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INVESTMENT AND TECHNOLOGY POLICIES FOR COMPETITIVENESS:

Review of successful country experiences

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PREFACE

This paper discusses the role of foreign direct investment in transferring technology, building technological capabilities and enhancing competitiveness. It highlights the important role that foreign direct investment can play in the transfer of technology, but also emphasizes that the latter should be maximized and complemented by appropriate country policies. The paper examines competitiveness in its contextual setting of globalization, growing integration and rapid technical change, before developing an analytical framework with which to consider technology and capacity building. On the basis of its evaluation of the case studies of South-East Asian countries, the paper considers the strategies used successfully to build domestic capabilities, providing a broad set of policy options from which to choose.

This paper was prepared for the United Nations Commission on Science and Technology for Development by Sanjaya Lall, Professor of Development Economics, Oxford University. Comments were received from Mr. Mongi Hamdi, Mr. Shin Ohinata, Ms. Philippa Biggs and Ms. Dong Wu of the UNCTAD Secretariat. Production assistance was provided by Ms. Laila Sède. The cover page was designed by Mr. Diego Oyarzun-Reyes. It draws on and synthesizes work carried for UNCTAD and other United Nations entities.

Comments were also received from Professor Slavo Radosevic, of University College London.

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ABBREVIATIONS AND ACRONYMS

ASEAN	Association of South-East Asian Nations
CETRA	China External Trade Development Council
CPC	China Productivity Centre
CSTD	Commission on Science and Technology for Development
ERSO	Electronic Research and Service Organization (Taiwan Province of China)
FDI	foreign direct investment
GDP	gross domestic product
HAN	Highly Advanced National Project (Republic of Korea)
HT	high-technology (exports)
ICTs	information and communication technologies
ISI	import substituting industry
ISO	International Organization for Standardization
ITRI	Industrial Technology Research Institute (Taiwan Province of China)
KDB	Korea Development Bank
KIST	Korea Institute of Science and Technology
KOTRA	Korean Overseas Trade Agency
LAC	Latin America and the Caribbean
LT	low-technology (exports)
M&A	merger and acquisition
MENA	Middle East and North Africa
MIMOS	Malaysian Institute of Microelectronics Systems
MT	medium-technology (exports)
NAFTA	North American Free Trade Area
NIEs	newly industrialized economies
NSF	National Science Foundation
OECD	Organisation for Economic Co-operation and Development
OEM	original equipment manufacture
PC	personal computer
RB	resource-based (exports)
R&D	research and development
SMEs	small and medium-sized enterprises
TNC	transnational corporation
TSMC	Taiwan Semiconductor Manufacturing Company
UNCTAD	United Nations Conference on Trade and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization

VCR	video cassette recorder
VSLI	very large integrated circuits
WTO	World Trade Organization

EXECUTIVE SUMMARY

This paper addresses the role of foreign direct investment (FDI) in technology transfer and learning, particularly by Transnational Corporations (TNCs). It highlights the important role that TNCs can play in the transfer of technology, but emphasizes that the latter should be maximized and complemented by appropriate country policies. It identifies key trends in the global economy to demonstrate that technology-intensive products have the fastest-increasing share of growing world trade, and that developing countries should therefore develop capabilities in technology-intensive products. It further identifies the notable success achieved by South East-Asia.

The paper also discusses the role of FDI, research and development, licensing, information and communication technology infrastructure and human capital as key structural determinants of industrial competitiveness, which technology policy should focus on. It considers FDI-targeting strategies, and argues that there is a prominent role for policy interventions. On the basis of its evaluation of the country case studies in the Annex, the paper considers the strategies used successfully to build domestic capabilities, providing a broad set of policy options from which to choose. However, there is no single path to competitive success. The paper emphasizes the variety of paths followed by different countries. It summarizes conclusions from its review of the key issues surrounding strategic competitiveness and country strategies.

On the basis of its review of the success achieved by South-East Asian countries, the paper reviews and evaluates the country experiences of three old Tigers (Republic of Korea, Taiwan Province of China and Singapore) and three new Tigers (Malaysia, Thailand and Philippines) in the Annex. These case studies can serve as a practical illustration of some of the challenges involved, and the means and policy measures by which technological development can be achieved.

This paper was prepared as a background concept note for the Panel of the United Nations Commission on Science and Technology for Development on "Linking FDI, Technology Development for Capacity-building and Strategic Competitiveness", which met in Colombo, Sri Lanka, from 15 to 17 October 2002.

United Nations Conference on Trade and Development

INVESTMENT AND TECHNOLOGY POLICIES FOR COMPETITIVENESS:

Review of successful country experiences

INTRODUCTION

Rapid technical change and accelerating globalization are radically changing the context for economic development. These changes offer developing countries both enormous promise – of massive productivity increase and more access to new resources and markets – and considerable risk – of economic dislocation, stagnation and marginalization. This paper discusses the central role of technological capabilities in building competitiveness, focusing on the interaction between foreign direct investment (FDI) and domestic technological effort.

International competitiveness is more than ever before at the core of industrial success, and it is taking new forms. Trade liberalization is forcing enterprises to face unprecedented global competition in domestic as well as foreign markets. The falling "costs of distance" make this competition more immediate and intense than in the past. Rapid technical change forces producers to constantly upgrade their process technologies and introduce new products. It also changes patterns of trade, with product segments based on research and development (R&D) growing faster than less technology-intensive segments. Innovation itself is more costly and often more risky than before, with a continuing high concentration of advanced R&D spending by country and enterprise. There is now greater inter-firm and cross-national collaboration and networking in innovative effort.

One important consequence of liberalization and technical change is that technology and capital are far more mobile than before, with FDI playing a key role in resource mobility. However, the role of major foreign investors - the transnational corporations (TNCs) - goes much further than transferring productive resources: it includes the organization of economic activity across national boundaries in new ways, with production and services linked across far-flung sites to take advantage of fine cost, capability, logistic and market differences. The linkages involve not only TNC affiliates but also a whole array of linked but independent enterprises, both transnational and local.

The changing organization of international production, with tightening links to exploit location advantage in a context of constant technological ferment, has crucial implications for capability building in the developing world. Does it mean, for instance, that developing countries can benefit from the "global shift" in production (the term comes from Dicken, 1998) by simply opening their economies to world markets and resource flows? Or is there still a role for economic policy interventions by Governments? If there is, how should countries treat FDI (the import of technologies in internalized form) as compared with other forms of technology import (in externalized forms) to support the development of capabilities in national enterprises? Are FDI and local technology development complementary or competitive? What strategies have successful countries adopted with respect to FDI and indigenous technology development?

I. THE GROWING SIGNIFICANCE OF COMPETITIVENESS

International competitiveness has long been considered vital to growth in industrial economies. With globalization, it is also becoming crucial for the developing countries that have long insulated themselves from world markets (Lall, 2001). Attaining competitiveness is difficult, and needs much more than simply "opening up" passively to free markets. It is something that *has to be built*: and the process is generally complex, demanding and costly (UNIDO, 2002). Industrial countries worry greatly about competitiveness, about maintaining their competitive lead over new entrants, and their concerns are revealed by the steady stream of productivity and competitiveness analyses. The process is more difficult, and the stresses correspondingly greater, for developing countries, although a large body of theory suggests that with their wage cost advantages all they should do is open up to global trade and investment flows. The evidence shows that this is too simple a view, and that it is leading to growing divergence industrial performance rather than convergence.

The main reasons for the growing importance of international competitiveness are technological. The rapid pace of innovation – and the resulting promise of productivity increase – makes it more costly to insulate economies from international trade and investment. Since new technologies benefit all activities, traded and non-traded, rapid access to such technologies in the form of new products, equipment and knowledge becomes vital for national welfare. Insulation from global markets and technologies is no longer a viable option for any developing country. Then there is the shrinking of "economic distance" – a consequence of technological change in communications and transport – that reduces transaction and information costs and so forces economies together. The growing ability of firms to network far-flung activities, also a consequence of shrinking economic distance, allows production chains to be spread over longer distances, thus leading to closer integration of activities, processes or even specific functions.

The interplay of these factors is causing significant changes to the location of productive activity across countries, and so to new patterns of global trade and national comparative advantage. There is a continuing surge of activities and functions seeking more efficient locations across the globe, led mainly by multinational corporations but also in some cases by other agents such as buyers and retailers (Dicken, 1998). Global value chains are now more tightly knit and coordinated, particularly in technologically sophisticated activities. Since such activities are the fastest-growing segments of trade, entry into the most dynamic, technology-based activities entails "plugging into" TNC-dominated chains.

The growing mobility of productive factors does not, however, mean that they are spreading evenly across low-cost countries. On the contrary, there is a growing tendency – particularly in technology-intensive activities – for mobile resources to be concentrated in a few sites. There are, in other words, few "sticky places" in the "slippery slopes" of globalized activity. What is more important, this "stickiness" is tending to increase over time because of cumulative forces such as (path-dependent) capability, institutional and infrastructure development, scale and agglomeration economies, and network externalities. Moreover, as first movers enhance their location advantages and incomes grow, the attractions of their domestic markets increase and reinforce their draw as regards the mobile factors. This is why the process of industrial divergence, once started, builds up cumulatively; at some stage, of course, it may be reversed if costs rise in advance of productivity or if there is undue congestion, but this stage is still some way from being reached in the developing world.

The globalization of economic activity thus does not reduce the need for low-wage economies to become competitive (in non-wage terms): quite the contrary. As more low-wage sites compete for mobile resources, and as technical change erodes the competitive advantage of cheap unskilled labour, *the quality of local capabilities and institutions becomes the prime determinant of the ability to attract and use foreign resources*. What is more important is that emerging global value chains are not curtailed. Because of growing specialization, lead players in each value chain rely increasingly on independent suppliers of inputs, services and even innovation, even in highly concentrated technology-intensive industries. As a consequence, there is considerable scope for domestic enterprises to enter global value chains as suppliers and, in some cases, as independent players. By the same token, local supplier clusters become more important as draws for TNCs. Increasingly, therefore, there are competitive pressures to foster efficient local clusters.

Growing competitive pressures are also a consequence of policy liberalization. To a large extent, this also reflects technological realities – the realization that the only way for poor countries to benefit from new productive knowledge, reach large markets and share in the "global shift" of productive activity is to be more open. There is a growing belief that there is no other way to develop industrially than to participate in the dynamics of globalization.

Being "more open" need not, however, mean relying entirely on free markets. Competitive success in an innovation-driven global economy needs strong local capabilities, and the development of capabilities faces numerous market and institutional failures (Lall, 2001; Stiglitz, 1996, 2002). Free-market forces cannot lead to the optimal allocation of resources in a dynamic setting with such failures, and so may not facilitate structural change and dynamize competitiveness. A strong strategic role remains for proactive government. If anything, this role is stronger with the opening of markets and the increasing mobility of productive factors, as countries compete more intensely for market share and FDI. As shown below, the most successful countries in the developing world, the mature Asian Tigers, mounted extensive strategic interventions to build their technological capabilities.

However, there are two important points to note here. First, there is a risk of "government failure". Intervention requires strong government capabilities – skills, information, autonomy and honesty – in the agency entrusted with policy. Many Governments in developing countries do not have such capabilities, and the history of past interventions is rife with cases of poorly designed, badly implemented and rent-seeking policies. Where government capabilities are so weak that strategic policies would cause more harm than good, it may be better to leave resource allocation to market forces. However, it should be noted that the recent experience of the impact of rapid liberalization on technology development has not been very encouraging in many parts of the developing world; as UNIDO (2002) notes, lags between the leaders and laggards are growing apace. Moreover, government failures can be remedied by deliberate action. In fact, the building of competitive government capabilities has to be the first step in developing strong national technological capabilities.

Second, the role of government today now has to be very different from its role in the import-substitution era, when policy interventions were not geared so much to overcoming market and institutional failures as to replacing markets. Policies today have to specifically address failures in achieving international competitiveness, rather than building production capabilities in relative isolation. And since markets are much more open, resources more mobile and technical change more rapid, they have to try to "plug into" actively in order to maximize the benefit for local capabilities. The *need* for strategy remains, but the *kind* of strategy that will maximize technology development is new.

II. TECHNOLOGY AND CAPABILITY BUILDING: ANALYTICAL FRAMEWORK[1]

Technological effort is vital to developing countries, even though it is clear that they are not "innovating" at the frontier. They import new technology, equipment, patents and so on from more advanced countries, but they have to learn to use these inputs effectively. Using new technologies is not an automatic or simple process. It entails the conscious building of "technological capabilities", a mixture of information, skills, interactions and routines that firms need in order to handle the tacit elements of technology. Received theory assumes that technology mastery and diffusion in developing countries are relatively easy, that knowledge is not tacit, and that the markets involved are relatively efficient. Thus, developing countries simply import and apply existing technologies, picking them in line with their factor prices. Once selected, technologies can be used effectively from the start (apart from minor learning-by-doing). In this setting, free international trade and investment flows maximize the inflow of beneficial new technology.[2]

This approach is *oversimplified*. The international technology market is far from perfect.[3] Once imported, using technology efficiently is not easy, costless or automatic. Micro-level research on developing countries, based on the evolutionary theories of Nelson and Winter (1982), shows how complex and demanding the task can be. Technology is not sold in "embodied" forms. Its tacit elements need effort and time to master. Its efficient use cannot therefore be assumed for poor countries that expose themselves to more world markets and technologies. Technological mastery entails building costly new capabilities; it takes time and investment and is uncertain (Lall, 1992, 1993). Firms cannot therefore (when faced with competition from firms that have already undergone learning in a more advanced environment) predict how long and costly the capability-building process may be and so cannot raise the finance to fund it.

Apart from this "capital market failure", capability building faces severe coordination problems because enterprises do not develop capabilities in isolation. The process tends to be collective and interactive – in economic terms there are widespread externalities – so that individual actors cannot take socially optimal investment decisions. For instance, a new automobile assembler in a developing country cannot forecast the learning process in the myriad suppliers that provide components to it and thus may not invest in manufacturing capacity on its own. There is a larger coordination problem: the use of new technologies requires supporting changes in factor markets, i.e. in the creation of skills in education and

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[1] This section draws upon a previously published paper by the author (Lall, 2000a).

[2] Despite their emphasis on human capital and technology, endogenous growth models also assume that in developing countries openness to trade and investment (both conducive to technology flows) is both necessary *and sufficient*.

[3] The international technology market is fragmented and ill defined, and searching for the optimal technology deal can be costly and difficult. It is not easy to define the technology "product" or its price. The transfer can take many different forms (i.e. the product is not well specified). Much depends on how much technical and other information the seller includes (or the buyer asks for) and how it transmits this information and modifies it over time. The seller knows more about the "product" than the buyer does (otherwise it would have nothing to sell): the buyer thus operates under an information asymmetry, largely absent in transactions in physical products. Even with full information, the two parties can have different valuations of the technology, depending on their market positions, expectations and technological capabilities. Since technological information is constantly changing, the valuation also depends on which vintage is being transferred and how its future evolution is foreseen. For these reasons, the price and terms of technology transfer are subject to bargaining and the accompanying uncertainty and non-transparency: See Radosevic (1999).

training, technology support institutions, infrastructure and so on. These "markets" may not be fully aware of or responsive to the needs of new technologies.

The technology literature has long accepted the need for intervention to raise private innovative effort to socially optimal levels (Arrow, 1962). The argument applies to learning and capability-building in developing countries as much as to innovation in developed ones. The cost and risk to latecomer enterprises of absorbing complex new technologies, together with the coordination problems within the value chain and in relation to factor markets, can be overcome only by strategic policy interventions. As Stiglitz (1996) notes, the policy problem is not to solve a gigantic optimization problem (to replicate a perfectly competitive market) but to pick promising activities and create the right conditions for them to succeed: creating winners in imperfect markets is much more feasible than picking winners in a (hypothetical) perfect competition setting. That Governments can mount such interventions effectively is amply borne out not just by the experience of East Asia (see below) but also by that of the major industrialized countries in their early days of industrial growth (Chang, 2002).

