of introduction of technologies in Japan South Korea is a consequence of the prior or simultaneous development of a specific set of production capabilities. Both started with the idea of cutting edge technology, not with the idea of a rapid pace of introduction of technologies. The latter was a consequence of driving down cycle times first in production and second in new product development. Japan remains the undisputed Asian leader in rapid new product development and new technology industries.

Case Two. Industrial District Model

China-Taiwan: Like Japan and South Korea, Taiwan did not rely upon multination companies as the main vehicle for the introduction and development of new technologies. However unlike the other two, Taiwan has built a large population of small and medium sized firms, which collectively, have considerably technology management capabilities. In Taiwan, over 98% of manufacturing enterprises are SMEs that account for 60% of Taiwanese manufacturing exports.

Taiwan is virtually alone in East Asia in developing the (flexible-specialization) industrial district model. Such districts have a competitive advantage in fashion-related and design-intensive industries; they use inter-firm networks to develop and refine small scale technologies and spawn new, entrepreneurial firms at a high rate. Taiwan, like Silicon Valley and Route 128, has developed a version of the flexible specialization model to electronics. For example, unlike the specialization in high volume memory chips done by Japan or Korea, beginning twenty years ago Taiwan developed chip making plants for small scale or ASIC (application specific integrated circuits) chips. ASIC chips, combined with software engineering skills and entrepreneurial firms (old and new), means that Taiwan has Own-Design-Manufacturing (as distinct from OEM) new product development capabilities over a broader industrial range than elsewhere in East Asia.

Case Three: MNC's and Regional Procurement models

Hong Kong and Singapore: Both island-nation states have used multi-national companies as vehicles to develop indigenous production, organization, and technology management capabilities. Both have specialized in procurement from neighboring countries with large labor supplies. Both countries enjoyed a rapid rate of capital accumulation by multinational companies, which introduces cutting edge technologies. Singapore, in particular, instituted domestic skill formation programs which both locked-in the multinational companies and created the skill capabilities for national companies to emerge which are capable achieving world class performance standards.[81]

[81] Three types of dynamic industrial district can be contrasted: big firm dominated with a large SME supplier base (Japan); networked groups of small firms with a large presence (the Third Italy and the machine tool industry in Baden - Wurtemburg, Germany): networked groups of firms of all with high birth and death rates and distinguished by the of rapidly expanding firms (Silicon Valley).

Singapore and Hong Kong demonstrated that foreign direct investment can be a catalyst but sustainable growth demands the development the development and diffusion of production qualifications across a wide range of firms. Crucial to the diffusion process is the development of a broad class of product and process engineers and multi-skilled production workers.

Singapore built a targeted skill upgrading infrastructure to match the physical infrastructure is a network of training centres composed of craftsmen centres, technical institutes and programs such as Continual Upgrading Training and Skill Development Fund. Since the curricula was formed in partnership with technologically advanced business enterprise, foreign find they can transfer increasingly complex production activities to Singapore, Micropolis, for example, used the national training network to introduce disk drive production and open a regional R & D center in Singapore. By the late 1980's, Apple Computer's Singapore Division was engaged in concurrent engineering projects for components that affected the design of Apple computers in a state-of-the-art plant.[82]
Taiwan, Hong Kong and Singapore all rely heavily on the tightly-held Chinese family, international networking model. Indigenous firms in all three nations are networked by family and clan ties manufacturing in other parts of East Asia and to marketing organizations in the united States and elsewhere.[83] Taiwan, however, stands alone in terms of indigenous management capabilities. Neither Hong Kong nor Singapore has development a critical mass of indigenous industrial enterprise with products development TM capabilities. Both Hong Kong and Singapore are hosts of MNCs from Japan, the US, Europe and Taiwan which use the city-states increasingly as procument centers for manufacturing from surrounding regions.

Technology Policy in East Asia

The claim to this point is the following: Technology management at the national level is itself a capability that plays a key role in explaining growth. The East Asian economies that have achieved high rates of growth have each developed the capability first, to adopt, adapt, and diffuse technologies that originated in the most technologically advanced nations; second, to develop new products and processes based on refining, fusing and transitions. Together these are attributes system of technology management.[84]

Articulating a technology management strategy is central to economics policy making for a development state. We can identify distinctive technology management strategies in each of the high growth East Asian countries. In fact, the idea of national technology management is to the developmental state (and the New Competition)

[82] Magaziner, p60
[83] Countries investing in Malaysian 1994, in rank order, are Japan, Taiwan, the U.S., Singapore, Hong Kong, and then all others. U.S. investment was 13.7 percent of the total. The aggregate Japanese investment is 23.9 Percent. The U.S. 3.2 percent, and other Asian economics 54.6 percent (Joseph Coates, Research Technology Management; (Washington Jan/Feb 1996,6)
[84] Slow growth followers, on the other hand, lack the capabilities to tap the world's pool technologies. This is not surprising. Successful technology management itself requires the development of three distinct but interrelated capabilities, organizational, and production. Successful technology management, like the establishment of price for Alfred Marshall, depends upon both blades of a pair of scissors; supply mush is matched by effective demand. While demand in price theory is mediated by income, demand in technology is mediated by production capabilities.

what demand management was to Keynesian economics or money supply management is to monetarism or free markets is to the "Washington Consensus". Discussions of growth in conventional economic theory and much of the Western press, however, are generally conducted within a discourse, which does not have conceptual space for technology management. What follows are elements of distinctive TM strategies. The claim is not that TM strategies were always spelled out in advance but that each can be discerned by an examination of a country's experience.[85]

The challenge is to develop a national system of innovation and technology management. Every industrialized country has developed such a system but the institutional characteristics are unique to historical circumstance.

