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# Lessons in Technology Development: The Japanese Experience

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**Colin K. L. Chang**

**Visiting Research Fellow**
**APEC Study Center**
**Institute of Developing Economies**

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# Preface

This paper was prepared during my term as Visiting Research Fellow with the APEC Study Center at the Institute of Developing Economies in Tokyo from December 1997 to March 1998. I am deeply indebted to the Center for making possible this precious opportunity to study some aspects of Japan’s remarkable technology development.

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Finally, heartfelt gratitude is extended to Dr. Rajah Rasiah of the Institute of Malaysian and International Studies (IKMAS), National University of Malaysia, Prof. Fujio Hara and Mr. Shinji Hashimoto of IDE, as they are the individuals who contributed in more ways than there is space to my memorable and enjoyable time at IDE and Tokyo.

Colin K. L. Chang

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# 1. Introduction

The role of technology transfer in economic development has become central in mainstream economic development and economic growth theory. While technology transfer does take on different meanings depending on the perspective of the practitioner or the theoretician, this paper is concerned with the agents and conditions that explain the enrichment of technology that is imported from external sources to the status of a self-sustaining productivity enhancing entity in the country that imports it.

While many developing nations within the APEC region have achieved enviable technology transfer based on traditional measures such as growth in technology imports, and growth in production and exports of technology-based goods such as electronics, heavy industries and chemicals; there persists the troubling perception that such technologies have not taken deep roots in its new environment. Measures like expenditure on research and development (R&D) and design and engineering (D&E), numbers of new patents, and economically defined measures such as total factor productivity (TFP) growth which indirectly measures technological improvements, suggest that the transferred technologies remain fundamentally dependent on their originators for innovations and improvements. Developing countries, despite spending vast amounts on technology imports, do not seem to approach any closer to the technology frontier.

This study reviews technology development in Malaysia, which displays impressive growth in manufacturing output and exports of technology goods, but with limited signs of technological maturity in its capability to adapt, improve and innovate on imported technologies. It then looks to Japan, a country which has successfully negotiated its technology capability development to reach the technology frontier in many industries, largely on internally generated capability building. This study makes a comparison between the two, to uncover conditions that are necessary for imported technology to develop.

These identified differences are then used as a basis of policy implications and recommendations.

This report will first review the nature of technology, in order to build a framework for analysis in the following sections. This is done in Chapter 2. Chapter 3 will review Malaysia's state of technology capability development, while chapter 4 reviews the Japanese experience. Chapter 5 analyses the differences, and proposes what is significant in assisting technology development efforts. The report is concluded in chapter 6 with policy implications.

# 2. Theoretical Background

## *2.1 Discussion of Terms*

While the word technology itself carries connotations of modernity and novelty, as in its use in high-technology, the treatment of technology here is as accumulated knowledge applied in production. This knowledge may be proprietary, allowing for appropriation by the owners of the knowledge for economic gain, or as a public good that is not appropriable by private ownership. In recent times, the former knowledge have become the predominant form of technology.

Another more precise economic definition of technology is given in the neo-classical production function (Solow 1957):

$$Q = A\ f(K,L,I) \qquad (1)$$

where Q is a measure of real output; K, L and I are measures of capital, labour and intermediate (materials, energy etc.) inputs; A is an index of Hicks-neutral technical change; and *f* is a homogeneous function of degree one (constant returns to scale). Technology is the residual in explaining output growth after netting input growth. Beyond this simple model, there have been numerous refinements made, but they do not detract from the chief idea that technology is the difference between how effectively and efficiently a firm or a country combines the primary factors of production. Technology has become the shorthand to explain all organisational, machine-embodied, human-embodied and all knowledge effects in improving productivity. Within the simple model, lies the powerful idea that technology is the single most important determinant for long-run economic growth, since K, L and I have natural upper limits.

Two notable properties of technology are that of accumulation and appropriation.

Technology is not created in a vacuum, but requires some specific knowledge to pre-exist. For example, aspects of aerospace technology may be taught to less developed societies, with no observable loss of efficiency if it is reduced to simple set instructions of interacting with machinery. However, if there is no real appreciation of the technology, no visceral feel for its significance, then it is unlikely that further development and innovation will take place. Technology has context and meaning in its applications, and the environment in which it breeds and renews itself. Divorced from its tradition, and underlying foundations, the possibilities for real progress are reduced. Technology, as knowledge, needs to be accumulated. The more technology is accumulated, the more could be achieved with it. This property of technology dictates that there are no level playing fields. A late-comer, competing in the same arena with a firm or country with large technology accumulation faces an uphill battle if similar efforts is exerted by both sides. Yet the history of industrial development is littered with upstarts unseating established champions. Japan's conquest of leading technology in steel-making, electrical and electronic equipment and automobiles are notable examples.

The accumulation of scientific knowledge has progressed at accelerating rates, to the extent that the boundaries of technology lie beyond the reach of individuals. The primary agents for developing technology are organisations of individuals in firms and institutions. Entry level for participation in meaningful technology advancement today almost presumes individuals with advanced education, working together in synergetic groups. The technological frontier is a rapidly receding target, where late-comers to industrial development are severely handicapped. While the possibility of the late-comer leap-frogging advanced nations by by-passing obsolete technology has been proposed, two major obstacles reduce the value of this. One is that the accumulation of knowledge to benefit from, and to progress the imported technology is still a sizeable barrier, and the second is that the owner of the new technology has the means to protect their lead, by limiting the degrees of freedom a subsidiary technology adopter has in developing it.

The process of creating new industrial technology is both expensive and uncertain. One of the mechanisms to facilitate and encourage efforts to invest in technology development is the protection of the rewards that may accrue from the technology. This protection of intellectual property rights (IPR), is codified within the charter of the World Trade Organisation (WTO). This confers monopoly rights to appropriate benefits from the technology for a set period. Appropriability becomes a determining condition on whether a firm invests in a research and development (R&D) project. The upshot is that all recent industrial developmental technology has an owner, whose interest is served by restricting access to its technology to only those who can afford the licensing and other fee systems enacted. The technology owner husbands its intellectual capital as closely and jealously as a traditional entrepreneur with his traditional capital. Potential competitors may be precluded from sharing the technology, or be so restricted in their use of it, that innovation becomes impossible without the permission of the owner.

Making matters more difficult for technology licensees, an analysis of costs and benefits to the transferor (Suresh, 1997) suggests that the transfer of technology occurs only when the costs of keeping technologically ahead of the technology recipient is low. The implications are that it is likelier for technology recipients to receive obsolete technology, or technology where the frontier is receding at a quick rate, making the effort to catch up harder. Technology transfer programs, that do not plan ahead for technology advancement, through either niche or broad-based advancement strategies have poor chances of sustaining any advantage for the recipient firm or nation.

Technology can be captured or embodied in various forms. One that is most readily perceived is its embodiment in physical capital. There is a transfer of technology when a new piece of equipment is deployed in manufacturing. There is knowledge implicit within that piece of equipment, and its use would result in enhancing the productivity of the operator using it. This technology is manifested in the production function within capital.

There is also knowledge and skill implicit in a worker in producing a good. The more education and training the worker receives, would result in higher productivity. Productivity encompasses qualitative differences of the type of work. A R&D engineer has higher productivity than a skilled machine operator. Training and education show up as human capital, and it is human embodied technology. In the production function, such investments in human capital would show up in labour.

Productivity would also improve with better management and processes. A program to reduce waste, or to minimise stocks through better scheduling would result in increases in output, with no obvious increase in factor inputs. Such productivity improvements are manifested as increase in technology. From an economic standpoint, this is indistinguishable from the use of a new scientific procedure that is used to combine various ratios of input more efficiently, from the economic standpoint.

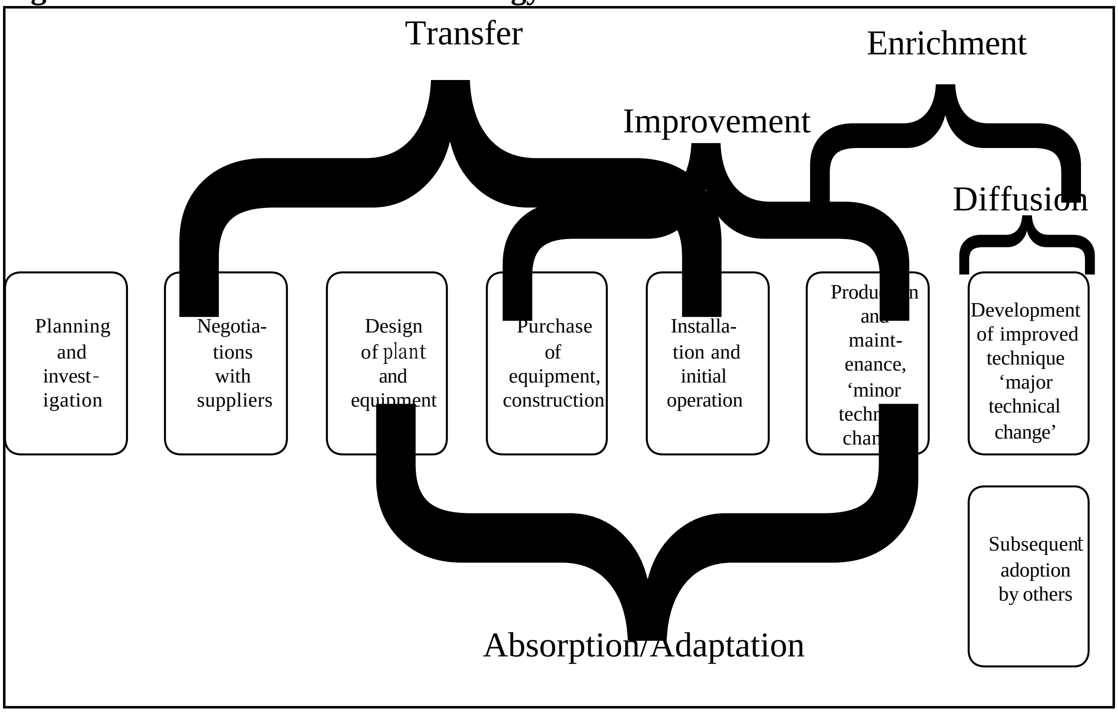
In real life, if one is to increase productivity through increased input of only one kind, say human capital, diminishing returns in output would eventually manifest itself. Yet when combinations of labour, capital and knowledge are increased together, output gains in ways that cannot be explained by the sum of each input. The effect is greater than the sum of its parts.

Technology transfer is usually narrowly defined as the transfer of the operational aspects associated with a specific industrial process. In this exchange, there is the technology owner, who has appropriated the specific knowledge through patents, proprietary industrial design and informal in-house know-how, and the technology recipient who believes that it will be able to reap benefits from the technology. The consideration given for the technology may be monetary, equity in the recipient, a profit sharing scheme or something other value to the technology owner.

Technology transfer may be narrowed to a series of activities (Enos *et. al.* 1988), see Figure 2.1. The specifics may include transfer of capital equipment; some form of operational transfer of learning, in the form of manuals, formal classroom training, on-the-job training; and the institutionalisation of operational and management practices. In practice, many technology transfer exchanges end when the technology recipient's plant is able to begin production.

This truncation of technology development is of serious concern to developing economies. Without the apparatus to renew and regenerate technology, the technology recipient remain essentially a perpetual client of the technology owner. There recipient gains little comparative advantage against another client of the technology owner, beyond its primary access to labour and raw materials. Although in appearance, the technology recipient has industrialised, in terms of control of its destiny, it is no different than a commodity producer in its dependence on endowments.

**Figure 2.1: Activities Within Technology Transfer**




Source: Author

The factor and conditions that influence the activities beyond operational capability is the central concern of this study. As a form of shorthand, the term technology enrichment is used.

