East and South-East Asia

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The East and South-East Asian region is vast and diverse. Rather than attempt a survey of individual countries, this chapter will discuss salient features of the paths taken by countries to develop science and technology (S&T) and highlight issues of common concern. Additional sections give more details about China and compare Hong Kong and Singapore.

PLANNING

All countries in the region have in place institutional mechanisms for S&T policy. In the national planning process, there is generally sufficient recognition of the importance of S&T and planning for S&T in socio-economic objectives. Most countries have explicit plans for S&T development. For the few where S&T objectives may be implicit, there is also definite planning.

A number of countries have earmarked budgets for S&T, whereas others have a development budget alongside the recurrent budget in which funding is allocated for long-term S&T activities. Thus, to a large extent, S&T no longer suffers from incremental budgeting, which has posed a constraint in the past when there was less understanding of the nature and importance of S&T. That is not to say that there are no financial problems: S&T development still suffers from a lack of funding in most countries but it is not a case of governments not being willing to spend on S&T; rather, it is a case of competing priorities when funds are limited.

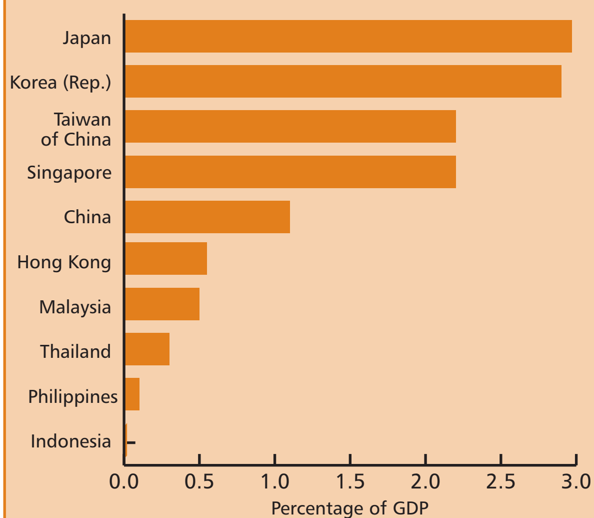
The Republic of Korea, Taiwan of China and Singapore have all broken the 2% barrier in terms of percentage of gross domestic product (GDP) spent on research and development (R&D), while China is on track to reach its target of 1.5%. Meanwhile, Malaysia and Thailand are struggling to keep up their domestic expenditure on R&D (GERD) as a percentage of GDP; their technological capabilities have been catching up despite the apparent lack of improvement in their scores (Figure 1).

TARGETING

In planning for the development of S&T, almost all countries have taken a targeting approach. They have targeted four universal fields: information technology, micro-electronics, new materials and biotechnology. These are so-called universal fields for targeting because all four are generally regarded as being important in the twenty-first century and have been targeted not so much because countries feel they have a strategic advantage in one or more areas but because they realize that they must invest in R&D in these fields in order to acquire the technological capability to make use of advances in the same fields developed in other countries. In addition to the four universal fields, countries in the sub-region also target fields specific to their own strategic advantage, for example, rubber in Malaysia, pharmaceuticals in Thailand and fruits in the Philippines.

In the early stages of development, when the strategies were export-promotion and import-substitution, essentially an industry approach was taken. Later, when technological innovation and development of indigenous capability were emphasized, a technology approach was taken. Countries in the region by and large take a mixture of industry and technology approaches to economic development.

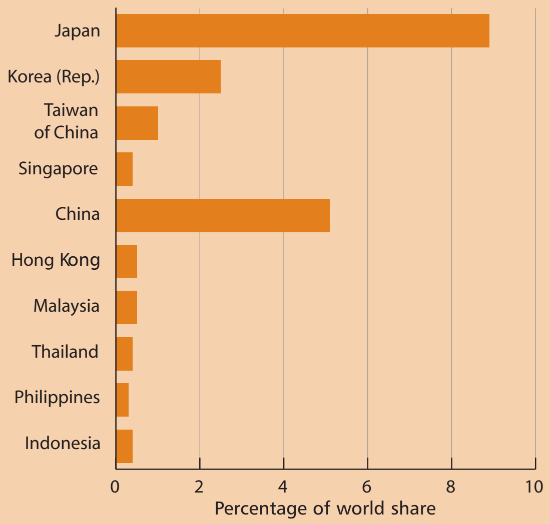
Figure 1
GERD/GDP RATIO IN EAST AND SOUTH-EAST ASIA, 2001*



* Japan 2000, Malaysia 2000, Philippines 1998.

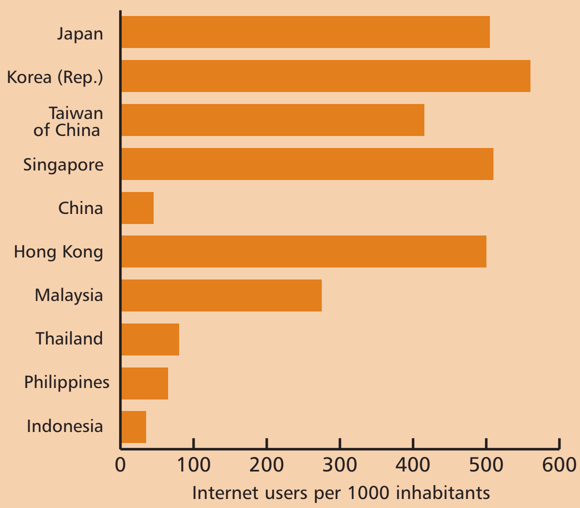
Source: International Institute for Management Development (2003) *World Competitiveness Yearbook 2003.*

Figure 2
COMPUTERS IN USE IN EAST AND SOUTH-EAST ASIA, 2002



Source: Computer Industry Almanac 2002.

Figure 3
INTERNET USERS IN EAST AND SOUTH-EAST ASIA, 2002



Source: Computer Industry Almanac 2002.

INFORMATION TECHNOLOGY

Information technology (IT) has been a great leveller for countries on their paths to S&T development. The Internet has made available a great amount of scientific information and technical data at little or no cost. Hitherto, such information was difficult to come by and this could pose a barrier to S&T development.