Every country or region operates in a global environment, which is itself subject to dynamic reconstitution. An initial set conditions existed when Japan began the historically unprecedented growth experience that culminated in the development of TM4. These include low wages in Japan, the US had not experienced the quality revolution, the NICs did not yet exits, and china was in the throes of its" cultural revolution". The very success of Japan undermined the initial conditions and created new conditions for Japan and other nations. By the mid-1990s, Japanese wages were high, the US was enjoying an industrial resurgence based on TM, and the NICs had successfully imitated many of Japan's organizational and production capabilities. Furthermore, the ASEAN nations plus China offered production platforms for assembly and parts productions that at a competitive advantage relative to Japan.

Increasingly, trade and growth patterns are shaped by competitive advantage based on organizational capabilities as distinct from "factors of production: This creates both opportunities and challenges. The opportunities come from a nation being able on create its own sources of competitive advantage rather than being subject to the abundance of nature or the wage level. The challenge is equally pervasive: the participants in marker places are constantly increasing in number and proving in capabilities. Central to the new competition is the drive establishes national systems of technology management and innovation. As yet, a consensus does on how to shape competitiveness by such systems, but lessons can be learned from a review of some of the major efforts.

One. Japan : Sector Strategy in the Development of the Computer Industry.

The organizational model for government promotion of technological advance has involved the simultaneous promotion of competition and cooperation. Put differently, strategic industrial policy is about shaping the dorm that competition takes. The following quote from Kenneth's Flam's study of the development of the Japanese computer industry illustrates the points:

[85] The role of technology in growth theory is ambiguous. Suffice it to say that technology in economic of growth is like the invisible man. It is both crucial to explaining growth rates and exogenous (thereby not defined) within the model. Solow attributed over 50% of growth to "technology" and "technical change". In fact, in explaining US growth, Solow: " It is possible to argue that about one-eighth of the total increase is traceable capital per man hour, and the remaining seven-eighths to technical change". Total factor productivity accounts share the same ambiguity: technology and technological change are both central to growth and not explained with the theory.

> Japan never handed over the entire domestic market to a favored company - - a "national champion". Instead, support was given to a small group of highly competitive firms, ad the virtues of competition were preserved even as limits on entry by outsiders were established. At an early date the government tested cooperative research projects as a vehicle for extending financial support for technological development. They proved successful and became the organizational model for subsidies to research and development.[86]

Flam describes how two organizations, the Electrotechnical Laboratory (ETL) and the University of Tokyo developed computing calculating machinery and private enterprise became involved. ETL, founded in 1891 as [art of Japan's Communication Ministry, built the first transistorized computer in Japan in 1956. ETL, which in 1952 had been transferred to MITI, collaborated with a number of then small firms, including Fujitsu, in building the early Japanese computers. In 1957 the Electronics Industry Development Provisional Act was passed by the Diet and, when imports of computers expanded in 1957 and 1958 MITI encouraged firms to establish the Japan Electronic Industry Development Association.[87] MITI gave little direct assistance to individual firms. Again in the words of Flam:

> ...the total subsidy to R & D awarded during the 1957-61 period was under $1 million. Direct technical assistance from government labs or joint development efforts with universities continued to be the chief instrument of support for computer development in private firms the early 1960s.[88]

In recent years the concept of fusion has become a guiding principle in the shaping of government sponsored consortia. In one industry, machine tools, the result were spectacularly successful and redefined MITI's approach to sector strategies.

Two. Japan's Technopolis Program

Japan's record of sustained growth was driven by new models of technology management, which was grounded in the Kaisha but enjoyed support and, at times, leadership from government policy market.[89] The Japanese model of technology management, described as TM4, was successful in propelling Japan to global leadership Japan to global leadership in a range of complex production industries such as consumer electronics and automobiles (quadrant 3 activities). Japan has a considered lead over the rest of Asia in the breadth and depth of modern industry. She alone in Asia has the "full-set" of production capabilities (3 technologies of Seko Mitsuhiro) and a deep reservoir of technology management capabilities.

Technology management in Japan has been a central concern to MITI beginning in the interwar period. But MITI's role was complimentary to a form of oligopolistic competition amongst eight closed system *Kieretsu.* A distinctive feature of the Keiretsu was networking within a closed system.

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[86] Flam, Kenneth (1988), p173
[87] Flam (1988), p179
[88] Flam (1988), p 179
[89] Footnote on Flam and computer industry from Lake Bled paper. Also reference to Chalmers Johnson and Best, Ch. 6 on MITI.

The strengths have been made abundantly clear in terms of the rapid growth of Japan's industry. But shortcomings have also been noted. First, since technology management had been centralized in the Kaisha, it has nor been widely diffused across independent enterprises or geographical region. The headquarters of the Kaisha are concentrated in Tokyo as are the R&D activities of the Kaisha. In electronics, for example, this means that the R&D id concentrated not only within each of eight companies but that electronics R&D is concentrated near company headquarters in the Tokyo area.

Innovative industrial districts are associated with geographical concentration but two qualifications are in order: a large nation can have more than one regional concentration and the regional concentration can itself benefit from a wide diffusion of innovation sites (at least more than 8; Silicon Valley and Route 128 have thousands). Second, while Japan enjoys undisputed leadership in "downstream" innovation, her technology management capabilities have not extended to basic innovation on the same scale.