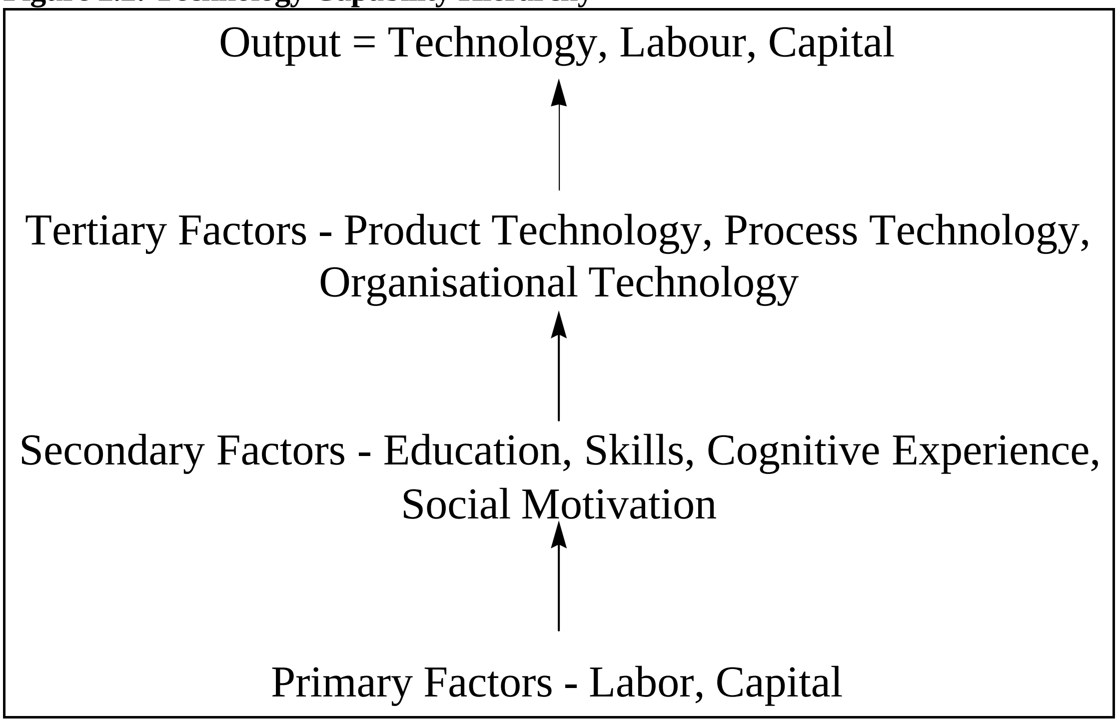
Technology capability is an idea that is useful in explaining the differences between nations in their ability to extend technology. As an extreme example, a nation with extremely low literacy rates, poor physical infrastructure and no market for fighter jets, would not intuitively suggest itself as a successful site for fighter jet technology. Two useful definitions of technology capability are given below:

> … the ability of a given country to chose, acquire, generate an apply technologies which contribute to meeting its developmental objectives (ILO 1986).

> The existence of people with a foundation/training in the basic (scientific) aspects of knowledge relevant to the particular area of concern; the possession by these people of a 'certain amount' of operational experience; the existence of an organisation in which the skills are resident, and which can harness and deploy them in the pursuit of given goals; a problem-sensing and solving mechanism within the organisation; a certain complex of values and attitudes which are important with respect to approaches to problems (Girvan 1986).

The main idea in both definitions is that humans, and their accumulation of certain basic knowledge that determines technology capability. A theoretical framework for technology capability is given by Enos (1991).

**Figure 2.2: Technology Capability Hierarchy**




Source: Author

In the framework for technology capability building, technology is treated as an output, with primary inputs being labour and capital. Intermediate goods in producing technology is seen as education, cognitive experiences, and even favourable social and cultural attributes. At the next level are the intermediate components of technology in their various embodiments.

Effective R&D in the context of technology capability is an integral part of technology transfer. R&D enhances learning during the adoption phase, and gives the adopters the cognitive understanding of the technology's significance, and where the possibilities of enrichment lie.

## *2.2 Models of Technology Development*

*Technology in Economic Development*

Among the many development framework for industrial advancement, one that provides a useful model for technology capability attainment is Akamatsu's wild-geese-flying pattern (Akamatsu, 1962). The framework outlines a series of transitions that a country must negotiate in climbing the ladder of economic growth (see Table2.1). An important feature in this framework is the close succession of capital goods production capabilities following consumer goods production. This framework explains the technology development in Japan, and the first wave of the Newly Industrialised Countries (NICs). However, on the next wave of industrialised Asian nations, namely Thailand, Malaysia and Indonesia, we see the ability of producing and exporting sophisticated consumer goods, and industrial intermediates, but very limited abilities in producing machinery and equipment on which these consumer goods depend.

The other feature of this framework that has proven useful is that it explains the dynamics of the upgrade of capabilities. Any flying goose that straggles in formation in failing to upgrade technological capabilities will be quickly overtaken by the next wave of geese.

Another useful framework for analysing technology development is described by Hayashi (1990) as the five components of technology, which are given the mnemonic the five Ms. They are:

1. Raw materials and resources (including energy): M1
2. Machines and equipment: M2

3. Manpower (engineers and skilled workers): M3
4. Management (technology management and management technology): M4
5. Markets for technology and its products: M5

**Table 2.1: Akamatsu's Development Stages**

| *Akamatsu's Stages* | | | | *Technological Capabilities* |
|---|---|---|---|---|
| Import of crude consumer good | | | | Simple crafts |
| Production of crude consumer good | Import of capital goods for producing crude consumer good | Import of advanced consumer good | | Basic operations, maintenance |
| Export of crude consumer good | Production of capital goods for producing crude consumer good | Production of advanced consumer good | Import of capital goods for producing advanced consumer good | Basic engineering, design |
| Homogenization of crude consumer good with advanced countries | Export of capital goods for producing crude consumer good | Export of advanced consumer good | Production of capital goods for producing advanced consumer good | Advanced engineering, application R&D |
| Lose competitiveness in crude consumer good | Homogenization of capital goods for producing crude consumer good with advanced countries | Homogenization of advanced consumer good with advanced countries | Export of capital goods for producing advanced consumer good | Leading technology, basic R&D |
| | Lose competitiveness in capital goods for producing crude consumer good | Lose competitiveness in advanced consumer good | Homogenization of capital goods for producing crude consumer good with advanced countries | |

Source: made by the author based on Akamatsu (1962)

This framework is unusually perceptive in describing the Japanese approach to acquiring technology. The five Ms are not successive stages, but five simultaneous and necessary components that are deliberated upon when a technology is considered. Using Japanese steel-making as an example (this is expanded in more detail in Chapter 4), after the initial piecemeal failures, the eventual success in Yawata encompassed the entire range of Ms from raw materials available (control of Korean and Manchurian ore and coal, and not just intermediates like imported scrap-metal and pig-iron, or substandard local ores and coke) - M1; the ability to master Western technology to manufacture and modify equipment - M2;

trained workers, from manual labour to metallurgist - M3; the organisational structure, from the beginnings of lifetime employment to the rewards and promotion policies - M4; and the demand for steel from integrated downstream industries such as shipbuilding, construction and machinery - M5.

Hayashi also posited the activities or stages towards self-reliance, which somewhat mirrors Enos' technology transfer activities (Figure 2.1). The stages towards technological self-reliance are:

1. Acquisition of operational techniques (operations)
2. Maintenance of new machines and equipment (maintenance)
3. Repairs and minor modifications of foreign technologies and equipment, both in the system and in operations (repairs and modifications)
4. Designing and planning (original design and creation of a system)
5. Domestic manufacturing (self-reliance in technology)

Kagami (1997) offers another normative model for technological acquisition, which conforms to the following step-wise developments:

1. existence of traditional technologies
2. introduction of foreign advanced technology
3. modification of foreign technology
4. production of hybrid machines
5. domestic production of new machines

The emphasis of both framework is on capital embodied technology.

## 3. Malaysia: A Case of Stalled Industrial Transition?

In order to appreciate the difficulties involved in a nation's effort to move towards the technology frontier, it is informative to review the efforts of a nation to achieve technological maturity. Malaysia has recorded impressive results in her technology acquisition efforts, going by measures such as the value-added contribution of technology-based industries, and the export contribution (see Table 3.1 and 3.2). The technology related industries are largely the electrical/electronics, chemical, transport equipment and textile manufacturing sectors. Together they account for the bulk of the growth in both value-added and exports.

**Table 3.1: GDP by Industry, 1990-95**

| | *Amount (1978 prices) RM mil* | | *Share %* | |
|---|---|---|---|---|
| | *1990* | *1995* | *1990* | *1995* |
| Agriculture, forestry, fishing | 14,827 | 16,406 | 18.7 | 13.6 |
| Mining | 7,757 | 8,938 | 9.8 | 7.4 |
| Manufacturing | 21,340 | 39,825 | 26.9 | 33.1 |
| Construction | 2,832 | 5,277 | 3.6 | 4.4 |
| Electricity, gas, water | 1,526 | 2,823 | 1.9 | 2.3 |
| Transport, storage, communications | 5,487 | 8,787 | 6.9 | 7.3 |
| Trade | 8,806 | 14,568 | 11.1 | 12.1 |
| Finance | 7,758 | 12,884 | 9.8 | 10.7 |
| Governmental services | 8,447 | 11,683 | 10.6 | 9.7 |
| Other services | 1,678 | 2,436 | 2.1 | 2.0 |
| Total GDP | 79,329 | 120,316 | 100.0 | 100.0 |

*Source*: Seventh Malaysia Plan

**Table 3.2: Gross Exports of Manufactured Goods (%)**

| | *1990* | *1995* |
|---|---|---|
| Electric/electronics | 56.6 | 65.7 |
| Chemicals | 3.1 | 4.3 |
| Transport equipment | 4.1 | 3.6 |
| Food | 4.2 | 2.2 |
| Rubber | 2.9 | 2.1 |
| Textiles and garment | 8.3 | 4.4 |
| Wood | 2.9 | 3.4 |
| Others | 17.4 | 14.3 |
| Total | 100.0 | 100.0 |

*Source*: Seventh Malaysia Plan

Malaysia's Industrial Co-ordination Act (ICA) which sought to promote technology transfer as a condition of industrial investment approval has provided another measure of technology transfer into the country. The statistics on Technology Transfer Agreements (TTAs) approved show a steady increase of technology based investments (see Table 3.3). Electric and electronics based technology agreements accounted for the largest share.

**Table 3.3: Technology Transfer Agreements by Industry**

| | *75-77* | *78-80* | *81-83* | *84-86* | *87-89* | *90-92* | *93* |
|---|---|---|---|---|---|---|---|
| Electric/electronics | 31 | 55 | 50 | 53 | 106 | 124 | 69 |
| Chemicals | 7 | 38 | 41 | 48 | 74 | 64 | 20 |
| Transport equipment | 9 | 22 | 34 | 52 | 20 | 62 | 25 |
| Fabricated metal | 16 | 29 | 43 | 34 | 45 | 33 | 11 |
| Food | 13 | 24 | 40 | 24 | 45 | 12 | 11 |
| Rubber | 7 | 15 | 23 | 22 | 48 | 26 | 5 |
| Non-metallic mineral | 8 | 13 | 29 | 31 | 26 | 26 | 5 |
| Basic metal | 6 | 15 | 28 | 7 | 8 | 13 | 5 |
| Textiles and garment | 15 | 12 | 12 | 14 | 12 | 20 | 3 |
| Plastic | 3 | 8 | 9 | 11 | 8 | 17 | 11 |
| Wood | 11 | 9 | 5 | 10 | 1 | 11 | 4 |
| Paper | 0 | 0 | 0 | 7 | 4 | 10 | 3 |
| Others | 16 | 43 | 42 | 25 | 61 | 48 | 13 |
| **Total** | 142 | 283 | 356 | 338 | 458 | 466 | 185 |

*Source*: Malaysia Industrial Development Authority (unpublished)

Delving deeper into the national technology acquisition efforts, available statistics tell another story. Innovation results from concerted and directed efforts at mastering a technology, asking what-if questions, and conducting systematic inquiry that is outside the normal operations of production. This is generally called research and development. Sustainability in comparative technology advantage compels R&D to not be an option in industrial development. Tables 3.4 and 3.5 show Malaysia's R&D statistics.

