SCIENCE TECHNOLOGY INDUSTRY

KNOWLEDGE-BASED INDUSTRIES IN ASIA

OECD

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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– to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

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FOREWORD

Following a Forum discussion by the OECD Industry Committee, the Directorate for Science, Technology and Industry (DSTI) published a report in 1999 entitled *Asia and the Global Crisis: The Industrial Dimension*. This study pointed to key structural weaknesses in the development of knowledge-based industries, especially those based on information and communications

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CURRENCY CODES

Country	Currency	ISO code	National currency per USD (July 1999)
China	Yuan	CNY	8.28
Korea	Won	KRW	1 172
Malaysia	Ringgit	MYR	3.80
Singapore	Singapore dollar(s)	SGD	1.70
Chinese Taipei	New Taiwan dollar(s)	TWD	32.3
Thailand	Baht	THB	36.9
United States	US dollar(s)	USD	–

Source: The Economist, 10 July 1999.

from foreign investment. China should develop its labour-intensive sectors in

INTRODUCTION

As the advanced OECD countries enter into a new era of knowledge-based economies, the question arises as to how well the Asian economies are doing in developing their knowledge-based industries. And, more broadly, how have Asian countries adjusted their policies in response to the challenge of the knowledge-based economy? In the 1970s and 1980s, Asian newly industrialising economies caught the world's eye for their achievements in rapid industrialisation and economic growth. In the 1990s, Asian countries impressed – and puzzled – many people by making major strides into some high-technology industries, notably those based on information and communication chemicals/biotechnology, ICT equipment and services, consumer electronics and the environment industry. These are the industrial sectors reviewed in this study; however, it should be noted that industry definitions and classifications vary widely by country and therefore do not allow for comparative quantitative evaluation.

The underlying conditions required for further development of these sectors are assessed, including in terms of national information infrastructure, education, innovation and foreign investment. Finally, the study summarises key policy issues facing different groups of Asian economies in the continued development of their knowledge-based industries.

FORMULATING NATIONAL STRATEGIES

Asian countries are at different stages of their transitions to knowledge-based economies due to differing levels of economic development and capabilities for producing and using ICT. In part, this reflects the fact that the Asian countries have different visions of how to develop knowledge-based economies as well as varying governmental traditions and styles. They thus emphasise different aspects of the transformation into knowledge-based economies. At a deeper level, their approaches reflect differences in the social institutions, cultural values and capabilities that underpin the political and economic systems of individual Asian societies. They all tend to be top-down approaches, raising concerns about excessive government intervention. These factors have a strong influence on the abilities of various Asian countries to manage the challenge of developing knowledge-intensive industries.

Korea

The Korean Government's vision of a future knowledge-based society emphasises that it will be a creative nation, with competitiveness and living standards at the level of advanced OECD countries. Work on the first draft of the *Cyber Korea 21 Vision* began in March 1997, building on the Master Plan for information promotion (1996-2000) and was further developed in June 1998 under Section 5 of the "Framework Act on Information Production". It comprises three parts: *i)* the vision of a creative, knowledge-based society; *ii)* key initiatives of *Cyber Korea 21*; and *iii)* promotion strategies. The quantitative targets to be achieved by 2002 are shown in Table 1. The basic objectives of the *Cyber Korea 21 Vision* are set out as follows:

- Early establishment of an information infrastructure.
- Increasing productivity and transparency of all economic players, including business, government and individuals, through the utilisation of advanced ICT.
- Promoting new businesses and creating new jobs through the utilisation of ICT.

Singapore

Singapore is following its *Industry 21* blueprint for future industrial development which envisages that its knowledge-based economy will be driven by the twin engines of manufacturing and services. Development will be nurtured under key programmes for electronics, chemicals, life sciences, engineering, communications and media. Singapore also plans to develop high-value-added services in education, healthcare, logistics and headquarters for multinational corporations. A recent competitiveness report by the Committee on Singapore’

- *Developing a global hub* for Singapore to become a switching centre for goods, services, capital and information worldwide, and a hub for business, services and transportation.

- *Improving the quality of life* through a wide range of electronic applications in the economy, society and households.

- *Boosting the economic engine* by using ICT to revitalise Singapore's traditional economic sectors.

- *Linking communities locally and globally* to enhance communication between the Singaporean community at home and abroad and with the rest of the world.

- *Enhancing the potential of individuals* through government provision of improved opportunities and technologically advanced means for lifelong learning.

The action plan entitled *Singapore One* is a major milestone in the markets by developing mechanisms to encourage innovation, foster start-ups,

Box 1. **Malaysia's Multimedia Super Corridor**

On 1 November 1995, Prime Minister Dr. Mahathir Mohamad announced the

Other objectives of the plan are to further develop human resources, research and development, technology acquisition, absorptive capacity, physical infrastructure and business support services; to nurture Malaysian brand names and manufacturers; and to develop more information-intensive processes through adoption of ICT in manufacturing. The eight industry clusters to benefit are electrical goods and electronics; chemicals, including petrochemicals and pharmaceuticals; textiles and apparel; transportation, including automotive, motorcycles, marine and aerospace; materials, including polymers, metals, ceramics 9(ma8.9(e Tw.p -1.1r2.7(ing.)10.6(;ug.)10.661 757 0 0 11.)0.)10.9(9(e)8.2(1 improved environment and natural resource conservation; and new directions for building economic strength and social harmony. There are three action agendas:

- *Investing in information infrastructure* to empower human ability and enhance the quality of life.
- *Investing in people* to build a literate population and adequate ICT manpower.
- *Investing in good governance* to re-engineer the public sector and enhance government service.