With these shortcomings in mind, MITI launched it technopolis program, an effort to create a 26 Silicon Valley's in Japan. *MITI's Vision for the 1980s,* released in 1980 described the vision:

> "Technopolis" (Technology-intensive city) is a city that effectively combines an industrial sector composed of electronics, machinery and other most advanced technologies with an academic and residential sector. This concept aims at promoting regional development and creating a new regional culture under the lead of industrial and academic progress. A possible model scheme in and after the 1980s, it differs in its approach from the conventional ideas of regional development centering on land utilization and infrastructural improvements.[90]

The technopolis program had two central goals: world leadership in technological innovation and regional development. A third goal was to counter "hollowing-out", the tendency Japanese manufacturing enterprise, large and small, to produce offshore. The program was passed into law in 1983, began to operate in 1984-5 and is expected to be in full operation early in the first decade of the 21st century. But assessments in the early 1990s of its success have not been encouraging. Summarizing other assessments Castells and Hall offer 2 main conclusions. First, it has not been very successful in generating 8 located within 200 miles of Tokyo and the rest for which the prospects are poor.[91] Second, "even the limited success mainly lie in promoting branch-plant type operations which have little innovative and are highly vulnerable to the risk offshoring".[92]

Two of the more successful technopolises are on Japan's southern island of Kyushu, sometimes referred to as Silicon Island. Over 40 percent of Japan's IC output comes from Kyushu. But this was the case before 1980. The attraction of the island was

[90] Castells and Hall, p115
[91] Some evidence suggest that the more successful technopolises have been those that stressed transforming" traditional local industry" into "modern local industry". Casttels and Hall, p199
[92] Castells and Hall, p142

"pure fresh underground water, clean air, hard-working people, a forward-looking prefectual government, and excellent centers of technology learning and research".[93] Boston's Route 128, and North Carolina's Triangle Park, provided the model for Kumamoto technopolis. The plan was to develop not just production but research activities; thus the construction of a research park in the center of the planned corridor.

Even here, however, the technopolises have a disappointment both in terms of expanding production activity and in promoting research. Most of the production is of a routine assembly type character; the facilities execute design drawn up in Tokyo or Osaka. The manufacturing of chips demands high quality labor; it is rarely done offshore foe this reason. But the differences between the skills required to make chips, done on Kyushu Island, and assembling, packaging and testing, done in Malaysia is relatively minor. Both are variants of branch plants; the system and systems integration research and developments is done near headquarters. This not changed with the two technopolises established on Kyushu Island.[94]

In general, Japanese R&D and technology management has not moved to provincial areas but remained located close to corporate close to corporate headquarters; in fact, recent suggest that closeness to headquarters has increased in Japan. The Kyushu Island experience is part of a division of labor common to industry in Japan which separates factories producing prototype models, called" mother factories", from factories producing standardized models. "Mother factories" stay close headquarters; standardized mass production plants can be established anywhere.

The high value of the yen following the Plaza Accord in 1985 added to foreign direct investment abroad. In the decade to 1994, Japanese FDI I Asia nearly quadrupled from under $70 billion.[95] The share of total FDI by Japanese SMEs doubled from 40% in 1990 to 80% in 1994. The entire region is increasingly viewed by Japanese companies as a production base to supply global markets. Offshore productions have been more attractive than lagging regions within Japan to set up standardized plant facilities. But in both cases, the branch plants are not sites of innovation or technology management.[96] These activities remain concentrated in an integrated system which links generic research with "mother " factories.[97]

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[93] Castells and Hall, p133

[94] The lack of high quality software workers is common in Japan. A robotics firm located a branch plant at Oita technopolis on Kyushu Island partly because "it was difficult to get op-quality software workers in Osaka"(Casttels and Hall, p131). The prefecture established R&D and engineering training programs at Oita University. Oita technopolis is recognized the most successful but Oita University's activities notwithstanding, Casttels and Hall write that "..in Oita one crucial ingredient –support and involvement of universities-appears lacking" p132. This is consistent with the lack of integration of R&D and production on Kyushu Island. Casttels and Hall note that the technopolis program does nor provide for upgrading of skills(p133).

[95] Hatch and Yamamura, p5

[96] List the 11 criteria of successful districts, p140 and 248 of Casttels and Hall

[97] Why? Part of the answers is the same as the answers to the question of why Japan does not have a large presence in microprocessor chips. Compared to TM Model 5, Japan lacks open systems and the capabilities to integrate software and hardware. The corporate centralized model of technology management is exceptionally strong at system integration but not systems integration. The later requires a strong industrial district, which combines opens systems and decentralized technology management capabilities.

Three. Japan's Kosetsushi Technical Research Centers

The Fraunhofer Institutes of Germany have long provided the model of technical research centers that services SMEs, but today, Japan is perhaps the most innovative. Japan, like Germany, has an extensive group of SME's with roughly the same number of enterprises as the U.S.

Japan's public technology program for SMEs is conducted through 178 "kohsetsushi" centers or public testing laboratories. The kohsetsushi centers are sponsored by the Small and Medium Enterprise Agency of MITI but are administered by prefecture governments. The central government provides 10-20% of the estimated $1 billion annual spending on kotsetshusi and prefecture and local governments pay most of the balance.[98] The kohsetsushi centers offer research services, technology assistance, testing, training and management assistance to industrial enterprises with 300 or fewer workers Of the 6900 people who work at the kohsetsushi centers about 5300 are engineers. About half of staff time is spent on research.[99]

The model for the industrial extension program which influenced the design of the kohsetsushi centers is the American agricultural extension program established early this century. The American agricultural extension program diffused technologies and new practices through a system that linked small firms with agricultural experiment stations, and university agricultural research departments via extension agents. Lacking an extensive university system, MITI organized the kohsetsushi centers to conducts research. They also cooperate with the Japan Small Business Corporation, a public corporation established by MITI to implement the whole range of assistance programs for SMEs across all sectors including the promotion of fusion groups.

All of these agencies illustrate the importance of cooperation for the provision of services that have substantial economics of scale or that involve public goods. To leave the provision of such services to the market generates a large consultancy sector in America but their task is to parcel out information to individual firms and this promotes rivalry. The quasipublic agencies, on the other hand, have an incentive to diffuse management practices, oraganizational innovations, training programs, etc., across a broad range of enterprises.

Four. Taiwan: Hsinshu Park

Taiwan's Hsinshu Park demonstrates that governments can create high-tech industrial districts. Government played a more direct role than in Silicon Valley, Route 128 or the Keihin region of Japan. The government planned Hsinshu Park, in the other cases government fostered innovative milieu that were created independently of government intention.