Software development requires little equipment and, unlike other forms of technology, can be undertaken without major capital investment and on a small scale. The return cycle is short. Late starters are not necessarily disadvantaged. Because of these factors, most countries in the region have a growing IT industry.

The build-up in IT industry and the general availability of scientific information have strengthened the technological capability of the countries in the region. This is not well reflected in the usual input indicator, GERD as a percentage of GDP, because IT does not necessarily incur large expenditures.

One indicator of the pervasiveness of IT in the region is the number of computers in use. China, with 5.1% of the world share of computers, ranks fourth in the world, which is hardly surprising as China is the most populous country in the world. It is significant that the Republic of Korea, with 2.4%, ranks ninth (Figure 2).

When computers per 1 000 inhabitants are calculated, Singapore and Hong Kong rate higher than the Republic of Korea and Taiwan of China; their statistics are comparable with those of European countries. Malaysia, with 137 computers per 1 000 inhabitants, also qualifies for this league, and is significantly ahead of Thailand's 43 per 1 000 inhabitants.

The Republic of Korea ranks sixth in the world in per capita Internet usage, closely followed by Singapore, Hong Kong, Taiwan of China and Malaysia, all of which have usage comparable to industrialized countries. Further behind is Thailand with 79 Internet users per 1 000 inhabitants, followed by the Philippines, China and Indonesia (Figure 3).

Is there a digital divide in Asia? It is a matter of degree. There is some distance between Malaysia's 269 Internet users per 1 000 inhabitants, which is the lowest of the more

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industrialized countries in Asia, and Thailand's 79 and the Philippines' 57. With regard to computers per 1 000 inhabitants, Malaysia has 137, which is more than three times Thailand's 43. This is a not insignificant difference but Thailand and the Philippines do not appear to be greatly disadvantaged. To some extent, it is a mere size effect because Thailand and the Philippines are more populous countries.

The digital divide may perhaps be seen as an internal problem for the region's two most populous countries, China and Indonesia, where there are great differences in development within the country. The coastal regions of China are much more developed than the western region and the outlying islands of Indonesia are far less developed than the region around Jakarta. Seen in the context of such inevitable differences within a large country, the digital divide does not seem to be significant.

BIOTECHNOLOGY

Biotechnology is a relatively new field and as such may be seen as offering more equal opportunities for newcomers and latecomers such as researchers in Asian countries. There is, however, a formidable threat from the giant pharmaceutical companies. The judicial decision to grant patent rights to genetic codes caused roadblocks to be set up. There is still scope for scientists in Asian countries in this obstacle course. When they lack the funding to pay licence fees to remove the roadblocks, they have to go around them or find a clear path elsewhere. It is, however, difficult for Asian scientists to compete in areas requiring expensive equipment. One factor in their favour is that there is an abundant variety of life forms in the warmer climate of Asian countries.

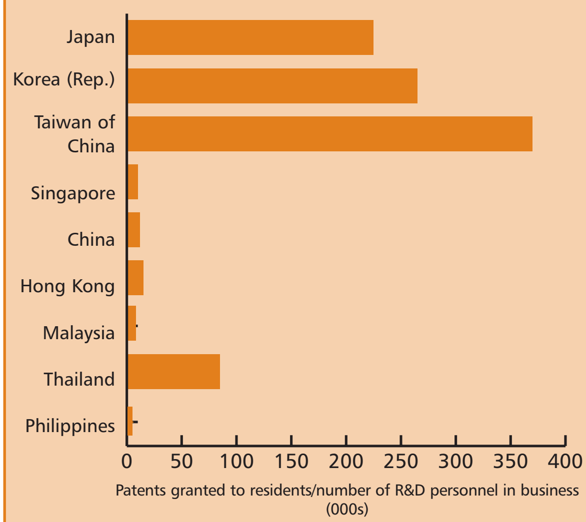
Almost all Asian countries engage in some form of research in biotechnology. Biotechnology is especially significant in Thailand where pharmaceutical research has distinguished itself. In Malaysia, the focus of biotechnology is more on agricultural products. Advances in biotechnology have boosted Thailand's technological capability and narrowed the gap with Malaysia. When the GERD/GDP ratio is considered, Thailand spends only slightly more than half as much as Malaysia: Thailand registered 0.27% and Malaysia 0.49% in 2001. When total GERD is considered, however, due to Thailand's greater size and larger GDP, the difference looks smaller, at US$ 440 million in Malaysia and US$ 306 million in Thailand. Also because of Thailand's larger population, it has more R&D personnel than Malaysia – 20 000 compared with Malaysia's 10 000 – but on the basis of the number of R&D personnel per 1 000 inhabitants, Malaysia is ahead of Thailand at 0.43 compared with 0.33.

Thailand's natural advantage in biotechnology has helped its scientists to secure patents for their research. Thailand's performance in patent productivity has now surpassed that of Malaysia, although it has not quite reached the same level as the Republic of Korea and Taiwan of China (Figure 4).

HIGH-TECH EXPORTS

When it comes to high-tech exports, it is not surprising that China leads the way but it is significant that Malaysia has more high-tech exports than the Republic of Korea and that the Philippines has overtaken Thailand. When high-tech exports are considered as a percentage of manufactured

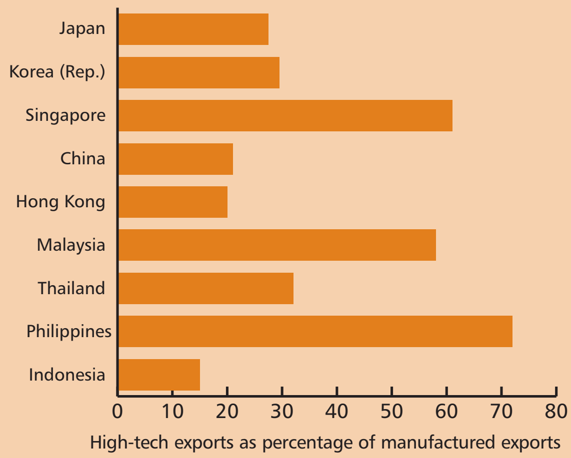
Figure 4
PATENT PRODUCTIVITY IN EAST AND SOUTH-EAST ASIA, 2000*



* Japan 1999, Thailand 1997, Philippines 1998.