Compared with more developed countries like Japan and Korea, Malaysia's and Thailand's capacity for R&D is significantly less, in terms of human capital capable of producing R&D output, as well as in capital invested. The numbers of R&D capable personnel in Malaysia overstates its capability, as the majority of them are employed in academia and administration. The largest sector for R&D expenditure is the electrical/electronics sector by foreign firms, and in the transportation sector by locals.

**Table 3.4: Research and Development Statistics**

| | *Scientist and technologist per 1000 pop. 1986-90* | *R&D scientists and technologist per10,000 pop. 1986-89* | *R&D expenditure as % of GNP 1987-92* |
|---|---|---|---|
| Japan | 110 | 60 | 2.8 |
| S. Korea | 46 | 22 | 2.1 |
| Malaysia | na | 4 | 0.4 |
| Thailand | 1 | 2 | 0.2 |

*Note*: na = not available

*Source*: UNDP (1995); MASTIC (1994)

**Table 3.5: R&D Expenditure in Selected Industries, Malaysia 1992 (RM mil.)**

| **Industry** | *Local ** | *Foreign *** | ***Total*** |
|---|---|---|---|
| Electrical/electronics | 9.7 | 102.7 | 112.4 |
| Transport equipment | 82 | 0 | 82 |
| Food | 14.8 | 1.3 | 16.1 |
| Rubber | 1.2 | 1.4 | 2.6 |
| Textiles | 0.4 | 0.4 | 0.8 |
| Chemicals | 1.9 | 11.7 | 13.6 |
| Total | 123.7 | 122.6 | 246.3 |

*Note*: * - local ownership exceeding 50%;
** - foreign ownership exceeding 50%.

*Source*: MASTIC (1994)

The return on R&D investments is technology. Proxies include the number of patents, industrial designs and other intellectual property registered, and very indirectly, in the increase of productivity, as measured by total factor productivity growth (see Tables 3.6 and 3.7).

**Table 3.6: Patents Filed and Granted 1995**

| **Country** | *Applications Filed* | | | *Patents Granted* | | |
|---|---|---|---|---|---|---|
| | *Residents* | *Non-residents* | ***per mil pop*** | *Residents* | *Non-residents* | ***per mil pop*** |
| Japan | 335,061 | 53,896 | 3,112 | 94,804 | 14,296 | 873 |
| S. Korea | 59,249 | 37,308 | 2,170 | 6,575 | 5,937 | 281 |
| Singapore | 10 | 11,871 | 4,097 | - | 1,968 | 679 |
| Malaysia | 141 | 3,911 | 206 | 29 | 1,724 | 89 |

*Source*: WIPO (1997)

The major portion of patents filed and granted from Malaysia belongs to foreign firms. The amount of technology enrichment as measured by this proxy shows considerable lag compared with Japan and Korea.

**Table 3.7: TFP Growth**

| *Country* | *TFP Growth (1960-85) %/year* |
|---|---|
| Japan | 3.5 |
| S. Korea | 3.1 |
| Singapore | 1.2 |
| Malaysia | 1.1 |
| Thailand | 2.5 |

*Source*: World Bank (1993)

Most of output growth in Malaysia can be explained by input growth, going from the results, although methodological and data difficulties with TFP calculations do produce widely varying results in other measures.

The Malaysian government is conscious of the need for home grown technology development to drive of her economic growth. There has been a series of policies and programs to address this. They include:

- the 1986 National Science and Technology Policy,
- emphasis on science and technology from the Fifth Malaysia Plan (1986-90) onwards,
- the successive Industrial Master Plans (1986-95) and (1996-2005)
- the Action Plan for Industrial Technology Development (APITD)
- the National Information Technology Agenda (NITA)
- establishment of Technology Parks
- the championing of technology based national development projects like the multimedia super corridor (MSC)

While state support of technology development has been strong, especially since the late 1980s, the results have been disappointing when one examines the state of new technology development in the individual industries.

### 3.1 Electrical/Electronics

The industrial structure of the electrical/electronics sector is pyramidal, with large transnationals like Intel, Motorola, Seagate, Matsushita and Sony at the apex, supported by a community of small and medium sized suppliers (Suresh 1997, Rasiah 1996, 1997, Jomo *et. al.* 1997). The products ranged from the assembly and testing of semiconductors to consumer electronics. The transnationals are the principal source of both product and production technology. Malaysia was selected as an operational site for exports, based on its liberal investment environment, good physical infrastructure, and relatively competitive labour that had the requisite skills, or capacity to absorb those skills.

Local involvement in the design and construction of the manufacturing facilities have been largely limited to the buildings housing the equipment. Capital machinery, especially the integrated components were sourced from foreign equipment suppliers. Several local engineering firms were subcontracted in assembling portions of the assembly line. While the majority of management and process workers were recruited locally, and given intensive training and development, the emphasis is on production operations. Engineers and technicians were charged with maintenance and manufacturing-based problem-solving responsibilities. If one looks at the statistics of local personnel in technical capacities, one can assume that technology has been 'transferred'.

However, the capacity of local technical staff in developing aspects of the technology is limited. In the area of electronic components, the products are usually proprietary designs that are re-exported to other plants within the transnational's orbit. Control of the technology remains with the technology owner, either the transnational or the liscensor. Looking at the mechanisms for technology development in the hands of the technical personnel in the plant, assuming that they have been charged with innovation responsibilities, the obstacles grow. The ambit of their competencies is within the product and production methods. Innovation in a tightly networked manufacturing system involves changes. One cannot draw a box around part of the process and demand innovation within it without affecting input to or output from the box. If one does that, any gain would probably be trivial. Any process innovation in all probability would affect the product. These changes would cascade like a ripple, both upstream and downstream. While the total gains to the entire system could be a large positive, selling these changes to upstream and downstream units implies changes (a negative) but not necessarily benefits to the affected units. Transaction costs reduces the likelihood of such propositions. Without control of entire production value-chains, the benefits of incremental innovation are unlikely to overcome transaction costs.

While some transnationals have reported activity in R&D (Rasiah 1996, Suresh 1997), the program was usually designed in the lead R&D centres, and the efforts of the local team tended to be limited to adapting innovations to local conditions. This does not lessen the skills and competencies developed by local personnel, but the freedom to set research agenda and priority by the local team is limited. Should R&D personnel opt to set themselves up as entrepreneurs in competition with their former employer, without the massive support of the proprietary systems that nurtures such efforts, the prospects remain bleak. The path towards a nationally developed technology system at the technology frontier from 'technology transfer' from transnationals is not obvious.

When the product involved is a consumer electronics product, inordinate power lies in the hands of marketers within the consumers' markets. Product design and features become a function of market consultants and focus group studies. As most of Malaysia's manufactured consumer electronics are exported, product design skills are outside the locus of engineers and technicians toiling in Malaysian plants. At best, skills are developed to retool manufacturing to meet the specifications made elsewhere. Such skills have indeed by developed by the Malaysian fraternity of engineers. Ultimately in consumer products, brand and product management reside in corporate head-quarters. Malaysia is handicapped by a relatively small domestic consumer market.

The awareness that Malaysia's manufacturing industry is centred on the low value-added production activities has prompted policy makers to encourage greater local ownership of technology corporations, and encouragement to gain competencies of entire technologies from R&D through to marketing (Malaysia, 1996). A Malaysian owned company called Malaysia Electric Corporation (MEC) was established to gain a foothold in the international consumer electric market. However, it would be a difficult struggle, competing against well-entrenched international competitors with household name recognition for quality and reliability.

Beyond the transnationals, there is the community of subcontractors and vendors. Among them are regional firms from Taiwan and Singapore like Lite-On that have previously established a relationship with the transnationals in their home countries, and have followed the lead of the transnationals with investments in Malaysia. They in turn subcontract local suppliers, but act as both a conduit and a filter for technology flows from the transnationals.

And there are the local suppliers. They include firms that have been established by former personnel from transnationals like Intel, AMD, National Semiconductor and Motorola (Rasiah 1996). Intel has used its employees co-operative as its investment arm to start several local firms. Beyond that, it has actively worked with local firms in fabricating their machinery and equipment. The competencies developed in first tier subcontracting firms include high precision tools and automated production systems. Second tier firms developed competencies that include manufacturing precision tools, parts and machinery, third tier firms engage in mould and dies fabrication, and the next level supporting services like welding and stamping.

In the interviews and surveys of local firms done to date, the responses are difficult to assess as small business proprietors have a tendency to overstate technology capability, as it is seen as a means of winning more business. The result of one survey is given below.

**Table 3.8: Stages of Technology Absorption in Local Supporting Firms**

| | *No. of firms* | *%* |
|---|---|---|
| Operations | 27 | 69 |
| Maintenance | 15 | 38 |
| Repair/Modify | 12 | 31 |
| R&D | 4 | 10 |
| Total Sample | 39 | 100 |

*Source*: Suresh (1997)

Extrapolating the progress of such local firms along their technology development trajectory, with the assumption of no external intervention, would see them innovating and gaining productivity in their major areas of competencies. This would make Malaysia an attractive investment target for other electronic technology firms that would like to access their productivity. This confers sustainability in the competition with locations with a lower cost base. But realistically, the ownership of product technology, would reside with existing owners. Investments in R&D in supporting services would strengthen the accumulation of knowledge.

### *3.2 Automotive*

Malaysia had only automotive assembly operations until 1983, when Perusahaan Otomobil Nasional (Proton) was established as a joint-venture between the state, Mistubishi Corporation and Mitsubishi Motors Corporation as the first national car project. The objectives of the national car projects include the transfer of automotive technology to the extent of localisation of all operations including design and engineering. Proton was followed in 1994 with the second national car company, Perodua, which is a joint-venture between the government, a Malaysian company United Motor Works and Daihatsu.

Among the important milestones in the history of Proton, from a technology standpoint includes the introduction of new models Wira and Perdana, which are largely Mitsubishi designs, Tiara, which is a Citroen design, and Satria and Putra which are Malaysian redesigned variants of the Wira. Proton has also acquired Lotus Engineering of Britain, and has since manufactured the Elise model in its Shah Alam plant.

A noteworthy feature of Proton's technology transfer program was the broadly defined range of technology, that included organisational and procedural practices such as multiskilling and *kaizen* as well as production operations. The other noteworthy feature was the Vendor Development Program (VDP) that to some extent attempted to institute the Japanese system of linkages between a major automotive organisation with a community of small and medium sized suppliers. This industrial structure has been credited with some of the Japanese successes in automotive technology resulting from the flexibility and free flow of knowledge throughout the network. This is thought to reduce cycle times in design, reduce manufacturing defects due to better design, and concentrates human capital in highly productive groups. There are now more than 134 component manufacturers supplying about 3,000 components (Malaysia 1996). Local content is now around 80%. Proton accounts for 60% of the domestic passenger car market, and exports about 20% of its production.

To date, certain engine and transmission components are still imported from Mitsubishi. With the economic downturn in East Asia in 1997, Proton has delayed its schedule for its integrated manufacturing centre at Proton City. Proton from its inception until the present has enjoyed preferential lower import tariffs of components under its national car project status. If its production volume stays at around 200,000 vehicles a year, Proton does not have competitive production costs position even in the ASEAN region. This is significant with the ASEAN Free Trade Agreement targeting the year 2003 for reductions of tariffs to 5% or less.

On issues of technology enrichment, Proton and its community of vendors still lack a design team that has the potential to advance a design from drawing board (or CAD station) to line production capabilities. There are many automotive competencies that remain undeveloped. This appears critical in an industry that is one of the most globalised, with the leading players pushing technology frontiers at accelerating rates. Global threats/opportunities like global warming, stricter emission standards, alternative fuel systems, electronic navigation systems and higher safety standards are just a small sample of technology drivers that are pushing design limits on engines, transmissions, composite material design and manufacture, advanced information technology innovation in manufacturing and a raft of other technologies.

Can Proton prosper in this environment, when its rate of absorbing and enriching obsolete technology does not seem to be able narrow the technology gap? Is there a technology strategy that will enable Proton and other automotive industry firms a way to contribute value at a sustainable rate for the Malaysian economy, instead of diverting resources towards what could be an evolutionary industrial *cul-de-sac*?