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[98] Shapira, -1995a, Table III

[99] A powerful stimulus for cooperation has been the lack of engineering and technical capabilities within technical development. 69% cited a shortage of engineers and researchers (Subramaniam, p316). During this stages, engineering intensity of the intensity of the projects leads to shortages. In a survey in 1988. Over 80% of the enterprise cited shortages of engineers as a bottleneck. This is in spite of the difference in engineering graduation rates. A recent Science editorial made the following comparison:

> In 1990, six Asian countries (including Japan) produced more than 250,000 first degree engineers. The United States graduated 65,000 (vol.266, 9 Dec.1994, p1623).

Taiwan's industrial planners studies both Japanese and South Korea industrial transformation from low skilled labor intensive first to energy intensive and second to complex production consumer products and their drives into knowledge intensive processes. But with the first oil crisis of 1973, the high cost of energy shifted the emphasis toward non-energy, technology intensive sectors including machine, semi-conductors, computers, telecommunications, and robotics. At the same time Taiwan did not have the conglomerate corporate structure of the Kaisha or Keiretsu of Japan or the Chaebol of South Korea to drive R&D and technology management.

SMEs dominated Taiwan's industrial structure. But rather than advancing technology intensive sectors by fostering the concentration of industrial activity in giant corporations, the Taiwan vision was to create government owned R&D institutes in strategic areas. The visions was laid out in National Guidelines for Long Run Scientific Development in the 1950s and Council on Long Run Scientific Development was formed to implement the vision.

The Industrial Technology Research Institute, (ITRI), a major technology transfer agency with an eventual staff of 4500, was established in 1973 by the Ministry of Economy and funded by the Science Committee. ETI wasted no time in beginning a process that has established Taiwan as a world center in electronics. In the words of Castells and Hall:

> In 1973 ITRI bought integrated circuit design technology from the American multinational RCA. The aim was to transfer design capability to Taiwanese companies; a senior executive of RCA was recruited by the Taiwanese Government to supervise the project. Forty young Taiwanese engineers were sent for 18 months to RCA centers in the United States foe advanced training. The first group of these engineers came back to Taiwan in 1994, and that very year they designed the first integrated to be entirely made in Taiwan. [100]

The same engineers formed the staff for the Electronics Research and Service Organization (ERSO), one of five ITRI research organizations, which was created in 1976 and housed in Hsinchu Park. ERSO parlayed the transfer agreement with RCA into the opening of a model shop for wafer fabrication in the same year. An Information Industry Task Force was created and headed by two senior cabinet ministers who reported directly to the premier (wade). ERSO emphasized design as well as production and in the process created the largest pool of software design capability in Asia outside of Japan.

Robert Wade describes the next stage:

> Commercialization of the advanced microelectronics technology development in the public research lab has been undertaken primarily by United Microelectronic, a subsidiary of ERSO established in 1979 with a 45 percent equity share held by five private local firms. In 1982 Microelectronics opened a state-of-the-art fabrication facility to make various kinds of ASICS. It also formed agreements with three Silicon Valley Chinese American firms

[100] Castells and Hall, p 102

relocated in Hsinchu Science Park, emphasizing advanced semiconductor design rather than production. By early 1985 a 256K CMOS DRAM chip had been designed, any by 1986 a one-megabit chip.[101]

In 1986 ERSO orchestrated the formation of Taiwan Semiconductor Manufacturing Corporation and contributed roughly half of the staring up costs to form a joint venture between Philips and several domestic public private companies with purpose of establishing a state-of-the-are fab to make VLSI chips in Taiwan. By 1988 TSMC (47 percent government owned) claimed to be only 9 month behind TI and Intel in ASICs chips.

TSMC concentrated on ASICs rather than compete with Japan and Korea in memory chips the US in microprocessors. In fact, TSMC established the first merchant fab which produces chips to order rather than design its own. Today is produces for leading OEM chip companies including Cirrex and AMD.

The ASIC was to the burgeoning Taiwanese industry what the machine tool was to the Connecticut River Valley in the establishment of America's first metal working industrial district. ERSO played the role of the Springfield Armory in diffusing a generic technology across thousands of firms and dozens of sectors. But besides the whole range of consumer electronics, Taiwan moved quickly computers, computer software, and telecommunications. A plethora of design house linked semiconductors to manufacturers of all types of products.[102] Taiwan's computer industry virtually exploded to over 100 firms. ACER, the largest, became a major world player producing clones within month of new product launches, often with superior operating characteristics.

Taiwanese semiconductor companies enjoy substantial world share in logic chip sets that go into every PC. Thus, reminiscent of the Italian industrial districts in light industry, competition is intense in the Taiwan computer industry as new companies can enter the market by purchasing virtually all of the components required in a PC.

ERSO has continued to play a lead role with strategic investment in over 20 information industry research projects in the early 1980s. But always ERSO has encouraged its engineers to leave and start up companies. The Taiwan government offers a wide range of incentives, including low interest loans and joint venture options up to 49 percent of paid-up capital (some of the private investors capital can be the capitalization of patents and -know-how). ERSO is also an active licenser of foreign technologies that it in turn sublicenses to various firms in order to advance the sector's competitiveness. Along the way, Taiwan has created a vast pool of skilled labor that, in turn, has attracted virtually every major electronic company in the world to Taiwan.

Five. Beijing's Silicon Valley.