Source: IIMD (2003) *World Competitiveness Yearbook*.

Figure 5
HIGH-TECH EXPORTS IN EAST AND SOUTH-EAST ASIA, 2001



Source: World Bank (2003) *World Development Indicators.*

exports, the Philippines leads at 72%, followed by Malaysia with 50% and Thailand with 32%. For China, high-tech exports constitute 21% of manufactured exports (Figure 5).

Multinationals and companies in developed countries have been stepping up original equipment manufacture (OEM) operations in Asian countries; this explains the remarkable level of high-tech exports as a percentage of manufactured exports in the Philippines, Malaysia and Thailand.

INTELLECTUAL PROPERTY PROTECTION

There is generally adequate protection of intellectual property in East and South-East Asian countries. It may be possible to distinguish three elements of intellectual property protection. First is the enactment of adequate legislation. Second is whether the apparatus exists in the country to pursue rigorously infringements of intellectual property. Here, there are two subdivisions. One is whether, and the extent to which, the government assumes its responsibility for enforcing intellectual property legislation – a matter of intention as much as of the effectiveness of measures taken. The other is the process and efficiency through which redress can be provided when an aggrieved party institutes civil proceedings. The third element is the propensity of people in the country to take illegal advantage of protected intellectual property. This is in turn dependent on two factors: the technological capability in the country and the willingness of entrepreneurs to risk litigation.

From this analysis, it can be seen that the first element is generally present in all countries in the region. There is some provision in the second element but it is difficult to assess its adequacy. Governments have generally expressed willingness to pursue intellectual property violations but it is difficult to judge the adequacy or the rigour with which they pursue violators. Similarly, there exist channels and processes for aggrieved parties to seek redress but the efficiency of the process is again difficult to assess.

Often it is the third element which becomes the deciding factor in location decisions of multinational corporations. Consideration of this element would have prompted many companies to set up OEM operations in the Philippines and Thailand. The increase in OEM factories in these countries has resulted in an increase in high-tech exports from these countries.

HUMAN RESOURCES

The region has a generally well-educated workforce. For most countries, more than 30% of the adult population are university graduates (Figure 6), while in the Philippines the proportion is 26% and in Thailand 13%. The most populous countries, China and Indonesia, have a pool of only 5% and 6%, respectively, but it is a not a problem for them. China has the world's second-largest workforce in R&D. In many Asian countries, nearly half of university degrees are obtained in science and engineering; in China nearly three-quarters (74%) are (Figure 7). The exception is Thailand, where the figure is 26%.

There are no serious problems of 'manpower mismatch', something which has caused difficulties in other regions. Worker unions have never been strong in the region, which is a main reason why there is no entrenched resistance to change. Asian workers are pragmatic and flexible; they are

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generally adaptable and willing to learn new skills. However, employers are sometimes reluctant to invest in training employees and would sooner hire new workers with ready-made skills. Thus, while there is little 'manpower mismatch', workers and jobs are not particularly well matched.

In the Republic of Korea, company loyalty is emphasized; in turn, the company is committed to the career development of its employees. This was particularly so in the heyday of the *chaebols*. Since the end of the financial crisis of the late 1990s and the gradual dismantling of the *chaebols*, attitudes have been changing.

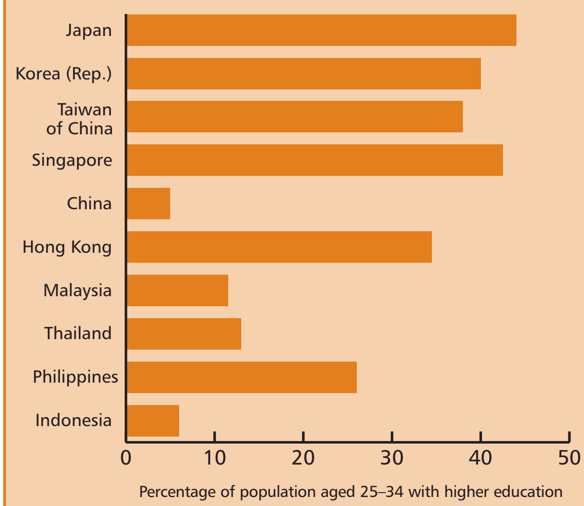
In centrally directed Singapore, there is no fear of 'manpower mismatch'. When the universities were told to step up their output of engineering graduates, there was no concern about employment prospects for the graduates because the government would create jobs for them.

Brain drain

'Brain drain' has been a perennial problem. East and South-East Asia has been a net exporter of talent. It is not clear whether this has been harmful to the region. If there is insufficient opportunity for the personal development of individual talents, it is to the benefit of the individuals to go abroad to find scope for their development. Emigration of talents means fewer human resources are available for national development and, on occasion, countries have found it difficult to recruit local talents to important positions. However, when the country cannot offer sufficient opportunities for the professional development of some of its people, it may be better for the country that these people go overseas to find a meaningful career because they can be useful to the country even while living abroad and may some day return to help the country's development.

China has adopted a liberal policy towards its nationals going abroad. As early as 1978, Deng Xiaopeng said, 'Even if half of those sent abroad would not return, it is better than not sending or sending less.' Now, approximately one-third of those who go abroad are returning to China every year.

