1994 MALAYSIAN SCIENCE AND TECHNOLOGY INDICATORS REPORT

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- The Malaysian S&T Indicators Committe.

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1. Introduction

1.1 The Use of Science and Technology Indicators

Industrialised countries recognise the central role that scientific and technological advance play in economic and social development, and are increasingly using science and technology (S&T) indicators to describe and map the 'national system of innovation' in order to identify and promote their own national competitive advantages. The national innovation system is taken to include not only the research and technological innovation that takes place within individual companies, but the public science and engineering base (both research and training) that supports this, and the knowledge and technology transfer paths and mechanisms that link them.

Gaining a better understanding of the national innovation system is particularly important for Malaysia. The economy is expanding rapidly - at over 8% in real terms - driven by export-oriented industries that manufacture high-technology goods using, in many cases, advanced production processes. In the vast majority of companies, however, the core technologies and knowledge are imported. There is a strong public research base which has historically been oriented towards the primary industries and downstream processing of their products, as well as to social and medical research. Despite rapid increase in the quantity and quality of graduates from local universities, severe skills shortages have been experienced.

S&T indicators already contribute to Malaysia's well-developed national and industrial planning processes. In turn, these plans set goals for science and technology which require quantitative indicators in order to assess their progress and achievement. Over the next five years one can expect that the following national objectives will become central to S&T policy and management:

- A greater emphasis in manufacturing industry on production for the export market, in part through greater use of technology and skilled human resources to achieve higher quality product with lower production costs.
- An intensification of effort in relation to industrial R&D, quality standards, process innovation and product development, together with greater use of technology and the development of a strong domestic technology development capacity.
- Emphasis on upgrading the skills and knowledge of the work force, and, for higher education, a boost in enrolments in the science and engineering fields and expansion of postgraduate training in technology engineering.

- Increased R&D funding, more formalised collaboration within and among universities and research institutions, and a greater focus on cooperative links with industry.
- A continued focus on key technologies, especially information technology, information centres and networks.
- if in 1994 they applied for any patent in Malaysia or overseas.

1.2 Development of S&T Indicators in Malaysia

The development of formal S&T indicators has taken place rapidly over the last three years, led by the Ministry of Science, Technology and the Environment. An analysis of the expenditure patterns under the major research granting scheme, IRPA* , took place in 1993. In the same year, a national research and development (R&D) survey (for the year 1992) was initiated, the first to use international (OECD 'Frascati Manual') concepts and definitions. The survey was preceded by a series of nationwide workshops to inform and educate respondents about the purpose and requirements of the survey. The R&D survey was repeated for 1994. In 1994, an important national survey of innovation in industry (covering the period 1990-94) was carried out, and the results have proven to be a valuable complement to the R&D surveys.

These surveys have been assisted by the development and adoption, after broad consultation with the research community, of detailed national classifications for R&D by socioeconomic objective (SEO) and field of research (FOR). The classification was first published in 1993, with a revised edition in 1995.

In addition, two surveys of public awareness of S&T were commissioned. One looked at the S&T awareness among secondary school students and a second surveyed the level of awareness, perception and acceptance of S&T among a sample of 5,000 drawn from the Malaysian public. The reports of both surveys were published in 1994.

Details of these S&T indicators publications may be found in the bibliography.

1.3 Scope of the Report

This report follows on from the earlier *1992 Malaysian Science and Technology Indicators Report*, published in 1995. That report reviewed the status and availability of various categories of S&T statistics in Malaysia and made recommendations about the most appropriate indicators that should be developed, and how this might best be done. It also presented the available indicators in a number of areas, notably R&D expenditures, and preliminary data on patents as well as human resources.

The current report expands the previous work in three significant ways. First, it provides a comprehensive review of the most important findings to be drawn from the four main survey series carried out by MASTIC:

- National R&D expenditure and personnel;
- Technological innovation in industry;
- S&T awareness among secondary school students; and
- S&T awareness and perception among Malaysians. As indicated above, these four surveys were either carried out in, or for, 1994. The results of each survey have already been published in full. The current report therefore concentrates on making comparisons and connections between the different surveys and indicators, and on highlighting the most significant policy-related conclusions that can be drawn from each survey.

Second, the report extends the analysis of statistical information provided to MASTIC by other government Ministries in three important areas:

- Patenting patterns in Malaysia;
- Technology balance of payments and trade in technology-intensive products; and
- Human resources for science and technology (beyond those employed in R&D). As this information has not previously been studied in detail from a science and technology perspective, the report presents a full analysis of the data available in these areas. The currency of the available data varies. Generally, MASTIC has been able to obtain data for the period 1990 up to 1994, or in some cases, 1995.

For the industry sector in particular, the report attempts an integrated approach, incorporating both the input indicators (e.g. research expenditure or technology purchasing) and output indicators (e.g. high technology exports or patents granted) of research and technology. It is thus the most comprehensive quantitative record to date of the research and technology patterns within Malaysian industry.

As far as possible, data in the report are presented according to internationally accepted definitions and methods. This allows Malaysia's performance to be compared, wherever useful, with that of other countries from the ASEAN region, east Asia, and the western industrialised nations.

Not all data presented here are complete or internationally comparable. The third purpose of the report is therefore to make a number of suggestions for improving the coverage and quality of Malaysian S&T indicators, and for new indicators that should be developed.

Finally, a few comments on methodology are necessary. Generally, the conceptual basis of each of the S&T indicators is discussed only briefly here. A fuller explanation may be found in the 1992 Malaysian Science and Technology Indicators Report. Calculation of the rate of change in time-series financial data requires that expenditures are adjusted for the effects of inflation. In Malaysia, national accounts are customarily expressed in terms of 1978 prices, and this practice is followed here. International financial comparisons must first be adjusted to a common currency, invariably the United States dollar. In the current report, this is achieved using official exchange rates (OER) at the time of the expenditure. A more appropriate comparison, particularly when comparing countries with widely different costs of living, is achieved using the purchasing power parity (PPP) exchange rate. Unfortunately, PPP exchange rates were not available for Malaysia and most other countries in the region at the time of writing. The basic socioeconomic statistics used are shown in Table 1.1.

2. National Overview of Research and Development

2.1 Introduction

The results of the broadly-based Research and Development (R&D) Surveys carried out for 1992 and 1994 allow a detailed analysis of the distribution of human resources (R&D personnel) and expenditure on R&D in Malaysia. The survey results provide useful information on the distribution of research effort, whether in the private sector, the government's own research institutes or laboratories, the higher education and the small non-profit organisations sector. They also allow a breakdown of research effort by 'socioeconomic objective', i.e. the intended purpose for which the research was carried out, and 'field of research', i.e. the scientific or academic discipline it falls within.

As the 1992 and 1994 surveys were carried out as far as possible on a comparable basis, some indication is available on trends in the level and distribution of the national research effort. Caution must of course be used in drawing conclusions from only two series points, and the relative novelty of the survey process for respondents must also be borne in mind. The reports of the two national R&D surveys emphasise that their coverage is incomplete, particularly in relation to R&D expenditures in the higher education sector. The survey findings should therefore be regarded as minimum values for national R&D effort.

2.2 Growth in R&D Effort

One of the first questions to be asked about Malaysia's national research effort is whether the level of R&D is keeping pace with the expansion of the economy and the infrastructure generally (e.g. higher education enrolments, reported in Chapter 4)

2.2 Growth in R&D Effort

2.2.1 Growth in the R&D Work Force

Table 2.1 shows the total number R&D personnel and of researchers (the most highly qualified R&D personnel - sometimes called 'research scientists and engineers' (RSEs) - in 1992 and 1994. Two bases of calculation are given: 'headcount' is the number of individuals employed, while 'full-time equivalent' or FTE adjusts for those individuals who devote only part of their time to R&D activities. Reliable 'headcount' figures are not available from the 1992 Survey.

On the basis of FTE counts of the R&D work force, the national R&D effort increased very substantially between 1992 and 1994. The number of FTE R&D personnel grew from around 4,500 in 1992 to nearly 6,700 in 1994. The figure for researchers grew by a closely similar rate (40%) rising from 1,600 in 1992 to 2,300 in 1994. From Table 2.1 it can be seen that, in the case of researchers, most of this growth took place in the private sector where the FTE jumped from around 400 to over 1,000. Taking R&D personnel as a whole, a large increase was also seen in the government research sector, but not for researchers alone. In contrast, the R&D work force for the higher education sector fell between 1992 and 1994 whatever measure is used. Researchers, on a FTE basis, decreased by 26% and R&D personnel as a whole declined by 57%. Unless this is solely due to under-reporting, it could indicate that increased pressure of teaching and other duties is taking academic's time away from R&D.

In summary, R&D work force figures suggest a rapidly increasing national R&D effort, with the great majority of the growth emanating from the private sector.

2.2.1.1 Characteristics of the R&D Work Force

It is worth examining some of the characteristics of the national R&D work force, since they explain how some of the rapid changes outlined above can take place. The base of Table 2.1 shows the ratio between the FTE of the work force and the number of individuals. For researchers in the private sector, the ratio is 0.79, indicating that, on average, the individuals employed are spending a high proportion of their time on R&D. In the government research institutes and universities, this ratio falls to around 0.37, suggesting that more researchers are either employed part-time, or spend a minority of their time on R&D. This is an expected finding for the universities where most academics have teaching and administrative responsibilities. It is perhaps surprising to find the ratio as low for the government research institutes, although no doubt administrative duties, testing, extension and other activities encroach on the time available for R&D. However, these ratios do indicate the relative ease with which the public sector can potentially increase (or decrease) its research effort quite dramatically without changing overall staff numbers.

Table 2.1 also provides information on the level of support staff (technicians and other R&D support personnel) in different research sectors in 1994. Nationally, researchers made up nearly 40% of the R&D personnel (somewhat lower if FTE figures are used). In the private sector, nearly 45% of personnel were researchers, indicating that, on average there were almost 1.25 support staff for every researcher. In the government sector, the figure was closer to 2.5 support staff per researcher, while the higher education and NPOs had closer to one support staff member for every three or four researchers. These ratios may reflect the prevalence of labour intensive agricultural and environmental field work in the government research sector, and the higher proportion of social sciences and humanities (SSH) research in the universities and NPOs.

2.2.1.2 Female Participation in the R&D Work Force

The extent of female participation in the R&D work force is of importance to a country trying to maximise the use of its skilled human resources. The proportion of women among the researchers, technicians and other support staff is shown in Table 2.2. Nationally, women comprise around 26% of all R&D personnel, and the proportion is somewhat higher for female researchers and technicians. The most evident feature of Table 2.2, however, is the well below average representation of female researchers and technicians in the private sector. This may indicate that fewer women than men are obtaining qualifications in the 'hard' sciences, engineering and technical occupations that are presumably sought by industrial employers. It may also be that fewer women are attracted to the predominantly full-time R&D jobs in industry. By contrast, a larger than average proportion of women are employed as researchers (though not as technicians) in the higher education sector.

2.2.2 Growth in R&D Expenditure

With such a rapid expansion of effort by research personnel, one would expect a concomitant rise in R&D expenditure. Table 2.3 suggests that, in aggregate, growth in financial resources for R&D has been more modest, however. Total national expenditure on R&D (GERD) rose from RM551 million in 1992 to RM611 million in 1994. In real terms, this amounted to an increase of 3.6%. Expressed as a percentage of Gross Domestic Product (GDP), GERD accounted for 0.33% of GDP in 1994. As GDP is growing at an annual rate of around 9% in Malaysia, this represented a slight fall from the 0.37% of GDP recorded in 1992. Clearly, if the intention is for a relative increase in research spending, it is a matter for concern if Malaysia's growth in R&D expenditure is not keeping up with the more rapid growth in GDP.

National expenditure on the current costs (salaries and other running costs) of R&D declined slightly between 1992 and 1994, while investment in capital facilities (such as equipment and buildings) for R&D rose by nearly 12% in real terms.

The financial data in Table 2.3 do however confirm the expansion of private sector R&D. Overall, the private sector increased its R&D investment from RM246 million in 1992 to RM293 in 1994. Expenditure on current costs grew by 43% in real terms (matching the increase in FTE researchers), while spending on capital costs fell by 22%.

In the public sector, government research institutes reported a substantial fall - nearly 40% - in R&D expenditures in 1994, with current expenditure falling more rapidly than capital expenditure. In the universities, current expenditures fell by 18% between 1992 and 1994, a decline far less than the reported fall in FTE researchers. Capital investment in R&D in higher education jumped five-fold to RM73 million in 1994.

2.2.3 International Comparison of National R&D Effort

By international standards, Malaysia's GERD is low, at around 0.4% of GDP. This is less than that of China (0.7%), India (0.8%) medium-sized OECD economies like Australia and Canada (1.4%) and newly industrialised economies like Taiwan (1.82%)(MASTIC 1996, Table 1.17). However, Malaysia's R&D expenditure compares favourably with several of its neighbours in ASEAN (Table 2.4). Malaysia's GERD/GDP ratio is nearly double that of Indonesia, the Philippines or Thailand. Of the countries in Table 2.4, only Singapore approaches the average level of expenditure for the OECD-member countries.

Malaysia's annual growth rate in GERD at around 1.8% is equal to or higher than many OECD countries, including Germany and the United States where expenditure is static or even contracting. However it is lower than that shown by Malaysia's ASEAN neighbours (see Table 2.4), as well as Taiwan and South Korea (MASTIC 1996, Table 1.18).

2.3 National Research Priorities

2.3.1 Balance Between Public and Private Sector R&D

According to the returns from the R&D Survey, the private sector was responsible for around 48% of GERD in 1994, a rise from the 45% recorded in 1992 (Table 2.3). This figure is confirmed by the number of researchers (FTE) working in industry, which is nearly 49% of the national total (Table 2.1). For the public sector, significantly differing figures are obtained depending on whether comparisons are made on the basis of total expenditure, current expenditure, researchers or R&D personnel, and the most appropriate comparator is not obvious. It is likely that the university sector under-reports current R&D expenditure by up to 50% (MASTIC 1994), and comparisons of total R&D personnel are skewed by the high number of technical and support staff in the government research institutes. On the basis of FTE researchers, it appears that the university sector performed about half as much research as the government research institutes in 1994 (Table 2.1). On the other hand, if the comparison is made based upon total expenditure, both sectors contributed around one-quarter of GERD in 1994 (Table 2.3).

An institutional breakdown of resources committed to R&D in the government research and higher education sectors is given in Table 2.5 and Table 2.6 respectively.

It is interesting to compare this deviation of R&D personnel (headcounts) in Malaysia with those in neighbouring countries (Figure 2.1).

Figure 2.1: International Comparison of R&D Personnel by Sector
Source : Table 2.7

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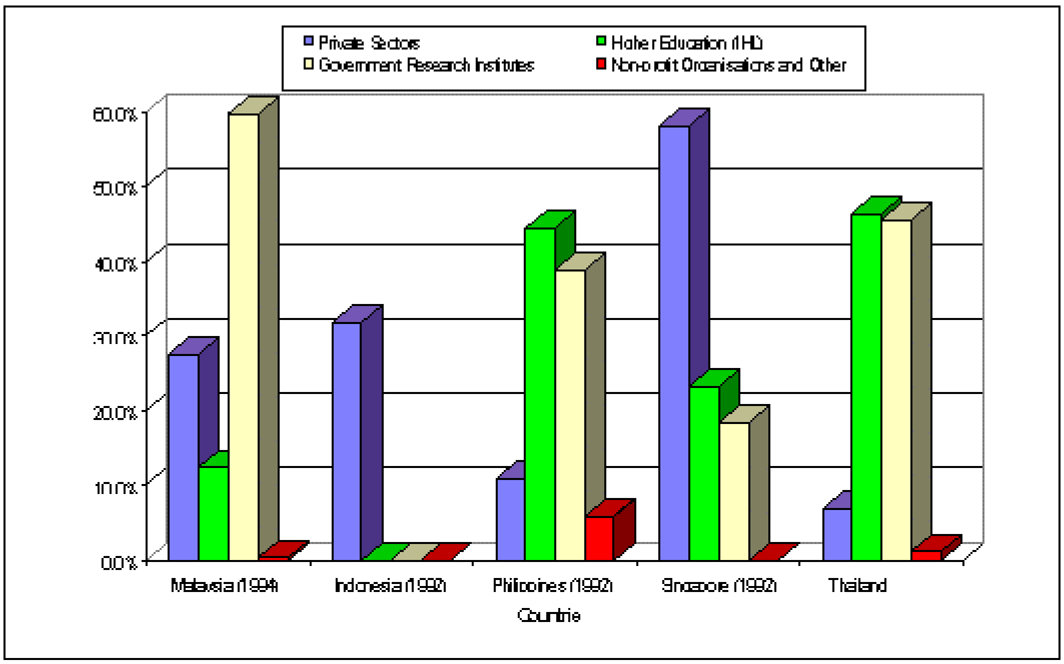

Source: Table 2.7

Overall, Malaysia reported slightly more R&D personnel than Singapore, somewhat fewer than the Philippines, and less than half the total for Indonesia. Malaysia records the highest proportion of R&D personnel in the government sector (60%) and the lowest proportion (12%) in the higher education sector. As explained above, a comparison based on researchers (FTE) - were this information available for the other countries - would tend to favour business enterprises and universities in Malaysia (as they have lower proportion of R&D support staff), although the same may also be true for the other countries. Even so, Malaysia reports a significantly higher level of business R&D personnel than do the Philippines and Thailand.