The Beijing zone for the Development of New Technology Industries is located in a Zone rich in research and academic institutions including Beijing University, Qinghua

[101] Wade, Robert, p 140

[102] Wade estimates that by early 1990s Taiwan had 58 design houses compared to 218 in all of Europe (p106)

University, Beijing Science and Engineering University, and Chinese People's University and the Chinese Academy of Science.[103] Beijing's Silicon Valley has a number of similarities with Route 128 and Silicon Valley: first, ongoing relations between industry between industry and technology oriented university which foster technology development and transfer; second, a dense concentration of high-tech companies perhaps as many as 2000 formed by university instructors and researchers; located within or adjacent to vibrant urban environment; and close proximity to a full-set of metal working, machine making and precision-engineering specialist shops. In addition, along the main street of Beijing's experimental zone is the Zhongguancum Electronics Town, China's equivalent to Tokyo's Akihabara or electronics town. Her stores are packed with the latest electronics products and parts and the streets are filled with young people.

In a recent study of innovation in china, Qiwen Lu applies the case study method to process.[104] He argues that "Among one dozen or so key technological breakthroughs underpinning the Founder systems, the major were developed by graduates students (MS or Ph.D. candidates) of ICST [Institute of Computer Sciences and Technology]".[105] ICST was created in 1976 at Beijing University. Beijing Founder Electronics is "the leader in Chinese software" and one of leading PC makers in China which is described by the head of Intel's China operations as "very advanced systems and very competitive with multinationals".[106] The Founder Group's predecessor organization was Beijing University New Technology Development Company itself founded in 1985 to commercialize technologies developed at Beijing University.[107]

Qiwen Lu offers a number of example of breakthrough innovations in information technology by Beijing University faculty and graduate students. Wang Xuan, for example, developed a "mathematical representation of Chinese fonts" for addressing the complexity of generating high-resolution Chinese fonts in a computer system. The resulting to the "Hint" technique widely used in the West for representing alphabetic fonts in the mid 1980s was advanced by Wang in 1975. Wang invented a procedure for mapping the contours of Chinese fonts in ways that reduced the reduced the requisite memory space by several hundred times. The ICST emerged out of this research and, in turn, developed a product that integrated the core technology, a "faster image processor for Chinese font information processing with a range of technologies across precision machining, lasers, and electronics.

A high-end Chinese electronic publishing system requires more than 20,000 characters and has more than 50 font types. The challenge was to build a conversion program that would enable the requisite font information every time a character was chosen in a time span similar to alphabetic font processing, otherwise publishing in Chinese would remain interminably slow. A graduate student of Wang invented an algorithm that was capable of "executing one curve-to-dot operation in one computer clock cycle".[108] This enabled Wang to design an ASIC chip, named PostScript co-

[103] Seki Mitsuhiro, p112
[104] Changing Organization of Innovation in China: the Case of Founder Group Co", CIC. University of Massachusetts Lowell.
[105] Lu, Qiwen, p16
[106] *Business Week*, April 14, 1997, p58
[107] Lu, Qiwen, p 10
[108] Lu, Qiwen, p 14

processor, to accelerate the conversion program. Adobe was simultaneously developing the Type I co-processor, indicating that ICST was on par with Adobe in technology development.

Beijing Founder Electronics has ridden this innovation capability to become an internationally competitive Chinese enterprise. The innovations have been both technological and organizational. ICST's extraordinary technology development achievement is described by Wang Xuan as a strategy of "following up and leaping forward". In his words:

> "In high tech areas, there are big lags between our country and the advanced countries. Lots of new ideas and methods originate abroad. Following up is inevitable. However, we should not be satisfied with merely following up, because mere following up would not come with competitive products. It was inevitable that we would follow up in a quite long time. However, it was possible to leap forward based on our indigenous innovative capabilities".[109]

ICST, according to Qiwen Lu, triggered the concept of the National Key Laboratory and the National Engineering Center. The idea was to create 100 national key laboratories in fields in which china was on the frontier of basic scientific research.

Six. Korea: Taedok

Linsu Kim has documented the transition of Samsung from fabricator of wafers (discrete devices) beginning in 1975 to the world leader in DRAM design 1994 with exports of $5 billion. Samsung entered VLSI production under foreign license in 1984 and became independent in DRAM design and productions in 1988. Korean production of semiconductors grew from $32 million on 1970 to $424 million in 1980, $1155 million in 1985, $5104 million in 1990, and $14,800 million in 1994. The Korean industry began in the mid-1960s when foreign multinationals, Signetics, Fairchild, Motorola, Control Data, AMI, and Toshiba, began packaging discrete dives with low cost Korean labor. In 1974 the first local semiconductor firm was established by a Korean-American scientist with semiconductor design experience at Motorola; Samsung bought out the financially troubled company within the company's first year. Samsung used the company to produce a range of transistors and integrated circuits on a small scale for Samsung's consumer electronics products. In 1983 Samsung purchased chip design and processes from distressed small semiconductor companies in the U.S.

Inter-regional Production Networks

Japan's global production networks: regionalization of the Keirestu

The focus on national systems of technology management and technology policies must account as well for changes in the dynamics of global production networks. Differences in the industrial organization of the electronics industries in Japan and

[109] Lu, Qiwen, p 15

America are reflected in different pattern of global production networks. Recent developments of each are explored.

In the decade to 1994, Japanese FDI in Asia nearly quadrupled from under $20 billion to over $70 billion.[110] The share of total FDI by Japanese SMEs doubled from 40% in 1990 to 80% in 1994. Hatch and Yamamura estimate that by the mid 1990s, Japanese firms will produce more of many products outside Japan than inside, including televisions, VCDs and Stereos. The entire region is increasingly viewed by Japanese companies as a production base to supply global markets. Unlike the Ota ward centered industrial district, the large population of Japanese SMEs that produce abroad in Asia consider themselves part of a Japanese based production network that engages in extensive intra-regional trade within their respective keiretsu Umbrellas.[111] The following quote captures the idea of company intranetwork production and training:

> "...to manufacture VCRs at its assembly plant in Bangi, Malaysia, Sony uses integrated circuits and other sophisticated components imported from Japan and printed circuit boards and other semifinished goods imported from Singapore. It purchases tape decks, as well as many other basic pats, from local suppliers in Malaysia, many of them Japanese".[112]

Some argue that Japanese manufacturers guard their technological advantage by locating discrete links in the production chain at different sites throughout the region. Whether planned or not, the effect is to limit Asian neighbors from integrating the production systems, a prerequisite to advancing technology management capabilities. It also sustains the large trade deficit in electronic high tech components that all Asian countries face with Japan.