In the technological capability approach, the learning process is differentiated by technology. Some technologies are more difficult to master than others because the learning process is longer and more uncertain, involving greater effort and more externalities and coordination problems. At the same time, more difficult technologies also tend to offer greater potential for further learning and have greater scope for the application of new knowledge. Some complex technologies, particularly in generic activities such as machinery or electronic manufacture, have strong linkage and spillover effects, acting as "hubs" for technical progress and diffusion. In order to increase productivity over the long term, countries need to introduce more complex technologies and more difficult functions within given technologies; otherwise, competitiveness will erode with rising wages and exports will stagnate. This is the essence of the case for analysing the technological structure of exports.

The technological capability approach has important implications for export and industrial strategy. Countries with similar "endowments" and openness to technology flows can have different kinds of comparative advantage and different patterns of evolution over time, depending on the *national learning system*. Traditional determinants of comparative advantage do remain relevant – but *through their effects on learning*, when their assumptions conform to technological realities. For instance, simple neoclassical trade theory explains trade patterns when the activities concerned have low scale economies, simple skills, short learning periods, limited externalities and undifferentiated products. In these conditions, wage cost differences per se can be important determinants of competitiveness. Since these are also activities that developing countries tend to start with, the theory seems to "explain" a substantial part of their exports. However, even here such trade theory misrepresents reality. There may be large differences between countries in competence, dynamism and depth in these simple, labour-intensive technologies, expected in the capability approach but not explicable by neoclassical trade theory. There are significant variations in export performance between low-wage countries in simple manufactures, even when differences in location, resource endowments and trade policy are taken into account – these can be explained only by differences in national learning (Lall, 2001).

It is therefore important to understand the determinants of "national learning systems". Such systems are the outcome of a complex interaction of many factors. The most important are trade and industrial policies, macroeconomic conditions, location and resource endowments, human capital, technological effort, and the nature of factor markets and institutions. From the technological perspective, the critical ones relate to how enterprises access, master and improve upon new (and increasingly difficult) technologies. There are two broad approaches: fostering learning by *domestic firms* (autonomous), and *depending on FDI* to drive technological upgrading. Both entail the extensive use of foreign technologies, but the different agents for learning involve different strategies to import, absorb and build upon new technologies. We return to these points below.

Some important features of the capability-building process are described in box 1. The learning curve is not known in advance. Learning is technology - and firm - specific, and often occurs in an uncertain environment where the skills, information, networks and credit needed are not available. Many enterprises do not even know how to go about learning, and have to "learn to learn". They interact intensively with other agents, with extensive spillovers. Once launched, the process is difficult to change. The learning process is, in other words, rife with externalities, agglomeration, path dependence and cumulative effects. Technology development can thus face market failures (Stiglitz, 1996).

Box 1. Ten Features of technological learning in developing countries

1. Technological learning is a real and significant process. It is conscious and purposive rather than automatic or passive. Firms using a given technology for similar periods need not be equally proficient: each would travel on a different learning curve according to the intensity and efficacy of its capability-building efforts.
2. Firms do not have full information on technical alternatives. They function with imperfect, variable and rather hazy knowledge of technologies they are using.
3. Firms may not know how to build up the necessary capabilities — learning itself often has to be learned. The learning process faces risk, uncertainty and cost. For a technological latecomer, the fact that others have already undergone the learning process is both a benefit and a cost. It is a benefit in that they can borrow from the others' experience (to the extent this is accessible). It is a cost in that they are relatively inefficient during the process (and so have to bear a loss if they compete on open markets).
4. Firms cope with uncertainty not by maximizing a well-defined function but by developing organizational and managerial "satisfing" routines (Nelson and Winter, 1982). These are adapted as firms collect new information, learn from experience and imitate other firms. Learning is path-dependent and cumulative.
5. The learning process is highly technology-specific, since technologies differ in their learning requirements. Some technologies are more embodied in equipment while others have greater tacit elements. Process technologies (like chemicals) are more embodied than engineering technologies (machinery or automobiles), and demand different (often less) effort. Capabilities built up in one activity are not easily transferable to another.
6. Different technologies have different spillover effects and potential for further technological advance. Specialization in technologies with more technological potential and spillovers has greater dynamic benefits than specialization in technologies with limited potential.
7. Capability building occurs at all levels — shop-floor, process or product engineering, quality management, maintenance, procurement, inventory control, outbound logistics and relations with other firms and institutions. Innovation in the sense of formal R&D is at one end of the spectrum of technological activity; it does not exhaust it. However, R&D becomes important as more complex technologies are used; some R&D is needed just for efficient absorption.
8. Technological development can take place to different depths. The attainment of a minimum level of operational capability (know-how) is essential to all activity. This may not lead to deeper capabilities, an understanding of the principles of the technology (know-why): this requires a discrete strategy to invest in deepening. The deeper the levels of technological capabilities aimed at, the higher the cost, risk and duration involved. The development of know-why allows firms to select better the technologies they need, lower the costs of buying those technologies, realize more value by adding their own knowledge, and develop autonomous innovative capabilities.
9. Technological learning is rife with externalities and interlinkages. It is driven by links with suppliers of inputs or capital goods, competitors, customers, consultants and technology suppliers. There are also important interactions with firms in unrelated industries, technology institutes, extension services, universities, associations and training institutions. Where information flows are particularly dense, clusters emerge with collective learning for the group as a whole.
10. Technological interactions occur within a country and with other countries. Imported technology is generally the most important initial input into learning in developing countries. Since technologies change constantly, moreover, access to foreign sources of innovation is vital to continued technological progress. Technology import is not, however, a substitute for indigenous capability development — the efficacy with which imported technologies are

used depends on local efforts to deepen the absorptive base. Similarly, not all modes of technology import are equally conducive to indigenous learning. Some come highly packaged with complementary factors, and so stimulate less learning.

Source: Lall (2000.b)

In sum, learning to use new technologies ("new" to a particular user or location) needs investment and conscious effort. Much of the effort lies within the firm, but a significant part lies outside, in other firms, factor markets and support institutions. While the capability-building process is essential in both developed and developing countries, it tends to be more difficult in the latter, with weak enterprises, networks, markets and institutions. Furthermore, mastering new technology is not a once-for-all task. Most developing countries start with comparatively simple, labour-intensive technologies where skill needs are low, learning is short and relatively less risky and there is little need for inter-firm or inter-industry coordination. Once mastery is achieved, continued development (with rising wages) involves the *upgrading* and *deepening* of technologies. Otherwise, countries that establish a competitive niche in a low-technology activity may stagnate at the bottom of the technology ladder. To sustain competitive growth, they must move into more advanced technologies and technological functions within activities. At each stage, learning needs new knowledge, skills, institutions and policies.

A useful way to analyse this is to divide technological capabilities into four levels. At the bottom are the simplest (operational) ones, needed for running a technology efficiently: these involve basic manufacturing skills as well as some more demanding troubleshooting, quality control, maintenance and procurement skills. At the intermediate level are duplicative skills, which include the investment capabilities needed to expand capacity and to purchase and integrate foreign technologies. Next come adaptive skills, where imported technologies are adapted and improved, and design skills for more complex engineering learned. Finally come innovative skills, based on formal R&D, that are needed to keep pace with technological frontiers or to generate new technologies.

Continuous access to new technologies is essential to sustaining competitiveness (Radosevic, 1999). Such access can take two broad forms: *internalized* (from a multinational company to affiliates under its control) and *externalized* (between independent firms). While internalized modes necessarily involve TNCs, externalized ones may also involve TNCs selling technologies on contract (TNCs are the largest sellers of licensed technology). However, there are other sources of technology: national enterprises without overseas investments, consultants, capital goods producers, research institutions or Governments. The sale can take a variety of forms: minority joint ventures, franchising, turnkey projects, sale of equipment, licences, technical assistance, subcontracting or original equipment manufacturing arrangements. Internalized transfers bring a package of supporting inputs to ensure their efficient deployment. Externalized transfers may involve additional inputs by the technology seller, but generally tend to call for greater learning effort by the recipient.

III. ROLE OF FDI IN TECHNOLOGY TRANSFER AND LEARNING

The TNCs that dominate global FDI flows are also the main source of innovation: innovation is often the main competitive factor that allows them to become (and remain) multinational. Despite the recent growth of small technology start-ups, concentration in R&D remains high. For instance, in 1997 the largest 2 per cent (by employment) of manufacturing companies undertaking R&D in the United States accounted for nearly 80 per cent of industrial R&D spending (calculated from NSF, 2000). Such concentration is even higher in small OECD industrial countries (UNCTAD, 1999). It does not seem to have declined over time.

As major innovators, TNCs are the main sources of international technology transfer. Their role is naturally greater in high-technology activities, where they possess the strongest advantages. Before considering transfers to developing countries, we shall consider the main features of recent FDI (box 2).

Box 2. Salient features of recent FDI

- FDI flows are growing faster than other economic aggregates such as national gross fixed capital formation, world trade and GDP. International production (by TNCs and affiliates) is steadily increasing its share in global production.
- TNCs increasingly dominate world trade: around two thirds of visible trade is handled by TNCs, and the share is growing particularly in activities with significant scale economies in production, marketing or innovation.
- Of the visible trade handled by TNCs, between 30 and 40 per cent is within TNC systems, between affiliates and parents or among affiliates. Such internalized trade contains the most dynamic exports today, moving within integrated international production systems, where TNCs locate different functions or stages of production to different countries. Affiliates participating in such systems produce on massive scales and use the latest technologies, skills and managerial techniques. Examples of complex integrated systems in which developing countries are important are automobiles (mainly in Mexico, Brazil and Argentina) and electronics (Malaysia, Singapore, Philippines and Mexico). The globalization of the value chain is likely to spread across many other industries, and linking local production chains to them will become a major source of growth, technology transfer and skill development.
- Some TNCs are locating non-production functions such as accounting, engineering, R&D or marketing to affiliates – these are high-value activities that feed into manufacturing competitiveness and local capabilities. This is what UNCTAD terms "deep integration" in international production, in contrast to earlier "shallow integration" where stand-alone affiliates replicated many functions and related to other affiliates or parents via trade. However, the transfer of functions such as R&D lags behind that of production, particularly in developing countries. Over 90 per cent of overseas R&D by US TNCs is in other industrial countries. TNCs from smaller countries are more international in terms of relocating R&D overseas, but TNCs from economies such as the United Kingdom are also conducting a very substantial amount of R&D overseas. However, much of such R&D remains confined to other industrial countries. For deep integration to occur, host countries have to be able to provide not just cheap labour but the whole array of modern skills, infrastructure, institutions, efficient business practices and supplier networks that TNCs need in order to be fully competitive in world markets. Very few developing countries are able to meet these needs.
- Large companies with transnational operations increasingly dominate the process of *innovation*: the creation of new technologies and organizational methods that lies at the core of competitiveness in all but the simplest activities. Most such companies originate in mature industrial countries. About 90 per cent of world R&D expenditure is in the OECD. Within this group, seven countries (led by the United States) account for 90 per cent, the United States alone for 40 per cent. Access to new technologies thus involves getting knowledge from technological leaders in these countries. Many are increasingly unwilling to part with their most valuable technologies without a substantial equity stake. Thus, FDI becomes the most important – often the only – way of obtaining leading edge technologies.
- TNCs are often central to *exports by local firms* of technology-intensive products. Many such products are difficult to export independently because of the need for expensive branding, distribution and after-sales servicing. Thus, 60–70 per cent of consumer electronics made by the Republic of Korea and Taiwan Province of China is sold to TNCs on an OEM (original equipment manufacture) basis. The significance of OEM for the Republic of Korea is shown by the following statistics. In 1985, over 40 per cent of the Republic of Korea exports were in the form of OEM. In 1989, around 50–60 per cent of VCR and TV, and about 80 per cent of PC, exports by the Republic of Korea were under OEM. In 1990, 70–80 per cent of total Republic of Korea electronics exports were under OEM. TNCs are also active in *exports of low-technology products* where factors such as scale economies, branding, distribution and design are important.
- TNCs can help *restructure and upgrade competitive capabilities* in import-substituting activities. Where the facilities are already foreign owned, TNCs are often better able to respond to liberalization than local firms by investing in new technologies and skills. They can also help local suppliers to upgrade, or attract investment by their suppliers overseas. This has been commonly found in Latin America. Where local firms own the facilities, TNCs help them to upgrade through mergers and acquisitions (M&As). While cross-border M&As are often regarded with suspicion or resentment, they can salvage existing facilities that would not survive in a liberalized environment. In fact, with globalization and

liberalization, international M&As now constitute the bulk of FDI flows, accounting for over 80 per cent of FDI in developed countries and around one third in developing ones (UNCTAD, 2000).

- FDI in services is rising rapidly as formerly homebound providers (as in utilities) globalize activities and take advantage of liberalization and privatization in their industries. The entry of service TNCs can provide rapid improvements in productivity and efficiency to host economies, not only to their industries but also to their customers (many of which are important exporters).

Source: Lall based on UNCTAD reports.

In general, internalized technology flows are a very efficient means of transferring a package of capital, skills, information and brand names to developing countries. For many new technologies, internalized transfers are the *only possible* mode of transfer, since innovators are unwilling to part with them to unrelated parties. Even where technologies *are* available at arm's length, internalization may be the most efficient way of transferring the tacit knowledge involved because of the commitment of the transferor and its capability to support learning. If the technology is changing rapidly, internalization provides the most direct access to improvements. If the activity is export-oriented, internalized transfers offer the additional advantages of international marketing skills and networks, established brand names or, of increasing relevance, access to integrated production structures spanning several countries.

However, internalized technology transfers also carry costs. Profits are realized by the TNC on the package as a whole rather than just the innovation component. If the host country already possesses other elements of the package, it may be cheaper to buy the technology separately (economies such as the Republic of Korea and Taiwan Province of China did this because their enterprises had the necessary capabilities to master the technology). In general, the more standardized and diffused the technology and the more capable the buyer, the more economical will externalized modes be. However, there is a more subtle reason: the existence of learning benefits, deepening and externalities may tilt the choice in favour of externalization, even for relatively complex and difficult technologies. In these activities, reliance on foreign investment can shorten the learning period but reduce the other benefits of technology transfer and capability building.

One advantage of internalized forms of technology transfer lies in the long-term commitment of the foreign partner to the project and its ability to provide the elements needed to operationalize new technologies. At the lowest level, therefore, foreign investment is a very efficient way of transferring technology. Since all technologies need adaptation and improvement, foreign affiliates, with their base of high-level management and technical skills, tend to be in the forefront of such activity in developing countries. In addition, TNCs have the experience of other affiliates in the developing world to draw on, and can shift knowledge and personnel across countries to help with the upgrading of local capabilities.

As capability development progresses to the top level, where local innovative efforts become viable, there can be a conflict of interest between the host country and the foreign investor. Internalized technology transfer and local capability development can, in other words, become *competitive rather than complementary*. There are good reasons for international investors to keep innovative work centralized at home or in a few developed countries; these reasons include ease of coordination, skill availability, proximity to main markets, and more advanced science and technology infrastructures. At the same time, it is important for countries at a certain stage of industrial development to deepen their capabilities and move into innovation. *TNCs tend to transfer the results of R&D rather than the process itself*, whereas the sustained technological growth of developing countries calls for increasing local innovation. There is clear potential for a clash between the social interests of the host economy and the private interests of TNCs. At this stage, there is a case for restricting reliance on internalized forms to promote local R&D capabilities based on externalized forms or for intervening in the FDI process to induce TNCs to transfer more advanced technological functions.