2.3.2 Objectives of R&D

Of more interest than the gross sectoral distribution of resources is the purpose or expected benefit for which they are employed. Are the research objectives of the different sectors similar, or complementary? This type of information may be useful in identifying appropriate collaborative linkages between private and public sectors research groups, for example.

Table 2.8 present a comparison of the national and sector objectives of R&D based on the number of researchers (FTE). These can be read as de facto national and sectoral research priorities. By far the greatest R&D effort in 1994 - 87% of the total - was directed towards the objective of economic development, largely benefiting manufacturing and plant production and primary products. Almost all the private sector research was directed towards economic development, but so was the great majority of research in the other sectors. This majority is lowest (at 61%) in the higher education sector. Nationally, no more than 5% of researchers' effort was directed towards the objectives of society (i.e. social development, particularly health and education research), environment or advancement of knowledge. Not surprisingly, the government research institutes and the universities gave greater emphasis to social and environmental objectives. However, only in the universities was the objective 'advancement of knowledge' significant, accounting for nearly 17% of researcher's effort in 1994.

Within the objective of economic development, there was a fairly strong concordance in 1994 between the private sector priorities and those of the government institutes and universities. The private sector's priorities were (in rank order) R&D on manufacturing, information and communication services, plant production and primary products, and energy resources and supply. The public research sector also committed a substantial proportion of its resources to these objectives, with the exception of information and communication services. Research objectives given greater emphasis by the public sector than by business included plant and animal production and primary products and natural resources.

Are these national research priorities changing? The foot of Table 2.8 suggests that they are, driven largely by the growth in private sector R&D. Comparing the distribution of researchers in 1994 with that in 1992 suggests that a greater emphasis was placed in 1994 on R&D for economic development, environment and advancement of knowledge at the expense of social development research. Within the economic development objective, the biggest rises were in R&D for energy resources, transport, energy supply, information and communication services and manufacturing. In the private sector, above average growth was seen in research for energy resources and supply, information and communications services, and health and environment. This was matched by a growth only in energy resources R&D in the public sector. Other private sector 'growth areas' suffered relative decline in the public sector, notably research with expected benefit for information and communication services.

In summary, the objectives of public and private sector R&D are partly concordant, and partly complementary. But there is little evidence that strong trends in business R&D exert a controlling influence over research priorities in the public research sector.

2.3.3 The Research Skills Base

Another way to compare national and sectoral research priorities is to examine the disciplinary base, or 'field of research' (FOR) upon which it draws. Here, it is particularly important to look at any differences in 'priorities' between the potential research employers (the private sector and government research institutes) and the producers of highly qualified researchers - the higher education sector.

Table 2.9 examines researcher effort (FTE) by main field of research. Almost all research reported in 1994 fell within the natural sciences and engineering (NSE), and this proportion had increased since 1992. Nationally, only 2.5% of reported research effort took place in the social sciences and humanities (SSH) in 1994, and only in the NPO sector were a majority of researchers employed in SSH. Within the NSE, the greatest proportion of researchers at the national level were occupied in the field of agricultural science, engineering, information technology and applied S&T. There was however, quite a marked divergence in priorities between the research sectors. The four most important fields for the private sector in 1994 were information technology (30%), engineering (26%), applied S&T (17%) and material sciences (9%). For the government research institutes the major fields were agricultural science (with over 52% of researcher effort), followed by biological sciences, applied S&T and engineering (each with less than 10% of the sectoral effort). In the universities, the FORs with the most researchers (FTE) in 1994 were biological sciences (accounting for 24% of the total), agricultural sciences (17%), followed by applied S&T, engineering, and medical and health sciences. This breakdown suggest that the 'research priorities' of the universities in 1994 were more closely allied to those of the government research sector than they were to industry.

The foot of Table 2.9 shows changes in the number of researchers in each main FOR between 1992 and 1994. At the national level, five fields grew faster than average. These were earth sciences, information technology, engineering sciences, biological sciences and agricultural sciences, largely led by strong growth in the private sector.

2.3.4 International Comparison of Research Priorities

Researchers are potentially highly mobile resources. It is therefore of interest to consider the research priorities of Malaysia's neighbouring countries, since Singapore in particular employs a high proportion of foreign researchers. This comparison is made for Malaysia, the Philippines and Singapore in Figure 2.2 using a simplified FOR classification.

Figure 2.2: Comparison of National Research Priorities in Malaysia, Philippines and Singapore

Source : Table 2.10

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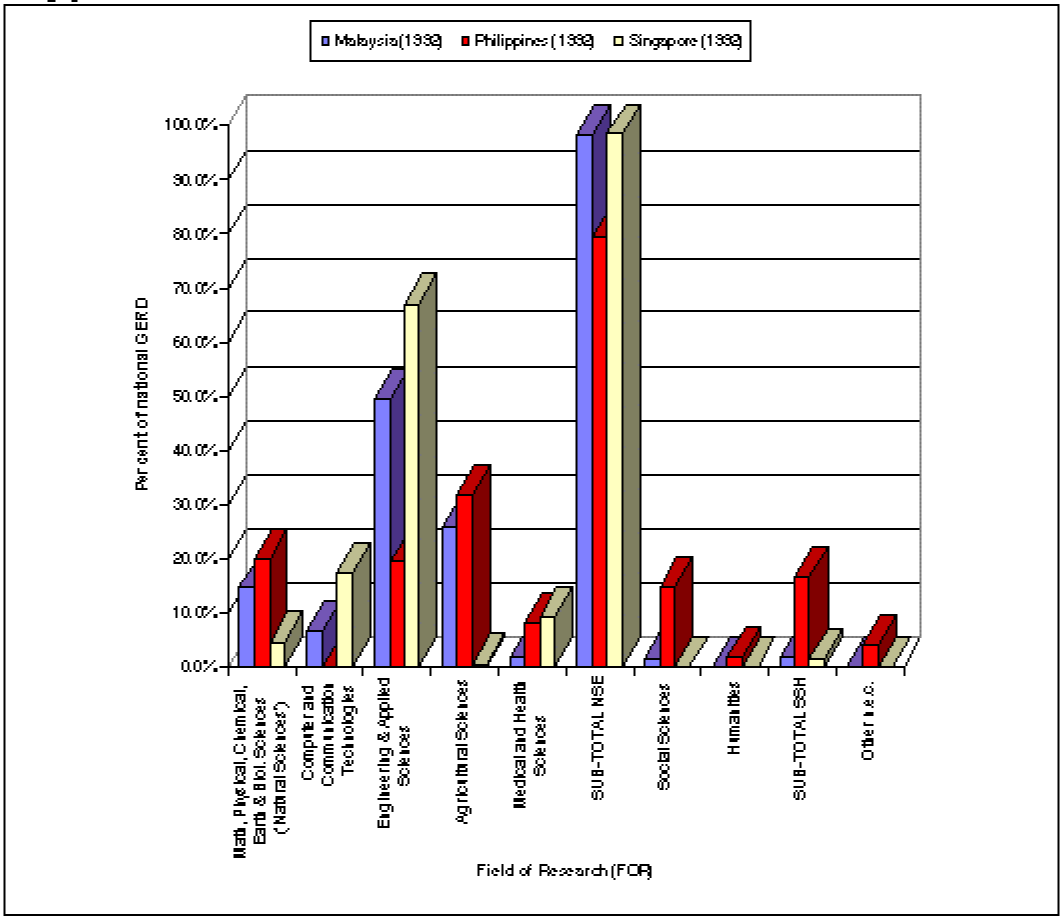

Source: Table 2.10

The breakdown of expenditure by major field of research illustrates the significant differences between the ASEAN countries. In Malaysia and Singapore, national expenditure is concentrated almost exclusively on R&D in NSE, whereas over one-fifth of R&D expenditure in the Philippines is dedicated to SSH.

Within the NSE there are also major differences of emphasis. Singapore focuses overwhelmingly on applied S&T, engineering and information technology related fields. While these are important fields in Malaysia too, the country has a broad portfolio of R&D covering the agricultural sciences and the more fundamental natural science fields (mathematics, physics, chemistry, and earth and biological sciences). The Philippines also places emphasis on the agricultural and natural sciences. Medical and health sciences is an important secondary field of R&D expenditure in Singapore. Comparisons based solely on proportion of GERD can be misleading, however. As the bottom part of Table 2.10 shows, Singapore, because of its higher level of R&D overall, actually spends a similar or greater proportion of its GDP on R&D in the natural sciences as the other two countries.

3 Science and Technology for Industry

3.1 Introduction

The manufacturing sector is leading the rapid industrial growth of Malaysia, contributing nearly one-third of GDP in 1995. Increasingly, the sector is dominated by the electrical and electronics products sub-sector, accounting for 30.3% of manufacturing value-added in 1995. The industry is characterised by a small number of multinational companies, and has a high dependence on imported electronic components and other precision parts. Increasingly the industry is diversifying into higher value-added products. Industrial development strategies likely to continue in future include:

- · promoting the manufacture of capital and intermediate goods for the construction and energy sectors, as well as for the manufacturing sector (notably electronics and motor vehicles), to reduce the trade deficit in manufactured goods;
- · expanding new growth industries such as petrochemicals (higher value-added products from gas and oil feedstocks) and aerospace (light aircraft, components, avionics and services);
- · increasing investment in downstream processing of agricultural and resource-based commodities and products; and
- · intensifying efforts in acquiring technology and commercialisation of new and improved technologies, by increased investment in scientific and engineering R&D and collaboration with the higher education and research institutes.

Each of these will require substantial S&T skills and investments, as well as accurate data to track their progress.

3.2 R&D Performance of Industry

In 1994, the private sector in Malaysia spent RM292.6 million on R&D, and employed 3,164 R&D personnel, of whom 1,416 were researchers (Table 3.1 and Table 2.1). Companies employed nearly 28% of R&D all personnel, and carried out around 38% of the nation’s R&D effort in terms of FTE human resources, or 48% measured by expenditure.

By far the majority of private sector research expenditure - over 72% - was made by companies in the manufacturing sector. In the primary industry, utilities and services sectors, the main investors in R&D came from agriculture, the infrastructure-related industries of electricity and telecommunications services, and the computer services industry (Table 3.1).

Figure 3.1 shows that, within the manufacturing industry, R&D expenditure in 1994 was contributed mainly by three sub-sectors: electronic equipment and

components, electrical machinery and apparatus, and petroleum products and refining, each of which spent in excess of RM30 million. The food, beverages and tobacco, and transport equipment industry each spent more than RM15 million on R&D in 1994. In contrast, very low expenditure was reported by the pharmaceuticals, machinery and instrument industries.
Figure 3.1: R&D performance of industry by ownership

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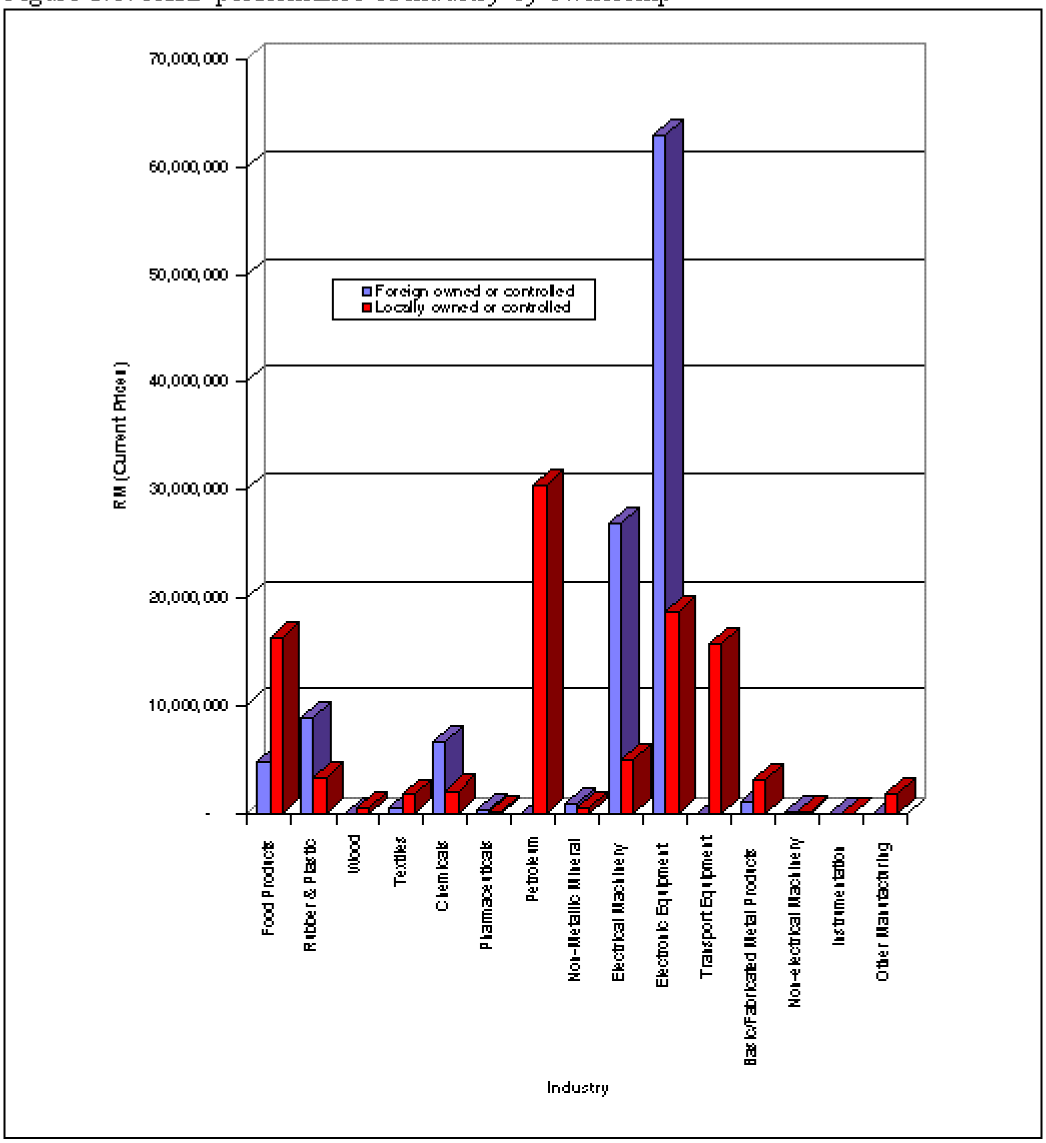

Source: Table 3.1

3.2.1 R&D and Company Ownership

> *'A major factor which constrains the growth of technological capabilities of the local industries has been the tendency of Malaysian firms to disregard research and development as an integrated part of investment'. (Ministry of Finance, 1995)*

Figure 3.1 also shows the predominance of foreign-owned or controlled companies in several of the large R&D-performing sectors, notably in the high-technology-intensive manufacturing industries. Overall, foreign companies performed nearly 39% of industry R&D in 1994. This rises to 53% of the R&D expenditure of manufacturing industry, and nearly 80% of expenditure in the electrical and electronics industry. Foreign-owned companies also dominate R&D expenditure in the rubber and plastics and chemical products industries. On the other hand, locally-owned companies account for most or all of the R&D spending in the food, petroleum products and refining, transport equipment, and basic metal products industries.

Are locally-owned or controlled companies improving their R&D performance relative to foreign-owned multinationals? The data presented in Table 3.2 give mixed signals but provide some cause for optimism that they are. Across industry as a whole, the proportion of R&D expenditure by Malaysian companies increased from just over 50% in 1992 to 61% in 1994. In manufacturing industry, however, the proportion of R&D attributed to local companies fell marginally. But in the important and foreign-dominated electrical and electronics industries, local companies' share of R&D expenditure rose (although from a low base) from less than 10% in 1992 to over 20% in 1994.