### *3.3 Chemicals*

The global chemical industry has been trending towards increasingly greater capital and knowledge intensity. This combination of accumulation gives the industry leaders positive returns of scale. Late-comers in the mainstream chemical industry compete on severely handicapped terms. How technology transfer and its subsequent enrichment is handled have enormous bearing on the survival of the late-comers.

Malaysia's traditional chemical needs were agricultural based. Fertilisers, pesticides, rubber processing and food processing chemicals were among the first to be manufactured domestically. As Malaysia is a net oil and gas exporter, the government with the government controlled petroleum company Petronas in the 1980s looked to adding value to the product before export, as well as import substitution. A petrochemical development master plan was compiled with strategic petrochemical building blocks identified, and technology partners sought. To date Petronas has established significant petrochemical capability and capacity with international joint-venture partners (see Table 3.9).

There have also been substantial foreign participation from a variety of transnationals who have either established petrochemical operations, of have announced plans for investment. They include Amoco (purified terephthalic acid), Eastman (co-polyesters), Grace (shrink films), Titan (polyethylene, polypropylene), Kaneka (MBS resin), BASF (acrylic acid), and DuPont.

**Table:3.9: Petronas' Petrochemical Projects**

| *Products* | *JV Partners* | *Capacity (tpa)* | *Commercial Operation* |
|---|---|---|---|
| Polypropylene | Idemitsu, Neste Oy | 80,000 | 1992 |
| Ethylene | BP, Idemitsu | 320,000 | 1995 |
| Ammonia / Urea | ASEAN partners | 432,000/648,000 | 1985 |
| Vinyl chloride monomer | Mitsui | 400,000 | 1998 |
| Paraxylene / Benzene | Mitsubishi | 420,000/150,000 | 1999 |
| Polyethylene | BP | 200,000 | 1995 |
| Methanol | | 660,000 | 1985 |
| MTBE / Propylene | | 300,000/80,000 | 1992 |
| Ethyl Benzene / Styrene Monomer | Idemitsu | | 1997 |
| Middle Distillates / Solvents / Paraffin | Shell | | 1992 |

*Source*: Petronas

Petronas has played a trail-blazing role for the petrochemical spearhead in Malaysia in several ways. Most of the trained process-workers that have attracted the foreign direct investments were substantially trained by Petronas. Petronas have also established a private university for engineers, chemist and managers for chemical based industries. The various chemical building blocks that Petronas has invested production facilities are in turn the raw material for many of the subsequent manufacturing investments.

Another cluster of chemical plants that have developed in Malaysia is based on palm oil as the raw material. The oleochemical plants include local companies such as Palmco and Natural Oleochemicals, and foreign joint ventures with Procter and Gamble, Unichema (Imperial Chemical Industries) and Henkel. The products include a range of fatty acids, esters and glycerines that go into food and detergents.

The leeway for innovation, and technology enrichment in a licensed petrochemical process is limited. Once a plant is set up and running, any modifications to any of the process parameters may affect product specifications. The costs to production is potentially enormous, as operational costs are stacked towards the start-up and shut-down ends of a continuous run. With the huge capital outlay for such plants, the operations needs to run at close to capacity with little downtime for break-even. This is not the set-up to encourage experimentation. In addition, license terms are restrictive on the extent of modifications allowed. The engineers and technologist may try out production ideas in a laboratory scale mock-up, but it would have little practical effect, as scaling up any positive effect to the production scale could mean shutting down production for months. The design of most chemical plants do not allow for much modification or experimentation. When technology is taken out from the equation, the competitive edge that a plant can hope for is within the narrow confines of product quality control and better up-time and throughput. A process licensor is captive to the technology owner for new innovations.

In the chemical process industry, investment in R&D is about the only way to develop process and product innovation. The capital equipment for R&D may be as large as a full scale plant itself. The accumulations of capital and knowledge for effective R&D is usually large enough to pose as a barrier to entry to all except the largest chemical transnationals and well-endowed research centres.

With such structural impediments to innovation, it is not surprising that Malaysia has not progressed far with closing the technology gap with those at the frontier in the short time that it has. Closing the technology gap requires massive and steady investments in building intellectual capital.

Another interesting feature of Malaysia's foray in the chemical industry is that it mirrors that of Thailand and Indonesia. The projected combined built-up capacity of many basic petrochemicals exceeds regional demand, without enjoying the economies of scale of other world-scale plants.

### *3.4 The Obstacles to Technology Enrichment*

The accounts above illustrates some of the difficulties that lie in the way of a late developing country at the end of the twentieth century in forging a path towards meaningful technology development to spur productivity and build sustainable prosperity for its people. While technology transfer has been achieved in many instances, the technology remains subsidiary to the technology in advanced nations. The threat of losing competitive advantage to other developing nations with lower costs remains. Ownership of leading edge technology remains elusive.

The chief obstacles identified are:

- the competencies developed as a result of technology transfer are fragmented to narrow areas where innovation paths are limited as they remain dependent on existing partnerships and linkages;
- ownership of leading-edge technology remain with the transnationals who have invested historically in technology accumulation, and it is not in their interest to surrender their competitive advantage;
- the domestic market for consumer products is small, and relatively unsophisticated compared to more developed markets. This reduces opportunities and returns on R&D investments to develop technological niches;
- the range of commercially exploitable technologies have been very efficiently mined by existing firms and research establishments in advanced nations, leaving a few poor seams unexplored;
- limited pool of technical skills, leading to rapid rises in wages, and job-hopping among workers, and labour poaching among employers;
- the technology accumulation in leading firms provide a substantial buffer against followers, and imitative efforts are made harder by vigilant defences mounted today by such firms;
- Schumpeterian creative destruction efforts still require some threshold technology accumulation;
- even state-assisted technology ventures are unable to bridge the technology gap between themselves and the leading technologies.

However, Japan has negotiated this difficult transition on her own efforts. In the following chapter, several cases of Japanese technology acquisition are studied.

# 4. Japan - A Nation That Could

The question that confronts this study is which period during Japan's phenomenal economic growth this century that is most relevant for lessons in technology enrichment. The post-war economic growth period, especially during the 1960s and 1970s established Japan as an economic super power from a base of virtually nothing (see Table 4.1). All of Japan's industrial physical capital had to be rebuilt, from extremely limited capital. There were many lessons that were derived from the tremendous efforts of the Japanese people, guided by a talented bureaucracy; from the central pooling of available resources like foreign exchange, raw material and energy to the informal system of Japanese capitalism that is a partnership between private businesses, the state represented by a meritocratic bureaucracy and elected political representatives (Beasley 1990, Johnson 1982).

**Figure 4.1: Japan's Post-War Technology Development Boom**

| | *Technology Imports US$ (1965)* | *Persons engaged in R&D ('000)* | *R&D expenditure bil. \ (1965)* | *Patent applications ('000)* | *Patent registrations ('000)* |
|---|---|---|---|---|---|
| 1955 | 26.6 | 112.8 | 76.2 | 34.5 | 8.6 |
| 1956 | 45.9 | 120.7 | 93.3 | 33.2 | 9.4 |
| 1957 | 57.5 | 131.0 | 123.2 | 33.2 | 9.8 |
| 1958 | 62.4 | 144.2 | 149.5 | 38.5 | 10.0 |
| 1959 | 76.7 | 161.0 | 188.7 | 41.5 | 10.3 |
| 1960 | 114.3 | 243.3 | 226.6 | 43.5 | 11.3 |
| 1961 | 132.2 | 225.2 | 290.9 | 48.4 | 20.9 |
| 1962 | 128.4 | 242.6 | 324.0 | 60.1 | 15.7 |
| 1963 | 148.9 | 272.5 | 351.0 | 71.0 | 23.3 |
| 1964 | 161.5 | 289.3 | 399.3 | 75.0 | 23.7 |
| 1965 | 167.0 | 303.8 | 425.8 | 81.9 | 26.9 |
| 1966 | 183.7 | 323.0 | 459.7 | 86.0 | 26.3 |
| 1967 | 219.0 | 327.6 | 497.0 | 85.4 | 20.8 |
| 1968 | 269.3 | 356.3 | 629.4 | 96.7 | 28.0 |
| 1969 | 296.0 | 367.3 | 697.0 | 105.6 | 27.7 |
| 1970 | 326.6 | 392.2 | 796.4 | 130.8 | 30.9 |
| 1971 | 345.5 | 429.3 | 823.2 | 105.8 | 36.4 |
| 1972 | 379.6 | 426.9 | 875.7 | 130.4 | 41.5 |
| 1973 | 447.4 | 459.2 | 913.3 | 144.8 | 42.3 |
| 1974 | 418.2 | 468.1 | 897.5 | 149.3 | 39.6 |
| 1975 | 381.7 | 491.3 | 864.4 | 159.8 | 46.7 |

*Source*: Sato (1978)

However, Japan in 1945, despite the severe physical deprivations, had a technological advantage over Malaysia in 1998. Although Japan paid an appalling price in human casualties during the war, retained in her survivors the human capital that had been accumulated till then. The technology of the steel plants, the machine shops and the chemical factories persisted in the engineers and managers. Although this is a gross oversimplification, when this stock of human capital was provided with physical capital, and the right development environment, the economic miracle was to be expected.

This vast sum of human capital accumulation occurred after the Meiji restoration. Prior to this, Japan was a feudal, pre-industrial nation, that was essentially shut off from the leading technology of the day. Her position of power *vis-à-vis* bargaining with the owners of technology was similar to that facing the late-comers to technology of today.

*Case Studies*

As the focus of this study is to uncover evidence to explain the success of Japanese firms in developing technology to the level of global leadership, the studies that follow concentrates on industries where Japan has or had established a technology leading position. The obstacles faced by Malaysia in their efforts are kept in mind.

The choice of industries should ideally correspond to those reviewed in the Malaysian section, for analytical rigour. However, as the electronics and automotive industries have not been developed substantially at the end of Meiji era, and that in the author's opinion, the technology and competencies that Japan used to develop these industries at a later date can be traced to that of heavy and electrical machinery, the author chose not to cover them extensively in this study. The author also made the decision not to focus on the Meiji chemical industry, because although competently managed, Japan did not go on to develop global technological ascendancy, hence failing the first criteria.

The case studies chosen are:

i) Iron and steel

ii) Shipbuilding

iii) Heavy and Electrical Machinery

### *4.1 Iron and Steel*

*Background*

Iron and steel objects have been in Japan for centuries before the dawn of the Meiji era. Skilful use was made of metal by craftsmen, fashioning swords and armours, cannons and firearms, pots and utensils. Open furnaces were used to produce iron from ore. Casting techniques were used for many objects. One indigenously developed technology was the see-saw bellows called *tatarabuki.* Alloying techniques were used with other metals. Sophisticated treatment such as tempering were used to produce extremely fine blades for swords. The scale of such industries were small, with each group of craftsmen serving their feudal lords. Skills were passed down within clans, and more commonly within families, through master-apprentice relationships.

When Commodore Perry first arrived in Japan, cannons were still cast from copper and brass. Perry was the event that woke Japan from her slumbering isolation. The awareness that foreign powers now possess the technology to enslave Japan (it was made from a feudal mindset) was etched deep in the national consciousness, and gave members of the aristocratic elite a rallying banner. This national consciousness mobilised the effort to strengthen Japan's defence capabilities. The Meiji emperor's restoration gave Japan an ostensibly modern government, that experimented, and eventually accrued the institutions that could administratively manage her modernisation.

Among the highest governmental priority was the need to upgrade military hardware. Import of even the smallest component was never an option, as self-reliance is inextricably woven into the insular national psyche. Towards this immediate end, the capability to manufacture iron and steel of a quality that could be cast into cannons and rolled to sheets for shipbuilding became an imperative. In 1854, shortly after Perry's first arrival, *A Study on the Seven Metals of the West*, written by Baba Sadayoshi became the first available systematic treatise on Western processing and manufacturing methods for iron. It was compiled from available Western texts. Japan's accumulation of technology has begun in earnest.