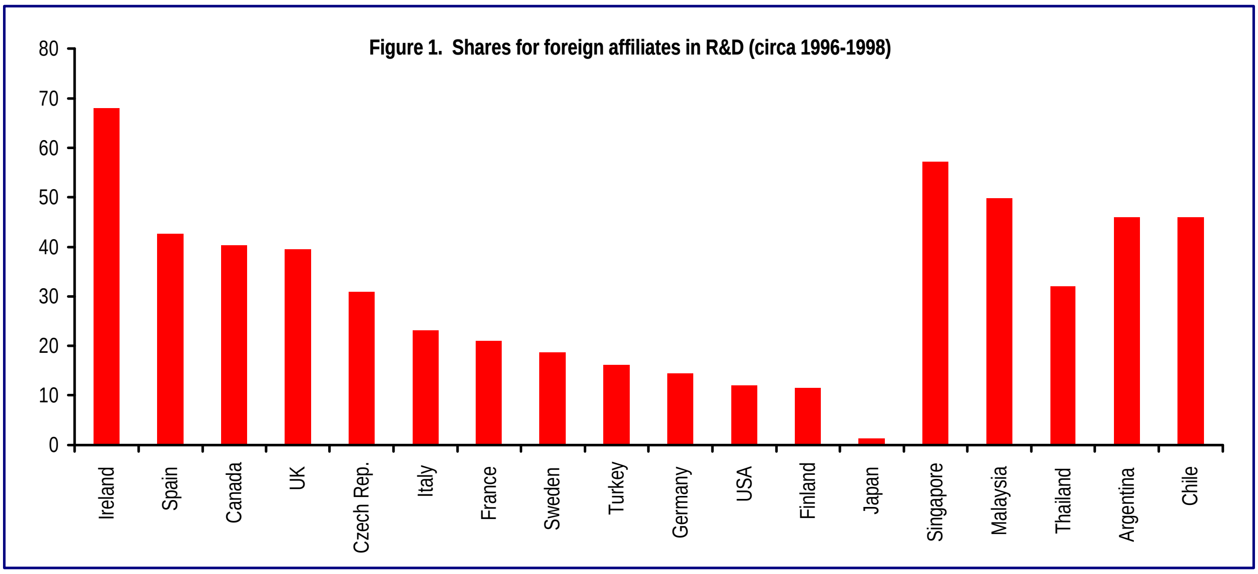
However, while the innovation function of TNCs is the slowest to relocate from the home country, particularly to developing countries, it *does* shift to affiliates over time. Given the availability of the high-level skills and infrastructure (including R&D institutions and universities of sufficient quality), affiliates in developing countries do start to conduct R&D. They initially start with simple adaptive tasks, move on to process development, then move to product development and finally to basic ("blue sky") research. Only a few economies have reached this stage, for example Singapore, Brazil, India, the Republic of Korea and Taiwan Province of China (China is catching up fast), and the amounts involved are small relative to TNC R&D in advanced economies, but the trend is clear.

Figure 1 shows the share of TNCs in R&D in a selection of countries for which the relevant data are available. There is enormous variation in both industrial and developing countries. In the industrial world, Ireland has an overwhelming share of affiliates in national R&D, and in Singapore there is a similarly high share. Both countries have very high FDI inflows relative to their economic size. Both have sought to attract TNCs and induce them to upgrade their manufacturing activities (from simple to complex) and functions (from manufacturing to design and development). Both have used instruments of selective industrial policy assiduously to achieve technological development and upgrading through FDI.

The important point to note is that technological upgrading *is possible* through heavy reliance on TNCs, but this requires considerable policy intervention. The pace and depth of technology development may not match that of countries that effectively adopt more autonomous strategies for building technological capabilities in domestic firms. We return to these points later in considering the East Asian experience.

IV. CURRENT TRENDS IN THE GLOBAL ECONOMY

Rapid technological progress is, as already noted, causing significant long-term shifts in the structure of industrial activity, and it is vital for developing countries to be aware of



these changes. While all activities undergo technical change, those with higher "technological intensity" - with higher than average expenditures on R&D - tend to grow faster than other activities. At the core of high-technology products is the group of information and communication technology (ITC) products that are one of the main engines of the current technological revolution.

The data in table 1, taken from NSF (2000), show that high-technology activities the world over are expanding in both production and trade much faster than other manufacturing activities. Note also that trade is growing much faster than production, indicating the globalization of all economies. The 68 economies in the NSF sample together account for over 95 per cent of world industrial production.

Table 1. Rates of growth of high technology and other manufacturing, 1985–1997 (percentage)

	All production	All exports	High-tech production	High-tech exports
68 economies	2.7	7.3	5.9	10.8
China	11.7	20.5	14.9	30.2
Republic of Korea	10.2	10.6	15.4	18.7
Singapore	8.0	15.0	13.1	21.7
Taiwan Province of China	4.7	12.0	11.6	18.9
Hong Kong (China)	-0.2	13.5	3.5	18.1
United States	2.9	8.8	4.7	10.1
Germany	2.2	4.1	3.8	5.8
United Kingdom	1.7	6.3	3.3	8.0
Japan	1.7	2.4	5.2	4.4
France	1.2	5.8	3.6	10.8

Source: NSF (2000).

Technology-intensive industrial activities offer benefits in addition to rapid growth, namely greater learning potential and greater spillover benefits for other activities. And such activities have become the most active field for international investment. This means that there are three arguments for developing countries to aim for deliberate technological upgrading of the industrial structure. First, there is a "market positioning" argument. A country that wants to locate its production and exports in the fastest-growing markets has to move into technology-intensive activities and upgrade its technology structure. Second, countries that want to deepen technological development and gain from the spillover effects of learning in lead sectors again have to focus on technology-intensive activities. Third, those that wish to share in the most dynamic segments of world trade—the international production systems of transnational companies—have to build the capabilities for technology-intensive activities. They can enter the assembly stage, but later have to upgrade within the system, moving up into manufacturing, design, development, and regional service activities.

Consider the detailed technological patterns of exports, broken down between primary products and manufactures, with the latter subdivided into four categories, namely R&B, resource-based; LT, low-technology (such as textiles, clothing, footwear and simple engineering products); MT, medium-technology (industrial machinery, automobiles, chemicals, and so on); and HT, high-technology (with ICT products shown as a sub-category). The medium-technology group is the largest — the heartland of heavy industry — but the high-technology group, with only 18 products at the 3-digit SITC level, is driving world trade and may soon be the single largest category.

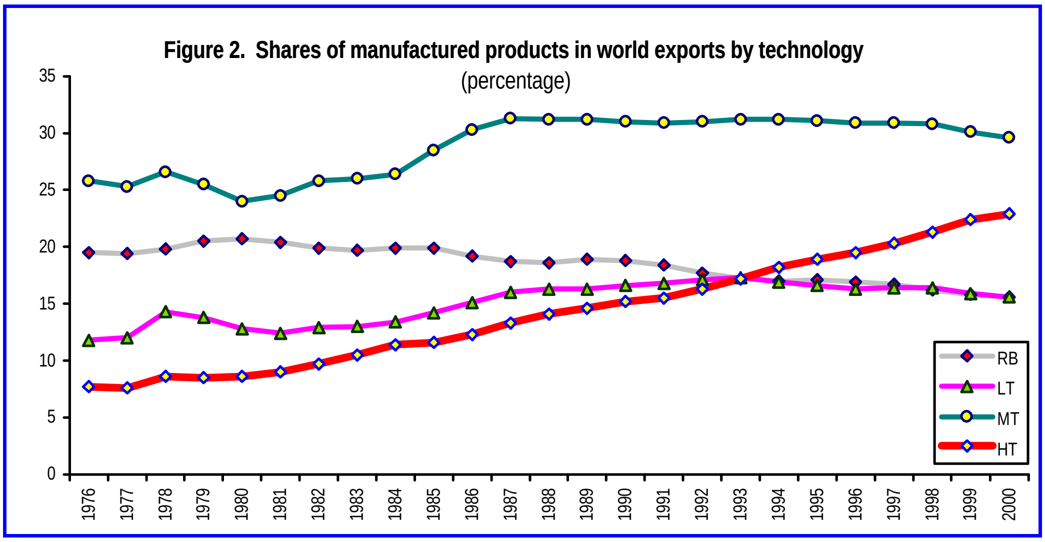
Table 2. Structure of world exports, 1985-2000 ($ billion and per cent)

Products	1985	2000	Annual growth rate	Distribution 1985	Distribution 2000
All sectors	1703582.5	5534008.6	8.17%	100%	100%
Primary products	394190.5	684,751.1	3.75%	23.1%	12.4%
Manufactures	1252573.7	4620266.8	9.09%	73.5%	83.5%
Resource-based	330863.9	863503.5	6.60%	19.4%	15.6%
Low-technology	241796.1	862999.0	8.85%	14.2%	15.6%
Medium-technology	485784.0	1639871.9	8.45%	28.5%	29.6%
High-technology	198029.7	1269587.2	13.19%	11.6%	22.9%
(of which, ICT)	90151.8	773119.2	15.40%	5.3%	14.0%

Source: Calculations by UNCTAD based on the UN Comtrade database, using classification developed by Lall (2001).

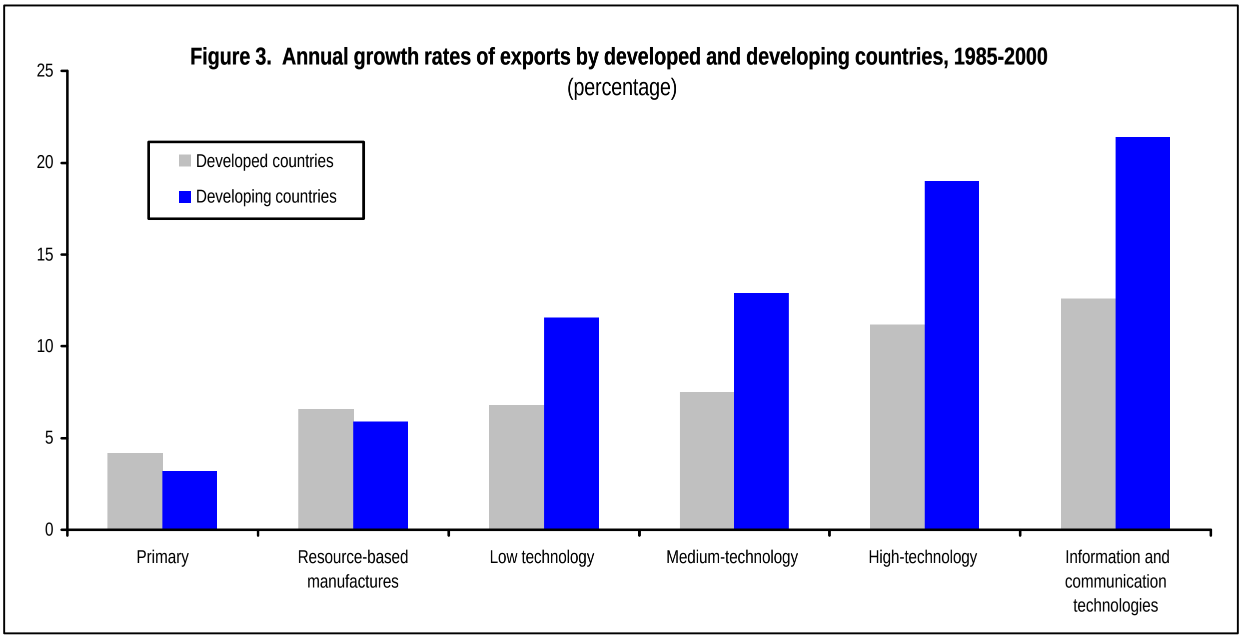
Table 2 shows growth rates for the period 1985–2000. Primary products grew the slowest, and nearly halved their share of total exports. Resource-based manufactures followed. Low - and medium-technology manufactures grew at more or less the same rate, and both slightly increased their market shares (in a more detailed calculation, not shown here, MT products grew faster than LT after 1995). The fastest-growing group was high-technology products. At the start of the period, in 1985, the 18 high-technology products accounted for about 10 per cent of total world trade; by 1998, they accounted for nearly a quarter. At current rates, these few products will soon account for the largest share of exports.[4] Of the 20 fastest-growing products in world trade (with export values of $5 billion or more) in 1990–2000, the five leaders are all high-technology products. Of these, four are electronic or electrical products and one is pharmaceuticals.

[4] At the 3-digit SITC (rev. 2) classification used here, there are 45 primary products, 65 RB, 44 LT and 58 MT products.



In terms of market shares, primary products have been losing ground steadily since 1976. Within manufactured products, RB products have lost shares since the early 1980s, LT since 1993 and MT since 1998 (figure 2). The only group to steadily increase its market share is HT. While these may not capture real long-term trends, they do suggest that exports of technologically intensive products are growing faster than those of other products.

As a group developing countries do rather well in this export scene. To start with, their total manufactured exports are growing faster than those of developed countries. This is to be expected, since they started from a lower base. However, the technological patterns of their growth are interesting, and somewhat unexpected. Developing countries grew more slowly than developed countries in primary products and resource-based manufactures (figure 3), presumably because of the faster application of new technology or because of trade barriers and subsidies in the industrial world. Within other manufactured products, their relative lead over industrial countries rose with technology levels. At first sight, this is a counterintuitive outcome: theory leads us to expect that developing countries would grow fastest relative to



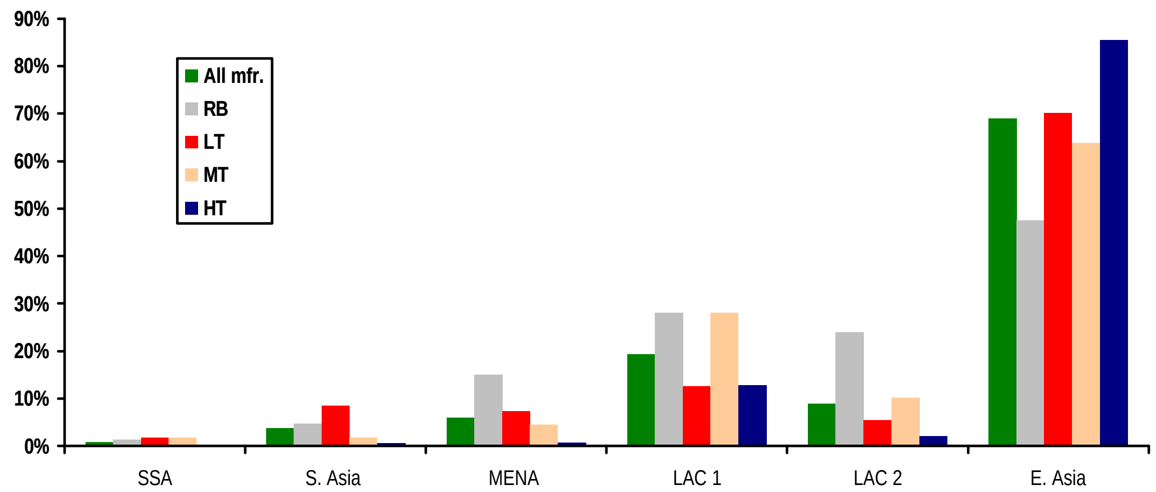
developed countries in low technology, less in medium technology, and least in high technology, products. The data show just the reverse.

Moreover, it is not just rates of growth that show this trend (caused, say, by the small base of high-tech products); the values involved are also very large. HT products are now the largest component of developing country manufactured exports. In 2000, at $445 billion, they were $60 billion larger than their primary exports, $210 billion larger than resource-based manufactured exports, $39 billion larger than low-technology exports and $140 billion larger than medium-technology exports (UNCTAD, 2002).

This pattern suggests that developing countries are doing very well under globalization, increasing their competitiveness overall and also moving rapidly into dynamic technology-based exports. Unfortunately, this is only partially true. Export dynamism and success in technology-intensive exports are *highly concentrated*, both by region and by country. Moreover, the local depth and "rooting" of high-technology activity vary greatly among the successful exporters; several large exporters of hi-tech products are only *assembling imported components*. While they are moving slowly up the technology ladder, undertaking more complex functions over time, those that do not move into deeper manufacturing (the manufacture of critical components and local design and development) will find it difficult to sustain rapid growth of exports as wages rise. It is important to consider these variations in order to assess how FDI and local technological effort affect competitive success in leading developing countries. The relevance of this to the new Tigers in Asia (Malaysia, Thailand and Philippines) is taken up later.