The foreign owners or joint partners reported in the 1994 R&D Survey were predominantly from Japan, Singapore, the United States, the United Kingdom and Germany (MASTIC, 1994; Table 5.6).

3.2.2 Patterns of Growth in Industry R&D

Derived from Table 3.3, Table 3.4 shows that industry R&D expenditure grew by 10.8% in real terms between 1992 and 1994. However, this growth is entirely attributed to the expansion of R &D in the non-manufacturing sectors. Manufacturing research expenditure actually fell by 16% overall, and in the electrical and electronics industries by nearly 6%. This decrease is partly explained by a decline in capital expenditure on R&D (i.e. spending for facilities and equipment). Capital expenditure was perhaps unusually high in the 1992 survey at just over half the reported manufacturing R&D expenditure. This proportion fell significantly in 1994 to around 40% of manufacturing R&D spending. In the electrical and electronic industries the trend was different. Here, capital expenditure rose as a proportion of the total, while reported current

expenditure fell by 28%.
Figure 3.2: Change in Manufacturing Industry Expenditure on R&D, 1992-94

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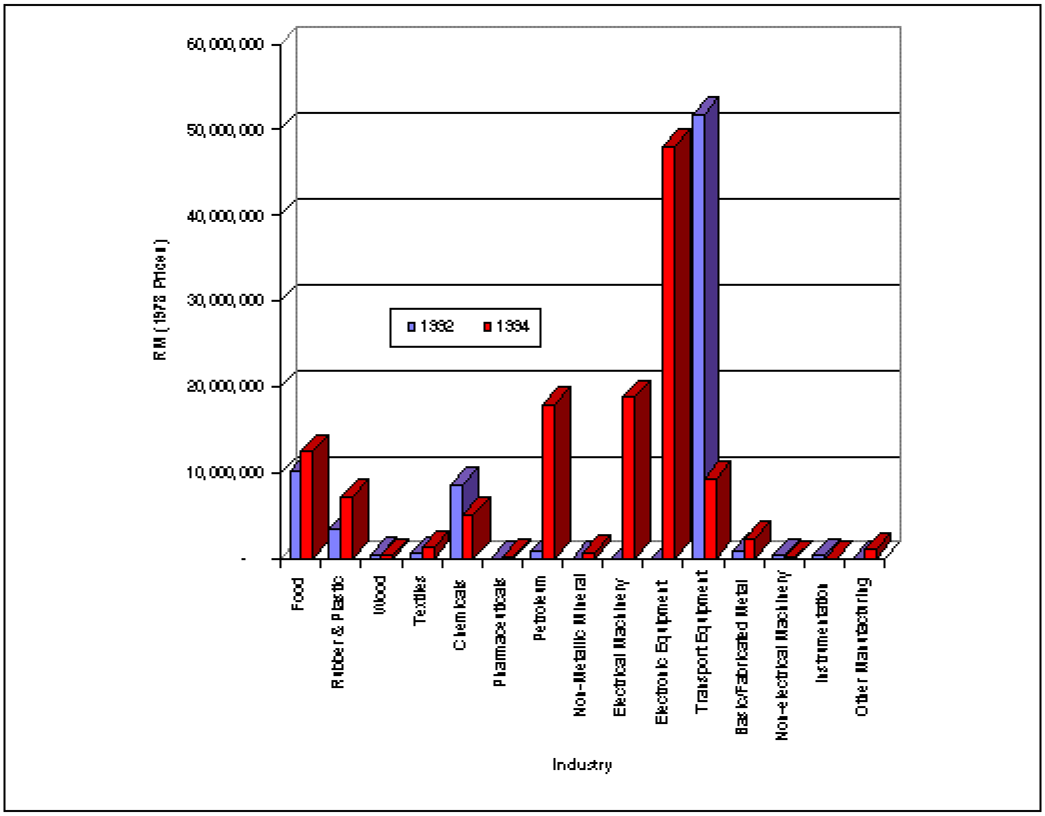


Source: Table 3.4

Figure 3.2 presents the change in R&D spending in particular manufacturing industries between 1992 and 1994. R&D expenditure rose in real terms in the food, rubber and plastics, and basic metals sub-sectors, and, (dramatically so,) in petroleum products and refining. The electrical and electronics and chemicals industries showed a fall in expenditure. Transport equipment R&D in particular fell heavily in 1994, partly due to much lower capital investment than in 1992.

In summary, manufacturing industry's expenditure on the current costs of R&D did not grow as fast as might have been expected between 1992 and 1994.

3.2.3 Effect of Company Size on R&D

The apparent lack of investment in R&D by small and medium-sized companies is a major policy concern in Malaysia. Examination of the proportion of R&D expenditure reported by the smaller companies in the 1992 and 1994 R&D Surveys (Table 3.5) gives some cause for encouragement that this situation may be changing. In both years, companies employing more than 500 people accounted for a majority of the R&D expenditure reported. However, the proportion fell from 69% of all companies' expenditure in 1992, to 54% in 1994. In real terms, expenditure by the smallest companies (under 75 or 100 employees) rose by 87% between 1992 and 1994, and spending by companies with 500 or fewer employees increased by 67%. In contrast, spending by the larger companies (those with more than 500 employees) fell in real terms by 14%.

Using sales as a measure of company size, the medium to large companies appear to have increased their share of R&D expenditure. Companies with sales of more than RM100 million performed 46% of R&D in 1992, but this rose to 66% in 1994.

3.2.4 Linkages with the Public Research Sector

The R&D Surveys show that the vast majority of industrial R&D is funded by, and performed within the same company. In 1994, about 8% of R&D was funded from outside the company. Private sector extramural R&D reported as contracts or grants to other local companies and research institutions increased significantly from RM270,000 in 1992 to RM6.8 million in 1994, about half to other companies and half to the higher education and public research institutes (1992 Survey: Table 5.16; 1994 Survey: Table 5.20). This represents only 2.3% of private sector R&D in 1994.

3.2.5 R&D Intensity

Manufacturing industries are customarily categorised by their 'R&D intensity', i.e., their R&D expenditure calculated as a proportion of the value of sales, value-added or other output measures. The OECD now recognises four categories of industries by R&D intensity: High, Medium-High, Medium-Low and Low. The manufacturing industry sub-sectors assigned to each of these categories (on the basis of their typical R&D intensity in OECD-member countries) are shown in the box. These R&D intensity categories are commonly (though not strictly correctly) used as synonymous with high, medium and low technology industries.

'R&D Intensity' Industry Categories Used in OECD ANBERD Database

High R&D Intensity Industries (R&D typically equivalent to 10-12% of value of production)

- *Aerospace*
- *Office and Computing Machinery*
- *Radio, TV and Communication Equipment*
- *Pharmaceutical Products* ***Medium-High R&D Intensity Industries (3-6%)***
- *Professional Goods (including Scientific and Medical*

Equipment)
- *Motor Vehicles*
- *Chemicals (excluding Pharmaceuticals)*
- *Electrical Machinery (excluding Radio, TV and Communication Equipment)* ***Medium-Low R&D Intensity Industries (0.8-2.0%)***
- *Non-electrical Machinery*
- *Other Transport Equipment*
- *Shipbuilding and Repairing*
- *Petroleum Products and Refining*
- *Non-Metallic Mineral Products*
- *Other Manufacturing*
- *Rubber and Plastic Products*
- *Non-ferrous Metals* ***Low R&D Intensity Industries (0.2-0.7%)***
- *Iron and Steel*
- *Metal Products*
- *Food Products, Beverages and Tobacco*
- *Paper and Printing*
- *Textiles, Wearing Apparel, Fur and Leather*
- *Wood Products and Furniture Based on ISIC (Revision 2)*

Need to mention here that Malaysia promotes high technology industries by the companies' activities and products (see box below for list of promoted activities and products). The Promotion of Investments Act 1986 empowers Malaysian Industrial Development Authority (MIDA) into promoting these high technology industries here.

'High Technology Activities Promoted by MIDA
- *Advanced electronics*
- *Equipment/instrumentation*
- *Biotechnology*
- *Automation and flexible manufacturing systems*
- *Electro-optics and non-linear optics*
- *Advanced materials*
- *Optoelectronics*
- *Software engineering*
- *Alternative energy sources*
- *Aerospace*

Both the 1992 and 1994 R&D Survey reports present figures for the R&D intensity of Malaysia's manufacturing industry (1992: Table 5.7; 1994: Table 5.7). What is immediately apparent from these figures is the general lack of concordance with the OECD industry R&D intensity classification. In 1994, for example, the R&D intensity reported by the electronic equipment industry in Malaysia was only 0.6% of sales, compared with an OECD average of around 21% of production value. The industries that tend to show the highest R&D intensities in Malaysia are those with a higher proportion of locally-owned companies performing R&D, notably the transport equipment, electrical and non-electrical machinery sub-sectors.

For the other manufacturing sub-sectors in Malaysia, R&D intensity appears to be a poor reflection of 'technology intensity'. This is presumably due to two main factors: the high production levels of relatively 'mature' technology products, and the high level of dependence on foreign sourcing of technological expertise. This expertise ranges from extramural R&D carried out abroad to import of entire turnkey production lines. Foreign R&D alone - a relatively minor component of foreign sourced technology - amounted nearly RM25 million in 1994, or equivalent to 8.4% of domestic research expenditure, although this was down from 19.6% in 1992. These data reflect global economic patterns and the dominant position of very large multinational corporations in key industries where Malaysia's economic growth has concentrated.

This relatively low industry R&D intensity, with other indicators presented in this report, underline the point that the development of industrial technologies in the country is not based solely or even substantially on Malaysian R&D, and that investment in R&D is but one of many indicators of Malaysia's S&T strengths.

3.2.6 International Comparison of Industry R&D Strengths

Even taking into account the caveats above, business performance of R&D, by industry sector, is a useful indicator of local industry's scientific and technological strengths. It is hard to make comparisons of industry R&D priorities with OECD countries since there is so much intercountry variation. BERD in non-manufacturing industry accounts for only about 10% of the total in the European Community and United States for example, but is significantly higher in Australia, Canada, Denmark and New Zealand with their economically important primary industries. On this measure, Malaysia's 'non-manufacturing' R&D spending was quite high in 1994 at 28% of private sector R&D expenditure.

It is particular interesting to compare the pattern of private sector R&D in Malaysia with some of its neighbours in ASEAN. Table 3.6 looks at the distribution of researchers (i.e. research scientists and engineers) among industry sectors in Indonesia (manufacturing sectors only), Singapore and Thailand, as well as Malaysia.

Both Singapore and Malaysia have a strong emphasis on R&D in the electrical and electronics manufacturing industries and to a lesser degree in chemicals and chemical products and oil refining. Indonesian and Malaysian researchers are also concentrated in the food products, wood, paper and textile products (in

Malaysia's case this is primarily textiles) and in the rubber and plastics manufacturing industries. Indonesia's greatest concentration of researchers is in the chemicals and petroleum refining sub-sector. Singapore's researchers may also be found in the basic metal and fabricated metal products manufacturing, and in the services industries. In Thailand, the largest industry R&D sectors are the primary industries, 'Other Manufacturing' and services.

These data illustrate the quite different industry structures of the ASEAN member countries. Thailand and Indonesia are dependent on the primary agricultural and extractive industries and the downstream processing of the products of these industries (such as food products, wood and paper, petrochemicals and plastics) and most of their business R&D is in these sectors. Singapore and Malaysia strongly emphasise the electrical and electronic manufacturing sectors. Over half the researchers in Singapore are concentrated in these industries, but Malaysia's industrial R&D base is less narrowly targeted.

3.3 Innovation in Industrial Technology

Industrial innovation is the sum of the processes of discovery, invention, product development, process creation and development and organisational change, and the diffusion and uptake of all of these processes. Examining discovery alone-for example through expenditure on formal R&D - cannot by itself measure a country's capacity to apply technology for industrial innovation. The limitation of using 'home grown' R&D as a proxy for technological innovation. is particularly noticeable for rapidly industrialising countries, like Malaysia, which currently import much of their research and technology needs.

For this reason, MASTIC carried out a survey o technological innovation in industry, based on international (OECD 'Oslo Manual') guidelines. The 1994 National Survey of Innovation in Industry targeted 815 companies that were identified as likely to be carrying out innovative activities. The great majority of respondents (84 per cent) were from the Manufacturing sector. The scope of the survey went beyond R&D and sought information on :-

- Innovation in Malaysian industry and the characteristics of innovative companies;
- The types of innovation activity being carried out;
- Differences in innovation activities between industry sector;
- The sources of ideas and knowledge for innovation;
- International flows (purchase and sales) of technology;
- The benefits and costs of innovation; and
- The major factors hampering innovation.

3.3.1 Patterns of Innovation

Over 65% of respondent firms indicated that they carried out some form of technological innovation (Table 3.7) Companies were considered to be technological innovators if, over the last 5 years, they : carried out R&D themselves; developed or introduced new or substantially improved products or processes; or acquired, sold or transferred technology outside the company; or if in 1994 they applied for any patent.

Table 3.7 shows, nearly 70% of manufacturing firms responding reported one or more technological innovation activity. Manufacturing industry sectors with the highest proportion of innovative firms are : Chemical and chemical products; Pharmaceuticals; electronic equipment and components, Petroleum refining and products, Transport equipment, and electrical machinery and appliances. The small sample of Primary industry firms was also highly innovative, whereas a lower than average proportion of firms in Construction and Utilities and Services reported innovation activities.

The survey provided information on the distribution of innovative firms by company size, age of firm, ownership and company orientation. The conclusions drawn were :

- Larger companies, and particularly the largest companies (in terms of number of employees, turnover and revenue), are more likely to be innovators. However, there is a high proportion of innovators even among the smaller companies in the sample.
- Start-up companies do not appear to be the most innovative firms in Malaysia. Companies established for more than five years show a greater likelihood of innovation than younger companies.
- Whether or not a company is foreign owned is not a major factor in determining whether it carries out any technological innovation.
- There is however a strong relationship between innovation and export orientation in companies. Non innovators show a much lower export performance - over 72% of innovators are exporters, whereas only 45% of non innovators export any of their product.

3.3.2 Types of Innovation

What types of innovation are most common in Malaysian companies? Table 3.8 shows that the most commonly reported form of innovation is the development and introduction of new products which was carried out by 70% or more innovators. This emphasis on new products belies the commonly made assumption that acquisition, particularly purchase of equipment, is the second most common form of innovation, undertaken by over 68% of innovators. The development of both new and improved processes are reported by almost as many of the respondent innovators.

Comparison of industry sectors in Table 3.9 confirms that product innovation is more commonly reported than process innovation in almost all industry sectors, with the exception of the wood and paper products, textiles, and pharmaceutical industries.

In addition to technological innovation activities, over 70% of innovative companies have systematic organisational arrangements for developing or acquiring new products and processes.

By contrast, innovation through research and development, patenting, and sale of technology are minority activities among Malaysian companies surveyed. Formal R&D is carried out by only 43% of innovative companies. Patenting of innovations and the sale or transfer of technology outside the company are reported by less than one in five innovative firms.

3.3.3 Sources of Information and Ideas for Innovation

Where do firms get their ideas and information for innovation? Companies consider 'internal R&D' as most important in generating ideas and information for technological innovation. This is perhaps surprising, given that less than half of the innovators carry out R&D. Many respondents apparently interpreted this question in abroad sense as including R&D carried out by parent and related companies. Interaction with customers and suppliers, human skills development, networking through professional associations and publications are also nominated as important sources of new ideas. Respondents gave significantly less emphasis to joint ventures with other companies, cooperation with public sector research institutions, acquisition of innovative firms and patent information as sources of ideas for innovation. Comparing these responses with those from a similar survey of innovation in Australian industry (Table 3.10) one sees strong agreement between businesses in the two countries on the most important sources of ideas and information for innovation. The main difference lies in the importance placed by Malaysian businesses on recruiting human skills as a source of innovative ideas.