Box 2. **Thailand's vision of social equality**

Thailand's information technology plan – *Thailand IT2000* – states:

> *Information technology can play a pivotal role, in particular to support many of the government's policies for better distribution of wealth and opportunities for rural inhabitants; for equal opportunity in personal and corporate development, healthcare and other public services; for solving the chronic traffic gridlock and worsening pollution; for conservation of the nation's natural resources and environment; in addition to making the country a regional hub for finance, manufacturing and trade, transportation and tourism.*

The government recognises that strategies for information technology development must be geared to reduce the substantial gap between the information "haves" and "have-nots", not to widen it. In most cases, it is easy for the more affluent and better-educated segments of society to gain most from the use of information technology while the city-poor and rural residents are likely to be left even further behind. The overriding objective is one whereby information technology applications in support of national development can create equal opportunity and provide benefits for all segments of society, including the underprivileged, the disabled and remote rural residents. Only then can national social and economic development be successful in transforming Thailand into the sustainable economic power-house of South-East Asia where a high standard of living is availab2T 9 0 0 tgrp(aila)12.9(b2T 9 0 0 tgr)16.9(p(aila)292.47010035 Tcv)1ndard of f

China

Apart from strategies for sectors such as science, education and telecommunications, China lacks a comprehensive vision for its transition to a knowledge-based economy. A strategy for revitalising the nation through science and education was framed in “The Decision on Speeding-up Scientific and Technological Progress” jointly issued by the Central Committee of the Chinese Communist Party and the State Council on 6 May 1995. The implementation of this strategy was launched at a national conference on science and technology later that month. Further progress on a national strategy can be expected in China’s next five-year plan to be issued in late 2000.

Despite the lack of a national strategy, in 1998 the Chinese Government initiated a campaign underlining the importance of the knowledge-based economy with the translation of relevant OECD publications, the issuance of a series of studies by Chinese research institutes, and dissemination of information on knowledge-based economies. Newspapers have carried a large number of articles on the topic. Today, there is a broad initial awareness in China regarding the knowledge-based economy, especially among government officials, intellectuals and well-informed citizens. A conference on “The Knowledge Economy and China’s Development: Analysis and Policy” held in July 1999 yielded the following impressions (Dahlman, 1999):

> *First*, there is tremendous interest in the knowledge economy in China, wherrs s [(w)6.8(h)2.2a4a.8(rt)8.2” Tc 0 whrhhsed

STATUS OF KNOWLEDGE-BASED INDUSTRIES

This section reviews current developments in knowledge-based industries in Asia by sector, although the coverage is not uniform across countries. The choice is made based on the importance of a given industry to a country's economy and, to a lesser extent, on the basis of data availability. The industries chosen comprise not only the knowledge-intensive sectors that have developed strongly in Asian countries, but also some that are yet to develop. An attempt is made to review the development of ICT-based sectors (including semiconductors, computers, software, electronics and telecommunications equipment and services) because of their key role in knowledge-based economies. However, the data used in this section are taken from official national sources which are not strictly comparable across countries and reflect differences in industrial groupings and classifications. Knowledge-intensive service sectors are not considered here due to the lack of reliable, systematically collected data on these industries in Asian countries.

Korea

Semiconductors

The semiconductor industry is expected to make a major contribution to Korea's economic recovery in the aftermath of the Asian financial crisis. Accounting for one-third of global production, Korea's semiconductor industry is the third largest in the world and generates some 10% of the value of Korea's exports. However, the sector suffers from certain structural shortcomings. First, the semiconductor market is characterised by cyclical and unpredictable market fluctuations. This increases the vulnerability of Korea's industry, which is dependent on a single product – memory chips –

Telecommunications equipment

Large investments in research and development in the 1980s have improved the technological capabilities of the Korean telecommunications equipment sector. In addition, the openness of the telecommunications equipment market improved after July 1997, when the *Basic Telecommunications and Information Technology Agreement* (ITA) became effective. Despite the forecast of sluggish demand between 1998 and 2000, production of telecommunications equipment has more than doubled over that period and the booming domestic market for cellular phones suggests that not all of the increased production was for export. The domestic market for telecommunications equipment is estimated at USD 6 billion, with imports of approximately USD 2.3 billion. Domestic production is about USD 6.5 billion, of which 42% is exported.

Despite continued research and development, the competitiveness of the Korean telecommunications equipment sector lags behind other advanced countries. Korean firms have acquired advanced production technologies, particularly related to electronic switching systems. However, the industry still lacks core technologies such as materials technologies, and high-quality human resources are also in short supply.

Software

The Korean computer software sector is rated behind more advanced countries, especially for advanced applications. The technology level of domestic firms is judged to lag 10-20 years behind that of the United States while, with regard to application software, Korean firms are still one level below Japanese firms. The sector is characterised by middle-level technology and is making progress in certain areas such as database management systems. Domestic production is valued at around USD 6 billion, with only 1.6% of output exported. The low level of exports and high reliance on imports for systems software (30%) is a continuing cause for concern.