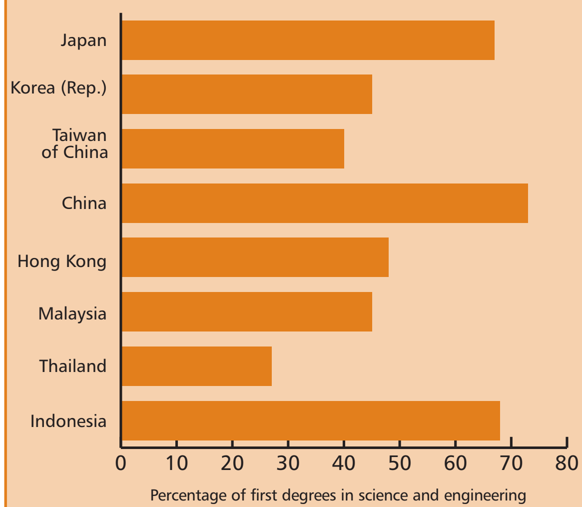
Figure 6
HIGHER EDUCATION ACHIEVEMENT IN EAST AND SOUTH-EAST ASIA, 2001*



* China 1998, Malaysia 1999, Thailand 1999, Philippines 1998, Indonesia 2000

Source: IMD (2003) *World Competitiveness Yearbook.*

Figure 7
SCIENCE AND ENGINEERING EDUCATION IN EAST AND SOUTH-EAST ASIA , 1999



Source: National Science Foundation (2002) *Science and Engineering Indicators*. Washington, DC, USA.

All countries have paid attention to attracting the return of their nationals. The Republic of Korea has appealed to nationalism. Taiwan and China have used high salaries. Singapore still uses a bond system to require nationals going abroad on scholarships to return to Singapore to work for a certain period of time. There is now mounting pressure for Singapore to review or dismantle the bond system.

Policy measures pale in significance compared with the natural attractions of a higher level of development in the home country. By the turn of the twenty-first century, economic development in the region had by and large reached a level such that there were flourishing markets for returning talents. Once they have overcome the sometimes psychological aversion to returning, many soon opt to embrace the new opportunities of their own accord. Indeed, more than ten years ago when the Asian miracle was first mentioned, there was much conjecture about the cause of the miracle. One of the factors was certainly the return of talents who had been trained and gained experience in Western countries.

Their return triggered faster economic growth, which in turn made their countries more attractive for nationals to come back to. Thus, there is a positive feedback loop between returning nationals and economic development. There is also a herding effect: overseas nationals seeing their compatriots returning would sooner consider returning themselves.

INTERMEDIARY INSTITUTIONS

Intermediary institutions were first conceived as bridging the gap between upstream S&T and downstream commercialization. The concept is especially relevant for East and South-East Asia because of the tradition for scholars and scientists to devote themselves to academic research, sometimes with a disdain for commercial applications.

Intermediary institutions were first promulgated by Choi Hyung-Sup, Minister of Science and Technology of the Republic of Korea, in the 1970s. He created the Korean Institute of Science and Technology, which was a mechanism for giving university professors an opportunity to work on the applied problems of industry. He considered the institutional initiative as being necessary because S&T development in Korea at the time was weak. In Western countries, the S&T infrastructure is generally better developed; consequently, there is less need for intermediary institutions and, where they exist, they are not as significant.

The Korean example was widely emulated. A few years later, the Industrial Technology Research Institute was set up in Taiwan of China and, in the past ten years, many more intermediary institutions have sprung up in East and South-East Asian countries, especially in Malaysia.

The institutions function as a half-way house, enabling scientists at universities to spend time working on applied problems then return to their academic work. At the same time, it is a useful opportunity for younger scientists and engineers to learn the workings of industry and is a spawning ground of entrepreneurship. Many young people eventually leave the intermediary institutions to join spin-off companies and they are encouraged to do so. In this way, the intermediary institutions fulfil the role of a conversion mechanism, converting academically trained graduates into useful members of industry. This conversion process is no simple procedure and is not inexpensive.

Without the help of intermediary institutions, entrepreneurs may opt to import ready-made skills from abroad rather than to train up local graduates, as in the case of Hong Kong. There, the situation is exacerbated by the propensity of young graduates to engage in 'job hopping'; lack of company loyalty means that investments in the development of employees may be lost to the company. Small and medium-sized enterprises (SMEs), which necessarily function with a short time horizon, are hard pressed to invest in staff training. They tend to find the experience of graduates irrelevant to their narrower scope of activities. In an economy where SMEs are predominant, it is difficult for graduates to find appropriate employment and they become branded as inexperienced and unsuitable. Thus, it becomes a vicious cycle. Intermediary institutions are seen as necessary to break this vicious cycle.

Intermediary institutions have now taken on a more general connotation to include entities created to overcome economies of scale or economies of scope for SMEs.

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Thus, the term is taken to embrace science parks, incubators and institutions offering S&T services such as information, management and financing. The term is also taken to include agency roles, as in marketing and sourcing.

There is an important application in the financing of technology, which requires bringing together funds, technical expertise and business acumen. The three attributes seldom come together by themselves. Intermediary institutions function as enabling mechanisms, for example the Korean Technology Development Corporation and the Malaysian Technology Development Corporation.

Another important function of intermediary institutions is to act as bridges in the triangular linkage between government, university and industry. For smaller economies where the level of S&T development is not high, it is especially important to harness the synergy from the triangular linkage.

PUBLIC–PRIVATE CONSULTATIVE MECHANISMS

Public–private consultative mechanisms are a special feature in East and South-East Asia. Their significance stems from the fact that the public sector is the major player in S&T in most countries in the region. With the notable exception of the Republic of Korea, Singapore and Taiwan of China, the public sector generally accounts for more than 50% of total R&D. Companies in the private sector are relatively small. Governments command better resources and have superior access to information. They nevertheless find it wise to tap the market sense of entrepreneurs.

An analogy may be made to power steering. The consultative mechanisms put the entrepreneurs in the driver's seat but their efforts alone, in terms of resources and finances, are insufficient to turn the wheels of the great vehicle of national development. There is a need for the government to supply power, in the form of resources and funding, to enable the steering to take place.

To be successful, the consultative mechanisms must be constituted in such a way as to make it incentive-compatible for entrepreneurs to give advice which is good for the country rather than to advance individual vested interests. This incentive compatibility is not always easy to achieve; it depends on an appropriate *mode d'emploi* of the consultative mechanisms and on a suitable selection of participants.