3.3.4 Acquisition and Sale of Technology

The purchase of both tangible (e.g., machinery) and intangible (e.g., license) technology is an important innovative strategy for most companies, with nearly two-thirds of innovative companies acquiring technology over the last five years. Slightly more than 30% of instances reported related to technology acquisition within Malaysia, while nearly 70% related to technology acquisition from other countries. Table 3.11 shows the types of technology acquired, and the source countries. It suggests that companies in Malaysia rely heavily on foreign sources of technology, mainly from the major industrialised countries. Overall, the five most important means of acquiring technology were nominated as :

- Purchase of equipment ;
- Sourcing from within own business group
- Hiring skilled employees (from Malaysia only)
- Rights or licenses from other organisations (less important from Malaysia); and
- Use of Consultants

Different countries are important for different types of technology acquisition. For equipment purchase, for example, Japan, Germany, Italy and Taiwan were most nominated. For consultants, the English speaking countries of the US, UK and Australia were considered the most important (Table 3.11)

Fewer than 14 per cent of the innovative companies responding to the survey reported that they had sold or transferred technology over the past five years. Of these, just over half of had sold or transferred technology within Malaysia. The main market for selling technology and technological skills to foreign countries were within south-east Asian and developing countries. The most common forms of technology sale or transfer were ‘loss of skilled employees’ (important within Malaysia only), ‘consultancy services’, ‘contract R&D’, ‘sale of equipment’ and ‘patent pooling and other contractual arrangements’ (Table 3.12).

The innovation survey this found quite different markets for technology purchase and technology sales. For technology purchases, the major vendors are Japan, United States, Germany and the United Kingdom - results that parallel the data given in section 3.4 For sales, the main customers are Indonesia, China, India and Thailand.

3.3.5 Benefits and Costs of Innovation

Companies innovate to obtain a wide range of commercial benefits, the most important of which are improving the quality of their products and increasing their market share. As Table 3.13 shows, the main objectives of innovation are common between Malaysia and firms surveyed in Australia, with ‘improving product quality’ being the primary objective of innovation nominated in both countries. Innovation is also important for firms in both countries as am means to maintain or increase market share and extend product ranges. Malaysian firms place greater importance on innovation as a means of creating new markets and for complying with government standards and legislation. To a lesser extent, innovation is also carried out for occupational health and safety and environmental reasons.

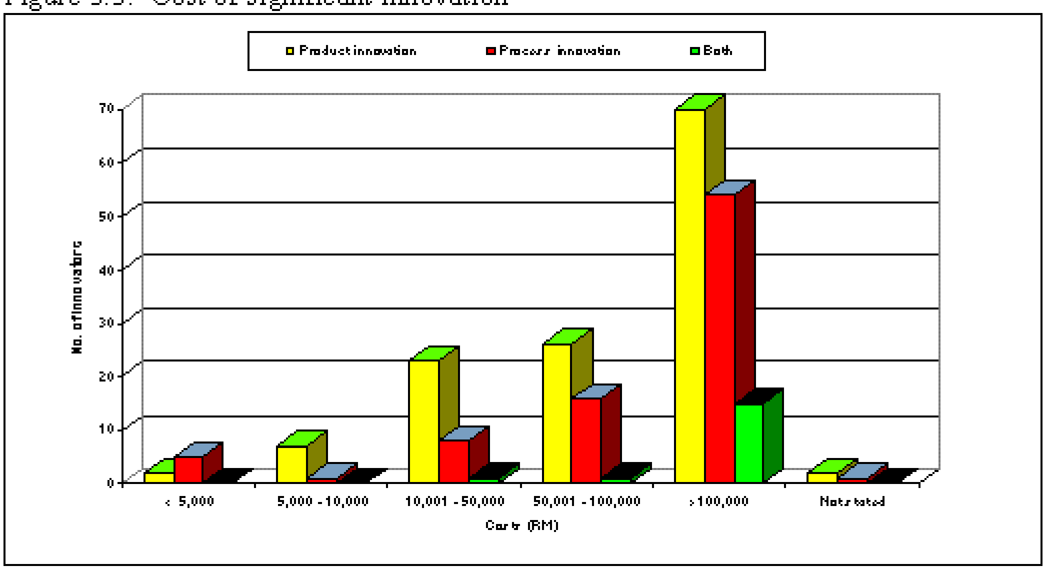
3.3.6 Costs, timing and pay-back of innovation

The total costs of innovation proved difficult for respondents to quantify. The best estimate is that tooling up, industrial engineering and manufacturing start up account for around 60% of the costs of technological innovation, while acquisition of machinery and equipment accounts for a further 20%. Research and development and acquisition of intangible technology (license etc.) each contribute less than 10% to the costs of innovation. The dominance of tooling up and start up costs is not surprising as it parallels findings in other countries. The investment in intangible technology by Malaysian firms surveyed appears low, and the proportion of expenditure reported on training-at less than one per cent of total innovation costs - is also low by international standards.

Respondents to the survey nominated 148 ‘most significant’ innovations which had been commercialised during the period 1990-94. Of these, 49 per cent were product innovations, 40 per cent were process innovations, and 11 per cent involved both product and process innovation. Most ‘significant innovations’ are commercialised within two years, but take up to five years to recoup their cost. Larger companies tend to invest more in their ‘most significant’ innovations. Product innovations appear less expensive to implement than process innovations (see figure 3.3) and recover their costs more quickly. However, they take slightly longer to implement to commercial stage. Innovations that involve both product and process development are the most expensive and take longest to implement.

Figure 3.3: 'Cost of significant innovation

Figure 3.3: ‘Cost of significant innovation’



Source: Table 3.14

Sources :Table 3.14

3.3.7 Factors Hampering Innovation

A key finding of the innovation survey for 1994 is the reason why many companies are not innovating, and the barriers faced by those who wish to innovate, or to increase their level of innovative activity. Table 3.15 shows the importance assigned by both innovators and non-innovators to various factors that might hinder innovation in their companies. Comparable figures from the

Australian survey of innovation in manufacturing are also given. The factors in Table 3.15 can be assigned to three main categories of barriers to innovation :-

a) A lack of technological information and skills (for example, ‘lack of skilled personnel’ and ‘deficiencies in technical services’);

b) Poor technological and financial management of innovation (‘lack of technological opportunities’, ‘uncertainty in timing of innovation’ and ‘innovation costs too hard to control’); and

c) Inadequate market response (‘lack of customer responsiveness’, or ‘no need to innovate’).

The most important barriers to innovation in Malaysia fall within the first category, i.e. lack of technological information and skills. Specifically, these were ‘lack of skilled personnel’, ‘lack of information on technologies’ and ‘deficiencies in the availability of external technical services’. A quite different picture is presented in Table 3.15 for Australia. Here, the main impediments to innovation identified relate to financial management of innovation by the company or by the national innovation system generally, e.g. ‘lack of appropriate sources of finance’, ‘innovation costs too high’ and ‘government legislation and taxation etc.’. In Malaysia, by contrast, the cost of innovation and availability of finance was perceived as a secondary impediment to innovation. In the third category (market responsiveness), resistance to innovation either internally (by the company) or externally (by the market) was not ranked highly as a barrier in either Malaysia or Australia. Both innovative and non innovative companies in Malaysia appear to face similar impediments in seeking to realise innovation in their business.

In summary, despite a high level of innovative activities among the firms surveyed, companies in Malaysia face significant problems in obtaining the skilled people, technological information and technical services that they require to undertake innovation.

3.3.8 Patents as Outputs of Technological Innovation

Patent documents are one of the few written outputs from industry-linked research and technological innovation. A patent provides a firm’s invention with protection from competition in a particular country or geographical area.

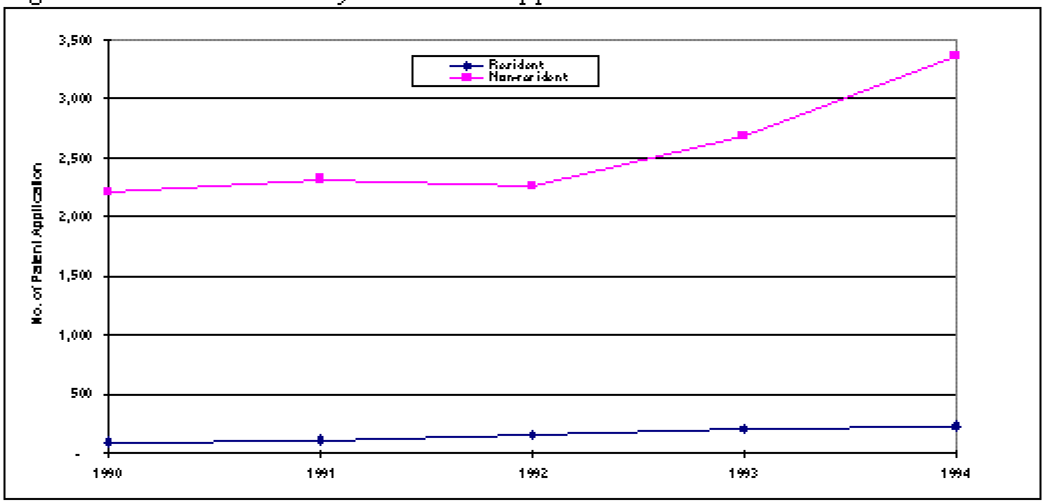
3.3.8.1 Methods of Protecting Innovation

The National Survey of Innovation in Industry showed that patenting was not highly regarded as a method of protecting innovation by Malaysian industry respondents (Table 3.16). In view of this, and the relatively weak industrial research sector, it is no surprise to find that patenting in Malaysia is dominated by foreign residents.

3.3.8.2 Patent and Utility Innovation Application and Grants

Figure 3.4: Patent and Utility Innovation Application between 1990-1995

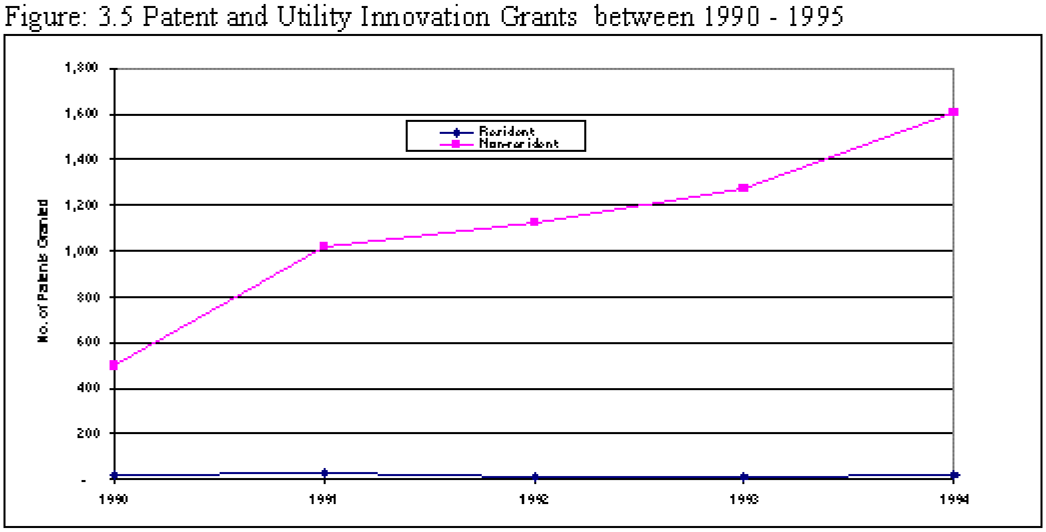
Figure: 3.4 Patent and Utility Innovation Applications between 1990 - 1995



Source: Table 3.17

Figure 3.5: Patent and Utility Innovation Grants between 1990-1995

Figure: 3.5 Patent and Utility Innovation Grants between 1990 - 1995



Source: Table 3.17

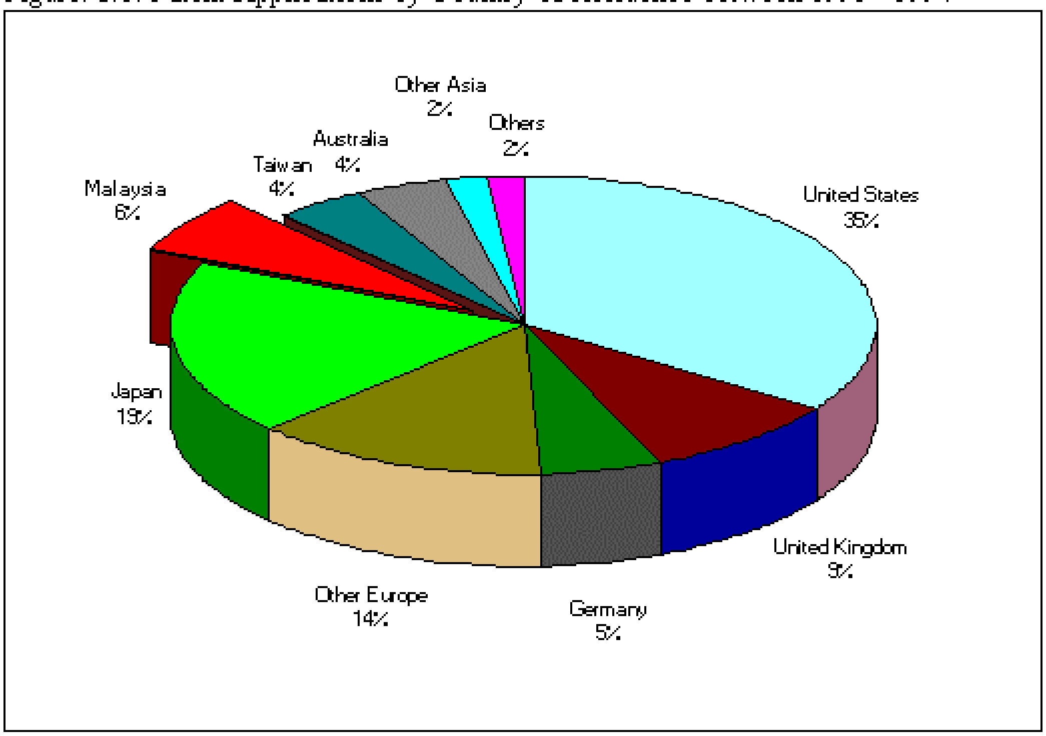
Figures 3.4 and 3.5 show the number of patents applied for and granted in Malaysia over the period 1990 to 1994. The numbers of both applications and grants have grown significantly during this period, nearly three-fold for grants and 60% for applications. This growth is largely accounted for by non-resident patentees and no large increase in domestic invention is apparent in the patent figures. Table 3.17 indicates that the 'autosufficiency ratio', i.e. the proportion of patent applications that originate from Malaysian residents, shows steady, though gradual, increase, rising from around 4% of patent applications in 1990 to around 6% in 1994. This is also reflected in a rise in the 'inventiveness coefficient', i.e. the number of patent applications made by residents of the country, normalised by the country's population. However, the autosufficiency ratio for patents grants to Malaysian residents shows no consistent growth.

Firms tend to apply for patents in countries which they regard as strategic industrial or marketing centres for their activities. The strong increase in non-resident patenting suggests a rapidly growing international interest in Malaysia as an important market for, as well as producer of, technology-based products.

3.3.8.3 Patent Applications in Malaysia by Country of Residence

Figure 3.6 illustrates the countries and industrial blocs that applied for patents in Malaysia over the period of 1990 to 1994, and therefore can be assumed to be particularly interested in the Malaysian technology market.
Figure 3.6: Patent Application by Country between 1990-1994

Figure: 3.6: Patent Applications by Country of Residence between 1990 - 1994



Source: Table 3.18

In 1994, more than one third of patent applications were from United States residents. Residents of European countries - primarily the United Kingdom, Germany, France, Switzerland and the Netherlands - accounted for almost a further 30% of applications, and Japanese residents for nearly one-fifth. Overall, the major industrialised blocs were responsible for more than 80% of the patent applications in Malaysia in that year. What is perhaps surprising is the very dominant position of the United States. As Table 3.18 also shows, this pattern did not change greatly between 1990 and 1994. The United State's relative share of applications declined somewhat and Japan's rose. There is also evidence of increased interest from Australia and Taiwan in patenting in Malaysia.

3.3.8.4 International Comparison of Patenting Activities

How does the level of patenting in Malaysia compare with that in industrialised and other industrialising countries? International comparisons of patent data are not easy to interpret, partly because the national propensity for, or ease of, patenting varies widely. It is also true that the advantage of patent protection varies between industry sectors and is not applicable to many information industries. Patenting patterns are thus influenced by the industrial strengths of the country.