Problems stem from a lack of brand-name recognition as well as a dearth of qualified software engineers. Korean software companies have experienced difficulties in raising capital in the wake of the Asian financial crisis. Software development is also somewhat hampered by the lack of adequate protection of intellectual property rights. According to the Business Software Alliance, Korea ranks sixth among countries in software piracy, which was as high as 78% in 1994, and the country has been among those on the watch list of the Special 301 Review of the United States. Piracy makes it difficult for software companies to earn adequate returns to investments, which in turn leads to difficulties in raising funds on capital markets.

Specialty chemicals

Despite sustained growth since the mid-1970s, the Korean specialty chemicals industry has not advanced technologically due to a continued reliance on imported components. This sector includes pharmaceuticals, pesticides, cosmetics, dyestuffs and organic pigments, paints and printing inks, and other high-value-added chemicals. Production value is estimated at USD 18 billion, with pharmaceuticals and cosmetics serving as twin engines of growth. Since 1990, exports have increased from about 4 to 9% of the value of output.

The Korean specialty chemicals sector is highly reliant on imports for high-technology and high-value-added core inputs, while purely domestic products are generally low-value-added goods. The industry imports 60-70% of its intermediate inputs from abroad and had a trade deficit with the United States of USD 3 billion in 1997. Approximately 56% of firms in this sector rely on imports for key technology-intensive components, while 44% of firms have developed their own production processes and inputs. It is estimated that in some areas, *e.g.* the development of new pharmaceuticals, Korea’s technological capability is 50% below that of US firms.

Biotechnology

The Korean Government has designated biotechnology a key industry for the 21st century and is supporting research and promoting technological advances in related fields. However, there are considerable gaps between scientific research, applications research and technology commercialisation, and most production technology is imported from abroad. In 1993, the government initiated the *Biotechnology 2000 Programme* to fund research for a period of 14 years. Implementation involves seven government ministries, and the budget for biotechnology has been increased by 40% over earlier years.

There are an estimated 150 Korean companies in the biotechnology sector, of which two-thirds are large businesses and the remainder SMEs. Of the 3 000 people employed in this industry, more than half are engaged in research and development. Production was valued at USD 900 million, of which 40-50%

the larger firms, biotechnology is a sideline activity to their core businesses in

Figure 2. **Composition of Singapore's electronics exports, 1980-93**

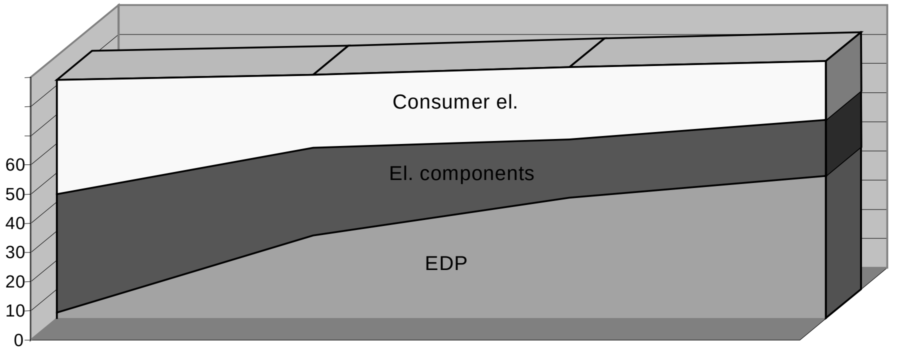


Figure 3. **Singapore'**

categories. The comprehensive and internally consistent structure of its IT industry has helped Chinese Taipei develop into a "one-stop shopping centre" for importers.

Chinese Taipei's onshore IT production value was USD 16.4 billion in 1996, a 20.8% increase from 1995. Main products include monitors (32.6% of

Technological and structural upgrading of the electronics industry has increased the proportion of value-added products in exports such as electronic data processing equipment, including mainly personal computers and laptops (Box 4). The importance of low-end consumer electronics is declining, while the proportion of relatively low-value-added electronics components has remained low (Figure 5).

Box 4. **Chinese Taipei's information technology industry**

Through continuous upgrading of its technological capabilities and industry structure, Chinese Taipei's information technology industry managed to stay internationally competitive while climbing upwards in the value-added chain. In the early 1980s, the country specialised in low-cost assembly with price as the main competitive advantage and slender profit margins. In the mid-1980s, Acer, Mitac and other vendors in the electronic games segment began assembly of semi-finished goods, and established the foundation of Chinese Taipei's PC board-based peripherals industry centred around domestic motherboards. During this period, competitive advantage derived from an abundance of skilled engineers who, operating out of SMEs as specialist manufacturers, became a vital part of the global IT manufacturing structure.

In the early 1990s, Chinese Taipei began to face high land and labour costs which, in addition to lower tariffs granted other nations through GSP preferences, created pressure on the labour-intensive segments of the industry. Many manufacturers moved their labour-intensive procedures offshore. Mass production capability created huge demand for components and the bulk of investment went into semiconductor components, which in turn made 8-inch semiconductor wafer production a driving force in the industry. Effective competition depended on access to capital and technology.