Consider first the concentration at the regional level (figure 4). Sub-Saharan Africa (even including South Africa, which accounts for over 40 per cent of its industrial production and even more of its manufactured exports) is very weak, and is losing its small shares over time. Its virtual absence in high-technology exports is one sign of its marginalization in the dynamics of world trade. In contrast, East Asia now accounts for about 75 per cent of total manufactured exports, and about 90 per cent of high-technology exports. What is more, its dominance has increased in practically all categories since 1985. It is this success of East Asia in technology-intensive manufacturing and export markets and its growing dominance across the board that justifies the focus of this paper on the Asian Tigers as insightful case studies, for policy lessons that may prove useful elsewhere.

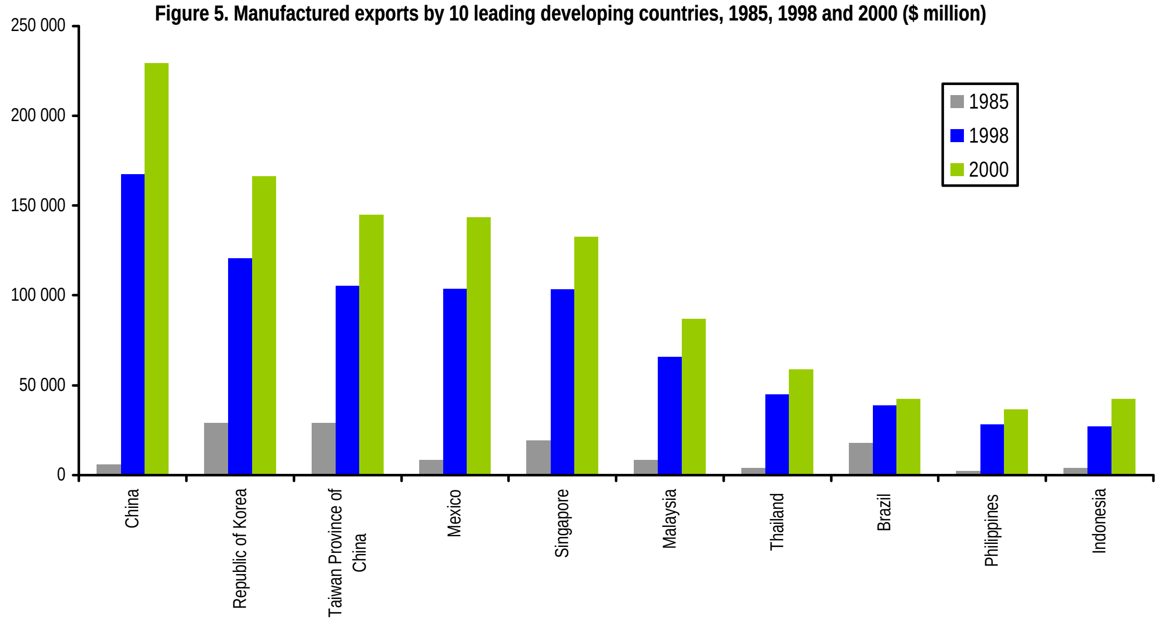
Figure 4. Regional shares of developing country manufactures exports, 1998



South Asia does well in low-technology products, basically clothing, but greatly under-performs in other categories (this excludes Indian software exports, not captured by these data). Latin America and the Caribbean (LAC) are shown twice: LAC 1 includes Mexico and LAC 2 excludes it (owing to the NAFTA effect, giving Mexico access to United States and Canadian markets). LAC 2, without this privilege, does poorly in dynamic products in world trade.

Figure 5 shows the 10 largest developing world exporters of manufactures in 1985, 1998 and 2000. These countries now account for over 80 per cent of developing country exports and their dominance is rising over time. Moreover, levels of concentration are higher in more advanced products, growing steadily from RB through LT, MT and HT products. Thus, liberalization and globalization appear to be leading to higher rather than lower barriers to entry for new competitors, with the barriers rising with technology levels.

Figure 5. Manufactured exports by 10 leading developing countries, 1985, 1998 and 2000 ($ million)



Figures 6 to 9 show data for the leading performers in the developing world for each technological category of manufactured exports during 1985–2000. Their most striking feature is the explosion of exports by China in every category, belying the initial impression that it is primarily an exporter of simple, labour-intensive products. In fact, its exports span the whole spectrum of technological complexity.

The countries in most charts tend to be the same: success in one category of exports tends to lead to success in others. *Competitiveness is, in other words, cumulative and widespread.* We now turn to the rationale for technology policy, and the strategies that the competitive countries adopted.

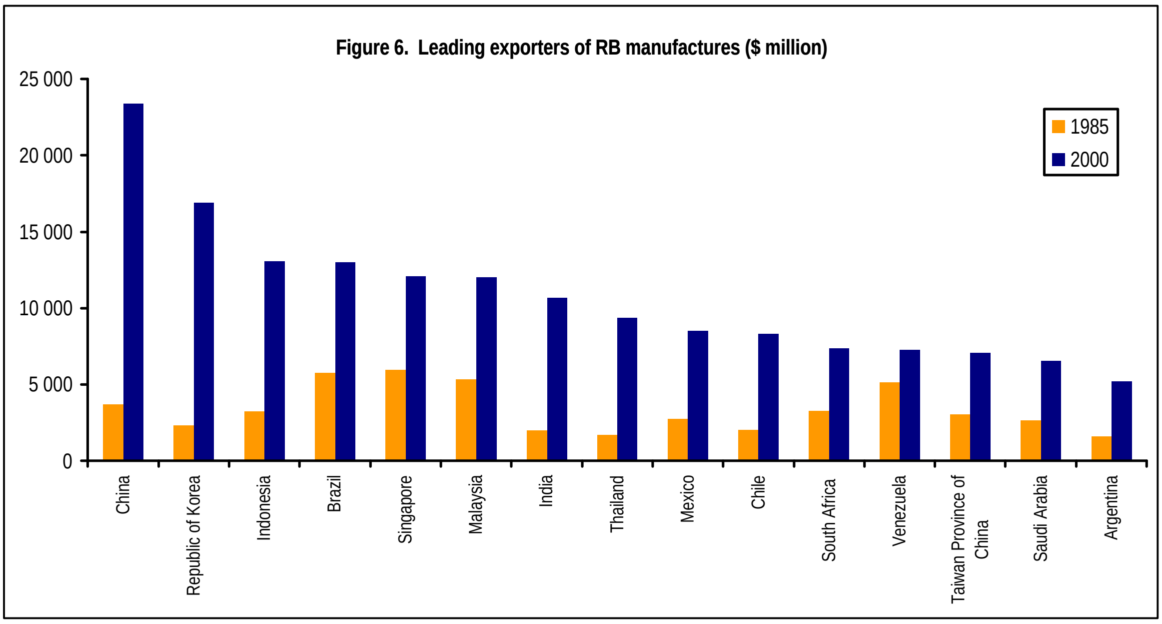


Figure 6. Leading exporters of RB manufactures ($ million)
25 000
20 000
15 000
10 000
5 000
0
1985
2000
China
Republic of Korea
Indonesia
Brazil
Singapore
Malaysia
India
Thailand
Mexico
Chile
South Africa
Venezuela
Taiwan Province of China
Saudi Arabia
Argentina

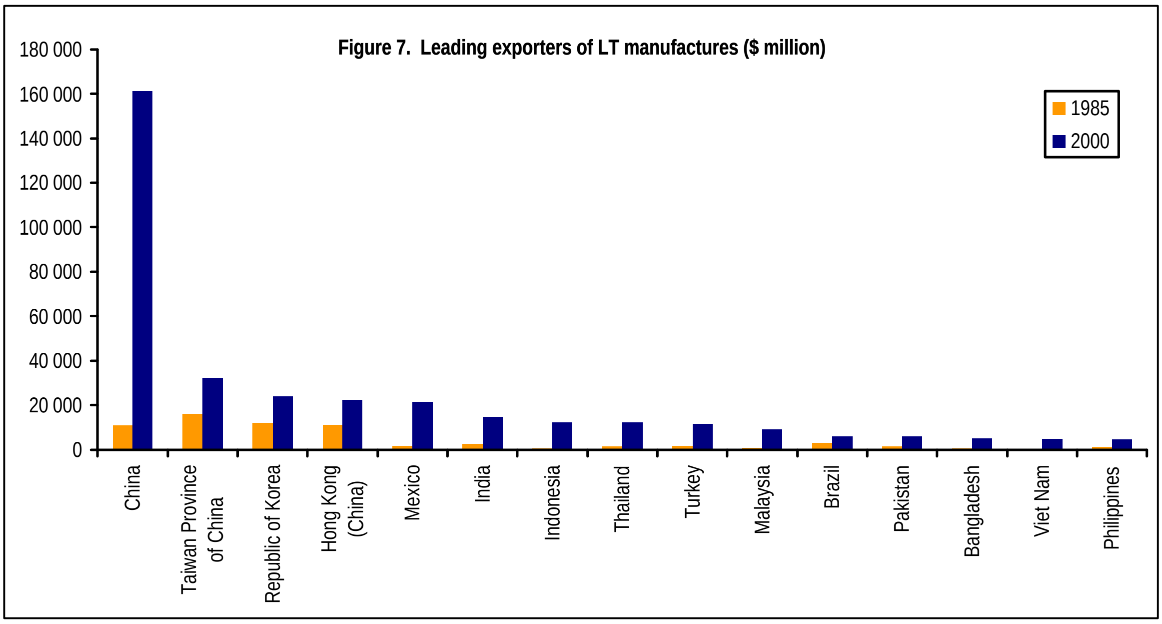


Figure 7. Leading exporters of LT manufactures ($ million)
180 000
160 000
140 000
120 000
100 000
80 000
60 000
40 000
20 000
0
1985
2000
China
Taiwan Province of China
Republic of Korea
Hong Kong (China)
Mexico
India
Indonesia
Thailand
Turkey
Malaysia
Brazil
Pakistan
Bangladesh
Viet Nam
Philippines

Figure 8. Leading exporters of MT manufactures ($ million)

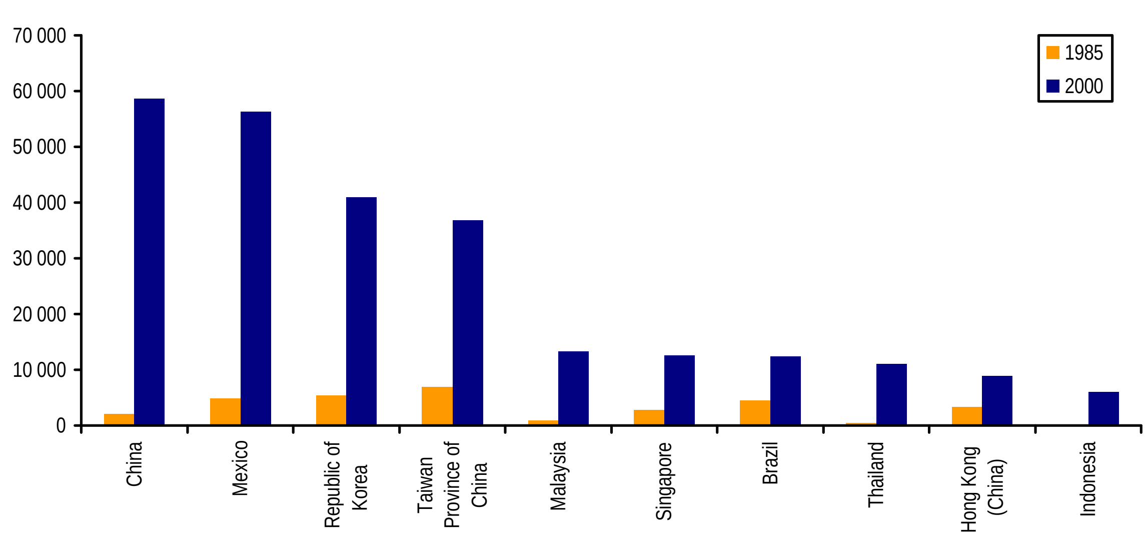
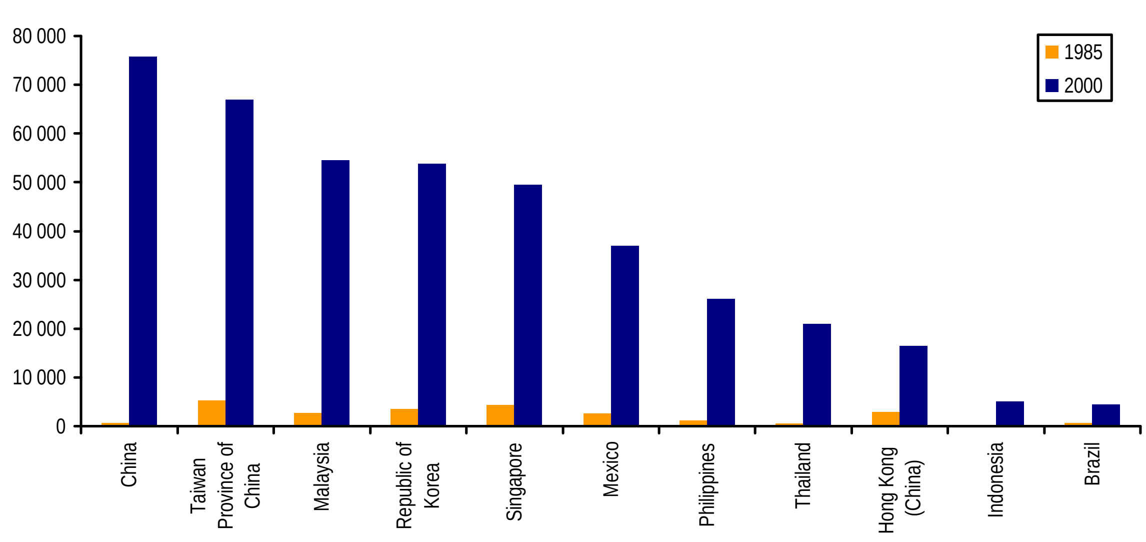


Figure 9. Leading exporters of HT manufactures ($ million)



V. RATIONALE FOR TECHNOLOGY POLICY

In economic theory, the case for technology policy is made by two things: market failures that call for remedial action to restore equilibrium, and the ability of the Government, taking into account the risk of government failure, to undertake measures so that the benefits of intervention exceed their costs. Technology policy is only justified where market failures are clearly established and the investment is able to create net social benefit.

This neoclassical approach to technology assumes that markets are *generally* efficient and that it makes sense to treat technology markets as being prone to "failures" that can be remedied in principle.[5] It is not clear that this is the best way to analyse technology policy, where market failures revolve around information in the future: such failures are very diffuse and it is not clear that a theoretical optimizing solution exists even in principle (Stiglitz, 1996). This is even truer of developing countries, where the basic conditions for technology use and development are very different from those in developed countries. In these circumstances, policy interventions need to go well beyond restoring a unique static equilibrium. Economists accept that technology markets are prone to widespread failure even in mature industrial countries with well-developed markets, institutions and property rights. These failures are much greater in developing countries and they vary by level of development, the industrial structure and the initial base of skills and institutions.[6]

Perhaps more important, the need for intervention differs according to the *vision of the society or Government regarding the desirable technological development path*, which then affects what constitutes "market failure" in technology development. For instance, Hong Kong (China) had - under the colonial administration - a vision of the free market determined by industrial and technological structures: for it, specialization in low-technology activities would be optimal, not a deficiency. The Republic of Korea, with a completely different vision of future development, would regard the same activities as a serious deficiency, calling for remedial action. Thus, the same objective situation would evoke no policy response in the former (i.e. market failure) and massive interventions in the latter (i.e. serious deficiency). "Vision" is very difficult to incorporate into neoclassical models that seek unique equilibria.