Table 3.19 attempts a comparison of patenting activities, by ranking a range of industrialised and industrialising countries by their 'inventiveness coefficient'. On this measure, the residents of Japan, Taiwan, South Korea and the larger OECD member countries clearly emerge as the most profuse patentees. Malaysia's 'inventiveness coefficient', at around 11 patents per million population in 1994, was of the same order as its ASEAN neighbours Thailand and the Philippines. One significant difference can be seen between Malaysia and these countries in relation to the 'autosufficiency ratio'. In Malaysia's case, as noted above, this ratio is very low: only about 6% of all patent applications. However, rather than a sign of weakness in home-produced innovation, the low autosufficiency ratio can be interpreted as indicating a very strong interest by foreign companies in patenting their inventions in Malaysia's growing industrial economy and market. This interpretation is supported by the fact that the total number of non-resident patent applications in Malaysia in 1994 exceeded that in Thailand and the Philippines combined.

Overall, the patent-based indicators show that Malaysian residents have not been strong patentees, either in the country or externally. In the United States, one of the world's major technology markets, only 56 patents were granted to Malaysian residents during the period 1980 to 1993. This is about the same level of patenting as Chile or Portugal, and greater than that of Indonesia, but only one-third of the number of patents granted to Singapore residents in the same period (NSB 1996, Appendix Table 6-14). However, there is evidence of an increase in Malaysian patenting both domestically and in the United States in recent years. Further, there is a clear indication that foreign patentees regard Malaysia as a very important market in which to have patent protection, more so than in several of its ASEAN partners.

3.4 Trade in Technology

3.4.1 Balance of Payments in Intangible Technology

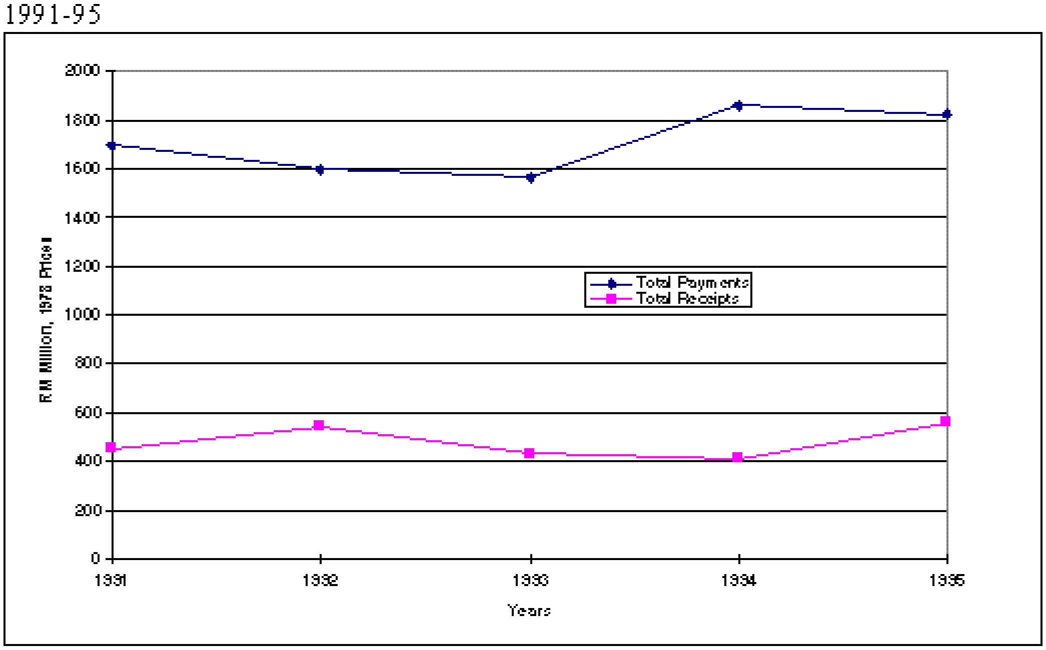
Technology balance of payments (TBP) statistics aim to measure international trade in intangible technology including trade in techniques, transactions involving intellectual property, services with a technical content such as consultancy and payments for R&D carried out in foreign countries.

Data from Malaysia's Bank Negara cash balance of payments reporting system relating to royalties, contracts and professional charges allows some measure of TBP to be obtained. However, because of limitations in the information, it does not equate to TBP. The main difficulty is that many payments and receipts are included which are not considered to be technology related (e.g. business franchising). In addition, some payments or receipts which are technology related are excluded. A full discussion of the scope of TBP and the coverage of the Malaysian statistics may be found in the 1992 Malaysian Science and Technology Indicators report.

3.4.1.1 Balance of Payments for Royalties, Contracts and Professional Services

Malaysia runs a considerable trade deficit in both royalties and in contract and professional service charges, as can be seen from Figure 3.7. Figure 3.7: Balance of Payments for Royalties, Contracts and Professional Services, 1991-95

Figure 3.7: Balance of Payments for Royalties, Contracts and Professional Services, 1991-95



Source: Table 3.20

In 1995, this deficit amounted to over RM900 million in royalties, and nearly RM1,300 in contract and professional charges. With the currently available data, only an unknown proportion of these payments can be attributed to science and technology related knowledge or services: the proportion for royalties is likely to be higher than for professional charges. Overall, the balance of payments in two items has not shown any strong trends over the last five years. However, it may be significant that the trade deficit for royalties more than doubled in real terms between 1991 and 1995. As noted in the previous S&T indicators report, a significant deficit in TBP is to be expected, and can be regarded as a strong sign of investment in developing the intellectual capital necessary for continued industrial development.

3.4.1.2 Payments for Royalties, Contracts and Professional Services

Looking at where these payments are going provides an indication of the countries from which Malaysia is obtaining licences and knowledge-based services, including S&T related knowledge and services. Table 3.21 reveals that most payments, especially for royalties, are remitted to the major industrial countries, especially Japan and the United States. Switzerland's prominence may reflect its strength in the pharmaceutical and food manufacturing industry, as well as its financial services sector.

United States receipts for royalties and licence fees for the exchange and use of industrial processes from unaffiliated residents of Malaysia increased, from around US$2 million in 1990 to US$18 million in 1994 (NSB 1996, Appendix Table 6-3).

3.4.1.3 Receipts for Royalties, Contracts and Professional Services

Table 3.22 shows the sources of Malaysia's receipts for royalties, contract and professional services in 1995. While the pattern of receipts is less concentrated than for payments, the major industrial countries still feature prominently, along with developing nations like Brunei and Indonesia.

In summary, the limited information on knowledge-based trade in intangibles available for Malaysia tends to support the conclusions obtained from other data, such as the national innovation survey. Malaysia relies on foreign sources for much of its professional knowledge and skills, although it too is slowly developing an export market for home-grown professional skills and technologies. Knowledge and skills are sourced primarily from the major industrialised countries, notably the United States and Japan, but some of the smaller European countries are also important sources.

3.4.2 Imports and Exports of Technology-based Products

> *'... economies which are able to expand their level of economic activity and exports in high technology goods and knowledge-intensive services are likely to be well placed in the emerging world economy.' (Sheehan et al,1995)*

Of crucial importance to Malaysia is the trade performance of its technology-based industries. In 1995, the manufacturing sector contributed over three-quarters of the value of the nation's exports (Ministry of Finance, 1995). Also of interest is the level and source of high technology imports, particularly where these are intermediary or capital goods. This section of the report examines the contribution of 'high technology' products and industries to exports and imports, examines the balance of trade in these products, and considers Malaysia's high technology trade with one of its major customers and suppliers, the United States.

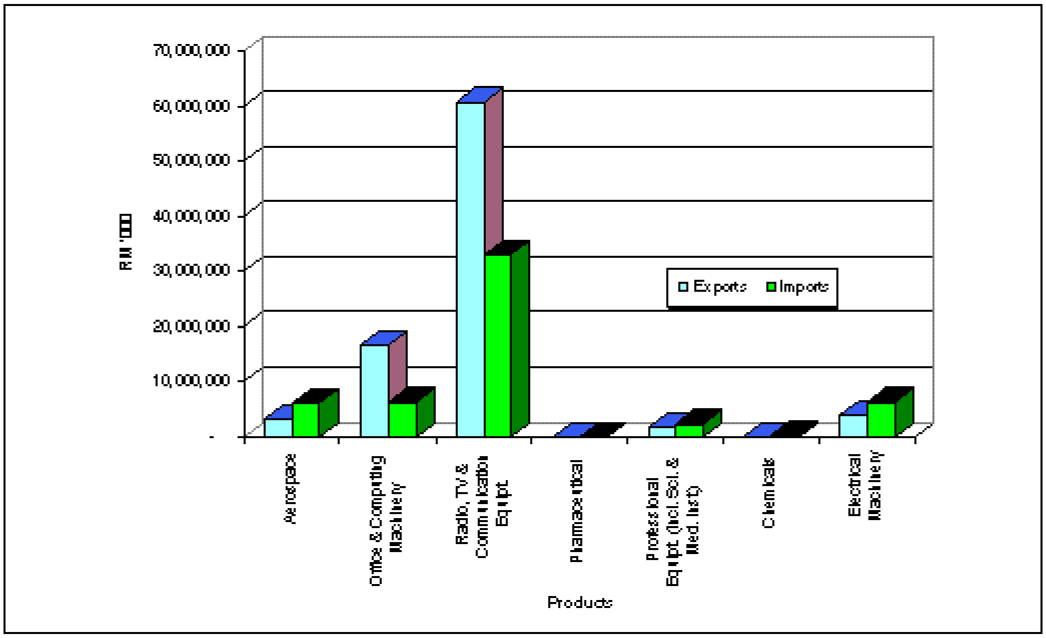
The methodology used follows that of the OECD in calculating export/import ratios for various highly R&D intensive industries. The value of imports and exports in specific Standard International Trade Code (SITC) categories is assigned to particular industries (by ISIC code). Necessarily, this exercise is somewhat subjective, especially when dealing with 'generic' products or intermediaries that can be used by several industries. The list of the products considered, the value of trade and the industries to which they have been assigned is at Table 3.23. While this list is not fully compatible with the OECD list, we are confident that the major products are captured. Some industry sectors have been omitted from the analysis, notably the motor vehicle industry.

3.4.2.1 Trade in High R&D Intensity Products

A summary of the trade data in Table 3.24a shows the changes in Malaysia's trade in highly R&D intensive products over the period 1992 to 1995. In 1995, the import and export of products associated with highly R&D intensive industry sectors (i.e. those from the 'High R&D Intensity' and 'Medium-High R&D Intensity' industries, with the omission of motor vehicles), was as shown in Figure 3.8

Figure 3.8: Exports and Imports of Selected Highly R&D-Intensive Products, 1995

Figure 3.8: Exports and Imports of Selected Highly R&D-Intensive Products, 1995



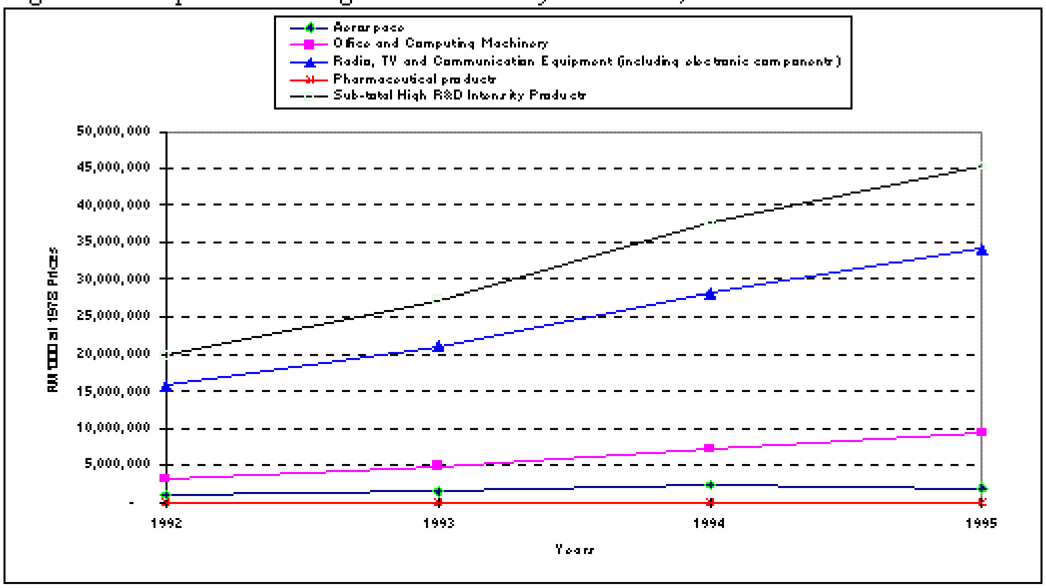
Source : Table 3.24a

Exports were dominated by two industry sectors, namely radio, TV and communications equipment and office and computing machinery. These are also the only two industries represented in the Table that show a substantial trade surplus in 1995. Other sectors, notably the aerospace and electrical machinery industries, show a trade deficit.

The constant price series in Table 3.24b (summarised in Figure 3.9) show the rapid growth in exports from these two important 'high tech' industries. The fastest growth was in radio, TV and communications equipment exports, which more than doubled in real value between 1992 and 1995. Exports of office and computing machinery grew even faster, the real value of exports more than tripling over the period. Growth in pharmaceuticals and aerospace exports was more variable and from much lower bases, but both still grew substantially. As a result, these high R&D intensity industries as a group increased the value of their exports by 128% between 1992 and 1995. This was very substantially higher than manufacturing exports as a whole which increased by 84% over the same period. The high R&D intensity industries' share of exports thus grew to 57.6% of manufacturing exports in 1995, up from 46% in 1992 (see Table 3.25)

Figure 3.9: Exports from High R&D Intensity Industries, 1992-95

Figure :3.9 Exports from High R&D Intensity Industries, 1992-95

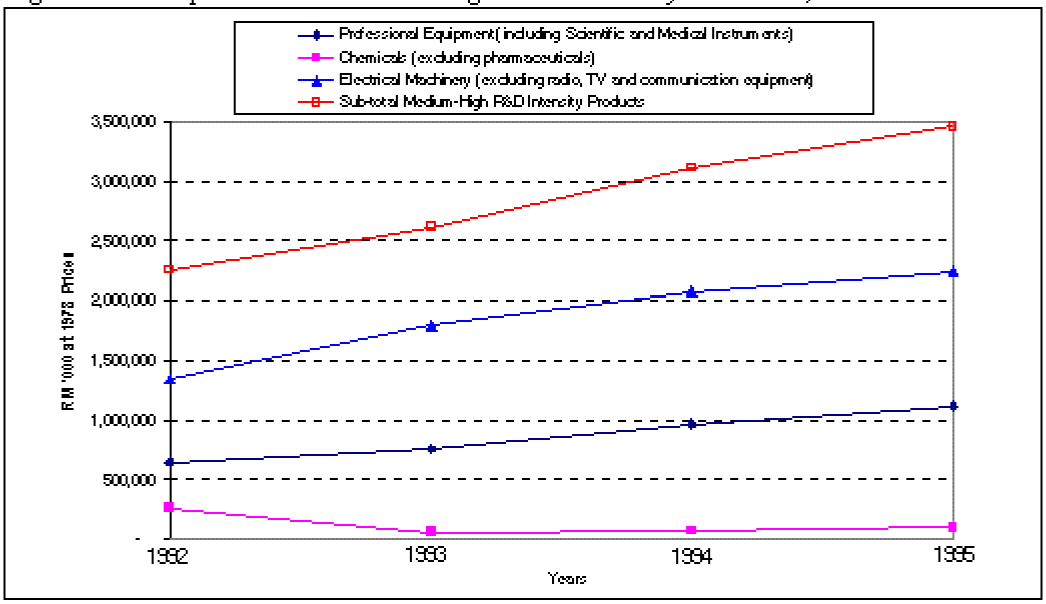


Source: Table 3.24b

The Medium-High R&D intensity group of industries also shows strong export growth between 1992 and 1995 as seen in Figure 3.10. Professional equipment (which includes medical and scientific instruments) and electrical machinery grew by 73% and 67% respectively, although the latter showed some slowing in growth later in the period (see Table 3.24b). Chemicals industry exports declined from a low base.