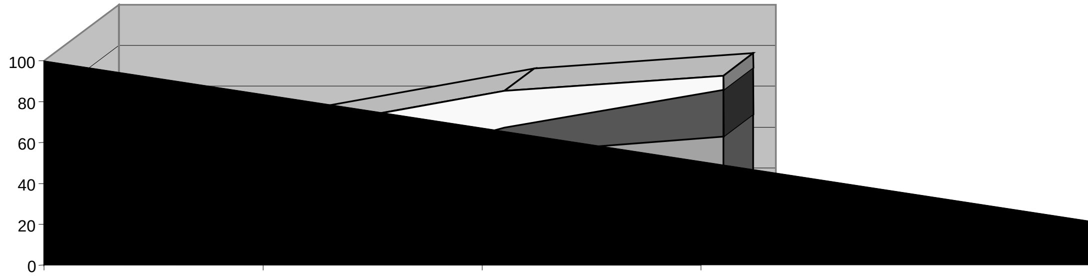
In 1995, new logistics systems jointly invented by Compaq and Mitac required IT manufacturers to gain proximity to markets, marketing support and maintenance services. Companies set up assembly plants in their main markets and the ability to attract staff with international experience became a key to success. Many companies contracted out production to Chinese Taipei and other Asia-Pacific countries, who invested heavily in production facilities and established assembly plants close to main markets.

The focal point of international competition in the IT industry will continue to change. Due to the lack of cutting-edge key technologies, Chinese Taipei will need to rely on its mature operational structure to remain competitive. Over the years, it has evolved a high level of integration between production and marketing, a competitive advantage that new entrants to the market will find difficult to match. Furthermore, many IT companies in Chinese Taipei acquired access to capital through stock issues, which facilitated their expansion.

Well-established IT companies such as Asustek have begun to target the top end of the major international markets in order to earn premium profits, while companies such as GVC, Elite and FIC have chosen to target the major international vendors. These companies have worked towards a global production strategy and maintenance system and are well positioned to benefit when IBM, Compaq and other major firms increase their global market share. Motherboard manufacturers that target vendors at the national level, such as Microstar, Gigabyte and Soyo, are also well established in their respective markets. Although Chinese Taipei's motherboard manufacturers will continue to face competition from Intel, they are likely to retain their leading world position.

Source: Chinese Taipei Industry Technology Information Service (1997).

Figure 5. **Composition of Chinese Taipei's electronic exports, 1980-93**



Until 1997, telecommunications services in Chinese Taipei were dominated by ChungHwa Telecommunications, an offshoot of the General Directorate of Telecommunications. Total revenue for 1996 was

Biotechnology

Since the inception of its biotechnology programme in the early 1980s, Chinese Taipei has made considerable progress. Supported by the government's biotechnology and pharmaceutical research programmes, a research infrastructure has begun to take shape in various institutes within Academia Sinica and other research centres related to the biotechnology industry.

electronics industry has more recently benefited from increased domestic demand. Future prospects are somewhat mixed (Box 5). Measures initiated to address the Y2K problem, progress on the Multimedia Super Corridor project, the launch of the Malaysian Exchange of Securities Dealing and Automated Quotation (MESDAQ), combined with ongoing corporate investments in enterprise software, are providing a platform for recovery of the industry and production of electronics products.

Box 5. **Prospects for the Malaysian electronics industry** components and parts, semiconductors, and consumer and industrial electronics. Yet, the industry remains concentrated on low-end assembly operations with a high import content of inputs. Recognising this, the government is encouraging the development of upstream higher-value-added activities such as wafer fabrication facilities and the development of the information technology and multimedia industries.

Chemicals

The chemicals industry, which remains concentrated on industrial

Partnership Programme (MMBPP) under the current development plan. In the present stage, the programme is developing products derived from oil palm and other indigenous natural resources. Research focuses on development of natural products to increase the value of traditional herbal medicines and on enhancing the economic value of oil palm (MNCSRD, 1998). It is hoped that the programme, which emphasises research as well as human resource development, will lay the technological basis for Malaysia's future biotechnology industry.

Thailand

Information technology

Thailand's IT industry experienced dramatic, double-digit growth for more than a decade from 1989 to the onset of the Asian crisis in mid-1997. The IT market in Thailand, broadly defined to include hardware, software and services, was worth THB 27 109 million in 1998, a decrease of 39% from 1997 (Figure 6). Hardware accounted for 50%, software 20%, and IT services 30%, respectively, in 1999 (Figure 7). The share of hardware fell from 70 to 50%, and those of software and IT services increased from 15 to 20% and from 16 to 30%, respectively, over the second half of the 1990s. Telecommunications was estimated to have increased in Thailand by 42.3%, from USD 1 647 million to USD 2 344 million, between 1992-97.

Despite impressive growth, the information technology industry in Thailand faces a number of challenges and structural weaknesses. First, Thailand's national information infrastructure, especially telecommunications and Internet access, was under-invested and over-regulated, which led to high levels of user charges that prevented an increase in telecommunications and Internet use. Second, the weakness of the Thai education system and the lack of research and development presents a long-term obstacle to upgrading the IT industry into a serious player in the global technology market. The industry

Electronics

Thailand's electronics industry is an important growth sector, with shipments of electronic products, particularly computer parts and integrated strong bargaining positions. Wages increased faster than prices. As a result of rising labour costs, the electronics industry is losing its advantage as a labour-intensive industry. Recent years have seen relocation of the industry to China and the Philippines, such as the board-assembly testing plant of Hana Microindustry Plc from Lumphun to Shanghai, China, where labour costs were said to be 40% lower. It has been argued by Mr. Sompong Nakornsri, President of the Federation of Thai Industries' Electronics Club, that if the electronics industry cannot manage to move beyond the assembly stage, it is set to become a "sunset industry" within five years, following the path of other labour-intensive industries such as textiles and footwear.