*Sources of Technology*

The pattern in the search for technology is repeated over the next decades for a whole range of technologies that Japan was to master. The agent that carries out the accumulation is the interdependent duality of state and entrepreneur/firm.

The first step to the accumulation was usually the consultation of local experts. These are men, who by experience or learning, have had some familiarity with the technology that is targeted. In the ensuing consultation, an approach or plan is formulated. Sources of information that are in the public domain, or those easily available is compiled and studied. The approach to accumulation is team-based. A select team of able individuals are the basis of more than a few successful technology acquisitions.

The team from this point may feel sufficiently informed to begin a prototype or pilot. The cognitive experience gained from learning by doing appears to reinforce subsequent learning. The value of 'R&D' running concurrently with learning or transfer is that it reinforces learning, more than the possibility of any immediate new innovation. In most cases, failure is encountered at this stage. Around this point, friendly local foreigners are consulted. This usually meant the Dutch at Deshima. The motivations for assistance on the part of the Dutch appear to stem partly from altruism, and partly from the hope of extended trading concessions. This was the window to Western thought and technology through which many of Japan's technology scholars first gazed, and who in turn started 'schools' in their districts, teaching what they have learnt, albeit with highly distorted bias. The Japanese mind was never a *tabula rasa* for Western thought, but interpreted any information gained through its own distinctive perspective.

Insights gained at any time are tested back at the prototype. The next step if repeated failures are still encountered is the hiring of Western teachers. Japan seem to have its fair share of poor deals in this matter, as individuals with dubious qualifications became self-styled experts. But among the chaff, were *bona fide* experts who did pass on valuable insights. Still many teachers were rigidly inflexible, comfortable in the superiority of Western technology, and attributing repeated failures in transferring technology to poor local conditions and materials. It is not surprising that a section of Japanese technologist began to regard this source of technology as money ill spent, and real success was sometimes achieved after the experts have been sent home.

Concurrently, Japanese students of technology, usually members of the study teams are sent overseas to learn and to absorb new ideas. Japanese diplomatic missions have a long history of assisting such efforts. These students upon their return oscillated between the technology development teams and academia, where they imparted their learning to boost the pool of available human capital. This tradition of the blurring of academia with industry was to serve Japan well, as academics have contributed greatly to technology development for example at Kamaishi (with Prof. Noro) and Miyoshi Electric Machine Manufacturing Company (Levine *et. al.* 1980).

Where possible, capital machinery was purchased. Japanese reverse engineering efforts seems inevitable, as such machinery hold vital clues to earlier failures, and pointers to future improvements. In Hayashi's 5Ms technology acquisition model, the ability to manufacture and modify equipment used in an industrial process is seen as an integral part of the technology. Self reliance imbues every action.

Finally, if a technology still eludes the development team, then some formal technology transfer arrangement is made with a technology supplier. The choice of the supplier is often not the one that is considered the leading technology of the day, but more often the one whose 'spirit' resembles most closely that of the technology absorption team. For example, even though British steel-making technology was considered the best, Yawata chose Krupp of Germany instead because it was thought to be more sympathetic to Japanese conditions.

**Table 4.2: Major Events in Japan's Steel-making History**

| *Place/ Company* | *Start Year of Ops* | *Technology* | *Major Raw Material* | *Main Product(s)* | *Design Capacity* | *Achieved Production Capacity* | *Operations Workers* | *Design & constr.* | *Machinery Imported* |
|---|---|---|---|---|---|---|---|---|---|
| Saga | 1850 | Reverberating furnace | Pig iron, charcoal | Wrought iron | | failed | | | None |
| Satsuma | 1854 | Blast furnace | Iron ore, charcoal | Pig iron | | | | Haguenin design, local constr | None |
| Kamaishi | 1880 | Blast furnace | Iron ore, charcoal | Pig iron | 2 X 25 t/day | 15 t/day Product quality unusable | | Bianchie plan, British engrs & f'man constr | Furnaces, materials handling eqmt |
| Kamaishi | 1881 | Blast furnace | Iron ore, charcoal | Pig iron | | | | Tanaka C. re-engineered | |
| Kamaishi | 1894 | Rolling machine | Pig iron | Rails, plates, bars, flats | | 13,000 t/yr | | Noro K. designed | |
| Yawata | 1901 | Blast furnace, open hearth furnace, Bessemer converter, puddling furnace, rolling machines | Iron ore, coke | Misc steel products | 90,000 t/yr | Production difficulties | 20 German f'man (up to 1904/5), 10 workers from Kamaishi | Luhrman, W. design, German supervision on construction | Furnaces, converters made by Gutehoffnung-s hutte Co. |
| Yawata | 1904 | Second blast furnace | | | | Production improvement | Replacement with Yawata trained workers | Hattori, S. re-engineered | |
| Sumitomo Iron Works | 1901 | | | | | | ex Yawata workers | | |
| Kobe Steel Works | 1905 | | | | | | ex Yawata workers | | |

*Sources*: Hayashi (1990); Levine *et. al.* (1980), Nippon Steel Corp. (1973)

The above account is by no means a description of the only route to technology transfer and enrichment that occurred in Japan. There were often combinations of other strategies, significant detours, and outright failures. But the purpose of the above passage is to capture elements of many of the successful efforts. Some specific details of the technology growth of the Japanese iron and steel industry is given in Table 4.2.

*The Role of the State*

Both Kamaishi and Yawata were state-led projects. It is instructive that both projects were problem plagued, although the state cannot be held accountable for all of them. After repeated failures Kamaishi was abandoned, and eventually sold to Tanaka Chobei, a purveyor for the government. Tanaka through his own efforts and through repeated failures finally made the necessary modifications to get the plant working. The state re-entered the picture, to force plant upgrades.

It was only after Yawata was established that smaller non-integrated steel mills sprouted by the private sector. Among them were Sumitomo Iron Works (1901), Kobe Steel Works (1905), Kawasaki Shipbuilding Hyogo Steel Mill (1906), Nippon Steel Works (1907), Hokkaido Coal Mining Wanishi Steel Manufacturing Plant (1907), Manchurian Honkeiko Steel Company (1910), Korean Kenjik Steel Manufacturing Plant (1911) and Japan Steel Tube Factory (1912). They supplemented Yawata's role as basic steel producer, catering to complementary markets with associated product ranges. Yawata remained the keystone, accounting for 70-80% of total production during these early years.

Yawata played a central role in the expansion of the steel industry through its provision of enterprise-based technical training. The created the pool of skilled manpower that the other companies needed. This also established the model where employers became responsible for the training of young workers that they employed.

*Human Resource Development*

The structure of training and selective promotion from within of only personnel who have joined as young recruits, became an integral part of operational stability. Workers who moved from plant to plant were penalised in this respect. This budding lifetime employment scheme assisted in the technology development as firms were able to appropriate the benefits of training its technology workers to a high degree, and were able to provide them with broad experience in broad aspects of steel-making. The stratification of workers to permanent, temporary and casual status gave the firms the flexibility of adjusting labour to production. The core permanent workers were accorded the most training, and were the elite among workers.

The rise of militarism in the mid 1930s institute a combination of military and industrial training. This was thought to inculcate loyalty. Loyalty became valued above technical skills

### *4.2 Shipbuilding*

*Background*

The capability to build modern naval vessels was one of the primary drivers for steel-making. Japan had, prior to its rude awakening by Perry, little experience as a seafaring nation, due to the Tokugawa seclusion policy. Artisans were involved in traditional boat-building using simple technologies, with wood as the primary material.

The pattern of technology acquisition is very similar to that described for steel-making. The Satsuma clan first translated a Dutch book on the building of steamships in 1849. Dutch naval officers began teaching Japanese workers consisting of former craftsmen on work at the new shipyards at Nagasaki in 1855. A navigational school was established the same year, and Dutch teachers were employed the following year. The Dutch then presented the shogunate with the 250 ton *Kanko Maru* as a training ship. This was followed by other steel ships that were purchases or presents from the British, American and Dutch governments. Japanese students were sent to various Western maritime academies for formal instructions in modern shipbuilding and navigation. Different clans approached different Western powers. The French were installed by the shogunate at Yokosuka, and remained after the restoration of the emperor, supervising all aspects of iron-ship construction. Yokosuka subsequently played a role similar to Yawata's as a generator of skilled workers for private shipyards that proliferated.

Shipyards were initially involved in repair and maintenance. The first modern warship built in Japan was the 138 ton *Chiyodagata* in 1870. Up to 1880, the total tonnage built still amounted to only 3,000 tons. A boost came only with the Sino-Japanese war in 1895, and a larger boost with the Russo-Japanese war. Demand was certainly the key to production and technology extension in this industry. By 1910, 26 shipbuilding companies were established, and Japan became the sixth largest shipbuilding nation in the world.

*The Role of the State*

In any industry, where the products are large, and capital intensive, the state is instrumental to its growth in its early stages, by creating demand. Naval vessels constituted the largest orders, followed by orders from state owned shipping companies. An important factor in the conception of this demand was the simultaneous training of navigational skills and naval operations together with the acquisition of shipbuilding technology. Had this M5 market factor been delayed or neglected, the shipbuilding industry could not have grown at the rate it did.

The state also passed various laws in support of the industry, including the prohibition of old-style vessels in 1885 and the law to encourage shipbuilding/law to encourage shipping 1896 - which brought in subsidies, tariff protection, restrictions of imports. Another critical state support came in the form of building specifications for vessels. But perhaps the most important support came in providing for the creation of critical human capital by sponsored training, the setting up of shipbuilding colleges, the sending of students overseas and the setting up of craftsmen's schools. The shortage of workers was to some extent alleviated by the state's encouragement of skilled workers to move to shipyards.

*Human Resource Development*

One of the legacies that Meiji Japan inherited from its feudal past was the master-apprentice (*oyakata-kokata*) relationship of craftsmen. This institution was invaluable for the transmission of informal skills and learning, and gave opportunities for the master to appropriate benefits of labour from his apprentice for the knowledge that he imparts. However, this became an impediment in the new industrial environment, where skills are required to be transmitted to large numbers of new workers, and loyalties have to be redirected towards the firm rather than a free-lance master. The agent for learning and technology had passed from skilled transient individuals to permanent organisations. The creation of enterprise training, and the assumption of teaching responsibilities by the firm eventually replaced the *oyakata.* A remnant of this old relationship metamorphosed into the *quid pro quo* exchange of loyalty for lifetime employment. This stable relationship was critical for the accumulation of knowledge, and the concomitant enrichment of technology.

Firms gravitated to the recruitment of young workers with no prior industrial skills, to inculcate company values and culture. Skilled workers joining a firm in mid-career found themselves in limbo as temporary workers, without prospect of promotion. Firms like Mitsubishi recruited sons of employees within the *zaibatsu* as further emphasis of valuing loyalty over technical ability, and providing inter-generational lifetime employment. With such strong identification of worker with firm, the firm felt unconstrained to invest heavily in training for the long term.

### *4.3 Heavy and Electrical Machinery*

The shipbuilding and iron and steel industries found the skills needed to fabricate and modify machinery integral to the development of their technology. Machine shops were set up in shipyards and steel foundries. However, they remained as part of the larger industries, until after the Russo-Japanese war, when private sector machine shops began to proliferate as a result of the inability of in-house shops to cope with the rapid increase in demand for machinery. Within this relatively short space of time, Japanese machine shops managed to develop and manufacture a variety of machinery (see Table 4.3).

Despite these modest advances, the range of machinery manufactured remained narrow. Many sophisticated machinery such as cable manufacturing machinery and high voltage machinery still had to be imported. The major obstacles appeared to be that the machinery companies remained small, and lack the capital to embark on a major technology acquisition exercise. Even with encouragement from the state to upgrade capabilities, not many firms had the means to heed the call. Some large companies like Hitachi, which was buoyed by earnings from copper mining and its steel factories ventured into heavy machinery. Hitachi concentrated on developing new types of machinery, and recruited the top engineers in Japan to accomplish the task. Hitachi concentrated its engineering resource in a single complex. Soon other members of *zaibatsus* like Toshiba, Mitsubishi, Fuji and Nihon Denki established their heavy machinery units. The smaller firms from the earlier era that managed to survived evolved into subcontractors of these behemoths.