Figure 3.10: Exports from Medium-High R&D Intensity Industries, 1992-95

Figure :3.10 Exports from Medium-High R&D Intensity Industries, 1992-95



Source: Table 3.24b

Overall, the ‘Medium-High’ group grew more slowly than manufacturing exports as a whole and as a result lost relative export share, falling from 5.3% of exports in 1992 to 4.4% in 1995 (see Table 3.25)

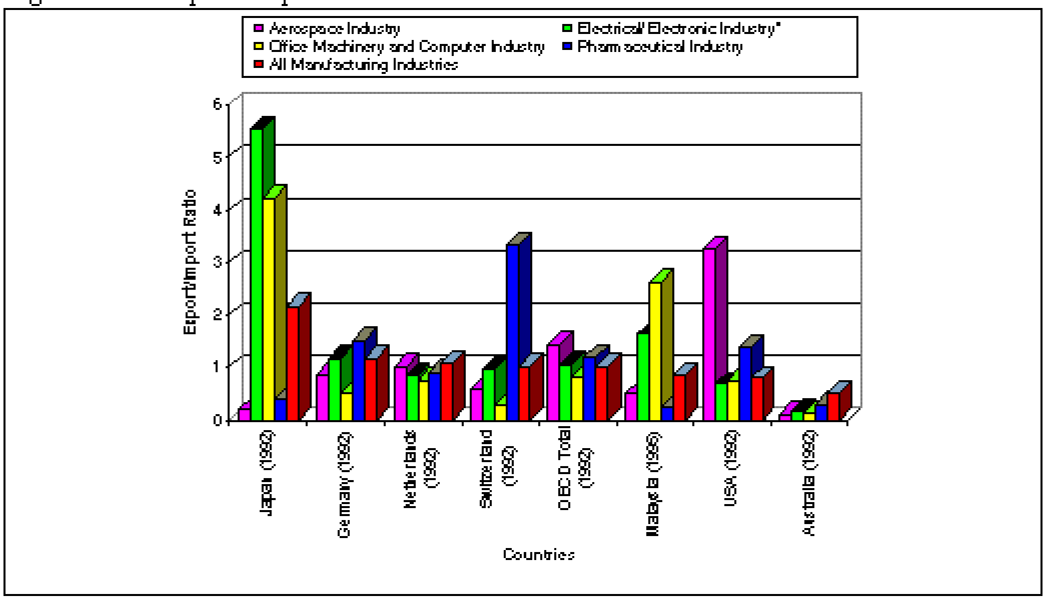
Table 3.26 shows that the level of imports is also high in many highly R&D-intensive sectors. Such imports provide components and intermediary goods for the industry (as is predominantly the case with electronics), furnish capital goods for production (hence the high level of electrical machinery imports seen in Figure 3.8) or to supply consumer demand that cannot be met by local production (for example, as in the case of motor vehicles). The interpretation of export-import ratios must therefore take into account the likely purpose for which the goods are imported. A trade deficit in, for example, advanced manufacturing machinery, can be regarded as a necessary investment in future production efficiency. Overall, however, export import ratios provide a good picture of a country’s internationally-competitive manufacturing strengths and weaknesses.

For the highly R&D-intensive industries shown in Table 3.26, exports consistently exceed imports only in office and computing machinery, and radio, TV and communications equipment. The lowest export-import ratios are shown by pharmaceuticals and chemicals products, suggesting a weak local industry in these sectors. Overall, the export-import ratio for the high R&D-intensity industry group fell slightly between 1992 and 1995.

3.4.2.2 Export-Import Performance of Selected Industrial Countries

Figure 3.11 provides a concise comparison of the export strengths of Malaysia and leading industrial nations by comparing export-import ratios for highly-R&D intensive industries.
Figure 3.11: Export-Import Performance of Selected Industrial Countries

Figure 3.11: Export-Import Performance of Selected Industrial Countries



Source: Table 3.27

Aerospace exports exceed imports for the United States, and the Netherlands. Pharmaceutical exports are similarly high for Switzerland, the United States and Germany. Japan shows very high export-import ratios in the office machinery and computers and electrical/electronics industries. Malaysia is something of a 'mini-Japan' in this regard showing high exports in both these industries and quite low ratios in pharmaceuticals and aerospace.

Compared to Japan, however, Malaysia's manufacturing industries as whole show a trade deficit. The manufacturing export-import ratio of 0.85 is on a par with the United States and significantly higher than Australia, but lower than Germany, the Netherlands and Switzerland. These figures serve to emphasise the critically important contribution of electronics and computing equipment manufacturing to Malaysia's economic and trade performance.

3.4.2.3 High Technology Trade with the United States

The United States is both a major supplier of high technology goods to Malaysia and a major market for Malaysian-produced high technology goods. In recent years, Malaysia's high technology trade with the United States has shown a sustained and spectacular reversal, from a trade deficit of over US$460 million in

1990 to a trade surplus of nearly US$2,400 million in 1994 (see NSB 1996 for full details and the methodology used). Table 3.28 shows the value of Malaysia's trade with the United States in 1994, by several high technology categories. Not surprisingly, in view of the data presented above, the biggest share of high technology trade lies in electronics (55.4%) and computers and telecommunications products (30.1%). In both these product categories, but especially in computers and telecommunications, Malaysia enjoys a significant trade surplus with the United States. The balance of trade is in Malaysia's favour also in optoelectronics (optical disc players, laser printers etc.) and in material design.

The case of material design is particularly interesting, as these products (which include semiconductor materials and optical fibres etc. which are the 'raw materials' for Malaysia's electronics industry) showed a large trade deficit with the United States in the early 1990s. In the other high technology product areas listed in Table 3.28. Malaysia's trade with the United States is in deficit, notably in aerospace, life science (medical technologies and drug manufacturing for example) and computer software. Of course, without further information it is impossible to say whether Malaysia's improved performance in high technology trade with the United States indicates an increase in local sourcing of products and materials, a switch to other foreign suppliers such as Japan or Taiwan or, as is likely, a combination of both factors. Certainly, Malaysia's imports from Japan, particularly of capital and intermediary goods, are growing strongly (Ministry of Finance, 1995), but also, as noted above, Malaysia's export-import ratio for high technology products is strongly in surplus and improving rapidly.

4. Human Resources for Science and Technology

4.1 Introduction

Human resources, especially the rising demand for professional, skilled and semi-skilled workers, are a major policy concern in Malaysia and are analysed in some detail in national planning documents, notably the Malaysia Plan. It is impossible, and indeed undesirable, to divorce the treatment of HRST (human resources for science and technology) from national human resource planning The data here should be seen as supplementing other published studies.

The rapid growth of the Malaysian economy in the last five years [during the period of the Sixth Malaysia Plan (6MP)] has created a strong demand for human resources at all level. The national unemployment rate stood at an all-time low of 2.8% in 1995.

During the 6MP period, the demand for workers in professional, technical and related occupations grew rapidly, at an average annual rate of 6.8%. Professional and technical occupations made up 8.8% of all jobs in 1990, rising to 10.3% in 1995, and are expected to rise to 12.1% of employment by the year 2000. Over the period 1991-1995, the education and training system was unable to respond adequately to the demand for skilled personnel: a high turnover of skilled and professional workers and skill shortages resulted, especially in new technology areas. Severe shortages were recorded in the supply of engineers and engineering assistants, and significant shortages in school teachers - especially secondary teachers - and medical and health professionals.

4.2 Production of Skilled People

4.2.1 Introduction

Malaysia’s higher education system is expanding at a rapid pace, and is giving greater attention to science, engineering and technical courses. Over the period 1991-1995 there was significant growth in higher education, including the establishment of two new universities in East Malaysia [Universiti Malaysia Sarawak (UNIMAS), and Universiti Malaysia Sabah (UMS)] and four new polytechnics. Training institutes run by the major public petroleum and energy corporations upgraded their engineering and applied science courses to degree level. The last five years have also seen an emphasis on quality of skills. The Industrial Technology Development and Management Program was launched during the 6MP to provide advanced postgraduate and postdoctoral training for R&D personnel from research agencies and universities, and has trained at total of 1,617 personnel from 17 institutions.

Goals for higher education over the next five years include:

- to increase first degree enrolments in public institutions to 5.6% of the 19-24 year age group, up from 3.5% in 1995;
- to increase the capacity for science, engineering and technical-related courses, with the expectation that half of the degree level enrolments will be in these subjects by the year 2000;
- by the year 2000, to increase the capacity for postgraduate courses from 11% of degree level enrolments in 1995 to at least 14%, of whom 41.5% are in science and engineering courses; and
- to increase the capacity and capability of the higher education sector to undertake R&D, particularly in areas that are relevant to industrial and services sectors' requirements.

4.2.2 Enrolments of Degree-Level Students

The following section examines the training of people with the highest formal skills in science, technology and engineering - those who are undertaking a degree-level course (bachelors, masters or doctoral, i.e. ISCED levels 6 and 7) in a university or other institution of higher learning.

As at the academic year 1993-94 there were nine degree-granting institutions in Malaysia. These were: Universiti Malaya (UM), Universiti Kebangsaan Malaysia (UKM), Universiti Sains Malaysia (USM), Universiti Pertanian Malaysia (UPM), Universiti Teknologi Malaysia (UTM), Universiti Utara Malaysia (UUM), Universiti Islam Antarabangsa (UIA), Universiti Malaysia Sarawak (UNIMAS) and Institut Teknologi Mara (ITM). Of these, only the first five were major producers of natural science and engineering graduates. UM and USM are particularly important for medical subjects, UPM for agricultural science and technology, and UTM for engineering.

Enrolments for postgraduate diplomas have not been analysed: these are predominantly in vocational subjects, particularly education. Degree-equivalent higher diploma courses, have been included. In ITM there are many S&T-related higher diploma courses.

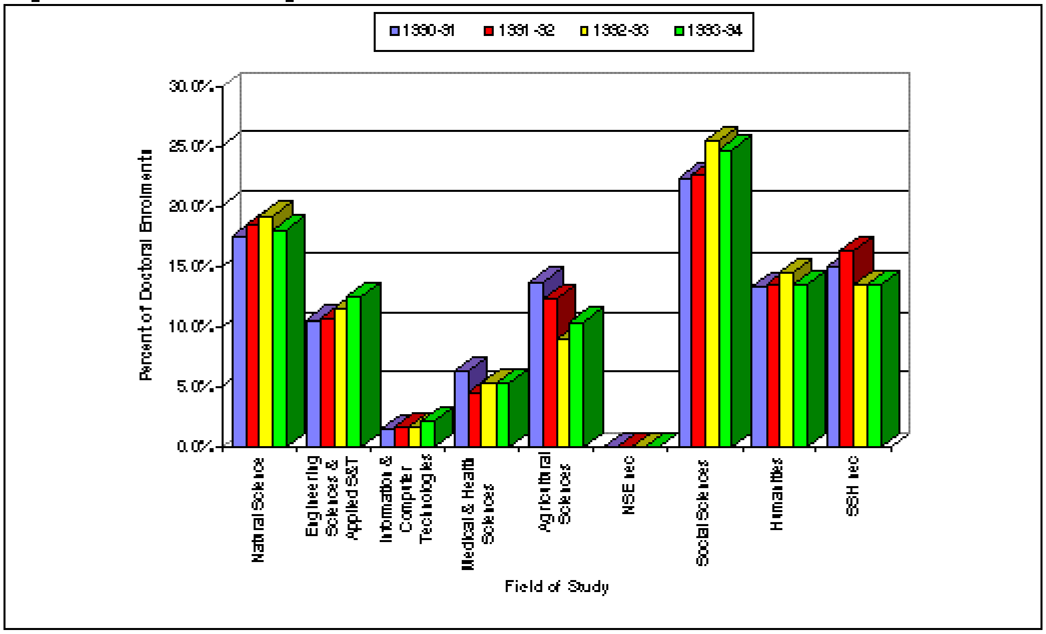
As far as possible, the enrolments data have been mapped to the same disciplinary classification used for R&D personnel and expenditure, i.e. the Malaysian R&D Classification System field of research (FOR) classification (see MASTIC, 1995). In the case of joint major students (e.g. education and science), enrolments have been regarded as related to natural sciences and engineering.

4.2.2.1 Doctoral Degree Enrolments

Figure 4.1 presents a picture of the changes in the numbers of doctoral (Ph.D.) students enrolled in particular fields of study over the period 1991 to 1994.

Figure 4.1: Doctoral degree enrolments, 1990-91 to 1993-94

Figure: 4.1 Doctoral degree enrolments, 1990-91 to 1993-94



Source: Table 4.1

In 1993-94, over 700 students were studying for a doctoral degree in Malaysian universities, a significant increase (of 32%) over the number three years previously. Students in the natural sciences and engineering (NSE) make up just under half the doctoral enrolments, and there is no indication that this proportion is increasing relative to the social science and humanities (SSH) students. Indeed, the relative proportion of NSE doctoral students fell slightly between 1991 and 1994.

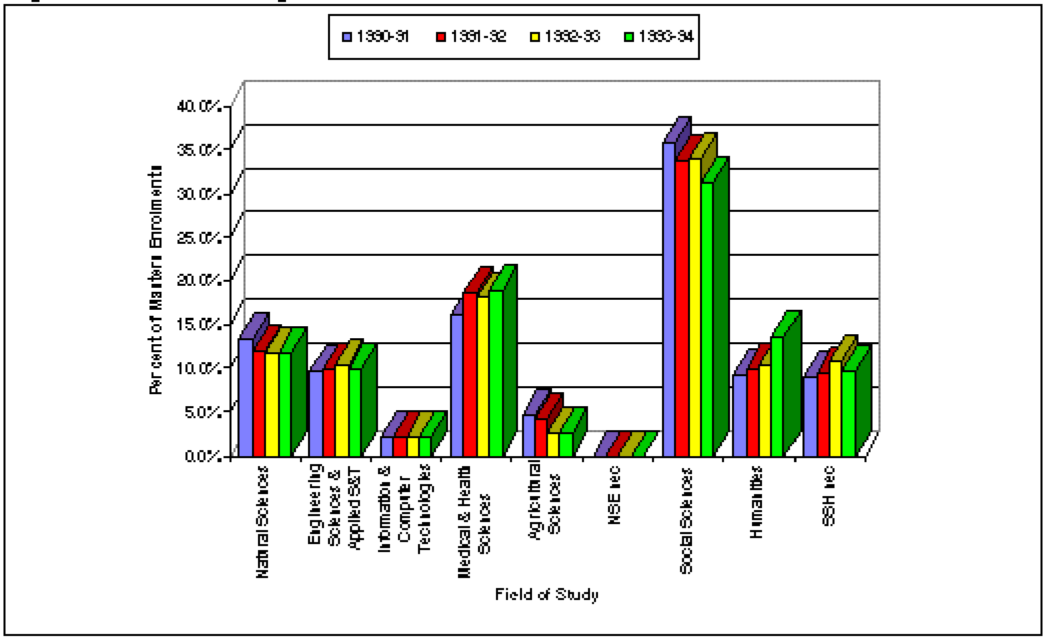
Within the main NSE fields shown in Table 4.1, natural sciences comprise the largest field with 18% of doctoral enrolments in 1994 - indicating the importance of fundamental research - engineering and applied S&T account for nearly 15% of enrolments, agricultural science attracts around 10% of doctoral students and medicine and related fields about 5%. Definite trends are apparent in the relative popularity of these fields. Enrolments in engineering and applied S&T show the greatest increase, their share of enrolments increasing by 18% over the period 1991 to 1994. In contrast, the share held by agricultural sciences and medical and health sciences has declined considerably, in the case of medicine by nearly 25%.

4.2.2.2 Masters Degree Enrolments

A somewhat similar trend is seen in enrolments for masters degrees, shown in Figure 4.2.

Figure 4.2: Masters degree enrolments, 1990-91 to 1993-94

Figure: 4.2 Masters degree enrolments, 1990-91 to 1993-94



Source: Table 4.2

Total enrolments have grown strongly from around 2600 in 1991 to 4000 in 1994 - an increase of over 50%. Enrolments in the natural sciences and engineering made up about 45% of all masters students in 1994, and again there is some evidence in a slight decline in the relative proportion of NSE students over the four-year period.

The dominant field of study for masters students is medical and health sciences, with nearly 19% of enrolments in 1993-94. Natural sciences attracted around 12% of enrolments and engineering and applied S&T about 10%.