Another issue facing the Thai electronics industry is its low margin of value added. According to the Minister of Industry, the local content of electronics products has remained between 20-30%. In spite of improvements made in the late 1990s, the level of local content was still 29% in 1998 (Table 2).

and the price of local Thai components are not internationally competitive. The Thai electronics industry is faced with other constraints due to its high degree of reliance on foreign firms. Many Thai manufacturers are branch plants with limited procurement and marketing authority. Further difficulties are caused by the lack of transportation and communications infrastructure in Thailand.

Tariffs and trade policy have also affected the development of the Thai electronics industry. Prior to March 1994, most electronic components were subject to import duties of 35%, except for components imported for use in computer and television assembly. Since then, the import duty on the majority of electronic components has been reduced to 1% to favour local assemblers. However, this impedes the development of the electronics industry, as imported parts are taxed at 1% and materials at 20%, which tend to make it more expensive to manufacture components in Thailand than to import them. Recently the government has decided to cut import duties on some raw materials used by the electronics industry as part of a major tax overhaul.

Software

The Thai software industry was estimated at THB 7 billion in 1999 and was projected to grow to THB 53 billion over the next five years (Sribhibhadh, 1999). The Thai Government has identified the software industry as a sunrise sector and expects it to develop into a main foreign exchange earner. In 1999, a Software Park was established to promote the development of the industry. Nevertheless, the Thai software industry has experienced setbacks in recent years. There used to be more than 1 000 registered software houses, but today less than 500 firms remain in business, with 90% having around 30 staff (Karnjanatawe, 2000a). Some 18 local software developers have set up at the Software Park, well below the target of 100 units for forming a national cluster for the software industry in Thailand. According to the software industry, lack of support and funding from the government have affected the ability of the Software Park to attract firms. Weaknesses include inadequate telecommunications services and poor meeting and training facilities.

Other obstacles include a lack of protection of intellectual property rights. First, the country has a very high rate of piracy – over 80% – including both end-users and counterfeiters, despite the introduction of a Copyright Law covering software in 1995. For the consumer software market, there was a 90% piracy rate, which dampened the size of this market from an estimated THB 1.5 billion to a mere THB 200 million (Waltham and Dasaneeyavaja, 1999). Second, the Thai software industry suffers from a severe lack of qualified software technical personnel. Third, there is a lack of R&D activities in Thailand, including on reverse software engineering. Fourth, it is difficult for software companies to raise capital from banks.

For the development of a healthy Thai software industry, the government should take the lead as a user of software to help boost domestic market demand. Government agencies should not compete with the private sector in providing services such as professional training. It should help make available market and technology intelligence to cater for the urgent need for information. There is a need to create venture capital markets for the development of software companies. In the initial stage, the government can help by making available seed capital and soft credits for software companies to get off the ground. Government assistance might be given to encourage the use of IT in the restructuring of traditional Thai industry. Finally, long-term infrastructure support in the areas of R&D, education and affordable and accessible telecommunications, and better protection of IPR are necessary conditions for sustainable development of the software industry.

Telecommunications

Thailand's telecommunications sector is run by two state-owned companies, the Telephone Organisation of Thailand (TOT) and the Communications Authority of Thailand (CAT). TOT controls all national telecommunications and services to neighbouring countries, such as Laos, Cambodia, Myanmar and Malaysia, while CAT is responsible for all international telecommunications services except countries covered by TOT. Private sector participation in the provision of telecommunications services started in early 1988 when Cable and Wireless signed an agreement with the Posts and Telegraph Department to provide satellite service. Since then, TOT and CAT have entered into Build/Transfer/Operate (BTO) agreements with a host of private sector firms to provide telecommunications services in Thailand.

In 1994, a decision was made to allow for greater private sector participation in the telecommunications market. A National Telecommunications Committee was to be set up to replace the regulatory functions of TOT and CAT. According to the telecommunications master plan approved in 1997, TOT and CAT would in turn be privatised in 1999. The objective is to open the market in the form of concessions to operate telecommunications networks and services in competition with TOT on a zone basis. TOT will predominately be responsible for long-distance interconnecting facilities between each zone. The terms of concessions will be shifted from BTO to BOO (Build/Operate/Own) licences once the regulatory framework is put in place (TBOI, 1996b). However, the process has been slow due to vested interests and the impacts of the Asian crisis. It is estimated that the sale of shares might take several more years than expected and telecommunications market liberalisation will not be completed before 2006.

Before the Asian crisis, the Thai telecommunications industry invested heavily in expansion of capacity mainly through foreign borrowing, which became expensive to repay because of the devaluation of the baht in 1997. As a result, all telecommunications companies reported losses and were struggling in 1999. There was debt restructuring during 1999, which proceeded within the framework of payment rescheduling and the issuance of preference shares. All but one telecommunications company listed on the stock market had entered debt rescheduling with their creditors by the end of 1999. The Thai telecommunications sector is thus confronting both the implementation of the liberalisation programme and the problems of foreign-exchange-related losses and return to profitability.

China

Information technology

China’s information technology industry, comprising semiconductors, computers and telecommunications equipment, produced goods worth USD 46.3 billion in 1997. Supported by strong domestic demand, this industry grew on average by 27.5% per year between 1992-97. As one of China’s main export industries, the sector exported products to the value of USD 25 billion in 1997, reflecting a 16% increase on the previous year. The sector also includes colour television sets, of which China is the world’s largest producer, with output of 240 million sets in 1997.