Governments in fact use technology policy to go beyond correcting static market deficiencies to changing the basic parameters within which markets function: creating new factor endowments, industries, enterprises, capabilities, institutions and market structures. It is difficult to describe the latter set of interventions as remedying "market failures" in the neoclassical sense, since this defines failures with reference to a competitive equilibrium. In principle, markets can clear within a given set of endowments and parameters, even if these occur at low levels of income and growth. The conventional market failure approach has little to say about changing those endowments and raising the economy beyond "low level equilibrium".[7]

Technology policies can thus be divided into two groups: those that address market failures in the conventional sense (deviations from static efficiency), and those that change basic endowments and parameters in line with a strategy of long-term development. The latter can be described as *strategic*, the former as *static*. Most technology policies have mixtures of static and strategic elements, with the difference in balance and direction being their real distinguishing characteristic. This is true of East Asia, where technology policies had many common static elements regarding generic market failures that affect technology development in all developing, and most developed, countries. They also had striking differences in their strategic policies, reflecting different ideologies and political economies.

While it is common to regard the stimulation of industrial R&D as the main, or even the sole, aim of technology policy, that is only one component of measures to increase

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[5]These types of market failures are analysed in Stoneman (1987). On the theoretical limitations to this approach, and the distinction between remediable and diffuse market failures, see Stiglitz (1996).

[6]See Lall and Teubal (1998).

[7] On the possibility of multiple equilibria and the risk of low-level equilibrium for countries specializing in low-technology activities see Hoff and Stiglitz (2001).

technological competence, especially at low levels of industrial development. In developing countries, the bulk of technological activity consists in mastering imported technologies, adapting them to local conditions, improving them and finally using them as a base for creating new technologies. Formal R&D assumes increasing significance with industrial maturity, even in developing countries that have not reached the "frontiers" of innovation. As more complex technologies are imported and deployed, R&D is vital in order to absorb their underlying principles. It is also vital as a means of keeping track of new technologies as they emerge. A growing base of R&D capabilities also permits better and faster diffusion within the economy of new technologies, lowers the cost of technology transfer, and captures more of the spillover benefits created by the operation of foreign firms. Most importantly, it permits the industrial sector as a whole greater flexibility and diversification of industrial activity, and allows it greater autonomy by creating a "technology culture".

There can be various market failures in stimulating the growth of a "technology culture" in a developing economy. There are well-known difficulties in appropriating fully the returns to private R&D; in newly industrializing countries the problems are compounded by the extra cost and risk involved in developing local research capabilities when technology can be imported from more advanced countries. There is a difficult choice to be made between importing “ready made” technologies and developing the capabilities to adapt, modify and improve upon them. Clearly, too much stress on one or the other can be uneconomical. A heavy dependence on technology imports can be costly and lead to a lack of technological dynamism; an over-emphasis on indigenous technology creation can lead to costly efforts to “reinvent the wheel”. Policies to stimulate local R&D clearly fall into the category of strategic choices — there is no clear market failure involved in remaining highly dependent on foreign technology.

Technology policy in developing countries should be seen as an *inherent part of industrial development policy*. It includes the elements of technology policy in the narrow sense – stimulating R&D, building technology support institutions, supporting small and medium-sized enterprises (SMEs) and so on – but it goes beyond into providing the setting in which industrial firms operate, seek technology and learn how to use and improve it. With this in mind, let us consider strategies by which countries have sought to become more industrially competitive.

VI. STRATEGIES FOR INDUSTRIAL COMPETITIVENESS

What were the strategies pursued by successful countries to expand manufactured exports? Part of export growth was based on the better exploitation of existing advantages (natural resources and unskilled or semi-skilled labour), while part relied on the creation of new advantages (skills, technological capabilities, clusters and so on). Thus, some strategies (or part of larger strategies) involved liberalizing export activity and attracting FDI to realize existing advantages; others went beyond, to "dynamizing" existing advantages by intervening in factor and product markets. The basic choice was between the *agents involved: local enterprises* or *TNCs*. All countries used both, but with differing balance and emphasis, depending partly on the nature of technologies involved (local firms with simpler technologies) and partly on strategic objectives.

To reiterate, the *main strategic issues* are as follows. The development of export competitiveness inevitably requires investments in capabilities of various kinds: procurement, production, engineering, design, marketing and so on. The realization of existing advantages in natural resources or unskilled labour tends to involve less effort and risk, and fewer externalities, than the development of new advantages in complex activities (although the regional data suggest that even this effort has been beyond the reach of many countries). Sustained and rapid manufactured export growth requires moving from easy to complex products and processes within activities, and across activities from easy to complex technologies. The choice between local and foreign firms to lead the capability-building process depends on the existing base of skills and experience and the demands of exporting. It also depends upon the ability of Governments and institutions to help enterprises to develop the necessary capabilities and tap externalities (e.g. coordinate investments in vertically linked activities or undertake collective learning).

TNCs and local firms face different markets and have to overcome different market failures in learning. TNCs have several advantages over local firms in using new technologies ("new" to a particular location) for export activity. They have mastered and used the technologies elsewhere; they may have created the technology in the first place. They have large internal reserves of skill, technical support, experience and finance to design and implement the learning process. They have access to major export markets, established marketing channels and well-known brand names. They can transfer particular components or processes from a production chain to a developing country and integrate it into an international system. This is much more difficult for local firms, not just because they may not have the experience or technological competence – they inevitably face higher transaction and coordination costs in integrating into TNC corporate systems. In addition, TNCs have considerable advantages in product markets: by definition, they have established international markets and brands and so can finance costly learning processes more easily and with less risk. They have "deeper pockets" to fund these processes.

While the TNC-led strategy has many benefits, and can be a highly effective and rapid means of exploiting existing advantages, a *passive* FDI strategy may not be the best way to dynamize competitiveness. TNCs may not invest in a particular country because of imperfect information or poor image. Thus, effective promotion and targeting of investors can allow a country to attract more and higher-quality FDI. Where TNCs do invest, they initially transfer equipment and technologies suited to *existing* skills and capabilities. To move on to more advanced activities and functions, they have to upgrade local skills, technological capabilities and supply chains. This is economical only where the education and training base is growing, local suppliers are increasing their capabilities, technology institutions are able to provide more advanced services, and so on. Such supply-side upgrading needs government support. Moreover, a policy to induce TNCs to enter more advanced activities by offering such incentives as specialized infrastructure and skills can accelerate the upgrading process. With a completely passive policy, TNC exports can remain at low, technologically too small, levels. Thus, a TNC dependent export strategy needs a proactive element for dynamic competitiveness.

More important, an FDI-dependent strategy is not a substitute for building domestic capabilities. There are many activities in which TNCs have no competitive advantage over domestic firms, particularly those served by SMEs. The development of national enterprises may also lead to broader, deeper and more flexible capabilities, since the learning process within foreign affiliates as compared with local firms may be curtailed. The very fact that an affiliate can draw upon its parent company for technical information, skills, technological advances and so on means that it needs to invest less in its own capabilities. This applies particularly to functions such as advanced engineering, design and R&D, which TNCs tend to centralize in industrial countries. It is imperative for developing countries, as they mature industrially, to undertake these functions locally to support their future comparative advantage. This is why some countries choose to promote technology development in local firms.

Different countries make different strategic choices in these respects. In leading developing country exporters, we may distinguish for such choices:

- *"Autonomous"*, based on the development of capabilities in domestic firms, starting with simple activities and deepening rapidly over time. This strategy used extensive industrial policy, reaching into trade, finance, education, training, technology and industrial structure. It involved selective restrictions on FDI, and actively encouraged technology imports in other forms. All these interventions were carried out in a strongly export-oriented trade regime, with favours granted in return for good export performance. The prime examples are the Republic of Korea and Taiwan Province of China.
- *"Strategic FDI-dependent"*, driven by FDI and exports to TNC global networks. There was a great effort to upgrade TNC activity according to strategic priorities, directing investments into higher-value-added activities and inducing existing affiliates to upgrade their technologies and functions. This strategy involved extensive interventions in factor markets (skill creation, institution building, infrastructure development and supplier support), encouraging R&D and technology institutions, and in attracting, targeting and guiding investments. The best example is Singapore.
- *"Passive FDI-dependent"*, also driven by FDI but relying largely on market forces to upgrade the structure (with rising wages and growing capabilities). The main tools were a welcoming FDI regime, strong incentives for exports, with good export infrastructure, and cheap, trainable labour. Skill upgrading and domestic technological activity were relatively neglected (although some countries had a relatively good base), and the domestic industrial sector tended to develop in isolation from the export sector. Malaysia, Thailand and the Philippines are good examples, together with the Special Economic Zones of China (and the *maquilas* of Mexico).
- *"ISI restructuring"*, with exports growing from long-established import-substituting industries where competitive (or nearly competitive) capabilities had developed. The main policy tool was trade liberalization or strong export incentives (some, as in Latin America, within regional trade agreements). This led to considerable upgrading, restructuring and expansion of these industries along with their supplier networks. In some countries the main agents were domestic enterprises, while in others they were TNCs. The main difference from the "autonomous" strategy was the lack of clear and coordinated industrial policy to develop export competitiveness, with haphazard (often weak) support for skills, technology, institutions and infrastructure. China and India are examples within Asia, the large Latin American economies elsewhere; elements of this strategy are also present in many other economies.

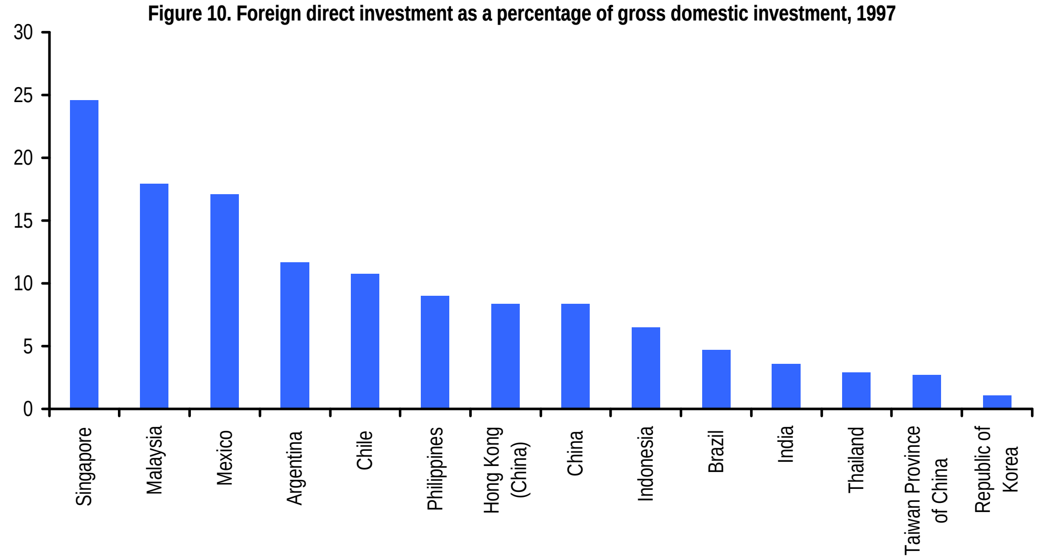
These strategies are not, of course, mutually exclusive. Countries generally combine them, and vary the combinations over time. Nevertheless, this simple typology is useful as an analytical tool, and we use it with appropriate caveats.

VII. FDI, R&D AND OTHER DRIVERS OF INDUSTRIAL COMPETITIVENESS

The main structural drivers of industrial competitiveness are *FDI, domestic R&D, skills, licensing and physical infrastructure* (based on UNIDO, 2002). This is not a comprehensive model "explaining" competitive performance, since it leaves out of account policies, institutions, governance and other factors that are difficult to quantify across a large number of countries. It is intended to provide a picture of the *structural factors* in industrial competitiveness, although the "drivers" do correlate quite nicely with industrial performance.

The first driver is *foreign direct investment* (FDI). Reliance on FDI differs sharply among the newly industrialized economies (NIEs), with very high reliance in Malaysia and Singapore in East Asia and in most of Latin America. There is very low reliance in the Republic of Korea and Taiwan Province of China, which deliberately restricted inward FDI in order to build up their innovative capabilities. Figure 10 shows FDI as a percentage of gross domestic investment in 1997 (the picture is similar over the longer term). This suggests a trade-off between deepening technological capabilities and relying on ready-made technology from TNCs.

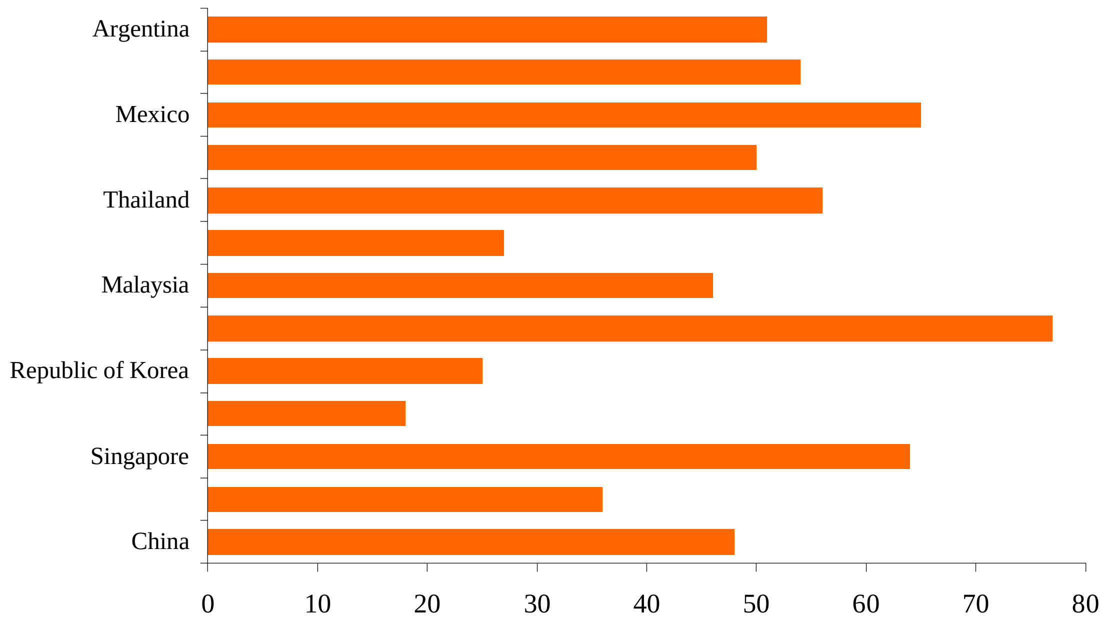
Figure 10. Foreign direct investment as a percentage of gross domestic investment, 1997



TCNs also play varying roles in exports by different countries. Figure 11 illustrates this for some countries on which data could be collected (see UNCTAD, 2002).

One of the main causes of export success in recent years has been *increasing participation in global production networks under the aegis of TNCs.* This has been particularly dynamic in HT activities, led by electronics, which has allowed countries (in labour-intensive assembly processes) to enter very fast-growing export activities and then to move up the value chain. All the major exporters from the developing world apart from the Republic of Korea and Taiwan Province of China have depended on such participation. The latter two economies, on the other hand, have tapped into global chains with domestic

Figure 11. Share of TNCs in exports, most recent year



enterprises, using such mechanisms as original equipment manufacture (OEM) contracts, licensing and copying.[8] This has entailed a massive development of technological and other capabilities on the part of local firms, sustained by extensive government intervention in all markets, including selective infant industry promotion (Lall, 1996, 2001).

The FDI-dependent countries have also used different sub-strategies. Singapore, for instance, has relied heavily on industrial policy to target and attract hi-tech TNCs, build local skills and institutions, and develop specialized infrastructure. As a result, it has moved to the top of the technological ladder, and is now targeting R&D and high-value service activities by TNCs. Malaysia, Thailand, Indonesia and the Philippines in Asia, and Mexico in Latin America, have been less proactive on FDI and the development of local skills and institutions (although they used industrial policy in other ways). As a result, they are much lower than Singapore on the technology spectrum. However, they are now acutely conscious of the need to upgrade capabilities and supplier networks in order to retain a competitive edge as wages rise and economies with lower wages emerge as competitors. As shown later, their technological capabilities lag well behind those of the Republic of Korea and Taiwan Province of China.