**Table 4.3: Technology Expansion in Heavy Machinery in Japan**

| *Date* | *Machinery* | *Event* | *Manufacturer* |
|---|---|---|---|
| 1857 | Boring machine | Imported | |
| 1857 | Lathes | Imported | |
| 1860 | Lathes | Manufactured | Iron works |
| 1879 | Various | Manufactured | Mita machinery (govt) |
| 1880 | Various | Manufactured | Akabane (govt) |
| 1880 | Electric generators | Manufactured | |
| 1886 | Various | Manufactured | Ishikawajima shipyard (pte) |
| 1888 | Electric lathe | Manufactured | Navy yard (govt) |
| 1892 | Cast steel engine | Manufactured | Yokosuka Naval Arsenal |
| 1897 | Miyahara boiler | Manufactured | Kawasaki Shipyard (govt) |
| 1903 | Ikeda boiler | Manufactured | Nagasaki Shipyard (govt) |
| 1904 | Parson turbines | Manufactured | Nagasaki Shipyard (govt) |
| 1907 | Curtis turbines | Manufactured | Kawasaki Shipyard (govt) |

*Source*: Levine et. al. (1980)

The history of Japanese technology development is characterised by advances brought about by teams, whose members' names remain unknown to most of the outside world, unlike that in the West, where great individuals like Edison, Bell and Ford are celebrated for their technological feats. The exceptions to this are men like Toyota Sakichi who invented the automatic loom in 1902 that revolutionised Japan's textile industry, and Matsushita Konosuke who began by manufacturing electric sockets. Both these men founded companies that bear their names, that today remain leaders in their fields. But perhaps the individual that best fits the role of a Japanese Prometheus is Tanaka Hisashige (1799-1881).

Tanaka, although without formal education in modern physics, had an uncanny feel for mechanical objects (Imazu, 1980). This innate ability for abstract reasoning of mechanical cause and effect was the wellspring of a fecund creativity that seemed to spawn new inventions at will. His focus appears to be on scientific principles rather than particulars, and this enabled him to be effective across many technologies, including the ability to produce a telephone from the mere inspection of one such apparatus. This talent was a harbinger of the talent within teams of engineers that powered Japan's technology development in the years following Tanaka. This competency to imagine a series of small mechanical actions culminating in a large desired outcome was the key to prodigious feats of reverse engineering, and the irresistible logic of small stepwise improvements. One almost suspects that had Tanaka been born in a later generation, his talents would have been subsumed into one such development team, and he would remain one of the many anonymous heroes in Japan's progress to technological leadership.

The heavy and electrical machinery industry in a sense became a facilitator to technical progress in other sectors in Japanese industry, including that of chemicals, automobiles and electronics. This was in a sense, the capability to shape its technological destiny. To borrow from a Confucian parable, Japan did not only learn how to fish, but to make fishing rods, nets and fishing boats. This model of economic progress came instinctively to Akamatsu (1962), who believed that the capability to manufacture capital goods follows naturally from the capability to manufacture consumer goods. As we have seen from the Malaysian experience, this progression is not inevitable.

# 5. Clues to Technology Enrichment

In this chapter, the major features that contributed to Japan's ability to absorb and enrich foreign technology are reviewed, with their corresponding significance in the Malaysian experience.

## *5.1 Cultural Factors*

The cultural and societal differences between Meiji Japan, and Malaysia in the late twentieth century are many, but the critical task here is to comment on those that have probable bearing on technology enrichment. Even if these factors appear compelling, it is unlikely that practical policy remedies can be administered from such lessons, as cultural and societal values are the precious attributes that marks a nation as distinct, and carries with it the basis of national identity. To dilute or modify such cultural identities for the sake of facilitating learning would be a price too high for many to contemplate.

*Self-reliance*

The common first response of a Japanese firm in confronting a new technology is that they have the abilities to master it on their own. Even if previous knowledge accumulation of the subject is meagre, the task force charged with the responsibility would take it upon themselves to solve the problems. The appeal for foreign assistance is the last resort. This trait establishes some initial accumulation on knowledge before the new technology arrives. When it arrives, the technology is readily appreciated, and when technology is applied with context and meaning, innovations can sprout. Because the goals of technology transfer seem so time driven today, a Malaysian firm does not seem to have the luxury to ruminate on a technological problem, but to head straight back to the technology provider for a quick fix. The cognitive process of problem solving is lost.

*Japanese spirit*

The Japanese people during the Meiji era shared the common myth that they will be enslaved by foreign powers if they do not build the strength of the nation. This fear was an extremely powerful motivator, that papered over differences between and within sectors in the country, and gave each member of the team a higher purpose in their efforts to the extent of large personal sacrifices. Malaysia is a democratic heterogeneous society, with a weakly developed set of national orthodoxy. The motivating forces that are available for harness are just as likely to be personal and/or sectoral rather than national. While contributing to the fast trajectory to technology independence, the Japanese spirit is probably not a primary factor in explaining the capacity to absorb and enrich technology.

*Thrift*

The Japanese have an almost national trait in their appreciation of thrift, efficiency and simplicity. Ostentation is considered wasteful. Simple lines are considered more aesthetically and spiritually pleasing than baroque decoration. There is a decided preference for order over chaos. The Japanese have practised 'Less is More' before the post-mordernist. This same trait is applied in their industrial organisation. It is not fanciful to see the connection of this trait with the industrial slogan to eliminate *muri*(overwork), *muda*(waste) and *mura*(irregularity). This trait is a virtue in industrial organisation where complexity tend to overwhelm organisations less devoted to order and form. This observance of order and form gave technology development efforts a guiding simplicity, that provided a ready avenue of improvement over imported forms of industrial organisation.

## 5.2 Indigenous Competencies

An industrial competency is a subset of formal and cognitive skills that make up the body of a technology. The idea of competencies was used by Pahalad and Hamel (1990) in the context of firms. Competencies break down a technology to its skills components. An attempt to illustrate this idea is given in Table 5.1.

**Table 5.1: Industrial Competencies in Japan 1850-1880**

| *Industry* | *Competencies* | *Sources of competencies in a craft-based economy* |
|---|---|---|
| Iron and Steel-making | Furnace design and operations | Iron-making, Ceramics |
| | Coke making | Charcoal making |
| | Materials handling | Carting, Distribution, Military |
| | Power driven mechanisation | Agriculture, Metal-crafts |
| | Refractory material | Ceramics |
| | Metallurgy | Metal-crafts |
| | Chemistry | Doctors |
| | Metal forming - rolling | Sword-making |
| | - casting | Cannons, bell-making |
| | Metal treatment - tempering | Sword-making |
| | - polishing | Sword-making |
| Ship-building | Fluid mechanics | Boatmen, |
| | Structural analysis | House-builder, boat-builders |
| | Material-forming | Metal crafts |
| | Mechanics | Agriculture, cart-builders |
| | Propulsion | Boat-builders, cart-builders |
| Machinery | Power-drive | Agriculture engineer |
| | Mechanics | Metal-crafts |
| | Metal stamping | Metal-crafts |
| | Metal forming | Metal-crafts |

*Source*: Author

The role of competencies in technology absorption is that it utilises available accumulations of knowledge where there may seemingly be no directly applicable knowledge. The first workers sent to shipyards to receive training were craftsmen. This selection was critical as these individuals were the few in Japan who would receive the greatest benefit from the scarce resource of training. The technology that was taught had some meaning and context to them, as a result of their previous accumulation of experiences with their competencies. This selection of individuals who were to receive training maximises the benefits of training. Samurais were selected for organisation and management training. Craftsmen and artisans were chosen as engineers. Surplus agricultural workers were employed for manual labour.

When technologies are targeted by policy makers for acquisition in late-developing countries today, the usual considerations are perceptions of high-technology for the reflected prestige of 'advanced' status, the capital to labour ratio of the technology, the earnings potential of the technology, and the terms and pricing of technology transfer. There is certainly less emphasis on the potential of generally available local workers in absorbing the technologies. Competency matching is a potential tool to this end. The selection of workers to be trained in an industry would also benefit from competency matching, as it maximises the value of training.

Unless a technology is absorbed and internalised by the workers, there is low probability that it would be enhanced, and real productivity gains become frustratingly elusive.

### *5.3 Industrial Linkages*

The inter-relatedness of Japanese firms within an industry and across industries facilitated a high degree of technological development. In the pre-war years, the *zaibatsus* wielded an inordinate amount of influence with its tentacle-like reach into all industries. These conglomerates dictated firm level decisions from the centre. The advantages it provided were:

- the ability to co-ordinate co-operative efforts across industry. In a market driven economy, the transaction costs of forging a series at joint-development co-operation on a project by project basis may rule out many potential ventures. Such co-operation may involve developing a steel with specific properties for a shipbuilder, or a piece of machinery to turn out a specific component for chemical plant.
- the ability to invest in necessary upgrades of technology, as in the case of heavy machinery investments.
- the ability to effect an efficient concentration and division of labour across industries.
- the ability to concentrate limited knowledge accumulation in special technology development units *c.f.* incubators in technology parks.

Linkages persisted after the war in new forms, *i.e. keiretsus*. Special relationships also linked large integrated technology companies with small and medium sized companies. Again such patron-client relationships reduced transaction costs in establishing and maintaining joint-projects, and the degree of openness an anchor firm has in sharing proprietary information. The bandwidth of information flow along such networks facilitates technology development.

Another significant benefit of this close relationship is that the process of step-wise continuous improvement usually involves some modification to related processes either upstream or downstream on the manufacturing value chain. Without this co-operative mechanism in place, an affected adjoining unit may suffer a small incremental cost, for some greater benefit that it does not directly accrue. Without trust the benefits of small step-wise innovations may never exceed the transaction costs needed to bring it about.

Japanese firms also tended to form long-term relationships with their technology providers in both buying and selling technology. They work at developing trust, which is valued more highly than perhaps technological sophistication.

Technology linkages developed in Malaysian industry tend to be long umbilical cords to the technology provider, rather than to supporting local industries. Information flow is sub-optimal for technology enrichment. The linkages between the technology export sector and the domestic small and medium enterprises are too shallow to bear substantial joint technology development program over the mid to long term.

### *5.4 Technology Acquisition Along Entire Value-Chain*

Another clear lesson from the Japanese experience is the comprehensive regard for technology. Steel-making, ship-building and heavy machinery industries were not seen as separate industries, but an organic whole. Apart from the core manufacturing know-how, the Japanese firms also considered creating markets for downstream products, technologies surrounding raw materials, intermediates and substitutes, as well as the capabilities to modify, design and build the capital goods for that industry (Hayashi's 5Ms). The co-ordinated acquisition of an entire value-chain allows for more rapid local development of technology, with shorter lines of communications, and higher degrees of influence on adjoining processes along value-chain.

Malaysia's most successful industrial sector by share of value-added and exports is the electrical/electronics sector. Yet inspecting the value chain of this sector reveals that only a very thin slice of total operations occurs in Malaysia. Taking semiconductors as an example, the chips are designed and fabricated elsewhere; assembled, tested and packaged in Malaysia; used in machines, computers and appliances elsewhere; the capital equipment for assembly, testing and packaging are designed elsewhere, many of its components are manufactured elsewhere. Many Malaysian electrical engineers are trained elsewhere. It is hard to imagine the scenario where the lowest value-added operation dictates technology development of this industry.

Table 5.2 shows the extent of technology integration of using the 5Ms in Malaysia. There is backward integration with local raw material (M1) supplies only in the chemical sector, although in automotive and electronics, there have been recent efforts to extend the value chain backwards. There is yet clear indications that capabilities to design, build and modify the important capital equipment (M2) in these industries are developed. Clear efforts have been made to upgrade human resources (M3) in all industries, although there is still substantial shortfall in terms on quantity produced. As for industry-wide management, process and organisational adaptations (M4), there have been structures in place along the value-chains that begin and end outside local control. However, industry-wide management between domestic partners have not really been worked out before technology transfer began, except with the automotive sector. Finally, real unfettered access all the way down to final consumers (markets M5) in the value-chain is only realised in the automotive sector.