Computers and telecommunications equipment are the fastest growing segments of the information technology industry in recent years. The production of personal computers reached 1.7 million units in 1997, a four-fold increase over 1992. Domestic computer production accounts for 60% of domestic sales. In 1997, computer exports were valued at USD 8.7 billion and imports at USD 4.4 billion, leading to a trade surplus of USD 4.4 billion for that year.

The main problem facing the Chinese information industry is its low technological capabilities, which will severely check further development of the sector. Both in terms of the scale of the sector and its technological level, China lags behind the advanced countries in international competitiveness. While China is dependent on imports for core technologies and for software, the industry's absorption capacity for imported technology and know-how is considered to be limited.

Telecommunications services

Despite limited progress in liberalisation of China's telecommunications services, the sector (which includes postal services) has grown very rapidly since the second half of the 1980s, with growth exceeding that of GNP (Figure 8). In 1997, telecommunications services in China were valued at USD 19.9 billion. Through heavy investment, China's fixed telephone net capacity expanded from the 17

2 000 software companies and approximately 100 000 software professionals. Growth in the software sector has been supported by: the active involvement of the government; the large number of well-trained software professionals in China; the high growth rate of the Chinese economy and increasing applications of information technology; and substantial public investments in information infrastructure.

The Chinese Government has taken active steps to promote the software industry in the last decade. As a result of the *Torch Plan* of the Ministry of Science and Technology, eight software industrial parks were established by the end of the 1990s (Table 3). Several other software parks have been developed under the initiative of China's Ministry of Information Industry.

However, China's software sector still suffers from a number of shortcomings. First, venture capital markets and other sources of financing need to be developed to fulfil the capital requirements of the software industry. Second, further development of the software sector awaits a regulatory framework including effective protection of intellectual property rights so as to provide rules of the game and their enforcement in the marketplace. Third, English is the common language of the international software industry and Chinese software engineers are at a disadvantage in this regard compared to their close competitors, *e.g.* the Indian software industry.

Table 3. **Main software parks in China**

Name	Starting year/location	1997 production USD million	2000[1] production USD million	1998 employees	2000[1] employees

Consumer electronics

China ranked fourth in world production of consumer electronics (*e.g.*

Chemicals

The Chinese chemicals industry is not a technology-intensive sector and suffers from structural problems, low efficiency and over-capacity. As a result, low-value-added chemicals and materials dominate production and exports, and the industry has not branched out to production of specialty chemical products. The production value of the Chinese chemical industry was USD 37.3 billion in 1997, marking an increase of 9% from 1996. However, sales revenues were just USD 33.5 billion, translating into an increase of 1.8% for the same year. According to a survey of some 4 386 chemical industry enterprises, profits decreased by 50% in 1997 and 41% of enterprises ran at a loss. State-owned enterprises were responsible for 52% of all losses in 1997. The export value of chemicals products was USD 34.5 billion, accounting for 10.6% of China's total exports in 1997. China is a net importer of chemical products, with a sectoral trade deficit of USD 5.8 billion in 1997.

Environment industry

China's environment industry is underdeveloped, particularly compared to the country's need for environmental protection equipment and services. The industry employed 1.7 million people, with production valued at USD 6.3 billion, accounting for only 0.7% of China's GNP at the end of the 1990s. There are about 9 000 enterprises in this industry, of which 90% have fixed capital of less than USD 1.8 million419uB6.2(h)2.6(em)81.5nn 0/70.8(t)-6r(of)-5y 94

DEVELOPING KNOWLEDGE-BASED INDUSTRIES

The Asian countries need to fulfil some key conditions in order to achieve continued development of knowledge-based industries. Broadly, these include enhancing market-based incentive mechanisms and improving framework conditions while reducing excessive government interventions in order to foster self-sustainable development of knowledge-based industries which are dynamic and responsive to market conditions and which are developed in line with Asian comparative advantages. A number of policy areas, such as enhancing market competition, fostering entrepreneurship and promoting SMEs, undertaking industrial restructuring, reforming corporate governance, stimulating investment in intangible assets, and developing the venture capital market, are important in in telecommunications from 0.73% of GDP in the 1980s to 1.52% in the 1990s. For the more advanced countries in Asia, such as Korea, Singapore and Chinese Taipei, the levels of investment in telecommunications decreased somewhat in the 1990s from that reached in the 1980s, reflecting that these countries have passed the period of intensive investment in infrastructures. All available statistics on Thailand indicate inadequate investment in telecommunications throughout the 1980s and 1990s. Thailand's level of telecommunications investment as a percentage of GDP and of gross capital formation was the lowest among these countries and, more importantly, there was a decline in investment during the 1990s.

To different degrees, the Asian countries have all achieved improvements in their information infrastructures. Telephone communication capacity has increased steadily over time. A comparison between the average between 1992-96 and the figure for 1999 indicates that telephone infrastructure

		China	Korea	Malaysia	Singapore	Thailand	Chinese Taipei	High-income OECD[1]

Gaps with regard to the provision of information infrastructure between urban and rural areas remain large in most of the Asian countries. In rural areas, facilities are mostly lacking and need to be significantly improved. For example, in Thailand, it is estimated that only one-third of the population residing in large cities would benefit from a doubling of the number of telephone lines from one for every ten persons to one for every five persons between 1996 and 2001. The 1 million telephone lines installed in the late 1990s by a private firm in the provincial areas still only serve large cities where revenues are highest. As a result, many sub-districts and villages in Thailand are

Table 6. **Commitments of selected Asian economies under the WTO Agreement on**

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Box 7. **Singapore's educational reform**

Learning without thinking is labour lost; thinking without learning is perilous
Confucius (quoted in a Singapore subway poster campaign)

Singapore, due to the strong influence of Chinese culture in its educational system, is faced with the same need to reform its educational system as China. Having learnt from the Asian crisis of the importance of innovation for a maturing economy in general and for the advanced IT industry in particular, Singapore is now pushing forward its educational reforms with renewed vigour. In its 1998 budget, education received an increase in funding of 30%, with expenditures of SGD 2 billion in 1998 (or 3.6% of GDP).