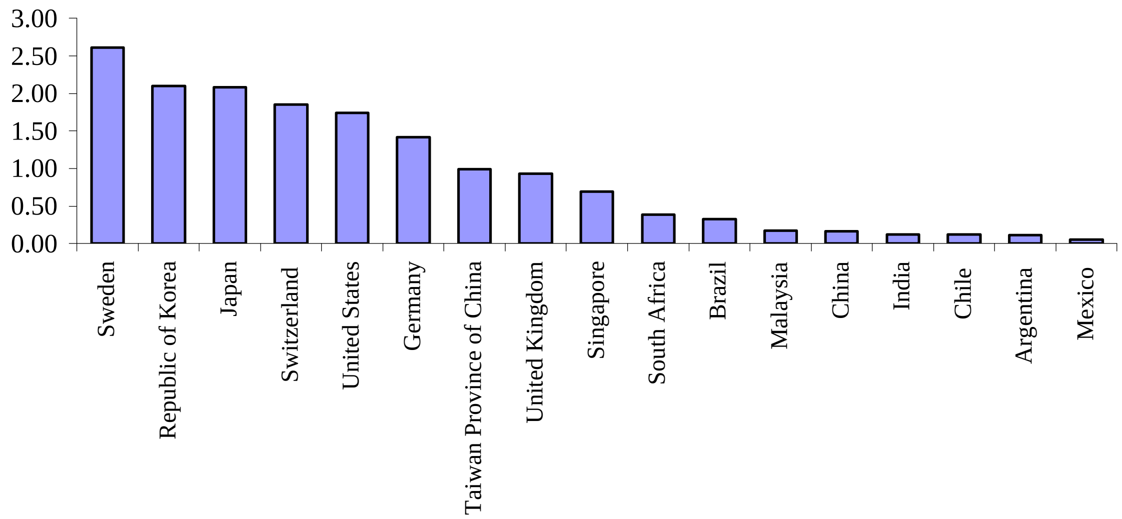
China is unique because of its size, industrial tradition, background and overseas ethnic linkages. It can combine elements from all the other strategies with its own policies to restructure and develop domestic enterprises (Nolan, 2001). While its base of skills and technological effort is low by international standards, it has enough to mount a spectacular surge in exports across the technological spectrum. And it is building its capability base rapidly while bringing its "surplus" human capacity into modern industrial activity, which suggests that the surge still has a considerable way to go.

[8] On the role of OEM contracts in technological learning and technology transfer in the Republic of Korea (see Cyhn (2002)).

The experience of these successful economies does not mean that other countries that liberalize FDI will automatically share their success. In fact, few developing countries participate in these emerging TNC systems. While FDI in developing countries is increasing rapidly (from an average of $29 billion in 1986–1991 to $208 billion in 1999), flows are highly concentrated. The top 10 developing countries account for nearly 80 per cent, and the top 25 for 95 per cent, of the total.

Let us now look at *R&D spending*, taking not total R&D (which can be misleading for analysing industrial technological activity) but that *financed by productive enterprises* (figure 12).

Figure 12. R&D by productive enterprises as percentage of GDP, most recent year



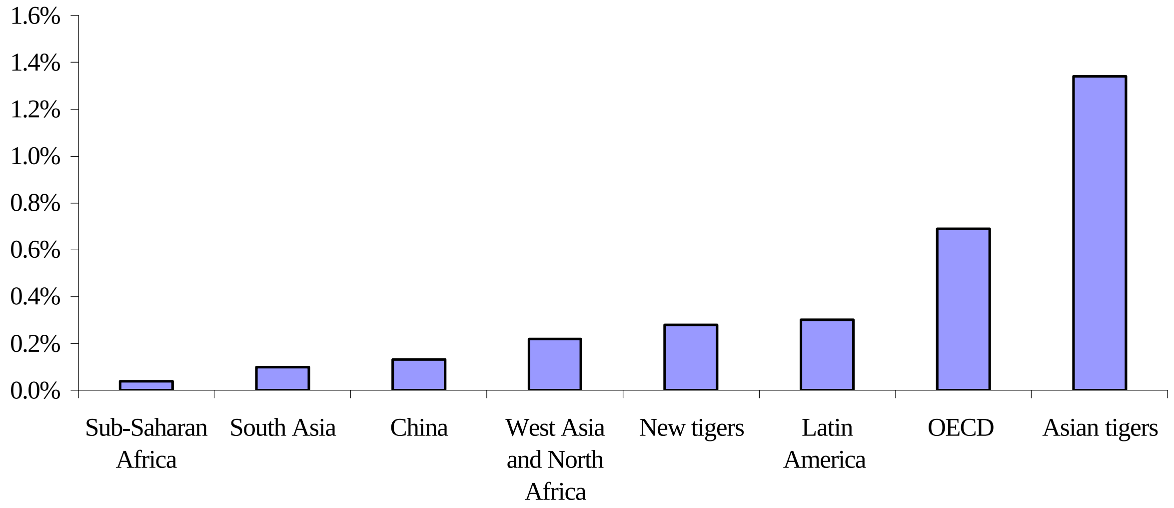
The leaders in the world in this activity (measured by R&D as a percentage of GDP) are Sweden, Japan and the Republic of Korea. Yet only some 20 years ago, the Republic of Korea was a typical developing country, with 0.2 per cent of gross national product going into R&D and 80 per cent of that coming from the public sector. Today, total R&D is over 3 per cent of GDP, with over 80 per cent coming from the private sector. Taiwan Province of China and Singapore come next in the developing world, with other economies well behind. Of these three mature Tigers, Singapore lags behind the others owing to its dependence on FDI – but such dependence does not prevent it from leading all other developing countries.

These data again show the highly differentiated responses to globalization and technical change among developing countries. Among industrializing countries, the three mature Asian Tigers are in the lead, with other countries in Latin American and Asia lagging behind. The "New Tigers" - Malaysia, the Philippines and Thailand - do well in technology-intensive exports. However, their capability base remains weak and shallow (that of the latter of two is so low that they do not appear in figure 12). This striking discrepancy between the technology intensity of their exports and their domestic skills and the technological capabilities of TNC assembly activities has to be reconciled if they are to maintain their past performance; otherwise, technical change and the entry of rivals with stronger skill bases will lead future dynamic activities to locate elsewhere. China is in an intermediate position, with a combination of capabilities and strategies from each of the three leading Tigers. Its size and established capabilities suggest that it will continue to catch up with the other leaders and possibly do better.

Latin American countries come fairly low on the R&D scale in comparison with East Asia, but the latter does much better than other developing regions. At the national level, Brazil is the leader in Latin America, and ranks fourth in the developing world after the Republic of Korea, Taiwan Province of China and Singapore.

The different strategies also have implications for *human capital formation*. For instance, FDI - dependent strategies in low-wage countries – at least in their initial phases – do not require high skill levels, while autonomous R&D - dependent strategies clearly do. This is borne out by the data: there are sharp disparities in the skills base in competitive countries. The figures are rough proxies for skill formation, since they deal only with formal school and university enrolments, ignoring quality and other differences in the education provided. The focus here is on high-level technical skills, as measured by tertiary enrolments in core technical subjects as a percentage of the population. Statistical analysis shows that this measure is the best (pure science, mathematics, and computing and engineering) variable for human capital in explaining export dynamism (figure 13).

Figure 13. Tertiary enrolments in technical subjects as percentage of population, 1995



The most striking fact about figure 13 is the enormous lead established by the four mature Asian Tigers (Hong Kong (China), the Republic of Korea, Taiwan Province of China and Singapore), far outpacing even the industrialized countries. Note, however, that this reflects mainly the investment in higher technical education by the Republic of Korea and Taiwan Province of China; Singapore and Hong Kong (China) are at significantly lower levels. The New Tigers (Malaysia, Philippines, Thailand and Indonesia) and the main industrial powers in Latin America (Argentina, Brazil and Mexico) follow much further behind. Sub-Saharan Africa lags the most in skill creation, with South Asia and China doing somewhat better.

In summary, using FDI to insert countries into global value chains is an extremely effective way to build competitiveness in the new globalizing environment, and almost all successful economies apart from the Republic of Korea and Taiwan Province of China have used it. Of course, there are many countries that have not been able to use such strategies, and we draw lessons for FDI promotion and targeting below. However, it is important to note that simply plugging into global chains at the bottom end is not necessarily a sustainable strategy over the long term. As more complex processes are introduced and technologies continue to evolve, it becomes imperative for countries to improve domestic capabilities: skills, supplier bases, R&D capabilities and the physical (particularly the ICT) infrastructure. TNCs contribute to building capabilities, of course. They train employees and diffuse technologies to local suppliers, but there are limits to how far this can improve national capabilities. Ultimately, it is up to the Government to support capability development by creating more skills, strengthening domestic firms and creating strong technology and research institutions. If this is not done, the most complex and value-creating activities may well be located in other countries – this is the strategic challenge facing the new Tigers, as China appears as a giant competitor with lower wages, massive domestic markets and capable suppliers.

VIII. FDI TARGETING STRATEGIES

A striking feature of current globalization is how TNCs are shifting their mobile assets (technology, skills, brands and production) across the globe to find the best match with the immobile assets of different locations. In the process, they are also shifting functions that create their ownership assets such as R&D, training and strategic management within an internationally integrated production and marketing system. The ability to provide the necessary immobile assets thus becomes a critical part of FDI – and competitiveness – strategy for developing countries. While a large domestic market remains a powerful magnet for investors, TNCs serving global markets increasingly look for other attributes, which are changing in response to policy liberalization and technical change. The opening of markets creates new opportunities and challenges for TNCs and gives them a broader choice of modes with which to access those markets. It also makes them more selective in their choices of potential investment sites.

Apart from primary resources – and taking a conducive policy and macro framework as given – the most attractive immobile assets for export-oriented TNCs are world-class infrastructure, skilled and productive labour, and an agglomeration of efficient suppliers, competitors, support institutions and services. Cheap unskilled labour remains a source of competitive advantage, but its importance is diminishing. Natural resources provide a competitive basis for growth as long as they are plentiful in supply and face growing demand. However, most primary exports face slow-growing markets and are vulnerable to substitution, while resource based manufactures are among the slowest growing in world trade.

The sites that will receive most FDI in the emerging economic and policy setting are those that provide for TNCs to set up competitive facilities able to withstand global competition. This means that the host country has to provide competitive immobile assets – skills, infrastructure, services, supply networks and institutions – to complement the mobile assets of TNCs. While transport costs and taste differences mean that large markets will continue to attract more investment than small ones, few countries can afford to take a continued inflow of FDI – especially high-quality, export-oriented FDI – for granted. This means that the ultimate draw for FDI is the economic base: FDI incentives and targeting cannot by themselves compensate for the lack of such a base.

The East Asian experience, particularly of the new Tigers such as Malaysia and Philippines, shows that attracting FDI into high-technology activities can happen without any particular government strategy. In their case, it was largely a matter of their economic base, which may have been helped by welcoming FDI policies. High-tech TNCs had already established a base in Singapore (on which more below). The rise of the semiconductor industry and the need for cheap labour for assembling and testing devices led United States companies to look for cheap labour overseas. Over time, Japanese and other firms joined in this quest (helped by the rise of the yen in the mid-1980s), and the tendency spread to a number of other export-oriented electronics activities. Countries with low wages, stable macro regimes, good export-processing zone facilities, English-speaking workers and attractive FDI incentives were able to attract investments relocating from the developed countries as well as from Singapore. Apart from these general attractions, therefore, FDI targeting did not play much of a role.

However, the surge of high-tech export-oriented FDI did not spread to other parts of the developing world – countries in South Asia, North Africa and Latin America that played host to TNC assembly for export continued to concentrate on garments and other simple products. The main exception was Intel’s investment in Costa Rica. Within South-East Asia, while TNCs invested in automation and skill creation in their high-tech assembly operations, sustained deepening of local content and technologies took place mainly as a result of government interventions. These interventions involved incentives for upgrading, and supply-side support in terms of skill and infrastructure creation and support for local suppliers. Malaysia adopted Singapore-style strategies to induce firms to raise local content; however, this was mainly by attracting other TNCs rather than by upgrading a (relatively weak) local skill and industrial supplier base. There was some increase in TNC R&D activity, but not to the levels reached by Singapore. Other countries in the region did not adopt similar proactive strategies. As a result, high-tech TNC operations remain fairly shallow in Thailand, the Philippines and Indonesia. This shallowness constitutes an important constraint on their future industrial growth and competitiveness, and their Governments are seriously concerned to improve their FDI targeting and upgrade local skills and supply capabilities.

There is thus a *strong case for policy interventions* both to attract higher-quality FDI and to induce investors to upgrade and deepen their activities over time. The economic rationale for interventions is threefold: high transaction costs; deficient information on the potential of the host economy; and insufficient coordination between the needs of TNCs, the assets of the host economy and the potential to improve those assets.

First, with regard to *high transaction costs,* while most FDI regimes are converging on a common (and reasonably welcoming) set of rules and incentives, there remain large differences in how these rules are implemented. The FDI approval process can take several times longer, and entail costs many times greater, in one country than another with similar policies. After approval, the cost of setting up facilities, operating them, importing and exporting goods, paying taxes, hiring and firing workers, and generally dealing with the authorities, can differ enormously (table 3).

Such costs can, *ceteris paribus*, significantly affect the competitive position of a host economy. An important part of competitiveness strategy thus consists in reducing unnecessary, distorting and wasteful business costs. This affects both local and foreign enterprises. However, foreign investors have a much wider set of options before them, and are able to compare transaction costs in different countries. Thus, the attraction of TNCs requires not just that transaction costs be lowered but also, increasingly, that they be benchmarked against those of competing host countries. One important measure that many countries are taking to ensure that international investors face minimal costs is to set up one-stop promotion agencies able to guide and assist them in securing necessary approvals.

However, unless the agencies have the authority needed to negotiate the regulatory system, and unless the rules themselves are simplified, this may not help. On the contrary, there is a risk that a “one-stop shop” becomes “one more stop".

Second, despite their size and international exposure, TNCs face *market failures in information*. They collect considerable information about potential sites, on their own as well as from consultants and other foreign investors. However, their information base is far from perfect, and the decision-making process can be subjective and biased. Taking stable economic fundamentals as given, it may be worthwhile for a country to invest in altering potential investors' perception by providing better information and improving its "image". However, such promotion efforts are highly skill-intensive and potentially expensive. They need to be carefully mounted, and they should be targeted to maximize their impact. Targeting can be general (countries with which there are trade or historical connections, or which lack past connections but are ripe for establishing them), industry-specific (investors in industries in which the host economy has an actual or potential competitive edge), even investor-specific. Note that targeting or information provision is *not* the same as providing subsidies or fiscal incentives: incentives play a relatively minor role in a good promotion programme, and good long-term investors are not the ones most susceptible to short-term inducements. The experiences of Ireland, Singapore and more recently Costa Rica suggest that promotion can be extremely effective in increasing the inflow of investment and increasing its quality (UNCTAD, 2002).