The same result, however, may not be a consequence of corporate strategies to divide (technologically) and rule. Instead, it may be due to of the success of Japan at developing TM3 and TM4 and the associated increases in wage levels and property values driving up costs for small and medium-size businesses. Add to this the appreciation of the yen making foreign purchases including investment cheaper and the concentration of R&D and new product development within Japan.[113]

Maturation of the Japanese electronics industry and closed global networks

The Japanese and American industries have followed different trajectories, face different challenges, and have fostered different global production networks. Japan's competitive advantage is in quadrant 3, complex production process activities. The Japanese have tended to sharply differentiate complex production oriented products from knowledge intensive products. The idea is to move from quadrant 4 product areas. The resurgence of American industry, to the country, is about redefining quadrant 3 in terms of quadrant 4 capabilities.

[110] Hitach and Yamamura, p5
[111] Hitach and Yamamura, p23
[112] Hitach and Yamamura, p25
[113] A third explanation is offered by Seki Mitsuhiro. And Tang, What Malaysia has is assembly technology capabilities. Actually the 3Ks include 7 machining sub-sectors (Seki) which "community property".

The Japanese electronics companies have continued to improve and refine production capabilities of quadrant 4 which has meant specialization in components. As labor costs have increased and labor availability for manufacturing has slackened, Japanese electronics companies have moved abroad both assembly and passive component manufacturing (referred to in Japan as the three Ks: *(kitsui, "difficult", kitanai, "dirty", and kiken, "dangerous).*[114]

The image of Japanese electronics tends to focus on the 8 electronics giants. Often ignored are the dense industrial districts constituted by SMEs that form the foundation of Japan's manufacturing industries. The district in and around Tokyo's Ota ward is the leading example of what the following quote refers:

> "If a single atomic bomb were dropped on the industrial district stretching from Meguro to Kawasaki cantering on Ota, what do you think would happen? The whole of Japanese industry would be wiped out in an instant".[115]

Eighty percent of the factories in Ota ward have less than 10 employees and 95 percent have fewer than 30. While Ota ward is referred to as "Ota for machinery", the adjoining wards is known as "Shinagawa for electronics products".[116] The Jonan area of Tokyo comprises the three of Ota, Shinagawa and Meguro. Jonan, in turn, merges with Kawasaki and Yokohama to form Japan's manufacturing heartland.

Descriptions of Japan's industry focus on the *Keirestu,"* interlocking business groupings", but this does not capture the industrial district character fundamental to Japan's industrial success. The distinction is drawn by Seki Mitsuhiro as follows:

> "Most [of the small shops] offer their services to a wide variety of companies. These shops limit themselves to performing specific functions that differentiate them from their competitors and that are required across the full range and all levels of the dense industrial milieu in which they work. They attain a very high level of technical expertise in their selected functions and offer their technologies and their expertise to a wide range of customers as a matter of course. In this way they are fundamentally distinct from the small plants in the provinces that have no choice but to align themselves with specific companies, thereby having the direction of their technical development defined for them. Moreover, since so many of these small shops are in such concentration, they are, in Professor Takeuchi's words," making possible the production of even the smallest lots and the implementations of any process." As such, they function as a foundation for Japanese industry as a whole – a kind of community property available for anyone to make use of".[117]

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[114] Seki Mitsuhiro, Beyond the Full-set Industrial Structure: Japanese Industry in the New Age of East Asia, LTCB International Library Foundation, Tokyo, p2.
[115] H.Karatsu, a former research director of Matsushita (cited in D.H. Whittaker, Small Firms in the Japanese Economy, p12).
[116] Seki Mitsuhiro, p16
[117] Seki Mitsuhiro, p 63-64

Professor Takeuchi Atsuhiko uses the term "complex area" to describe the capabilities of the "Tokyo-Yokohoma industrial district".

> "By pooling their know-how and by working together, the small companies at the end of the production chain are able to undertake portions of large industrial projects quite different from what they could handle on their own. In other words, each of the plants in a specific, highly concentrated region mingles with others in the region, thereby forming a large grouping of technologies. They form a "complex areas". Within their concentrated industrial areas, they are outstanding in their development capabilities".[118]

The problem for Japan is that these concentrated industrial areas have been suffering a "hollowing out" since the mid 1980s. Estimates of the decline in the number of factories in the Ota Ward suggest that fully one third were lost within the decade to 1995.[119] The immediate reasons are: escalation of rents with land speculation and associated high rise construction; the steep rise in the value of the yen following the Plaza Accord in 1985; the sustained 1990s recession in Japan; the rise of interest rates; and the unattractiveness of manufacturing jobs to Japan's more affluent children.

However the cause runs deeper: first, other regions in East Asia with lower wages and more willing workers have become competitive in some industries and became attractive to Japanese foreign direct investment; second, the emergence of TM5 and, with it, the systems integration capabilities which are subjecting all products to redefinition (Japan's industrial districts are, or were, ideally suited to TM4); and third, as parent companies and lead manufacturers lose their competitive edge inevitably the pressure is displaced downwards through the tiers of suppliers.

Contract Manufacturing: Growth and Change

The dynamics of America's electronics industry networking also works on a global scale but both the dynamic and the effects are different. TM5 and the integration of hardware and software, as noted, is leading to a range of new product concepts. Accompanying these developments has been the emergence of a contract manufacturing sub-sector. Which, increasingly, is engaged in the design and production of components. One model is the Intel model of setting up plants both at the home base and in production centers in Asia and Europe;[120] another model is to work closely with contract manufacturers at the home base which, in turn, produce in different locations around the world. The product concept, technology management and upstream engineering activities, including prototyping and pilot runs, are located at the home base. The ongoing volume production runs are done in a range of production plants.