Reform measures include: spending of SGD 2 billion in the next five years on installing computers in schools; reviewing university entrance criteria, with greater attention being paid to extra-curricular activities and less emphasis placed on grades; overhauling the entire syllabus on advice from Cambridge, Harvard and Japanese universities; allowing A-level students sitting literature exams to take their texts into the examination rooms as a way of encouraging literary appreciation rather than learning-by-rote. Other efforts aimed at boosting innovative ability include: implementing a *National Innovation Framework for Action* building on previous initiatives, encouraging industry to be more creative in R&D and encouraging links between educational institutions and industries as a way of fostering innovation.

Korea, China and Singapore are slowly recognising the shortcomings in their educational systems. In Korea, the national secondary education system, which emphasises preparation for university admission examinations, has bred uniformity and inflexible mindsets. Similar problems exist in the Chinese educational system, as indicated by recently released results of a national survey on education which concluded that the Chinese education system was too exam-oriented. Some Asian countries recognise that they can benefit from co-operation with Western universities, which teach more creative thinking, and are now using ICT for online educational exchanges. Singapore is actively exploiting opportunities for co-operation with Western universities, including the facility for electronically transmitting lectures conducted by an MIT professor in the United States to classrooms at the National University of Singapore. Singapore also provides incentives for world-class educational institutions such as INSEAD to set up facilities in Singapore (Box 7). In addition, Virtual College offers a large number of modules in engineering, information technology and business education, providing students in Singapore with access to programmes in the United Kingdom (Robertshaw, 1999). Chinese Taipei, which has the same cultural origins, has shown some entrepreneurial spirit and the ICT sector as a whole has been innovative. Benefiting from its pursuit of overseas education, Chinese Taipei has also been more successful than other Asian countries in fostering innovative mindsets (Box 8).

Box 8. **Chinese Taipei's experience with overseas education**

Efforts to develop Chinese Taipei's electronics industry began as early as 1974 when the Ministry of Economic Affairs set up the *Electronics Industry Development Centre* (EIDC) under the newly established *Industrial Technology Research Institute* (ITRI). Chinese Taipei's semiconductor industry got its start when EIDC, in collaboration with the Radio Corporation of America, developed a manufacturing process for integrated circuits. Thirty-eight young scientists and engineers, sent to the United States to receive training

experience after their education, meaning that the benefit of having experienced scholars and engineers returning from more industrialised countries will come to an end in 5-10 years (Sun, 1999).

Box 9. **Shortcomings in Korean innovation capabilities**

Technology imported from abroad has played an important role in Korea's rapid economic development. The most important sources have been the technology embodied in imports of capital and goods, and licensing arrangements. Following the liberalisation of licensing arrangements in 1978, royalty payments rose from an annual average of less than USD 100 million to USD 1 billion by 1990, and to almost USD 2 billion by 1995. In addition, Korean businesses have participated in joint ventures with multinational corporations and acquired foreign firms to gain access to technology. In contrast, the inflow of foreign direct investment, a major source of technology for many countries, has been very low in Korea, reflecting high barriers in the past. As Korean firms have become major competitors in many fields, foreign companies are less willing to sell them technology, making domestic research and development programmes in Korea more important.

Three-quarters of Korean scientists and engineers with PhD degrees are employed by universities, which accounted for less than 10% of total R&D investment compared to the OECD average of 18%. The relatively limited role of the universities has hindered basic research, which is considered to be important for building longer-term innovative capability. Although the government has sought to strengthen R&D activities in universities by expanding budgetary resources, the gap between university research and industry remains large.

Source: OECD (1998).

Singapore, which is to a large extent engaged in medium-level assembly, stands one level below Korea and Chinese Taipei in terms of technological sophistication. Countries such as Malaysia, Thailand and China, which are involved in basic electronics assembly, are further behind. Problems stem from the low level of R&D inputs, including both R&D personnel and expenditures (Table 8). Enterprise R&D expenditures and research co-operation between universities and companies are insufficient. Reforms are needed to stimulate R&D investments by the private sector, develop enterprise innovative capability, enhance the role of the universities in R&D activities, and disseminate technology and R&D results.