Table 3. Illustrative list of transaction costs related to the legal and regulatory environment

Area of operation	Transaction	Enterprise exposure	Effects on
Business entry	Registration Licensing Property rights Rules Clarity Predictability Enforcement Conflict resolution	Monetary costs to firms Time costs (including compliance and delays) Facilitation costs Expert evaluations of rules and their functioning Number of rules and formalities	Rate of new business entry Distribution of firms by size, age and activity Size of shadow economy Rate of domestic investment FDI inflows, quantity and quality Investment in R&D
Business exit	Bankruptcy Liquidation Severance/layoffs Rules Clarity Predictability Enforcement Conflict resolution	Rate of change of rules Changes in costs and number of rules Availability of rules and documents to firms Rates of compliance and/or evasion Use of alternatives to formal institutions	Rate of exit (and entry) Prevalence of credit Average and distribution of profitability of corporations
Business operation	Taxation Trade-related regulation Labour hiring/firing Contracting Logistics Rules Clarity Predictability Enforcement Conflict resolution	Cost of compliance Higher costs of operation Costs of conflicts & conflict resolution Search costs and delays Insufficient managerial control ‘Nuisance’ value Problems in making contracts Problems in delivery	Business productivity Export growth Size of shadow economy Growth of industries with specific assets or long-term contracting Rate of innovation and R&D Rate of business expansion Rate of investment in new equipment Subcontracting

Third, effective promotion should go beyond simply "marketing a country" into *coordinating the supply of immobile assets with the specific needs of targeted investors*. This addresses potential failures in markets and institutions for skills, technical services or infrastructure in relation to the specific needs of new activities targeted via FDI. A developing country may not be able to meet such needs, particularly in activities with advanced skill and technology requirements. The attraction of FDI in such industries can be greatly helped if the host Government discovers the TNC's needs and meets them. In Costa Rica, the fact that it was prepared to invest in training to meet Intel's skill needs was a major point in attracting the investment. Singapore goes further, and involves TNC managers in designing its ongoing training and infrastructure programmes, ensuring that it remains attractive for their future high-technology investments. The information and skill needs of such coordination and targeting exceed those of promotion per se, requiring the agency involved to have detailed knowledge of the technologies involved (their skill, logistical, infrastructural, supply and institutional needs) as well as of the strategies of the relevant TNCs.

IX. STRATEGIES TO BUILD DOMESTIC CAPABILITIES

Let us now briefly consider the strategies used by economies such as the Republic of Korea and Taiwan Province of China to build domestic technological capabilities. More detailed analysis is provided in the Annex, which also deals with Singapore, Malaysia, Thailand and the Philippines.

The Republic of Korea and Taiwan Province of China, the technological leaders in the developing world, adopted highly interventionist strategies on trade and domestic resource allocation, with a clear preference for promoting indigenous enterprises and deepening local capabilities. They imported technology vigorously from leading TNCs, but assigned FDI a secondary role to technology import in other (arm's length) forms. Their export drive was led by local firms, and comprehensive policy support allowed local firms to build impressive technological capabilities. The domestic market was not exposed to free trade; a range of quantitative and tariff measures were used over time to give infant industries "space" to develop their capabilities. The deleterious effects of protection were offset by strong incentives (in the case of the Republic of Korea, strong pressures) to export and face full international competition (Westphal, 2002). During liberalization, the same careful strategic approach was used to ensure that no damage resulted to local enterprises; concomitantly, these enterprises were encouraged to go transnational and set up integrated production systems of their own.

The Republic of Korea went much further in developing advanced and heavy industry than Taiwan Province of China. To achieve its compressed entry into heavy industry, its interventions had to be more detailed and pervasive, along the lines of Japan but probably more comprehensive (Amsden, 1989; Westphal, 2002). It relied primarily on capital goods imports, technology licensing and other technology transfer agreements to acquire technology. It used "reverse engineering" (taking apart and reproducing imported products), adaptation and own product development to build upon these arm's length technology imports and develop its own capabilities. It drew upon OEM contracts to access technologies and skills from TNCs (Cyhn, 2002). Its private sector R&D is now the most expensive in the developing world and second most expensive in the world as a whole. The Republic of Korea accounts for around 53 per cent of total private sector R&D spending in the developing world (UNIDO, 2002). The R&D risks undertaken by the *chaebol* were contained by the strict discipline imposed by the Government in terms of export performance, vigorous domestic competition, and deliberate interventions to rationalize the industrial structure. The Government also undertook various measures to encourage the diffusion of technology, putting pressure on the *chaebol* to establish supplier networks. Apart from the direct interventions to support local enterprises, the Government provided selective and functional support by building a massive technology infrastructure and creating general and technical skills.

Taiwan Province of China's industrial policy encompassed import protection, directed credit, selectivity on FDI, support for indigenous skill and technology development and strong export promotion (Wade, 1990). While this resembles the Republic of Korea's strategy in many ways, there were important differences. Taiwan Province of China did not promote giant private conglomerates, nor did it attempt the intense drive into heavy industry that the Republic of Korea attempted. Industry in Taiwan Province of China is largely composed of small and medium-sized enterprises (SMEs), and, given the disadvantages for technological activity inherent in small size, these were supported by a variety of inducements and institutional measures in upgrading their technologies. Taiwan Province of China probably has the developing world's most advanced system of technology support for SMEs.

In the early years of industrialization, the Government of Taiwan Province of China attracted FDI into activities in which domestic industry was weak, and used a variety of means to ensure that TNCs transferred technology to local suppliers (Lall, 1996). The Government also played a very active role in helping SMEs to locate, purchase, diffuse and adapt new foreign technologies. Where necessary, it entered into joint ventures in order to get into technologically very difficult areas such as semiconductors and aerospace.

X. CONCLUSIONS

What does this analysis suggest for strategies by developing countries to build local technological capabilities for competitiveness? Competitive success in industry depends vitally on the ability of each industrial system to cope effectively with technical change. This ultimately determines how a country's local value chain relates to the international chain: where it is located, how rewarding the insertion is, and the rate at which its position in the chain improves over time. Globalization means that resources such as finance, technologies and high-level skills are far more mobile than before and value chains are more tightly organized and controlled. Clearly, insertion into dynamic value chains is a very good way to build competitiveness, and the lead players are increasingly scouting the world for economical sites in which to locate their production and service activities. New technologies enable this to happen more efficiently and quickly than ever before.

However, all this *does not reduce the role of local technological capabilities*. On the contrary, it increases it because the efficiency of each location becomes the prime determinant of success. Technical efficiency requires access to new technologies from across the world, but simply exposing local industries to international trade, investment and information is not enough. It may even devastate them to the point of closure if measures are not undertaken to build up new capabilities and accelerate learning processes.

The evidence suggests growing divergence in industrial performance in the developing world. This is an unfortunate but perhaps intrinsic feature of the new technology-driven economy. The divergence is structural rather than a delayed response to liberalization: there is nothing endogenous in the globalization and liberalization process that will ensure that economies return to high growth paths. Skill development, industrial specialization, enterprise learning and institutional change create *cumulative, self-reinforcing processes* that promote or retard further learning. Countries set on a pattern with a low-technology, low-skill and low-learning specialization find it increasingly difficult to change course without a concerted shift in a large number of interacting markets and institutions. Economic liberalization may help them to realize their static comparative advantages, namely those based on inherited endowments such as natural resources and cheap unskilled labour. However, it may not lead them to develop the more *dynamic* (skill - and technology- based) advantages they need in order to sustain growth and structural change. Thus, they may become outsiders in a world of rapid and accelerating technological change, new skill needs and integrated production systems. They may suffer from long-term marginalization, having to export more products facing static or declining markets to import foreign services and products.

The insiders are the relatively few developing countries that have been able to launch on a sustainable high-growth path. The insiders also differ, depending on the strategies adopted. We may distinguish two strategies: *autonomous* and *FDI-dependent*. Autonomous strategies – as demonstrated by the Republic of Korea and Taiwan Province of China – entail a great number of industrial policy and accompanying interventions in factor markets and institutions. They lead to a massive development and deepening of indigenous skills and technological capabilities, with the national ability to keep abreast of new technologies and for domestic enterprises to become significant global players in their own right.

FDI-dependent strategies comprise two sub-strategies, *targeted* and *passive*. Targeted strategies – as in Singapore – also entail considerable industrial policy, but the intensity of government interventions is lower than with autonomous strategies. In particular, such a strategy needs free trade, if not for the whole economy then for the segments of industry that operate in export markets. The sources of technical change remain largely in the hands of TNCs, and there is thus less need to intervene to promote learning in domestic infant industries. However, industrial policy is still needed: to ensure the provision of the relevant skills, capabilities and institutions required by TNCs in order to transfer new technologies and higher-value functions. Passive strategies involve less industrial policy in export-oriented activities to start with (although there may be intervention in domestic-oriented activity). TNCs are attracted mainly by low wages for unskilled or semi-skilled labour and good infrastructure, given a conducive macro environment and policies that are welcoming to FDI.

Subsequent dynamism and upgrading in such passive strategies depend on whether TNCs are induced from simple assembly activities into more advanced, value-added activities with greater local "roots". If no strategies are adopted, growth and competitiveness may run down as the existing stock of human and technological capital is used up. Sustaining growth needs increasing policy intervention to deepen the local skill and supplier base and to target FDI itself. This is the challenge facing a number of developing countries (such as Bangladesh, Mauritius and Morocco) that have done well out of the relocation of the clothing industry in building simple manufactured exports, but have not been able so far to upgrade into more complex or technology-intensive activities.

Simply opening up to free trade and investment flows may not be an adequate strategy for countries at the low end of the technology ladder. Stabilization and liberalization can remove the constraints on growth caused by poor macro management, inefficient public enterprises, high entry costs for private enterprises and restrictions on FDI. However, they cannot by themselves allow the economy to build more advanced capabilities, to escape a "low-level equilibrium trap". Evidence about liberalizing countries such as Kenya, the United Republic of Tanzania, Zimbabwe and Ghana shows that after an initial spurt of growth, economies with static capabilities slow down as their inherited advantages are exhausted (Lall ed., 1999). The initial spurt comes from using existing unused capacity as imported inputs and spares become available. As import competition in the final product market increases, however, enterprises find it difficult to cope and close down or withdraw into non-traded activities. Without any strategic support from the Government, they find it difficult to bridge the gap between their skills, technologies and capabilities and those needed for international competitiveness.

New enterprises find it more difficult to enter into complex activities with increasingly stringent skill and technology requirements. There is a danger, therefore, that industrial structures in low-income countries with passive industrial policy will regress into simple activities that do not provide a basis for sustained growth and productivity increase. This is one reason why liberalization has shown such poor results in sub-Saharan Africa. Liberalization has also led to technological regression in many Latin American countries. These countries often have a large base of capabilities in such industries as food processing and automobile manufacture, but find it difficult to move into dynamic high-tech activities.

The rule-setting parts of the international system that deal directly with development (the Bretton Woods institutions and WTO) have so far been more concerned with *facilitating globalization* than with helping *countries cope with its demands*. This approach has been based on a strong, but largely implicit, premise that free market forces are efficient and will automatically accomplish both objectives: thus liberalization is the best policy for all countries. As a result of external pressures as well as domestic changes, there has been considerable liberalization in the developing and transition world. Governments are withdrawing from ownership of productive resources, from guiding resource allocation and, in many cases, also from the provision of several infrastructure services. The ultimate objective of current reforms is an open production, trade and investment framework where the driving force is private enterprises responding to market signals.

There is much to welcome in these trends. Many government interventions to promote development have a poor record and have constrained rather than helped growth and welfare. Giving greater play to market forces will contain many of the inefficiencies and rent seeking inherent in government intervention. However, as noted, simply opening up to market forces does not deal with many structural problems of development. The most successful developing countries in recent economic history (the Asian NIEs) intervened intensively in markets, with many different strategies to build up their competitive capabilities. Their experience suggests that there is a significant role for government in providing the "collective goods" needed for sustained development. The issue is not *whether* Governments should intervene, but *how*.

ANNEX: FDI AND TECHNOLOGY DEVELOPMENT POLICIES IN SOUTH-EAST ASIA

South-East Asia is of particular interest to the analysis of science and technology policies in the context of the developing world. It is by far the most dynamic region, in terms not just of growth but also of using new technologies effectively to drive the growth of manufacturing industry and exports. Yet it also presents many striking contrasts. Some countries have built up deep and diverse technological capabilities and are near world innovative frontiers. Others have proved adept at using technologies generated elsewhere rather than building their own capabilities (apart, obviously, from those needed for production). They have entered into sophisticated industrial activities with fast-moving proprietary technologies by plugging into the integrated production systems of leading multinational companies at the bottom end. Some have used industrial policy to move up the technology ladder within TNCs and have nascent national innovation systems, while others remain primarily assembly centres.

The strategic challenges facing these countries in the science and technology sphere are thus widely different. This annex deals with technology development policies (for manufacturing industry) in the main NIEs of East Asia with the exception of China and Hong Kong (China). As mentioned previously, technology policy in developing countries should be considered an *inherent part of industrial development policy*. It includes the elements of technology policy in the narrow sense – stimulating R&D, building technology support institutions, supporting SMEs, and so on – but it goes beyond these in providing the setting in which industrial firms operate, seek technology and learn how to use and improve it. With this in mind, let us consider technology policies in East Asia.

1. FDI AND TECHNOLOGY POLICIES IN THREE MATURE TIGERS

A. REPUBLIC OF KOREA

For the Government of the Republic of Korea technology policy was very much a tool of broader industrial policy. It combined selective import-substitution with forceful export promotion, protecting and subsidizing targeted industries that were to form its future export advantage. In order to enter heavy industry, promote local R&D capabilities and establish an international image for its exports, the Government promoted the growth of giant local private firms, the *chaebol*, to spearhead industrialization. One of the pillars of the Republic of Korea's technological strategy, and one that marks it off from the other NIEs, was the deliberate creation of these large private conglomerates. The *chaebol* were handpicked from successful exporters and were given a range of subsidies and privileges, including the restriction of TNC entry, in return for furthering a strategy of setting up capital - and technology-intensive activities geared to export markets. The rationale for fostering size was obvious: in view of deficient markets for capital, skills, technology and even infrastructure, large and diversified firms could internalize many of their functions. They could undertake the cost and risk of absorbing very complex technologies (without a heavy reliance on FDI), further develop it by their own R&D, set up world-scale facilities and create their own brand names and distribution networks. Industry in the Republic of Korea built up an impressive R&D capability by drawing extensively on foreign technology in forms that promoted local control. Thus, it was one of the largest importers of capital goods in the developing world, and encouraged its firms to obtain the latest equipment (except when it was promoting particular domestic products) and technology. It encouraged the hiring of foreign experts, and the flow (often informal) of engineers from Japan to resolve technical problems.

FDI was allowed only where considered necessary, and the Government sought to keep control firmly in local hands. Foreign majority ownership was not permitted unless it was a condition of having access to closely held technologies, or to promote exports in internationally integrated activities. The Government intervened in major technology contracts to strengthen domestic buyers, and sought to maximize the participation of local consultants in engineering contracts to develop basic process capabilities. In 1973, it enacted the Engineering Service Promotion Law to protect and strengthen the domestic engineering services sector, and the Law for the Development of Specially Designated Research Institutes to provide legal, financial and tax incentives for private and public institutes in selected technological activities.

The Government supported technological effort in Republic of Korea in several ways. Private R&D was directly promoted by a number of incentives and other forms of assistance. *Incentive schemes* included tax-exempt TDR (Technology Development Reserve) funds, tax credits for R&D expenditures as well as for upgrading human capital related to research and setting up industry research institutes, accelerated depreciation for investments in R&D facilities and a tax exemption for 10 per cent of cost of relevant equipment, reduced import duties for imported research equipment, and a reduced excise tax for technology-intensive products. The KTAC (Korea Technology Advancement Corporation) helped firms to commercialize research results; a 6 per cent tax credit or special accelerated depreciation provided further incentives.

The import of technology was promoted by tax incentives: transfer costs of patent rights and technology import fees were tax-deductible; income from technology consulting was tax-exempt; and foreign engineers were exempt from income tax. In addition, the Government gave *grants* and *long-term low-interest loans* to participants in "National Projects", which gave tax privileges and official funds to private and government R&D institutes to carry out these projects. Technology finance was provided by the Republic of Korea Technology Development Corporation (see below).