Malaysia has had notable success with public–private sector consultative institutional mechanisms. Such mechanisms have been very well developed in the Republic of Korea where there is a culture of sacrificing individual benefits to the greater good. In the closely knit society of Singapore, these public–private sector consultative relations become implicit, because communications can be direct. When the key people have many occasions and channels to meet, there is hardly any need to institutionalize explicitly the relationship.

This situation is in contrast to experience in Western countries where the government is not the largest player in R&D. Firms are large and the private sector generally accounts for more than 60% of total national R&D in Organisation for Economic Cooperation and Development (OECD) countries. In Western countries, governments are sometimes considered to be inept and have less access to market information than private firms. The welfare of the country is synonymous with the welfare of the firms in the country. The concept of a national vehicle of development is hardly viable. Rather, when individual firms get to go where they want to go, the firms are happy and that means the country as a whole is happy. In this Western scenario, there is little need for public–private sector consultative mechanisms and, where they exist, they are not considered to be important.

LEAPFROG

Is the region poised to leapfrog? There are favourable conditions. The advent of the Internet has helped to popularize science and has made vast amounts of information and data available at almost no cost, which has been a tremendous boost to under-privileged researchers. At the same time, IT presents a more level playing field for Asian researchers, who will not be severely handicapped by lack of resources.

Biotechnology is a field in which East and South-East Asian countries can have niche advantages. In medical applications, the populous Asian region has a wide range of diseases and large numbers of clinical cases. In pharmaceutical and agricultural applications, the region also has the advantage of a great variety of vegetation and life forms.

Levels of economic and technological development in the region have passed the threshold. Now there will be an increasing number of nationals who have studied and trained abroad returning on their own initiative to take advantage of the new opportunities in the fast developing region. Against this is the region's less than spectacular record for the percentage of GDP spent on R&D. While some Asian countries have risen above 2%, industrialized countries in other regions have passed the 3% mark. But this indicator should be interpreted in the context of increases in GDP in the denominator. Also, input is not the best way to measure technological capability. To conclude, the region is set to look forward to a period of accelerating growth and development in S&T.

S&T COOPERATION

Cooperation in S&T in Asia has not been easy. The region is diverse and countries are spread over vast distances. More languages are spoken than there are countries in the region. Although English is the medium for scientific publications and research communications, most universities teach in the local language. Language is already a barrier to scientific personnel gathering together to overcome critical mass thresholds. But it is not sheer numbers which count; it is complementarity, or mutual reinforcement, which leads to synergy in a cooperation. Such complementarity, concurring with benevolent intentions to cooperate and enabling institutional mechanisms, was difficult to achieve when levels of S&T development in individual countries were not high. By the turn of the century, East and South-East Asian countries have reached capabilities that make S&T cooperation feasible but it is still a daunting task to identify meaningful areas for synergistic collaboration.

It is not in the mainstream for students to go to a neighbouring Asian country for further study; Western countries are preferred by the better qualified or those who command sufficient finances.

As for pooling of resources and sharing of facilities, an institution has to achieve some degree of prominence before it can become a centre of attraction for scientists. Most examples of shared facilities tend to have benefited from the support of countries outside the region.

In the same way that intra-regional trade is less significant than trade with countries in other regions, notably Europe and America, S&T cooperation among countries within the region is less significant than cooperation with industrialized countries outside the region.

APEC

Asia-Pacific Economic Cooperation (APEC) was established in 1989 to enhance economic growth and prosperity for the region and to strengthen the Asia–Pacific community. It is a forum for facilitating cooperation, trade and investment. The Member Economies of APEC together account for one-third of the world's population and about 60% of world GDP. APEC's 21 Member Economies are Australia, Brunei Darussalam, Canada, Chile, China, Hong Kong, Indonesia, Japan, Republic of Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, Peru, Philippines, Russian Federation, Singapore, Taiwan of China, Thailand, USA and Viet Nam.

When China hosted the APEC Economic Leaders' Meeting in Shanghai in 2001, cooperation in S&T was successfully highlighted by way of human capacity-building. Many industrialized countries in APEC were understood not to be keen on S&T, being especially averse to technology transfer. The Fourth APEC Science Ministers' Meeting held in New Zealand in 2004 noted the need to have more and better engagement between the scientific community and society in APEC economies, and recommended a revamp of the Industrial Science and Technology Working Group of APEC.

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ASEAN

The Association of South-East Asian Nations (ASEAN) groups Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam. The goals of ASEAN encompass promotion and pursuit of cooperation in the arena of political and security matters, economic integration, as well as cultural and technical cooperation in areas such as social development, S&T, environment, agriculture and forestry, energy, tourism, transport and communications.

The goal for the coming decades, as encapsulated by *ASEAN Vision 2020*, is of 'a technologically competitive ASEAN, competent in strategic and enabling technologies, with an adequate pool of technologically qualified and trained manpower, and strong networks of S&T institutions and centres of excellence'.

The importance of cooperation in S&T has long been recognized. The ASEAN Committee on Science and Technology (COST) was established more than 20 years ago. There are nine COST Sub-Committees, namely: (1) Food science and technology, (2) Meteorology and geophysics, (3) Micro-electronics and information technology, (4) Materials science and technology, (5) Biotechnology, (6) Non-conventional energy research, (7) Marine sciences, (8) Space technology and applications, and (9) S&T infrastructure and resource development. COST maintains an ASEAN Science Fund to provide seed funding for its projects and activities, and also seeks external funding from ASEAN's Dialogue Partners: Australia, Canada, China, the European Union, India, Japan, Republic of Korea, New Zealand, Russia, the USA and the United Nations Development Programme.

Some examples of cooperation projects in 2004 are the China–ASEAN Training Course on Remote Sensing Satellite Technology; ASEAN–Pakistan Cooperation in Composite Materials, with a visit by Pakistani experts to ASEAN countries; a China–ASEAN Workshop on Conservation and Biotechnology Application of Tropical Biological Resources; and ASEAN–India Cooperation on S&T Policy and Technology Management.