Table 8. **R&D statistics for key Asian economies**

	CN	KR	MY	SG	TW	TH	High income OECD[1]
Scientists/engineers in R&D per million people (1981-95)	537	2 636	87	2 512	2 114[2]	173	3 175 (1993)
Technicians in R&D per million people (1980-95)	187	317	88	1 524	861[3]	51	n.a.
Expenditure on R&D as a % of GNP (1980-95)	0.6	2.8	0.4	1.1	1.5[3]	0.2	2.3 (1981-96)
Business expenditure on R&D as a % of total R&D expenditure (1997)	46	63	73	73	58	15[2]	56
Degree of technological co-operation among firms (2000)[4]	3.93	3.94	4.26	6.16	5.90	3.54	4.59
Degree of research collaboration between universities and firms (2000)[4]	3.58	4.11	3.59	6.03	5.27	3.05	4.77
Ranking in overall S&T competitiveness (out of 59 countries) (2000)	28	22	31	9	12	47	15

Key: CN = China; KR = Korea; MY = Malaysia; SG = Singapore; TW = Chinese Taipei; TH = Thailand.
1. 23 OECD countries with 1998 per capita GNP of USD 9 361 or more.
2. Researchers, 1985-95.
3. Average, 1985-95.
4. Measured on a scale of 1 to 10.
Source: World Bank, *World Development Indicators 2000;* Asian Development Bank, *Key Indicators 1998;* IMD, *World Competitiveness Yearbook 2000;* Council for Economic Planning and Development, *Chinese Taipei Statistical Data Book 1997*.

Countries such as China, Singapore, Korea and Malaysia (Box 10) have made the improvement of their innovation capabilities a priority in their development strategies. However, these countries face financial and human resource constraints due to their levels of economic development. There is also a need to develop a market-based innovation system, with public support facilitating – but not substituting for – private sector investment in innovative activities. Finding the right balance between the roles of government and industry is fundamental to developing innovation capacity in these countries, not least because of their traditionally government-led growth strategies. The development of a market-based national innovation system should place high priority on making knowledge-creating institutions more responsive, and on strengthening market mechanisms and framework conditions for innovation-based market competition. This will be key in encouraging firms to shift their attention and resource allocation to innovation, enabling them to become generally more competitive and raising their capacity to initiate novel products and activities.

Box 10. **Malaysia's innovation reforms**

Malaysia lacks the R&D capability required to support the development of the economy. Problems include: a low input level of R&D resources, at 0.22% of GDP, and a declining [redacted] and insufficient human resources, as seen in the large disparities between the type and number of scientific and technological workers produced and required by the nation. According to Malaysia'

Table 9. **Assessment of investment conditions in selected Asian economies**

	CN	KR	MY	SG	TW	TH	ID	PH	VN

engineers and managers are only one-third of those of their counterparts in Thailand and less than one-half of those of their Filipino counterparts (Panichapat and Kanasawat, 1999).

FDI competition will be on the basis of factors that individual Asian countries can provide, and each country must enhance those conditions which will best allow it to gain domestically from inward investment. For example, China is most competitive in terms of labour supply and costs, as well as providing a vast potential market. Singapore, with the highest labour costs in the region, is more attractive than China in terms of its infrastructure facilities and the network of local competent suppliers. China would have an advantage over Singapore in drawing investments in labour-intensive mass production of low-end components and sectors, while Singapore would be attractive for foreign interests investing in regional distribution facilities and logistics and medium-to-high-end components and sectors. Given the regional differentiation in comparative advantages, it is important for individual countries to develop new competitive edges over time while improving overall conditions for FDI. However, a strategy that depends exclusively and/or excessively on FDI and foreign technology, and that neglects the development of indigenous technological and innovation capabilities, is not sustainable in the long run.

level with industrialised countries in terms of microelectronics-based industry production, and in some instances, they may be even ahead of the industrialised countries. They have acquired a skill base (including production and consumption experience) and the technological capability necessary for maintaining a strong position in ICT industries. ICT sectors in these economies are maturing and firms are slowly but steadily graduating from the "catching-up" phase of development into a phase of regional technical leadership.

For these economies, the challenges of further development include:

- Although these economies are likely to remain export-oriented in their ICT industries, they should ***strengthen links between production and domestic demand***, not just gearing output to export markets. The links between ICT industries and domestic demand should be developed with regard not only to domestic consumer markets but also to other industries and sectors of the domestic economy in order to speed up the process of restructuring of traditional industries, and upgrading the economic structure in general, through ICT applications. This will in turn give a demand boost to ICT industries, as companies need to develop differentiated, price-competitive, high-quality ICT-related products and services to meet both domestic and overseas demand. It will also further the development of local suppliers of inputs and components, thus contributing to the process of industrial restructuring. In this context, further liberalisation and deregulation of regional markets could help to create economies of scale for Asian producers in locally oriented products.

- At this stage, these governments should focus on ***enhancing key framework conditions*** and fostering a market environment for knowledge-based industries, and should refrain from more direct and possibly distorting interventions. Further industrial development will depend on an efficient institutional and microeconomic infrastructure, including the efficiency of factor markets, extension of science parks, development of venture capital markets, enhancing conditions for SMEs, appropriate competition policies, and fiscal incentives to intangible investment such as R&D and personnel training.

- Progress in ICT-related sectors, particularly computer software and electronic commerce, will depend on governments should provide a conducive environment through the adaptation and creation of framework conditions to support progress in more advanced knowledge-based activities.

Malaysia and Thailand

Countries included in the second tier of Asian industrialising economies are Malaysia and Thailand (as well as the Philippines and Indonesia, which are not covered by this study). Despite the differences between these two countries in terms of income levels, information technology production and exports, and human resource and technological capabilities, they share the following

China

China’s present development policy focuses on low-end, labour-intensive electronic products and some other technology-based sectors. This policy seems viable in the medium term. China may have the potential to catch up to the lowest level of industrialised countries in ten years (most optimistic scenario) to

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