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[118] Seki Mitsuhiro, p 62 - 63

[119] Whittaker, p12

[120] Many companies, such as Compaq Computers and Seagate (disk drives) have substantial internal production capacity and use contract manufacturers extensively as well. According to Sturgeon, Seagate is currently building a $19 million PCB assembly plant in Malaysia to supply its disk manufacturing operations in Singapore and Indonesia (p45)

The growth rate of contract manufacturing is unprecedented. Timothy Sturgeon reports that between 1988 and 1992, the revenues of the 25 largest contract manufacturers in America grew at 30% per year; between 1992 and 1995, revenues grew by 46% per year. The revenues of the top 5 contract manufactures in America grew from under $1 billion to nearly $8 billion between 1986 and 1995.[121] Brand name companies like IBM, HP, and DEC, as well internet-related new firms like Cisco Systems, outsource component manufacturing to contact manufacturers like SCI, Solectron, Merix, Flextronics, Smartflex or Sanmina.

The transition to outsourcing has occurred simultaneously with the diffusion of surface-mount technology (SMT). The rapid pace of innovation including the miniaturization of chips has made automation necessary. However, automated systems while saving on direct labor are engineering intensive. It is not simple to keep automated systems working to high performance without suffering unscheduled shutdowns. The solution has been outsourcing to component specialist. This is occurring even though the growth rate of ICT of about 7% per year is small compared to that of the contract manufacturers.

So called "turnkey" contractors offer a range of services including manufacturing, testing, packing, parts purchasing and increasingly, design of manufacturing and process R&D. The OEM focuses on product R&D, product concept, functional design, prototype development, and marketing. This has important implications for production networks. Japanese OEMS tend to sub-contract to Keirestu members; increasingly American OEMs subcontract manufacturers. But the contract manufacturers of today are not mere sub-contractors; but systems integrators who can provide a range of engineering and products development service. In fact, America CMs are locating close to their OEMs market areas.

In addition, Singapore has developed a range of CMs with branch plants throughout Asia. While 6 America CMs have branch in Malaysia, 8 Singapore CMs have branches in Malaysia.

Sturgeon argues that most CMs:

> Have added a wide range of back-and front-end services, such as process R&D, design form manufacturability, product-specific process development and documentation, various forms of testing, final products assembly, final packing, software loading and document application, and shipping directly to distribution (Characteristics of CMs p45, 43 of Tim Sturgeon). Many of the components are modularized. The growth rate of contract manufacturing is spectacular; the successful contract manufacturers supply a range of engineering services (rate to Cary Kimmel). According to sturgeon, America "System" firms are now demanding that their key contract manufacturers have locations in each of the three major market areas.

According to Timothy Sturgeon's research, at least 6 of the largest America contract manufacturers have plants in Malaysia including SCI and Solectron, the two biggest,

[121] Timothy Sturgeon, "A window of opportunity for the Philippines? Turnkey production networks for electronics manufacturing", UNIDO, Vienna, NC/PHI/95/01D,p44.

and Jabil, Flextronics (which has 2), Dovatron/DII, and Manufacturers Services Limited. Four of the six are Silicon Valley companies. In fact, Malaysia is the most common offshore site, followed closely by Singapore and Scotland with 5 each.

Two further facts stand out. First, is the large number of Singapore (15) and Hong Kong (10) contract manufacturers and the relative few Japanese contract manufacturers (4). Second, is the fact that 9 Singaporean contract manufacturers have plants in Malaysia.

Criteria for Success

While individual countries utilized different technology management strategies and vehicles for accessing the world's technology pool, each acquired technology management capabilities. This is no simple task. Every country in the world has sought to take advantage of the world's technology pool to advanced growth. Few have succeeded. New technologies can not be implanted in any production systems or business or business enterprise. The success stories suggest a distinctive set of understandings.

1. Technologies are embedded in business organizations therefore technology management and R&D must be centered in firms.
2. Skill formation must accompany technology advance.
3. Technology may be a thing but technology management is a capability; therefore, technology can not become a vehicle for growth without technology management capabilities.
4. Technology management is intertwined with the development of production capabilities.

The last point is as easy to overlook as it fundamental. The rapid pace of introduction of technology in the success stories of East Asia is a consequence of the prior or simultaneous developments of a specific set of production capabilities. Japan, and her imitators, started with the idea of cutting edge technology, not with the idea of a rapid pace of introduction of technology. The latter was a consequence of driving down cycle times first in production and second in new product development. As noted elsewhere, an unintended consequence of rapid new product developments was an increase in the potential entry times for new technologies. New technologies tend to be introduced with new products or major products changes. Improved technology management will follow the development of the principle of flow and the associated practices required for flexible production systems. Without these developments, no amount of R&D or government incentives will have an effect on industrial growth.

This is a formidable challenge. Distinguishing features of electronics today include the fast-moving pace of change, the science base and scale intensity. All make the process of acquiring technology more difficult. Capital goods such as machines can readily be purchased but machines are not products and process technologies. Successful indigenous acquisition requires reverse engineering and imitative research and development.

The challenge for Malaysia is that MNCs locate only productions line activities in Malaysia. Corporate R&D, products R&D design, process engineering are centralized in the home country. This disconnect between technological management capabilities and production capacity is perhaps most severe in electronics. However the growth toward higher national incomes experienced in Japan, Taiwan, and South Korea make it clear that developing such capabilities is well worth the investment.

It can also be emphasized that the success of Singapore and Malaysia does not involve a zero sum game. Technology-led growth can be mutually beneficial if it involves an advance in capabilities for both. The region as a whole has considerable potential, enhanced by the internet, to develop a competitive advantage in flexible mass production in which one-piece flow is integrated with specialist design capability. This is the promise of real one-piece flow in which each piece is independently designed. Manufacturing to order, as presently practiced by Dell in Penang, is a first step in this direction.