**Table 5.2: Malaysia's Performance on the 5Ms**

| | *Electric/ Electronic* | *Chemicals* | *Automotive* |
|---|---|---|---|
| M1 | 🖰 | 🗐 | 🖰 |
| M2 | 🖰 | 🖰 | 🖰 |
| M3 | 🗐 | 🗐 | 🗐 |
| M4 | 🖰 | 🖰 | 🗐 |
| M5 | 🖰 | 🖰 | 🗐 |

*Source*: Author

### *5.5 Ownership of Firms*

In the case studies of Japanese technology transfer during the Meiji era, the technology acquiring firms were Japanese owned (and in many cases state owned) firms. The point is not so much the nationality of ownership, but of the freedom to access, develop, modify and appropriate benefits from the technology, and the attitude and commitment of the technology developing firms with regard to trust and investment in domestic human resources.

Many technology firms in Malaysia have significant foreign equity. Such firms may not have the same long term commitment to investing in the people, and have greater likelihood of regarding the venture in less than permanent (or at least long-term) terms.

### *5.6 Employment Patterns*

The firms that own, use or licence technology need special workers to act on it. Before these workers can add value to technology, they need to be converted to an intermediate product, the trained worker. Conversion consumes capital. Yet firms cannot own workers like they own capital equipment and raw material. Converted workers are free to offer their services to rival firms. Investment in training is not appropriable. The dilemma remains that without this investment in workers, the technology a firm possesses in not productive.

The great Japanese invention that allows firms to appropriate training is called lifetime employment. The worker identifies so strongly with the firm that a separate identity is not possible. The firm feels confident to invest heavily in their workers without fear of leakage of their investments. These workers become technology-enabled, and are in turn capable of producing more technology, as well as use technology productively.

In Malaysia, there are a limited pool of semi-finished workers, those with tertiary training in technology subjects. These workers still require some finishing to convert them to technology enabled workers. However, the investment in training the workers can be lost to other firms should these trained workers choose to leave. Because of the shortage of supply of even the semi-trained workers, there is rapid employment turnover of these workers. Given the prevailing employment patterns, firms have low confidence in training and empowering their workers to the extent that they can enrich technology.

### *5.7 The Role of the State*

The role of the state in the acquisition of technology is critical. The nature of increasing returns for accumulations in knowledge predicates that market forces alone cannot bring about the emergence of new firms that would be competitive at producing technology, against existing firms. The important roles played by the state in Japan include:

- the provision of education and training;
- the provision of capital, and capital allocation institutions;
- direct ownership and management of technology acquiring firms;
- the provision of a market for technology products;

- the establishment of supporting structures of the technology through firms providing raw materials, markets and supporting services;
- regulation of domestic competition;
- protection of fledgling domestic industries from foreign competition.

The Malaysian government, have to a large extent built its industrial policy following the Japanese model. The state interventions that made technology transfer and enrichment possible in Japan, are also present in Malaysia. Arguments may be made of the differences in quality and quantity of state intervention in explaining the variance in technology enrichment result. A study of these differences would be revealing, but is outside the scope of this present study.

However, the one telling difference that is noted in this study is in the management of human capital. At the early phases of technology acquisition, relevant human capital is a scarce resource. The state in Japan made conscious efforts to concentrate available human resources to designated industrial centres. In shipbuilding, it was at Yokosuka, in steel-making, it was at Yawata. A significant portion of the early experts of the technologies were deployed in capability building, in universities as teachers, and in enterprise training centres, and even in administrative policy making bodies.

In Malaysia, the state's efforts to build and concentrate early expertise is less pronounced. Market mechanisms played a larger role in the allocation of human resources. Technical expertise tended to dissipate to various transnational firms, and fewer in numbers were involved in teaching or in policy-making bodies. In knowledge and technology-driven industries, market-forces favour agents with large accumulations of knowledge. Intervention is necessary to initiate accumulations around new firms.

### *5.8 The Practice of Technology Transfer*

The chances of technology enrichment success increases in cases where there have been previous indigenous industrial attempts to develop technology. The technology that was imported had context and meaning to the team performing the absorption. The recognisable features of the imported technology reset the gestalt and enabled new innovation.

Conversely, in Malaysia, where the driving force for technology imports is generally to initiate a new industry, the technology absorption team buys into the mindset of the technology provider. There is acceptance of the way elements are defined within the imported technology setting. If something does not seem in place, there is less confidence in questioning the offending element. The lack of previous cognitive experience limits innovative behaviour, and encounters with problems prompts automatic consultations with the technology provider. This institutes a dependent relationship in matters of technology.

In Japan, the most innovative agents for technology absorption are nimble and relatively small private firms. Within these firms, there is blurred distinction between the engineering and management functions, for the chief reason that they reside within the same individuals. These firms made production and product decisions from the factory floors, and not in boardrooms. They had working relationship with their customers. They had the flexibility of showing a prototype to a customer, and eliciting feedback the same day. The selection and choice of technology imports are taken based on simple considerations like 'can we make it work in our workshops', rather than 'is this the latest technology', or 'are the financing terms the most favourable'.

The evidence of technology enrichment success through entrepreneurial small firms against state owned firms is seen in Tanaka Chobei's relative success with Kamaishi, and the nimble firms around Yawata against Yawata itself. In post-war Japan, innovation was left in the hands of privately owned enterprises. The state, with all its high calibre technocrats, have generally left the micro-management of technology absorption and enrichment to the firms.

The modern business is run differently today in Malaysia (as in Japan), with specialised functions, and departments. Decision-making in the large technology companies in Malaysia are invariably top down. Management boards take presentations from business development teams, with emphasis on market and financial projections. It is often assumed that engineering and plant operations are predictable quantities in the equation. There is almost an expectation that technical issues can be managed with further financial input, *i.e.* purchasing more technology. Investment in R&D is seen as another such lever.

### *5.9 Different Eras, Different Worlds*

Finally, a significant difference between Meiji Japan and late twentieth century Malaysia is that the world has changed. What was the technology frontier during the dawn of the twentieth century could conceivably be mastered with concentrated efforts in a few years. The same does not apply in areas of high-technology at the close of the century. The monitoring and management of proprietary technology is more effective today. With globalisation driven by new technologies in information technology and telecommunications, technology owners are not constrained as they were in the past in exploiting geographically and culturally remote markets.

These are serious challenges to the validity of methodology and structure of this study, as the argument that in today's global climate, even Meiji Japan would not succeed in adopting and enriching technology can be made. However, this is a spurious argument, as it assumes that an understanding of the factors and conditions that succeeded in enriching imported technology cannot be adapted to meet and suit different situations. There are compelling economic, social and humanitarian reasons that the capability for technology development should be made available to all nations and peoples.

# 6. Policy Implications

The economics of technology and accumulation in knowledge gives rise to increasing rates of return. The firm with the larger accumulation would generally outperform the firm with less accumulation. Given such dynamics, if events are left entirely to market forces, there would only be a few large technology firms. New technology firms would have great odds stacked against it.

Given the desirability of sustainable self-renewing technology industries in a national economy, for its ability to generate long-run productivity increases, and the scarcity of such industries in late developing economies, what are the policies that assists such technology enrichment?

Japan has overcome great odds during the Meiji era to modernise, and to surge towards the industrial technology frontiers. While it is to be acknowledged that the global environment was different from today, the mechanisms that were unlocked then are still relevant to policy makers now.

### Consider Technology as Value Chain

Policies that are framed to encourage technology imports should develop measures to co-ordinate the importation of supporting technologies of a targeted industry, and encourage firms that are inter-related along the value chain to make simultaneous investments. In isolation, an outpost on the value-chain has little chances of developing relevant new technology.

### Invest in Human Capital

The surest way to attract technology investments, is to upgrade the resource that is most critical to technology development. As science and mathematics is the language of technology, incentives to increase the mix and quality of basic science and mathematics education, institutions to cater to middle school level industrial skills, centres for higher education specialising in technology, and R&D institutions all contribute to the pool of human capital capable of technology enrichment.

The Third International Mathematics and Science Study (TIMSS) is periodic study that measures mathematics and science abilities of schoolchildren in selected countries. The results are very encouraging for East Asian countries, and it is a good basis for competitive advantage in technology (see Table 6.1) .

**Table 6.1: The Third International Mathematics andScience Study: Selected East Asian Results**

| *Country* | *School Level* | *Avg Mathematics Score* | *Avg Science Score* |
|---|---|---|---|
| Singapore | Primary | 625 | 547 |
| | Middle School | 643 | 607 |
| Japan | Primary | 597 | 574 |
| | Middle School | 605 | 571 |
| S. Korea | Primary | 611 | 597 |
| | Middle School | 607 | 565 |
| International Average | Primary | 529 | 524 |
| | Middle School | 513 | 516 |

*Source*: Mullis et. al. (1997), Beaton et.al. (1996a, b), Martin et. al. (1997)

## Strengthen Intra- and Inter- Industrial Linkages

Technology develops from interchange of ideas, and dialogue between technologists in industry, those in academia, and those in public office. Policies that extend the bandwidth of ideas exchanged, through formal and informal channels would stimulate technology development. Trust is an important element that cannot be bypassed, but must be built. Forums and institutions for the exchange of ideas include professional engineering associations, chambers of commerce, industry group associations, and government/ private sector dialogues.

### Encourage Development in Technology Niches

The history of technology development has been a battlefield of Schumpeterian creative destruction. The paradox is how could new technology firms successfully mount a challenge against technology heavyweights with substantial accumulations of knowledge. The answer is that Microsoft did not topple IBM on mainframe technology. It developed a new category of technology where there were no existing giants. By being first, Microsoft built the biggest accumulation of knowledge of personal computer software. Likewise Netscape challenged Microsoft, not where Microsoft had its huge accumulation, but in internet browsers which had the potential of undermining PC operating systems.

This highlights the tragedy of state sponsored ventures in aerospace industry, where precious national resources are used to build anthills of accumulation in competition with the mountains of the Boeings and the Airbuses of the world. The globalised world negates the possibilities of building technology accumulations in pockets where global leaders are not. National resources are too precious to be gambled on low (no) probability plays.

The technology niche strategy is a shortcut to the technology frontier. While there are no limits to the number of technology niches that exist, the difficulty with such strategy is that the industrial potential of many niches are small, and requires a certain amount of accumulation to recognise potential.

While a domestic automotive industry may be visible, would it accrue sustainable wealth for the nation if it cannot produce a car as cheaply or as good as someone else? While Japan may have directly challenged established technologies, she had by then accumulated significant technology in her manufacturing and process management armoury. When Japan surged ahead with electrical appliances, she did so on the back of the transistor niche which was still fairly new, and which Japan developed a way to manufacture cheaply.

### Match Technology Imports with Local Industrial Competencies

Not all technologies have the same potential of taking root, just as all nations have different mixes of competencies. A nation's history and economy hold clues as to the latent competencies within. Malaysia for example has leading competencies in plantation management. The competencies within include control of tropical weeds, genetic manipulation of tropical cash crops, design of surface drainage in plantation and as many skills and smarts needed to successfully manage a plantation. All these areas have technology potential, for those with the imagination and knowledge of matching competencies.

**Concentrate Scarce Accumulations of Knowledge**

Technology is the product of human capital and ingenuity. Real innovative breakthroughs occur when bright and talented people work together. The dissipation of talented people through brain drain to international organisations hampers technology development. Policies that are capable of attracting brain-power, and an environment which encourages creativity and hard work are likely to facilitate technology development.

The Multimedia Super Corridor project in Malaysia has the potential of sparking innovative technology activity.

**Encourage Worker/Firm Loyalty**

The best way to reduce rampant job-hopping is to ensure that there are adequate trained human capital for all firms, so that firms do not have to resort to poaching. But even with adequate supply of human capital, there will be labour turnover. This is a leakage of training investment. Policies that encourage trust between workers and employers, good employment practice by firms our element that would be likely to win worker loyalty. Japan's lifetime employment practice in the past facilitated a high amount of training by the firm.