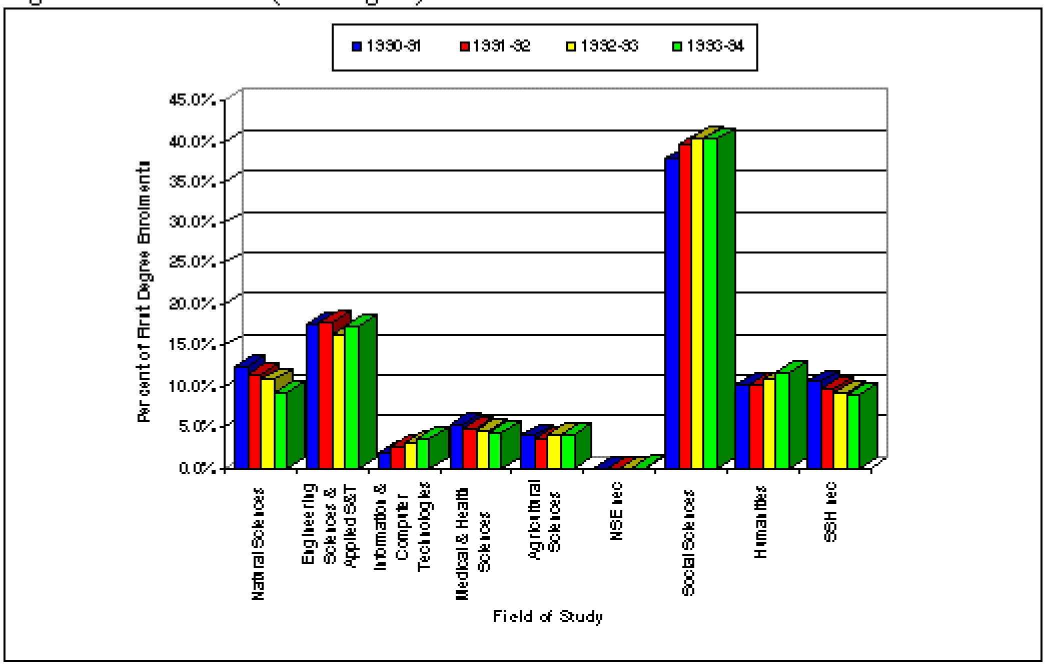
Like their doctoral colleagues, masters students appear to be turning away from agricultural science. The data show a decline in the numbers of masters students enrolled in agriculture, and a relative decline over the four-year period of more than 45%. A smaller relative fall is seen in Table 4.2 in the proportion of masters student taking courses in the fundamental natural sciences and the social sciences. Those fields of study showing the greatest relative growth are the humanities (47% increase) and the medical and health sciences (17% increase). This increase in masters - level health and medical studies contrasts with the relative fall in doctoral enrolments in the field. Engineering and applied S&T has grown at a rate slightly higher than the average for masters enrolments.

4.2.2.3 Bachelors (First Degree) Enrolments

Turning to undergraduate students, Figure 4.3 shows those enrolled for a first (bachelors) degree over the period 1991 to 1994. Again, enrolments have grown strongly over the period, although not as rapidly as for postgraduate students. The 28% increase over four years translates to an average annual growth rate of 8.6%.

Figure 4.3: Bachelor (first degree) enrolments

Figure 4.3: Bachelors (first degree) enrolments



Source: Table 4.3

The number of people enrolled in NSE-related courses increased by more than 18% during the period. However, because of the increase in enrolments overall, and the expansion of SSH courses particularly in UUM and UIA, the relative share of NSE enrolments declined from 44.2% of all bachelors enrolments in 1990-91 to 40.8% in 1993-94.

In 1993-94, nearly 18% of undergraduate students were studying engineering or applied science and technology, while about 12% of students were enrolled in the more fundamental natural sciences. Information technologies, and medical and agricultural sciences each accounted for between 4% and 5% of enrolments.

Over the period 1991 to 1994, strong growth is seen in first degree enrolments in information, computer and communications technologies. It is noted here that, despite falling postgraduate enrolment trends, agricultural science remained popular with undergraduate students and enrolments seemed to be more than keeping pace with the overall growth of student numbers. The natural sciences and medical and health sciences on the other hand contracted relative to other fields of study. Given national priorities, the slight relative decline in enrolments in engineering and applied S&T is also cause for remark.

It is clear from the student enrolment figures that the trend in NSE enrolments, particularly among those studying for a bachelors degree, is in the wrong direction if the intention is to bring NSE enrolments up to the level of SSH enrolments. In 1993-94, for example, an additional 11,000 or so science, technology and engineering students would have been required to place NSE enrolments on a par with SSH enrolments. To put it another way, and assuming that SSH enrolments remain static, achievement of the year 2000 target will require a greater than 40% increase in NSE students compared with 1993-94. This represents a very substantial increase, even in the light of the high growth rates in NSE students exhibited in Table 4.1-Table 4.3.

4.2.3 Graduations of Degree-Level Students

4.2.3.1 Graduations at Doctoral, Masters and Bachelors Level

As Table 4.4 shows, nearly 12,000 people graduated from Malaysian universities at degree level in 1993. About 43% of these degrees were in NSE subjects. Not surprisingly, this figure closely parallels the proportion of NSE students enrolled in university courses in the early 1990s. With the proportional decline in NSE enrolments noted above, the proportion of NSE degrees awarded can also be expected to decline over the next few years.

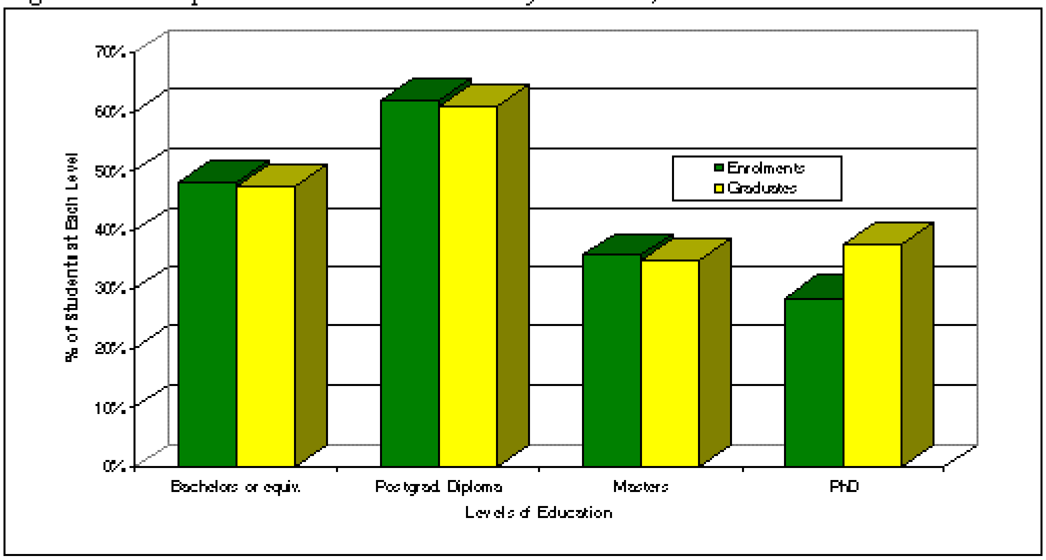
4.2.3.2 Completion Rate for Graduates

This calculation of the completion (successful graduation) rate for students is not straightforward, since it should take into consideration the fact that courses vary in length, and individual students may change courses, or repeat or defer their studies. Table 4.5 attempts to estimate the completion rate of students in particular courses, based on a comparison of 1990-91 enrolments (from Table 4.1-Table 4.3) with the graduation figures in Table 4.4. This rough estimate suggests that more than 70% of bachelors students complete their degree within three years, but that for postgraduate students the corresponding completion rate is lower. Less than half of the masters students appear to have obtained their degree within two years, and the proportion is lower for doctoral students graduating within four years. Further, the completion rate for NSE doctoral students appears lower than for SSH doctoral students. While the interpretation of these estimates requires caution, they may indicate a high dropout rate among postgraduate students (and especially NSE doctoral students), or difficulty in completing their course in a reasonable time. These findings would bear further investigation.

4.2.3.3 Female Students in the Higher Education

Figure 4.4: Proportion of Female University Students, 1991

Figure 4.4: Proportion of Female University Students, 1991



Source: Table 4.6

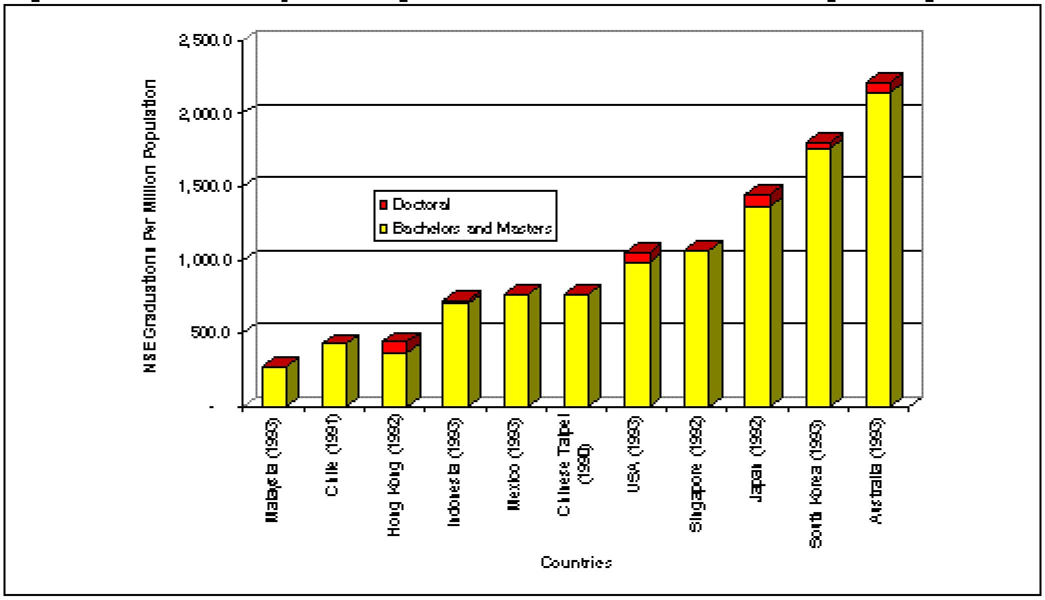
Achieving many of the government's targets for S&T education will require that women participate fully in formal scientific, technical and engineering education and training. The proportion of women undertaking science and engineering courses is therefore of interest for policy purposes. The current report is unable to provide a breakdown of female enrolments and graduations by field of study. However, Figure 4.4 shows the proportion of women in degree and equivalent courses at undergraduate and postgraduate levels in 1991. Women comprised about 48% of first degree enrolments and graduations in that year. The proportion of women was lower in masters courses (around 35%) and lowest in doctoral courses (around 29% for enrolments). Women formed a majority (61%) of those taking postgraduate diplomas. As noted earlier, these diplomas are often professional teaching qualifications. In conclusion, there appears to be scope to expand the number of women taking higher degree courses in all subjects.

4.2.3.4 International Comparison of Graduates in the National Sciences and Engineering

How does Malaysia's production of science, technology and engineering graduates compare with that of other countries? Figure 4.5 compares the annual output of doctoral, and bachelors/masters graduates for selected countries.

Figure 4.5: Annual Output of Degree in the Natural Sciences and Engineering

Figure 4.5: Annual Output of Degree in the Natural Sciences and Engineering



Source: Table 4.7

It is immediately apparent that Malaysia's domestic output of NSE graduates, at less than 300 per million population, is quite low compared with many countries. The comparable figure for Hong Kong, for example, is nearly 450, and for South Korea nearly 1800. In particular, the production of doctoral degrees in NSE in Malaysia is noticeably very much lower than the other countries in Table 4.7. These international comparisons suggest that the government's policy goals to increase the capacity for training in the natural sciences and engineering and to boost postgraduate enrolments are both essential in order to match the performance of other countries.

Many Malaysians choose to study abroad, and the domestic degree completions described above are significantly augmented by those with international qualifications. In 1995, an estimated 50,600 Malaysians were enrolled in higher education institutions in other countries. Of 20,000 government-sponsored students, 18,300 were undertaking first degrees, and nearly 60% of these were in science, medicine, engineering and technical-related courses.

4.3 S&T Skills in the Work Force

During the period of Sixth Malaysia Plan (6MP), several government initiatives on skill training programs (technical and vocational) have been introduced at producing adequate supply of skilled workers as required by the industrial sector, including:

- Expanding capacity of existing public training institution such as the secondary vocational schools, industrial institutes, MARA vocational institutes and youth skill training institutes.
- Establishment of advanced skill training institutes, namely German-Malaysian Institutes (GMI, established in 1992), Malaysia-France Institute (FMI, operated since October 1995) and Japan-Malaysia Technical Institute (JMTI, at the planning stage).
- Establishment of Human Resources Development Fund (HRDF) in 1992, to fund post-employment training programs conducted by private sectors.
- Introduced an investment tax allowance for private sector involvement in technical and vocational training.

A total of 145,670 skilled and semi-skilled workres have been produced by the local public training institutions during the 6MP. Out of the total, 92,250 trainees (63.3%) were in the engineering trade and 11% in the building trade. In terms of employment opportunities, the net increase in employment in selected professional and technical occupational such as those in engineering, medical and health, as well as teaching is expected to be 244,000 by the year 2000.

Government strategic policy emphases of particular relevance to S&T skills in the work force include:

- expanding and improving education and skills training;
- increasing the supply of R&D personnel, including scientists and technologists. For example, the Second Outline Perspective Plan sets a target of 1000 scientists and technologists per million population (10 per 10,000 population) by the year 2000;
- raising female labour force participation;
- encouraging capital-intensive, labour-saving production; and
- encouraging the growth and prestige of skilled technical occupations.

4.3.1 S&T Related Skills in the Employed Work Force

Malaysia's strong focus on human resource development is showing results in the increasing proportion of skilled people in the work force. The Malaysian work force is becoming progressively more educated, with about 55% in 1995 having undertaken secondary education. Some measure of this growth in skills levels can be gained from Table 4.8. In 1993, the number of workers with a college or university education was over 460,000, or 6.3% of the employed work force. This was a substantial increase over 1990, the number of university-educated employees having grown at a rate (22.3%) which was double that of the work force as a whole (10.6%). The number of professional, technical and related people in the work force grew at a similar rate, to reach 8.7% of those employed in 1993.

4.3.2 Registered S&T Professionals

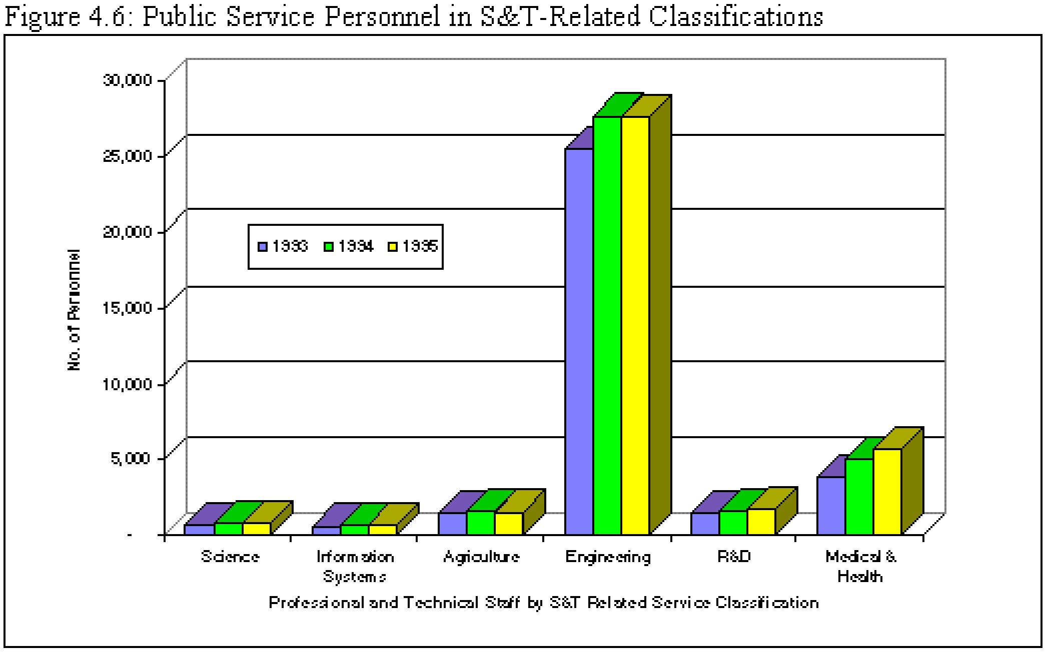
Table 4.9 examines the growth in selected professional occupations which have a scientific or technological basis, by examining the number of people registered by particular professional institutions and boards. The Table thus under-represents those science and technology professionals in less ‘vocational’ jobs such as manufacturing production, research or management, as well as the technical and related workers counted in Table 4.8. Overall, the Table shows an increase of 37% in people registered in the selected S&T professions over the period 1990-1995. The largest increase is seen in the surveying profession, and the smallest in dental and veterinary surgeons. However, it is clear from Table 4.9 that the ‘S&T-related’ professions have been growing at a lesser rate than the major ‘non-S&T’ professions (lawyers and accountants) which showed growth of nearly 70% over the period in question.