The prognosis is for the emergence of internalized forces unifying the region in cooperative efforts. The lead would come from China, the Republic of Korea or Malaysia, or from home-grown Asian multinationals. There will be a diminishing of external influences, which have tended to be divisive. It will be a far cry from the 'ASEAN complementarity' proposed by the Ford Motor Company in the 1970s with its plan for having different parts of a car made in different countries and for the Ford model to be eventually assembled as a so-called ASEAN car. The plan exploited economies of scale by producing large quantities of the same part in one location and made sure no country acquired the technology to make a complete car.

The channels are now open for countries to collaborate on national or regional products. The long period of stagnation in progress towards regional cooperation is coming to an end. After several false starts, institutions for regional development will eventually emerge. For example, a well-justified *raison d'etre* for an Asian Monetary Fund will eventually overcome objections from outside the region. Once regional institutions are in place, there will be additional impetus for cooperation and the region will be able to look forward to a heightened pace of S&T development.

Hong Kong and Singapore: a tale of two cities

Lee Kuan Yew made an allusion to Charles Dickens' novel, *A Tale of Two Cities*, when he compared Singapore and Hong Kong in a speech at the University of Hong Kong in 1992. Although there are similarities between the two island economies, they have taken significantly different paths to S&T development. A point often missed in casual references to Singapore and Hong Kong is that they are both anomalous cases. At times, others might try to emulate Singapore's and Hong Kong's apparent successes. On closer scrutiny, it will be seen that policy actions have been taken to suit the particular circumstances of these two economies, which in most cases are unique, and are scarcely applicable in other countries where conditions differ. With hindsight, it is also not at all clear whether the anomalous policies were desirable.

To set the scene for the comparison, Singapore's total expenditure on research and development as a percentage of GDP (GERD/GDP ratio) stood at 2.1% in 2001, while research scientists and engineers per 10 000 workforce numbered 70 in the same year. For Hong Kong, the GERD/GDP ratio was a meagre 0.6% in 2001 and there were only 10 research scientists and engineers per 10 000 workforce. For all statistical indicators, Hong Kong ranks consistently behind Singapore.

With respect to the institutional structure for S&T, Singapore's provision is deceptively simple. In the closely knit society of Singapore, S&T policy planning is made by a central core of top leaders who bypass formal institutional structures. The National Science and Technology Board was in essence involved only in second-level funding and implementation.

In the case of Hong Kong, which reverted to Chinese sovereignty in 1997, the functions of the former Industry Department have been regrouped to form the Innovation and Technology Commission. The Science Park was eventually set up, almost 10 years after its feasibility study was first undertaken in 1991. The Applied Science and Technology Research Institute was established to fill a void in the S&T infrastructure, into which the Hong Kong Productivity Council has grown, and is now struggling to identify a new role for itself. These are funding and implementation bodies; an adequate policy-making mechanism is lacking.

Singapore has taken bold proactive initiatives to promote S&T. Strenuous efforts combined with very favourable conditions in the form of generous tax and financial benefits have attracted many major technology-intensive manufacturing multinationals to set up operations there. The companies have not brought as much R&D as might have been hoped for but their presence has resulted in a general strengthening of Singapore's technological capability. The challenge now comes from competition from neighbouring Malaysia, Thailand and Viet Nam, where space is abundant and labour is far less expensive. A number of the multinational corporations which have set foot in Singapore are already moving operations to other countries with better natural conditions and many others are now considering their position. In the planned society of Singapore, it has been possible to engineer a decrease in salaries to some extent in order to stay competitive. The space limitation is a fundamental constraint which is difficult for policy action to tackle.

Another controversial policy is that Singapore has nurtured the development of many technology start-ups through favourable government procurement. Many technology-intensive companies are government-owned or -controlled; they help the start-ups by giving them business, such as by procuring their services or technology. This has created a favourable environment for new

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technology companies when it comes to developing and obtaining venture capital financing. A worry is that companies nurtured under such favourable conditions may not be able to compete successfully in the international marketplace. One solution might be to keep these companies within Singapore until they have grown sufficiently strong to be competitive. The question then arises as to whether it is possible to sustain government support long enough for the companies to reach the critical mass beyond which point they can manage by themselves and eventually compete internationally successfully.

Even if some manufacturing operations do eventually leave Singapore, the time they have spent in the country will have helped Singapore to develop its technological capability. The space problem is an essential issue which seems insurmountable. A niche for Singapore lies perhaps in technology-intensive services, drawing on the experiential support of its manufacturing sector and R&D institutes, rather than in technology-intensive manufacturing *per se*. This would capitalize on Singapore's position as a geographical hub.

Hong Kong has been fortunate, or unfortunate, to have avoided earlier pressure to upgrade its technological capability. In the 1980s, when Hong Kong's manufacturing was threatened by the technologically more advanced Republic of Korea, Taiwan of China and Singapore, low-cost labour across the border on the Chinese mainland became available. There has also been the crowding out effect of the real estate sector, before it crashed. The day Hong Kong eventually has to face up to making the transformation to a knowledge-intensive economy, it will be much more painful, like catching measles at a later age.

There are many in Hong Kong who would like to evade the ordeal, arguing that if Hong Kong is not going to excel in S&T, it should not invest in S&T. Given that Hong Kong is a small place and the head-start already taken by neighbours and other countries, Hong Kong does not have an advantage in S&T. This might have been sound comparative advantage thinking, but S&T are not like a commodity or a sector of industry. Like vitamins, S&T are essential to an economy, without which many knowledge-intensive activities become dysfunctional. It is unrealistic to resist the inevitable move towards a knowledge economy.

There is also the thinking that, since Hong Kong will be playing a marketing and sourcing role for the much larger and stronger technological capability on mainland China, there is no need for S&T in Hong Kong. This thinking is fallacious. Hong Kong needs to have an adequate level of technological capability to be able to provide proper marketing and sourcing services to the mainland. The Closer Economic Partnership Arrangement (CEPA) set up between Hong Kong and the mainland in 2003 has been much talked about. An adequate level of S&T capability in Hong Kong is necessary to give substance to closer cooperation and to enable Hong Kong to engage in dialogue at the appropriate level with mainland partners.