**Develop Regional Strategies, Pool Regional Markets**

The combined human and capital resource required to develop a technology value-chain is large. But in this age of regional co-operation, technology development is a project that is workable within regions. Costs and risks are shared, resources and markets are pooled. This implies a regional industrial co-ordinating institution. APEC as a regional grouping could be one such co-ordinating body.

The chemical industry in South East Asia is one that could have benefited from a regional approach to development. Instead of duplicated petrochemical complexes in Merak, Indonesia, Rayong, Thailand, Pulau Seraya, Singapore and Kertih, Malaysia, there could be world-scale plants for different parts of the region to service the entire regional market.

**Stable Political-Economic Environment**

Technology development efforts are usually long-term high-risk capital-intensive endeavours. Firms that undertake them require long-term capital at stable rates, and a highly educated work-force. They would need effective laws, institutions and professionals to assist in protecting their intellectual property at it is developed, and redress if they are violated. They require a physical location with access to information technology, telecommunications, transportation and other modern infrastructure.

Nations with the policies and institutions for the promotion of such an environment would be advantaged in their technology development efforts.

## 7. Conclusions

There are many late-developing nations today that have achieved substantial technology transfer in their economies. An inspection of such countries' GDP, or exports would reveal substantial contributions from goods that require advanced technology to manufacture. Are these countries now on the road firmly to technology development, having successfully absorbed and localised imported technology?

A review of Malaysia's technology economy reveals that the grasp on technology is still fragile. If access to the suppliers of technology is suddenly severed, Malaysia's capacity to support, enrich and renew the imported technology with internally generated resources is limited. Similarly, Malaysia's competitive position against a third country who receives identical technology support from her technology suppliers is not evidently sustainable.

The conditions and factors that confer the capability to independently enrich and develop imported technology were present in Japan during the Meiji era. It was during this period that Japan converted herself from a pre-industrial feudal country to a modern industrial nation. Japan became advanced, not through external aid, but by her own determined efforts.

The lessons that late-developing countries can learn from Japan are many. Among the most profound, is the regard of technology not as discrete, stand-alone units, but as an inter-related value chain that encompasses raw materials, machinery, special skills and training, a system of managing processes and the markets of the product associated with the technology. This comprehensive viewpoint prepared the firms receiving the technology to be completely self-reliant and comfortable with seeing to the developmental needs of the technology.

Another trait that afforded the Japanese firms the capability of enriching the technology is the high level of preparation of the individuals who work with the technology. This ranges from the selection of individuals with the highest competencies, to the elaborate and broad training that they will receive. Lifetime employment practices gave the firms the confidence to train their workers, and the workers to learn very specific skills that may not be applicable to other employers.

The linkages between firms across and within industries allowed for high levels of trust, for the sharing of competitive information, and co-operation on technology- based projects.

Although the global environment has changed tremendously over the course of the twentieth century, the understanding that technology is essentially accumulated knowledge pertaining to the production of goods and services, makes understanding conditions that applied a century ago, still useful today.

The implications of the nature of increasing rate of returns that technology has are markets will favour firms with more technology. Late-comers to technology are disadvantage against established technologies. Late comers to economic and technology development would require state intervention to compete against established companies.

The strategy a nation employs in its development of industrial technology have profound impact on the probability of successful technology development. However, because of the heavy demand of resources that technology development requires, regional co-operation among nations with similar technology development goals will improve the prospects.

## References

Allen, G. C. (1980) *Japan's Economic Policy.* London: Macmillan.
Akamatsu, K. (1962) "A Historical Pattern of Economic Growth in Developing Countries", *Developing Economies*, 1(1): 3-25.
Anuwar, A. (1992) *Malaysia's Industrialization: The Quest for Technology.* New York: Oxford University Press.
Asian Development Bank (1995) *Technology Transfer and Development.* Manila.
Beasley, W. G. (1990) *The Rise of Modern Japan.* Tokyo: Tuttle.
Beaton, A.E. et al. (1996a) Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study (TIMSS). Chestnut Hill: Boston College.
Beaton, A.E. et al. (1996b) Mathematics Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study (TIMSS). Chestnut Hill: Boston College.
Chatterji, M. (ed.) (1990) *Technology Transfer in the Developing Countries.* London: Macmillan
Coase, R. (1937) "The Nature of the Firm", *Economica*, 4(4): 331-51.
Enos, J. L. & Park, W. H. (1988) *The Adoption and Diffusion of Imported Technology: The Case of Korea.* London: Croom Helm.
Enos, J. L. (1989) "Transfer of Technology", *Asian-Pacific Economic Literature*, 3(1): 3-37.
Enos, J. L. (1991) *The Creation of Technological Capability in Developing Countries.* London: Pinter.
Freeman, C. (1982) *The Economics of Industrial Innovation.* London: Frances Pinter.
Fujita, K. & R. C. Hill (1997) 'Auto Industrialization in Southeast Asia', *ASEAN Economic Bulletin*, Vol. 13, No. 3.
Gerschenkron, A. (1962) *Economic Backwardness in Historical Perspective*, Cambridge: Harvard University Press.
Girvan, N. (1981) *Note on technological capability, Research Paper Series No. 1, Department of Economics,* University of the West Indies, St. Augustine, Trinidad and Tobago, July.
Hayashi, T.(ed.) (1990) *The Japanese Experience in Technology: From Transfer to Self-Reliance.* Tokyo: United Nations University Press.
ILO (1986) *Report of the Working Group on Building Endogenous Capacities in Science and Technology.* Geneva: ACC Task Force on Science and Technology for Development.
Imazu, Kenji (1980) 'Modern Technology and Japanese Electrical Engineers', Okochi, Akio & Uchida, Hoshimi (eds.) *Development and Diffusion of Technology*, The International Conference on Business History 6. Tokyo: University of Tokyo Press.
Johnson, Chalmers (1982) *MITI and the Japanese Miracle.* Stanford: Stanford University Press.
Jomo, K. S. (ed.) (1993) *Industrialising Malaysia: Policy, Performance and Prospects.* London: Routledge.
Jomo, K. S., Rasiah, R., Rokiah A., Jaya Gopal (1997) 'Industrial Policy and the Emergence of Internationally Competitive Manufacturing Firms in Malaysia', Paper presented in FASID Conference, Tokyo, December.
Kagami, Mitsuhiro (1997) New Strategies for Asian Technological Development: Problems Facing Technology Transfer and Backward Linkage, Discussion Paper Series No. 5, Development Studies Department, Institute of Developing Economies.
Katz, J. M. (1984) "Domestic Technological Innovations and Dynamic Comparative Advantage: Further Reflections on Comparative Case Study Program", *Journal of Development Economics*, 16(1-2): 13-38.
Kawabe, Nobuo & Daito, Eisuke (eds.) (1993) Education and Training in the Development of Modern Corporations, The International Conference on Business History: Tokyo: University of Tokyo Press.

Kim, J. I. & Lau, L. (1994) "The Sources of Economic Growth of the East Asian Newly Industrialized Countries", *Journal of the Japanese and International Economies*, 8(3): 235-71.
Krugman, P. (1994) "The Myth of Asia's Miracle", *Foreign Affairs*, 73(6): 62-78.
Lall, S. (1992) "Technological Capabilities and Industrial Organization", *World Development*, 20(2): 165-86.
Lall, S. (ed.) (1984) "Special Issue on Exports of Technology by Newly Industrialising Countries", *World Development*, 12(5-6).
Levine, S. B. & H. Kawada (1980) *Human Resources in Japanese Industrial Development*: Princeton, Princeton University Press.
Lynn, L. H. (1982) *How Japan Innovates: A Comparison with the U.S. in the Case of Oxygen Steelmaking.* Boulder, Colorado: Westview Press.
Magaziner, I. & T. M. Hout (1980) *Japanese Industrial Policy.* London: Policy Studies Institute.
Malaysia (1996) *The Second Industrial Master Plan 1997-2006.* Kuala Lumpur: Ministry of International Trade and Industry.
MASTIC (1994) *1992 National Survey of Research and Development.* Kuala Lumpur: Malaysia Science and Technology Information Centre.
Martin, M. O., et al. (1997) *Science Achievement in the Primary School Years.* Chestnut Hill: Boston College.
Mohd Nazari, I. (1993) "Technology Transfer via Linkages and Personnel Upgrading: A Study of the Malaysian Electronics Industry", *Malaysian Journal of Economic Studies* Vol. XXX no.2.
Mori, T. (1997) "Japan's ODA and APEC", Omura, K. (ed.), *The View of Economic and Technology Cooperation in APEC.* Tokyo: APEC Study Center, Institute of Developing Economies.
Mullis I. V.S., et al. (1997) *Mathematics Achievement in the Primary School Years.* Chestnut Hill: Boston College.
Nippon Steel Corporation (1973) *History of Steel in Japan.* Tokyo.
Peck, M. J. & S. Tamura (1976) 'Technology', from Patrick, H. & Rosovsky, H. (eds.) *Asia's New Giant: How the Japanese Economy Works.* Washington: The Brookings Institution.
Porter, M. (1990) *The Competitive Advantage of Nations.* London: Macmillan.
Prahalad, C.K. & G. Hamel (1990) 'The core competence in the corporation', *Harvard Business Review,* May-June.
Rasiah, R. (1995) *Foreign Capital and Industrialization in Malaysia.* London: Macmillan.
Rasiah, R. (1996a) "Malaysia's National Innovation System", IKMAS Working Papers Number 4, IKMAS, Universiti Kebangsaan Malaysia, Bangi.
Rasiah, R. (1996b) 'Innovations and Institutions: Moving Towards the Technological Frontier in the Electronics Industry in Malaysia', *Journal of Industry Studies*, Vol. 3, No. 2, December.
Romer, P. (1986) "Increasing Returns and Long-Run Growth", *Journal of Political Economy*, 94: 1002-37.
Sato, Kazuo (1978) 'Did Technical Progress Accelerate in Japan', from Tsuru, Shigeto(ed.) *Economic Growth and Resources Vol. 5: Problems Related to Japan*, The International Economic Association. London: Macmillan.
Schumpeter, J. A. (1934) *The Theory of Economic Development*. Cambridge: MIT Press.
Solow, R. M. (1957) "Technical Change and the Aggregate Production Function", *Review of Economics and Statistics*, 39: 312-20.
Suresh, N. (1997) "Technology Absorption and Diffusion Among Local Supporting Firms in the Electronics Sector", IKMAS Working Papers Number 9, IKMAS, Universiti Kebangsaan Malaysia, Bangi.
Toh K. W. (1998) 'Industrial Networks in Asian Economies - Human Resource Development in Malaysia', Paper presented for JETRO-IDE Symposium, 'Industrial Networks in Asian Economies'.
Tsuru, Shigeto (ed.) (1978) *Economic Growth and Resources Vol. 5 Problems Related to Japan*, The International Economic Association. London: Macmillan.

Uchida, Hoshimi (1980) 'Western Big Business and the Adoption of New Technology in Japan: The Electrical Equipment and Chemical Industries 1890-1920', Okochi, Akio & Uchida, Hoshimi (eds.) *Development and Diffusion of Technology*, The International Conference on Business History 6. Tokyo: University of Tokyo Press.

Uchida, T. (1997) 'Human Development in the Case of Small and Medium Enterprises', Omura, K. (ed.), *The View of Economic and Technology Cooperation in APEC.* Tokyo: APEC Study Center,
Institute of Developing Economies.

UNDP (1995) *Human Development Report 1995.* New York: Oxford University Press.

Wade, R. (1990) *Governing the Market: Economic Theory and Role of Governments in East Asian Industrialization.* Princeton: Princeton University Press.

World Bank (1993) *The East Asian Miracle.* New York: Oxford University Press.

WIPO (1997) *Industrial Property Statistics for the Year 1995 Publication A*, World Intellectual Property Organisation, Geneva.

Author: Colin Khong Lin Chang

Ph.D. Candidate / Researcher
Institute of Malaysian an d International Studies (IKMAS),
National University of Malaysia

(1997.12 - 1998.3)
Visiting Research Fellow,
APEC Study Center, Institute of Developing Economies (Tokyo)