Conclusion

Economic theories do not purport to explain high and sustained growth rates of 8-10 percent per year for periods ranging from 1 to 3 decades. The technology management perspective, on the other hand, posits a role for the development of production and organizational capabilities and thereby for strategic industrial policy. Furthermore, the technology management perspective focuses attention on production capabilities, technology management, and skill formation as targets of industrial policy. Successful industrial development programs have used trade and inward foreign investment to apply, adopt, adapt, redesign, and diffuse not only foreign technologies, but advanced production capabilities.

At the same time, however, the first law of strategy must always be kept in mind: success breeds failure as adjustments by rivals influence the overall system. Japan's very success at developing a set of intermediary agencies that targeted a core set of functions turned into a weakness once their goals had largely been achieved and the challenge, represented by the resurgence of the United State industry around a new open system represented by TM6, had itself shifted. This reverse dynamic is an important in understanding the growth process and the positive feedback effects associated with cumulative causation.

Appendix 10. Indicators of Technology Management Capabilities

Monitoring success will depend upon developing appropriate measures. Targets of industrial policy and measures of success are perspective dependent. Innovation, for example, is measured in the number of scientists engaged in the process of discovery, instead of part of ongoing activities that constitute the economy. The capabilities and innovation perspective calls for a much greater range of indicators of innovation. Setting goals in this area and building private-public collaborative programs is critically important for the growth process.

Metrics highlight the important from the unimportant and thereby focus attention and mobilise people around specific goals. Each of the following conceptual frameworks can be used to develop indicators appropriate to circumstances.

- the production capabilities spectrum
- the technology management models and the associated production principles
- cluster dynamics (entrepreneurial firms, new firms, spin-offs, new sub-sectors, diversity)
- internal assessment exercises such as those used to certify vendors
- skill formation

Each of these offers measures for the purpose of enhancing production capabilities and system performance. Successful industrial policy depends upon developing simple, usable measures. For measuring cluster dynamics, for example, indicators of entrepreneurial firms and new firm creation are particularly important for targeting industrial policy. Similarly, measures of spin-offs from existing companies in a region are monitoring a powerful driver of growth.

A broader range of innovation indicators would include the following. First, enterprise investment in R&D. **Table 6.1** shows that the range across countries is large. For example, Japanese and South Korean enterprises spend 10 times and Taiwan 5 times more than enterprises in Malaysia. A measure of the success of R&D expenditures is the number of patents granted. **Table 6.2** shows that while South Korea has ranks high in comparison to Hong Kong and Singapore, Taiwan is the outstanding performer amongst the NIEs in terms of U.S. patents granted. The South Korean chaebol based industrial organization has been granted less than one-third the number of U.S. patents of the small-firm based Taiwan economy. Taiwan has been granted 75 times more patents than Malaysia. Japan, however, holds a staggering 50 times the number of patents as Taiwan.

As shown in the **Table 6.3**, Taiwan, Singapore, and South Korea have all reached levels of scientists and engineers engaged in R&D as a percent of the population that is comparable with Western Europe. Malaysia, however suffers from a severe skills gap in engineers and scientists. Taiwan, Singapore, and South Korea have achieved a 10 fold advantage over Malaysia.

The success of Singapore suggests that the cause of Malaysia's skill gap is not due to heavy reliance on MNCs. Singapore, which has pursued a similar strategy attracting MNCs has, at the same time, developed indigenous production and technology management capabilities. Singapore, like Taiwan and South Korea, has major education programs to continuously upgrade their skill base.

Unlike Singapore, Malaysia has yet to turn heavy reliance on technology imports into indigenous production capabilities. The critical factor is the development of a local skill base that can serve as a medium for absorbing and diffusing technology and technology management capabilities in local firms.

Table 6.1. Scientists and Engineers/Population

Country	Year	Per 10,000	% 24-yr-olds with
		Population	NS&E degree
Japan	1993	43	6.4
United States	1991	38	5.4
Norway	1992	32	4.4
West Germany	1989	28	5.8
Taiwan	1993	26	6.4
Singapore	1992	23	7.6
Denmark	1991	23	6.5
France	1991	23	5.0
United Kingdom	1992	22	NA
South Korea	1993	22	7.6
Italy	1991	13	2.5
Mexico	1990	7	NA
China	1993	3	1.3
Malaysia	1994	2.3	0.8

The year refers to the column with the number of scientists and engineers engaged in R&D per 10,000 population. The United Kingdom figure is not included, as it was not comparable. The last column refers to the number of 24-year-olds with natural science and engineering degrees. The years vary.
Source: National Science Board, *Science and Engineering Indicators—1996* and *1998*. Washington DC: U.S. Government Printing Office, Washington DC 20402, p.3-25, 1996, Appendix Table 2.1, 1998: *1994 National Survey of Research and Development,* MASTIC, Table 3-19.

Table 6. 2 Enterprise Investment in R&D.

R&D (% GDP)

Country	Year	Total R&D	R&D by enterprises
Japan	1988	2.8	1.9
Korea	1992	2.3	1.9
Taiwan	1993	1.8	0.9
Singapore	1992	1.0	0.6
Hong Kong	1995	0.1	N/A
Malaysia	1992	0.37	0.17
Thailand	1987	0.2	0.03
India	1990	1.0	0.2

Source: Sanjaja Lall, Technology Policy and Challenges, Faculty of Economics and Administration, University of Malaya, 1996, Table 1.

Table 6.3. U.S. Patents Granted: 1963-91

Total Asian Region	231,298
Japan	224,551
NIEs	5,894
Hong Kong	576
Singapore	127
South Korea	1,221
Taiwan	3,970
EAEs	853
China	340
India	374
Indonesia	86
Malaysia	53