4.4 S&T Professionals in Public Employment

As seen above, national data on S&T related skills in the work force as a whole and in the professions is limited. More detailed data are available on people employed in the government service, about one-fifth of whom are engaged in S&T-related occupations.

An analysis of personnel in S&T related occupations employed in the public service is presented in Figure 4.6.
Figure 4.6: Public Service Personnel in S&T-Related Classification

Figure 4.6: Public Service Personnel in S&T-Related Classifications



Source: Table 4.10

In 1995, over 130,000 S&T-related personnel were employed, of whom nearly 30% fell in the managerial/professional and technical classifications, while the remainder were support staff.

Engineers dominate the professional and technical classifications, and there are substantial numbers of medical and health professionals, researchers and agriculturists. Over the period 1992-1995, numbers of S&T-related professionals grew by around 13%, with the strongest growth in the engineering and medical and health related occupations.

Apart from engineering, where all personnel are in the 'technical' category, the ratio of professional/technical workers to support staff is highest in the R&D category where 42% of staff are in the senior classification, and lowest in the agriculture and medical and health related professions, where over 90% of personnel are support staff. There is some indication in Table 4.10 that the proportion of professional/technical staff is slowly increasing in science, information systems, R&D and medicine, but not in agriculture.

Overall, nearly 44% of S&T-related personnel employed in the public sector are women. However, the gender balance varies markedly between occupational categories. Women make up over three-quarters of all information systems staff, and nearly two-thirds of medical and health staff, but only 8% of agriculture-related staff and 14% of engineers.

5. Public Awareness and Use of Science and Technology

5.1 Introduction

As discussed in the section of this report on human resources, Malaysia is seeking to increase the outputs of scientist, technologists and engineers in the work force, as well as increasing the level of technical skills in the work force. In addition, national development is proceeding through the introduction of technology based telecommunications, transport and information and social services that are targeted at the population as a whole.

A good understanding of science and technology concepts and issues is an essential prerequisite for an informed national discussion of the wider use of advanced technology in industry and the wider society - a fact recognised in the industrial Technology Development Plan of 1990. Of even more direct impact to the nation is the understanding of school and higher education students of what is involved in taking up a science or technology related career, and their attitude to these careers.

In 1994, MASTIC sponsored several national surveys of public attitudes towards S&T, with two main objectives. The first was to determine the level of awareness, perception and acceptance among the Malaysian public and students towards S&T. The second objectives was to assess the effectiveness S&T promotional activities by government and other research and technology organisations.

The first survey was a study on the level of awareness, perception and acceptance of S&T among a representative sample of over 5,000 Malaysians, both children (12-14 years), adolescents and adults.

The second area of study was an S&T awareness survey of form 5 students. The Ministry of Education and State Education Departments assisted MASTIC in the circulation of the questionnaires to 4,732 students throughout the country, from all ethnic groups. Both studies examined at career preferences, influences on career choice, level of interest in aspect of S&T, information supply, attitude to scientific and technological advances, and general S&T literacy.

The third study was conducted through structured interviews with S&T promotional personnel in the public and private sector. A total of 26 institutions were surveyed, comprising government agencies, universities, research institutions, non-government organisations and the media.

The main findings of the surveys are discussed briefly below.

5.2 Public Interest In S&T

Among the general public, sports and entertainment featured as the two top most media items of interest among the general public. There was however a strong interest among adult respondents, with women and family issues, sports, entertainment, economics and business as well as foreign and international issues taking precedence over S&T. The ranking rose to third for respondents in the child and adolescent age groups.

The mass media featured prominently as the main source of information on S&T with television being the most popular followed by newspapers. The mass media was the source of information for 68.3% of respondents while 16.6% cited schools as the main source of information.

The school survey showed that Malaysian students have a high level of interest in new scientific discoveries and new inventions and technology as compared to the United States, France, United Kingdom, West Germany and Canada. However, this comparison as with the following international comparisons have to be interpreted cautiously. This is in view of the fact that Malaysian students were compared against the general public of these countries.

5.3 Public Attitude To S&T

Several questions were asked during the school and general public surveys to gauge the attitude to S&T in Malaysia. In general there was a positive attitude to S&T in Malaysia among students, when compared internationally, and the interest was higher among science stream and vocational stream students than among their other classmates. A large percentage of students felt that :

- S&T improves the quality of life;
- Computers and factory automation create more jobs;
- It is important to know about science in our daily lives; and
- Most scientists are motivated to improving life for the average person.

There were some exceptions however to this positive attitude to S&T. For example, approximately 70% of students in Malaysia felt that science changes the pace of life too fast, compared with 49% of respondents in the developed countries surveyed.

5.4 S&T Literacy Among School Students

A quiz on scientific facts was used during the surveys to assess the level of S&T understanding and literacy. The questions were similar to those used in surveys in other countries. International comparisons showed Malaysian students to have a relatively high level of S&T literacy rate with a high proportion of correct response for questions such as :

- Source of oxygen;
- Size of electrons;
- How lasers work; and
- Movement of the earth around the sun.

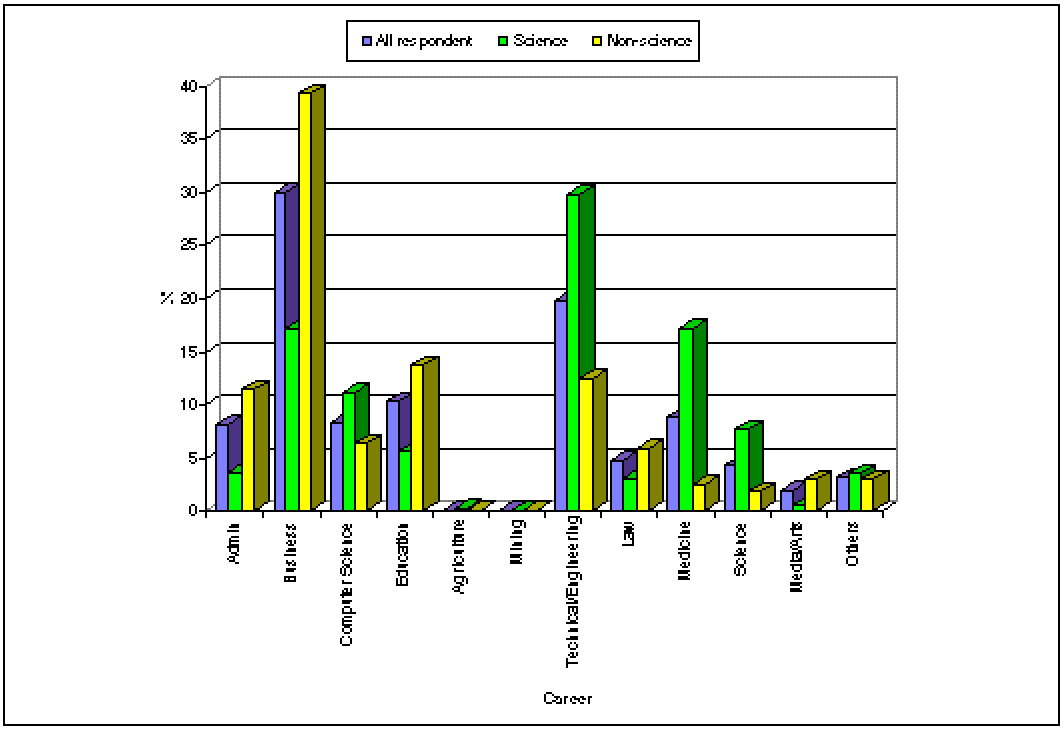
However, in total, Malaysian students scored marginally lower than respondents in the other countries. Malaysian students scored an average mark of 66.9 in contrast to 67.4 obtained by the general public of developed nations (see Table 5.1). In view of this, the survey report noted some cause for concern since it is to be expected that students would perform better than the public at large.

5.5 Impact On Career Choices

The student survey provides important information on the impact of students perception and attitudes to S&T on their likely career choices. The survey asked the question 'What sort of career would you like to have in the year 2020?' Respondents were asked to give a first and second preference from a list of twelve generalised career areas. The results (see Figure 5.1) indicate that the largest number (30.0% of first preferences) envisaged themselves holding a career in business and economics (including accountants, bankers and company managers). This was less so among science students, where 17.1% chose this option, making this the third largest group. The option was more marked among non-science students with 39.2% of respondents, more than three times that of the next largest group. Technical and engineering careers (including mechanics, engineers, designers, draughtsmen) was the second largest group with 19.8% (the largest group for science students with 29.8%, and third for non-science stream students with 12.57%). Government administration was attractive to 11.4% of non-science students, but only 3.7% of science students. Over 17% of science students opted for medicine, more than 11% chose computer science, and slightly fewer than 8% opted for science and mathematics.

Figure 5.1: Career Preferences (first choice) by Science Stream and Non-Science Stream Students

Figure 5.1: Career Preferences (first choice) by Science Stream and non-Science Stream Students



Source: Table 5.2

In summary, the results of the survey suggest that two-thirds of school science stream students intend to follow a career directly associated with science and technology (science and mathematics, medicine, technical and engineering, and computer science). Conversely, one-third of science already have no intention of following careers in S&T, even at this stage to their secondary education. This proportion is likely to increase as students progress into higher education and employment.

Significant differences in career preference were found in students from different ethnic backgrounds (see Table 5.3). Malaysian students of Indian descent were found to have the highest preference for an S&T career when compared to the Chinese and the Bumiputras. The Bumiputras had the least preference for an S&T career. This is in sharp contrast to the high percentage of Bumiputras reporting an interest in S&T. However, in the case of the Chinese and Indians, there was a close parallel between the level of interest and career preference.

The survey also found :

- A low level of participation in science stream courses by Bumiputra students;
- That career choice is primarily influenced by the students own interests, not those of their parents, teachers, friends etc.; and
- That students considered themselves poorly informed about most aspects of S&T, and make relatively little use of newspaper and magazine writings on science, or S&T-specific television programs.

Clearly, despite a strong level of interest in science and technology, a high proportion of students in general and science stream students in particular see their career paths leading elsewhere. This is particularly of concern, given the current and projected shortages of S&T trained personnel in the country. The school survey report identified a need to study and understand the career choice among students, undergraduates and graduates in order to formulate more effective strategies in promoting S&T as a career choice of the future. Any such study will need to be complemented by better information on the actual employment opportunities, avenues for advancement and rewards offered by S&T related careers in Malaysia today, by comparison with other professions which the students could become qualified to pursue.

6. Further Development of Science and Technology Indicators for Malaysia

6.1 R&D Surveys

Comparison between the results of the two R&D surveys, and between these and other sources of data, suggests some areas of incomplete coverage and/or under-reporting. The R&D survey is still a relatively unfamiliar concept to research managers in both the public and private sectors. In addition, the accounting systems of the higher education institutes are simply not set up to account for the full cost of their R&D activities. This may be expected to change with the move towards corporatisation of government research institutes and universities. Nevertheless, every effort will need to be made to ensure the highest quality of reporting of human resources and particularly of financial resources in future national R&D surveys. This will involve ongoing education campaigns to inform potential respondents of the purpose and coverage of the survey, and greater effort in following up respondents whose R&D expenditures or personnel appear to have changed markedly since the previous survey.

Future R&D surveys should also make a special effort to ensure that responses are obtained from the largest manufacturing companies (say the top twenty) operating in Malaysia. Firms should also be encouraged to report their expenditure on R&D in their company annual reports.

6.2 Bibliometric Indicators

The 1992 Malaysian S&T Indicators Report briefly reviewed available data on scientific publications outputs (bibliometric) indicators up to 1989. It was clear that Malaysia's world share of publications in the international scientific literature was quite low, ranking slightly below Thailand, but above the Philippines and Indonesia. The main fields of publication in 1986 were clinical and biomedical research, biology and chemistry.

Some more recent measure of the bibliographic output of Malaysian researchers would be a useful adjunct to the input statistics (expenditure and human resources) for the higher education and government research sectors. In particular, the level of R&D resources for particular fields of research should be compared with output of publications in the field. However, it is recognised that readily-accessible international bibliometric databases, such as those kept by ISI, carry a bias towards English language articles published in North American and European journals. For Malaysia, Asian language and locally published articles also need to be considered.

There exists an active, if small, group of Malaysian academic researchers who would be able to contribute to the analysis. For example, Dr. Szarina Abdullah of ITM has published several papers on the use of bibliometrics in the Malaysian context (see MASTIC 1995). It is suggested that development of bibliometric indicators be progressed with the assistance of task force which includes Malaysian academics with a research interest in bibliometrics.

6.3 S&T in Industry

The industry classification schemes used for the various S&T surveys have differed over the years. The most useful classification for the purpose of manufacturing industry S&T indicators is that adopted by the OECD (based on ISIC Revision 2) and shown in Section 3.2.5 of this report. It is suggested that MASTIC move towards using this classification for future surveys, recognising that it will only be fully useful if related industrial statistics can be obtained based on the same classification.

A useful addition to the patent data presented here would be some disaggregation of patenting in Malaysia by technology class, to see if the technologies that non-residents are protecting are changing. This would provide information on international perceptions of Malaysia's technology market and strengths.

The import-export figures presented for high technology products proved extremely useful, but, although a good approximation, are not strictly internationally comparable. It would be sensible to repeat the analysis of imports/exports in high and medium-high technology sectors using the OECD SITC-ISIC concordance list for the appropriate product categories and industry sectors. This analysis is likely to be of great interest to industrialists and policy makers. This interest may justify regular updating of the import-export analysis, certainly on an annual basis, and maybe even half-yearly or quarterly.

6.4 Human Resources for Science and Technology

HRST is a developing area with emerging standards. There is a need to be aware of international definitions. For example on professional occupations commonly included as 'S&T-related'. The OECD recommends including all post-secondary teachers, but not school teachers, for example. Currently, statistics in Malaysia are being presented on different bases, for example, the boundary between professional and semi-professional/technical occupations is poorly defined.

The use that can be made of the student enrolment, intake and graduation data collected by the Ministry of Education is limited by the lack of a standard classification system for the description of university courses. The higher education institutes appear to be reporting on the basis of their internal course designations and structures. We suggest that the Ministry come to an agreement with the institutions on a common basis for reporting student numbers in particular fields of study. The classifications in common use included the

International Standard Classification of Education (ISCED) and the United States Classification of Instructional Programs (CIP). The classification agreed should allow for particular fields of science and engineering to identified with as much precision as practicable. In the case of postgraduate research students, there is a strong case for aligning the classification as closely as possible with the field of research (FOR) classification used in the Malaysian R&D Classification System (Second Edition).

Additional indicators of HRST that would be useful include:

- Breakdown of the student data by sex and field of study to identify the proportion of women in science and engineering courses.
- Further analysis on the courses (level and discipline) being undertaken by Malaysian students in other countries, and on what proportion subsequently return to Malaysia to work.
- Student enrollment and completion (graduation) data from private sector colleges.
- Representation of women in the senior professional/technical public service categories.
- Detailed information on the relative salary levels achieved by S&T trained personnel in the business enterprises, industry sectors, higher education and the government sectors, and international comparison of salary level.

A further area of great policy interest is in measuring the rate of development and success of technical and vocational training (below the degree level). This will be quite difficult to achieve as international definitions and standards of measurement are not well developed.

6.5 Public Awareness

One of the key finding of the public awareness surveys is that, despite a high level of interest in S&T, many secondary students - even those from the science stream - are turning away from S&T-related careers. This finding suggests either that S&T professions are not sufficiently attractive to new entrants, or that students perceive them as unattractive. Better data on actual employment opportunities, avenues for advancement and rewards offered by S&T-related careers could assist in improving the image of science as a career. It would also help to identify the real impediments to new entrants. It may be appropriate for the Ministry of Science, Technology and the Environment, in collaboration with other agencies professional bodies and the academy of science, to sponsor further work including promotional activities on the career structures, paths and remuneration on S&T-related professionals (including engineers) in Malaysia today.

6.6 Collaboration on S&T Indicators

Many international and foreign organisations are taking a great interest in the development of science and technology skills, performance and industrial application in Malaysia and the other industrialising countries of Asia. ASEAN, APEC, PECC and the United States National Science Foundation (NSF) as well as many higher education institutes and policy groups have a keen interest in the development of quantitative S&T indicators in the region. The Ministry should be encouraged to maintain close contact with these groups and to enter into joint projects on the collection and analysis of S&T indicators wherever appropriate.

In particular, an effort should be made to agree a consistent purchasing power parity (PPP) exchange rate time series for Malaysia and other ASEAN countries to allow more meaningful comparison of S&T financial resources between countries. This might best be done through regional collaboration.

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