The most serious hindrance to S&T development in Hong Kong has been the dogma of non-interventionism, which has plagued Hong Kong for decades. Without proactive government support, Hong Kong's S&T development lags far behind its neighbours. Whereas other countries are actively supporting the competitiveness of their industries, Hong Kong had been cited as an anomalous example of the success of *laissez faire*, until the collapse of the real estate bubble after the financial crisis of the late 1990s led to recession.

Hong Kong boasts of being a most free economy. That freedom is favourable to short-term speculative investments but is irrelevant to long-term and technology-related investments.

Non-interventionism may no longer be government policy but non-interventionist thinking is still widespread among government officials. For the bureaucrats, non-interventionism is a good excuse for non-action, which minimizes the risk of making mistakes. Especially for the generalist who lacks specialist knowledge, non-interventionism is the safest approach. Hong Kong people have for many years been used to making proposals within the confines of non-interventionism; they find it difficult to think out of the box, even now that the restrictions have been officially lifted.

Although the promotion of innovation and technology is now government policy, government officials are still dragging their feet. Hostile attitudes towards S&T trace back to colonial origins. In the United Kingdom, the 1986 report of the House of Lords Select Committee on Science and Technology pointed out that advice from scientists seemed to fall on deaf ears in government because administrative officers were generalists and not in the least sympathetic to S&T or appreciative of their importance. As a British colony, Hong Kong had the same system of administrative officers, who were retained *en masse* in the change of sovereignty.

Hong Kong's niche lies in offering sophisticated and technology-related services to mainland China and the South-East Asian region. There is much potential, as yet undeveloped, for technology-related services; S&T and R&D are needed to provide experiential support to enable technology-related services to be offered. This would take advantage of Hong Kong's position as a geographical hub, like Singapore. Hong Kong has the additional advantage of being a gateway to a large hinterland, mainland China.

However, many championing the cause of S&T in Hong Kong argue that S&T are needed to support manufacturing and that an economy must have manufacturing. There is no doubt that manufacturing needs S&T but it is not true that an economy must have manufacturing. It may be true for a large economy but not for a small economy the size of Hong Kong. It has not helped the cause of S&T at all that proponents use the wrong justification for S&T.

There was some speculation in technology stocks, which proved to be unsound. People had their fingers burnt when the prices of these stocks plunged. This bad experience did not help to promote a positive attitude towards S&T. It was like trying to run before one can walk.

Indeed, Hong Kong needs to leap in order to catch up. One attempt is to use money to buy technological capability. It will be interesting to see the extent to which money can indeed buy technological capability.

CHINA

Present status of S&T

Expenditure on S&T in China totalled 267 billion yuan[1] in 2002. GERD stood at 129 billion yuan, amounting to 1.23% of GDP. R&D expenditure passed the 1% of GDP mark in 2000. In monetary terms, China ranked seventh in the world for GERD in 2001; China has a significant technological capability by virtue of its sheer size.

China had 3.22 million persons engaged in S&T activities in 2002. Of these, 2.2 million (68%) were scientists and engineers. In respect of the total number of R&D personnel, globally China ranked second in 2001, unsurprisingly, since China is the world's most populous country. However, when the number of scientists and engineers engaged in R&D is related to the size of the workforce, China has only 10 per 10 000 workforce (2000), much fewer than the USA at 81 per 10 000 (1997) or Japan at 97 per 10 000 (1999).

1. One Chinese yuan was equivalent to US$ 0.12 in June 2005.

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Government appropriation to S&T has been increasing steadily every year since 1981, taking up to 5.6% of the total government budget; since 1994 however, this percentage share has been gradually slipping and in 2001 amounted to 3.7%. Government expenditure on S&T has not decreased but nor has it kept pace with growth in total government expenditure.

China granted 132 000 patents in 2002, almost twice the number of patents granted in 1998 (67 900). The Chinese patent system distinguishes three categories: invention, utility model and design. In 2001, 95% of the patents granted to local residents pertained to utility model and design, with invention accounting for only 5%. This was in sharp contrast to the distribution of patents granted to foreigners, where invention took up 73% and utility model and design 27%. The rapid increase in the number of patents granted indicates the high growth of innovation, especially by industrial enterprises, which were the main recipients of patents in the categories of utility model and design.

High-tech goods now account for 21% of manufactured exports, with China ranking seventh in the world for the volume of high-tech exports. According to Chinese exports statistics, these fall into the categories of: computers and telecommunications, life sciences, electronics, weaponry, computer-integrated manufacturing, aeronautics and space, opto-electronic technology, nuclear technology, biotechnology and material design.

The launch of China's first astronaut into orbit in the Shenzhou-V spacecraft in October 2003 epitomized China's engineering achievements. Whereas the USA has greatly scaled down its space programme and the Russian effort has essentially stopped, China is forging ahead. Long March rockets have also provided a satellite launching service on a commercial basis for foreign governments and companies.

As a large country, China has taken a balanced approach, engaging in a broad spectrum of S&T fields. In the 10th Five-Year Plan (2001–05), information technology, biotechnology, new materials technology, advanced manufacturing technology, aerospace and aeronautics were listed as fields in which China should aim for breakthroughs. Micro-integrated circuit design and manufacturing, high-performance computers, opto-electric materials and equipment, biotech pharmaceuticals and agricultural bio-engineering were considered strategic areas in which the country needed to increase its independent innovative capacity. Genetics, ecology and earth science were also considered important priority areas.

As mentioned earlier, China has set itself the target of devoting 1.5% of GDP to R&D in the 10th Five-Year Plan. Having increased its GERD ratio by 0.4% in three years from 0.83% in 1999 to 1.23% in 2002, China seems set to reach this target. China's level of S&T development was summarized by the Minister of Science and Technology, Zhu Lilan, in 2003 as having reached the forefront among developing countries.

Technology-related legislation

With regard to technology-related legislation, China enjoys the rare distinction of possessing intellectual property laws a long time before the enactment of company law. In other countries, company law has usually existed well before intellectual property legislation, which is a relatively recent development. In China, the Trademark Law was enacted in 1982, Patent Law in 1984 and Copyright Law in 1990. China acceded to the Berne Convention for the Protection of Literary and Artistic Works in 1992 and joined the World Intellectual Property Organization the same year. On the other hand, China's Company Law was only enacted in 1993. China passed a Technology Contract Law in 1987, quickly following the enactment of intellectual property legislation, but it was not until 1999 that the more general Contract Law was enacted.

Policy-making structure

Alongside a more or less complete set of legislation, China possesses a well-developed national S&T system. An important change in the policy-making institutional structure occurred when the State Science and Technology Commission became the Ministry of Science and Technology in 1999. This change represented a departure from a structure common in centrally planned economies to one more usual in Western countries, a ministry dedicated to the portfolio of S&T.

The Ministry of Science and Technology is apparently less powerful than the former State Science and Technology Commission, which was chaired by a vice premier and state councillor. Is this a downgrading of the portfolio of S&T? One interpretation is that, as the development of S&T matures in China, the state can and should play a lesser role, leaving room for the private and academic sectors. Moreover, as S&T development is on course and progressing well by itself, there may be less need for state direction, and consequently less attention paid at the highest level of government.

The change came amidst the shift of functions from the State Science and Technology Commission to the Academy of Sciences. Technology transfer, relations with enterprises and many service functions were transferred to the Academy. For instance, the Academy now has the power to certify whether a company pertains to high-tech industry. In accordance with the decentralization directive of 1985, the Academy of Sciences has relinquished control of universities and many research institutes. Instead, the Academy has taken on new functions.

Basic science

In 2002, basic research in China received just 5.73% of GERD, compared with 19.2% for applied research and 75.1% for experimental development. The distribution of R&D expenditure among the three categories has been in similar proportions for more than 15 years. Comparison with other countries reveals a trend towards spending more on applied research and experimental development than on basic research, but the share China spent on basic research, 5.73%, was exceptionally small. The only other countries which spent less than 20% on basic research were the USA at 18.1% (2000) and Japan at 12.3% (1999). The level of S&T development is high in both the USA and Japan; business and industry spent more on experimental development, consequently the proportion for basic research appeared less. It is not a case of basic research being allocated less by the government or the academic institutions. China's small allocation to basic research is well out of line with the practice in other countries.

Up till the early 1980s, basic research was very much emphasized, seen as the necessary foundation upon which everything was built. It was during this period that the decision was made to construct the Beijing Electron Positron Collider, a very expensive facility used in experimental investigations of elementary particles.

In 1985, the watershed decision was made to emphasize the commercialization of S&T and to bring the fruits of science to the people. The pendulum then swung all the way from basic science to applied R&D.

Soon after this policy switch, grave doubts were expressed about the health and viability of basic science. In an effort to prevent its deterioration, a group of scientists initiated the '863' programme, so named because it was started in March 1986. The '863' programme ostensibly set out to maintain China's strategic leadership in the eight areas of: laser, space, biotechnology, automation, information, energy, new materials and ocean technology. In the following 15 years, the '863' programme was allocated altogether 10 billion yuan, a small amount compared with the 78 billion yuan invested in the Sparks programme for rural areas; as for the Torch programme, it has launched 52 High-Technology Development Zones all over China.

Basic science did not wither away immediately after the 1985 shift in emphasis because it had previously been very well supported and nourished. Also, the 1985 decision called for the decentralization of resource allocation, with the result that more funding went directly to the universities. Basic research was able to benefit from this increased direct funding to the universities.

The National Natural Science Foundation has been the main lifeline of the basic sciences since its establishment in 1986, although the Foundation spends the majority of its funding on applied research projects. Funding for the National Natural Science Foundation has been increasing at the rate of 20% each year for several years but its annual budget of 20 billion yuan is still a small proportion of the total national expenditure on R&D of 129 billion yuan. With the increase in its budget, the National Natural Science Foundation has also been elevated in status. As it grows into its second-level

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function of funding of S&T activities, it is fast gaining a status on a par with the Academy of Sciences, which has shed many of its first-level policy-making functions.

There is now much debate among the scientific community in China as to whether a more balanced approach should be taken towards the development of basic science *vis-à-vis* applied R&D. Some hold the view that the present imbalance is a factor why no scientist in China has as yet been able to win a Nobel prize.

Commercialization of S&T

Premier Zhu Rongji has stated that enterprises should become the mainstay of S&T. The Minister of Science and Technology, Zhu Lilan, summarized the direction of S&T development in the 10th Five-Year Plan as 'to innovate and commercialize'.

In 2002, 61.2% of R&D was performed by the enterprise sector, a high percentage compared with other developing countries and well in line with the average for OECD countries. China has surpassed Australia, whose enterprise sector performs 47.5% of R&D. China has emphasized commercialization of S&T since 1985 and has gone from almost totally public-sector-dominated S&T activities to the present position.

An extraordinarily low percentage of R&D is performed by the higher education sector, 10.1%. Countries just above this level are the Republic of Korea with 10.4%, Japan with 13.9% and the USA with 16.8%. These are all countries with a high level of S&T activity where the enterprise sector is very active, resulting in a relatively lower proportion for the higher education sector.

The pressure to commercialize has also fuelled a trend to privatize government functions; there have been many instances of part of a government department or agency becoming a company. Privatization involves the conversion of some public services into privately provided services. This usually results in an immediate gain in revenue, particularly when there is a monopoly provider of services, but when the privatized service should properly be publicly provided, there may be a net loss in social welfare in the long term. An example is the S&T information service, where the level of usage of some information may become much less than is optimal for the country because users may not be able to afford to pay.

While privatization may not be the optimal solution, some have argued that the profit incentive ensures that the service will be provided and at a good standard and that it is better than having no service at all. Privatization of services and goods which should properly be publicly provided is not confined to the S&T system and is quite widespread.

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