However, the main stimulus to the tremendous growth of industrial R&D came less from the specific incentives to R&D than from the overall incentive regime that created large firms, gave them a protected market to master complex technologies, minimized reliance on FDI, and forced them into international markets where competition ensured that they would have to invest in their own research capabilities. This is why, for instance, the Republic of Korea has 35 times more R&D by industry as a proportion of GDP than Mexico (with roughly the same size of manufacturing value-added), an economy that has remained highly dependent on technology imports.

The Government of the Republic of Korea intervened often in arm’s length technology imports to lower prices and strengthen the position of local buyers, but in a flexible way that did not constrain access to expensive know-how. The licensing policy was liberalized over the 1980s as the need for increasingly advanced technologies increased. The regime encouraged reverse engineering and R&D by technology-importing firms to develop indigenous technological capabilities; many of the larger firms were later able to enter into collaborative ventures with world technology leaders on a more equal basis. In the field of plant and process engineering, the Government stipulated that foreign contractors transfer their design knowledge to local firms, which quickly absorbed design technologies in some process industries.[9] Even more so than Taiwan Province of China, the Republic of Korea was able to use imported technology to develop its domestic base of capabilities in advanced activities, rather than remaining passively dependent on inflows of foreign skills and innovations.

The *chaebol* soon developed sufficient international presence to manage their technology imports. However, SMEs had to be given continued assistance to search for and buy technologies overseas. Like Taiwan Province of China (and Japan), the Republic of Korea compiled a database on sources and prices of technology supply. This was linked to similar databases overseas and provided on-line in major industrial centres. There was also a programme to increase SMEs' technological linkages with large firms (see below), but unlike in the case of Taiwan Province of China, this was directed mainly at local large firms rather than at TNCs. As with the other export-oriented countries, foreign buyers were a valuable source of technology.[10] The Government's export promotion efforts contributed greatly to this mode of technology acquisition. Several promotion measures were involved, including financial incentives, export targeting, other pressures to export (such as access to import licences) and information support.[11]

The Korean Overseas Trade Agency (KOTRA) played a significant role in providing contacts and market intelligence, and bringing together foreign buyers and Republic of Korea suppliers. The *chaebol* themselves were instrumental in promoting exports by other firms via their trading arms, modelled on the Japanese *sogo shosha.* These had the financial and marketing strength to be able to substitute for foreign trading companies that small exporters in Taiwan Province of China had to rely on (above), and contributed to the superior ability of the Republic of Korea to establish its own brand names in international markets.

The Republic of Korea's policies to selectively encourage activities and firms via credit allocation and subsidization were inherent to its industrial policy from the start (Amsden, 1989; World Bank, 1993). As the industrial sector matured and entered more demanding areas of technology and the Government reduced the direct allocation of credit, its role in technology financing increased rather than decreased.[12] This emphasis was also aided by the fact that the emerging "rules of the game" made other forms of subsidies and grants to industry unacceptable, while technology financing remained a permissible form of intervention.

The Government of the Republic of Korea provided technology financing in the form of both grants and loans (often directed and subsidized). A variety of institutions, such as venture capital companies, banks, credit guarantee companies and others, were used to channel funds to a variety of users in a variety of forms. These three forms of technology financing - subsidies, loans and institutional support - are described in turn.

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[9] For a study of this strategy in the petrochemicals industry, see Enos and Park (1997).

[10] Rhee et al. (1984).

[11] Export promotion was implemented by general measures such as devaluation and general tax incentives, as well as by discretionary measures such as access to restricted imports and direct cash subsidies. The State-controlled banking system was used to channel funds into export support, and export performance increasingly became the criterion for creditworthiness. These incentives were backed by powerful direct pressures to export: regular meetings between business leaders and the Government and detailed targeting of exports at the industry and firm levels (backed by threats of tax auditing and restrictions on imported inputs for poor performers). The export drive also received considerable support from institutional measures such as support for the giant trading and producing conglomerates, assistance to testing and quality assurance services, export marketing information, design assistance, and so on. Overt subsidies declined over the 1980s, but institutional support and the indirect influence of the Government continued strongly.

[12] Song (1995).

Subsidies. There are three main forms of subsidies for technological effort: the Designated R&D Programme (launched in 1982), the Industrial Technology Development Programme (1987) and the Highly Advanced National Project (1992). Together these have contributed large sums of money for research approved or targeted by the Government, conducted by firms on their own, by research institutes on their own, and by firms in collaboration with research institutes (box 3).

Box 3. Republic of Korea government subsidies for technology development

- The Designated R&D Programme has, since 1982, supported private firms undertaking research in core strategic technology development projects in the industrial area approved by the Ministry of Science and Technology. It funded up to 50 per cent of R&D costs of large firms and up to 80 per cent for SMEs. Between 1982 and 1993, this Programme funded 2,412 projects, which employed around 25,000 researchers at a total cost of around $2 billion, of which the Government contributed 58 per cent. It resulted in 1,384 patent applications, 675 commercialized products and $33 million of direct exports of know-how. Its indirect contribution in terms of training researchers and enhancing enterprise research capabilities was much larger. The value of grants under the Programme in 1994 was $186 million, 42 per cent of which was directed at high-technology products such as new speciality chemicals.
- The Industrial Technology Development Programme, was started in 1987 to subsidize up to two thirds of the R&D costs of joint projects of national interest (National Research Projects) [13] between private firms and research institutes. Between 1987 and 1993 this Programme sponsored 1,426 projects at a cost of $1.1 billion, of which the subsidy element from the Government was 41 per cent. In 1994, the Programme made grants of $180 million (with 31 per cent going to high-technology products), a significant increase from $69 million in 1990.
- The Highly Advanced National Project (HAN) was launched in 1992 to support two activities: the development of specific high-technology products in which the Republic of Korea could become competitive with advanced industrial countries in a decade or two (Product Technology Development Project), and the development of "core" technologies considered essential for the economy in which the Republic of Korea wanted to achieve an independent innovative base (Fundamental Technology Development Project). So far 11 HAN projects have been selected, and during 1992–1994 the Government provided $350 million of subsidies for them. In this brief period, the programme resulted in 1,634 patent applications and 298 registrations.

Loans. The Government of the Republic of Korea set up three funds to provide loans, usually at subsidized rates,[14] for technology development. The *first* was the Industrial Development Fund, providing low-interest loans for long-term productivity improvement and technology upgrading in high-technology industries. Several banks were used to channel the funds, which could total up to 70 per cent of the approved projects for large companies and up to 100 per cent for SMEs. The loans are given for five years, with a two-year grace period, and an interest rate of 6.5 per cent. The total funds disbursed during 1990–1994 came to around $618 million. The *second* fund was the Science and Technology Promotion Fund, started in 1993 to fund firms and research institutes undertaking HAN projects (noted above). Loans could total up to 80 per cent of the total value of the project, up to $1.3 million per project and $3.8 million per firm. They are for seven years, with a grace period of three years and an interest rate of 6 per cent. In its two years of operation the fund has offered $255 million. *Third*, an SME Foundation Formation Fund was set up as recently as 1994 to support technology development and environmental investment by smaller firms. The fund could finance 100 per cent of approved projects at an interest rate of 8.5 per cent over 10 years, with a grace period of three years. In 1994 this fund provides $400 million.

[13] These National Projects are mentioned below in connection with technology infrastructure.
[14] Commercial interest rates in the early 1990s were around 14–15 per cent.

Financial institutions' technology financing. The Republic of Korea has the largest and most successful *venture capital* industry in the developing world. Starting with the launching of the Republic of Korea Technology Development Corporation (KTDC), a joint effort by the Government and the *chaebol*, in the early 1980s, several private venture capital funds were set up. There are 58 venture capital companies in the Republic of Korea today, which disbursed loans and investment funds amounting to $3.5 billion during 1990–1994 (85 per cent of this was in the form of loans).

A number of *banks* (Korea Development Bank, Industrial Bank of Korea, the Kookmin Bank, the Korea Long-Term Credit Bank and others) lend money to firms and research institutes for technology development. The State-owned KDB, for instance, offers three kinds of finance: Technology Development Loan, High-Technology Industry Promotion Loan and Production Technology Development Loan. These three instruments lent $ 3.4 billion during 1990–1994, with 40 per cent going into the High-Technology Industry Promotion programme. Both this programme and the Production Technology Development Loan are for firms approved by the Ministry of Trade, Industry and Energy; finance is provided for eight years with a three-year grace period and a subsidized interest rate of 8 per cent. The Industrial Development Bank of Korea offers Technology Development Loans for SMEs, which amounted to $560 million during 1990–1994. These loans are for developing new technologies or improving upon imported technologies, and IDB offers up to 100 per cent of the cost of the project at 8.5 per cent interest (over 10 years with a three-year grace). Other banks also offer similar loans to SMEs.

The Korea Technology Credit Guarantee Fund (KTCGF) offers *credit guarantees* for loans made to help firms develop or commercialize new technology. It concentrates on SMEs (firms with under 1,000 employees) in new technology industries, as well as research institutes that need funds for technology development. The total value of its guarantees between 1990 and 1994 was about $8 billion. The fee charged is 1 per cent of the value guaranteed for SMEs and 1.5 per cent for larger companies.

The scale of technology financing in the Republic of Korea is truly impressive, although the Government feels that it is still inadequate for its needs. This accounts for the constant setting up of new schemes, targeted at smaller firms and the fostering of collaboration with research institutes. The figures also indicate that there is tremendous technological dynamism in the SME sector, although the *chaebol* continue to account for the bulk of R&D expenditures. The extent of selectivity in technological activity remains very high, with no remission in the strategy of identifying and targeting specific areas for research activity.

The Asian crisis, however, has forced technologically sound but financially weak the Republic of Korea firms to invite FDI to cope with pressing cash flow problems (Kim, forthcoming). They put not only peripheral but also core businesses up for sale. Consequently, unlike China and South-East Asian economies that witnessed sharp falls in FDI (e.g. Singapore 24.8 per cent and Taiwan Province of China and Malaysia 19 per cent in 1998), the Republic of Korea had a sudden increase in FDI. Thus, FDI in manufacturing rose from $2.3 billion in 1997 to $8 billion in 1998 and to $15.5 billion in 1999. The lion's share of the new FDI took the form of mergers with and acquisitions of existing Republic of Korea firms. Hewlett-Packard purchased a 45 per cent stake in its Republic of Korea subsidiary from its joint venture partner, Samsung Electronics, for $36 million. Dow Chemical took over Ulsan Pacific Chemical by purchasing a 20 per cent stake. Philips purchased a 50 per cent stake in LG's highly profitable flat panel display business for $1.4 billion. Volvo purchased Samsung's construction machinery division for $730 million.

If assets sales are included, the Republic of Korea's top five *chaebol* raised over $7.4 billion in the year after the crisis. The Republic of Korea's economy will now be far more linked with foreign multinationals than before. But in most recent cases the FDI transfers neither new processes nor new product technologies. It does transfer managerial capabilities, which introduces transparent and accountable management systems, which Republic of Korea firms previously lacked.

Some TNCs have also started to conduct R&D locally. Thirty-nine TNCs, or 1.4 per cent of the total number of TNCs operating in Republic of Korea manufacturing, have set up R&D centres. Thirty-three of these were established in the 1990s, after the Republic of Korea had developed a significant R&D base. TNC R&D units, however, account for less than 1 per cent of the total number of corporate R&D centres. Most of TNC R&D involves adapting products to local markets, which suggests that local innovation by TNCs is fairly insignificant compared with that of domestic firms.

Patent registration in the United States is often used as a measure of international competitiveness. The cumulative number of patents granted to nationals of the Republic of Korea by the United States between 1969 and 1992 was 1,751 compared with 4,978 for Taiwan Province of China. However, the Republic of Korea jumped from 35th place in the number of patents in the United States (among 36 countries listed in an NTIS report) in 1969 to 11th place in 1992, giving an average annual growth rate of 43 per cent (NTIS, 1993). This growth rate was the highest of the countries in that report. A more recent report shows that the Republic of Korea jumped to sixth place in 1999, with 3,679 patents, after only Japan, Germany, Taiwan Province of China, France and the United Kingdom. Samsung Electronics, the most R&D - intensive firm in the Republic of Korea, ranked fourth with 1,545 US patents, coming only after IBM, NEC and Canon. These figures again indicate how rapidly the Republic of Korea has gained in technological competitiveness.

The Government of the Republic of Korea invested in a large array of *technology infrastructure institutions.* In 1966 it set up KIST (Korea Institute of Science and Technology) to conduct applied research of various kinds for industry. In its early years, KIST focused on solving simple problems of technology transfer and absorption. In the 1970s, the Government set up other specialized research institutes related to machinery, metals, electronics, nuclear energy, resources, chemicals, telecommunications, standards, shipbuilding, marine sciences, and so on. These were largely spun off from KIST, and by the end of the decade there were 16 public R&D institutions. In 1981 the Government decided to reduce their number and rationalize their operations. The existing institutes were merged into nine under the supervision of the Ministry of Science and Technology. KIST was merged with KAIS (Korea Advanced Institute of Science) to become KAIST, but was separated again - as KIST - in 1989.

The Government's strategic thrust in this sphere was mainly a series of *National R&D Projects* launched in 1982. These were large-scale projects which were regarded as too risky for industry to tackle alone but which were selected as being in the country's industrial interest. National Projects were conducted jointly by industry, public research institutes and the Government, and covered areas such as semiconductors, computers, fine chemicals, machinery, material science and plant system engineering. "Centres of Excellence" were formed in these fields to boost long-term competitiveness. National Projects were a continuation of the strategy of interventions to identify and develop the country's dynamic comparative advantage, orchestrating the different actors involved, underwriting a part of the risks, providing large financial grants and filling gaps that the market could not remedy (for data on the amounts involved see above on technology financing).

Other policy measures to stimulate technological effort in the Republic of Korea were more addressed to static market failures. These included the setting up of *Science Research Centres* and *Engineering Research Centres* at universities around the country to support R&D activities, the *common utilization* of advanced R&D facilities by smaller private firms, and the construction of *science towns.* Daeduk Science Town has been under construction since 1974, and a large number of research and educational institutions are already well established there. The construction of Kwangju Science Town has started; others such towns are planned. Technology *diffusion* was advanced by the Korea Institute for Economics and Technology, which collected, processed and disseminated scientific and technical information to industry.

Since the early 1980s a number of laws have been passed to *promote SMEs*, leading to a perceptible increase in their share of economic activity (over 1975–1986 the share of SMEs in employment, sales and value added rose by at least 25 per cent). This policy support was crucial to the reversal in their performance: it covered SME start-up, productivity improvement, technology development and export promotion. A host of tax incentives was provided to firms participating in these programmes, as well as finance at subsidized rates for using support services, credit guarantees, government procurement and the setting up of a specialized bank to finance SMEs. A number of other institutions were set up to help SMEs (such as the Small and Medium Industry Promotion Corporation to provide financial, technical and training assistance and the Industrial Development Bank to provide finance). The Government greatly increased its own budget contribution to the programme, although SMEs had to pay a part of the costs of most services provided to them.

To promote subcontracting to SMEs, the Government enacted a law designating parts and components that had to be procured through them and not made in-house by large firms. By 1987 about 1,200 items had been designated, involving 337 principal firms and some 2,200 subcontractors, mainly in the machinery, electrical, electronic and shipbuilding fields. By this time, subcontracting accounted for about 43 per cent of manufacturing output and 65–77 per cent of the output values of the electrical, transport equipment and other machinery industries. Generous financial and fiscal support was provided to subcontracting SMEs to support their operations and process and product development. In addition, subcontracting SMEs were exempted from stamp tax and were granted tax deductions for a certain percentage of their investments in laboratory and inspection equipment and for the whole of their expenses for technical consultancy. Subcontracting promotion councils were set up by the industrial subsector and within the Korea Federation of Small Business to help SMEs in contractual relationships, arbitrate disputes and monitor contract implementation.

B. TAIWAN PROVINCE OF CHINA

The history of technological development in Taiwan Province of China has some similarities to that of the Republic of Korea, but there are also marked differences because of their different political economies and industrial structures: the Government of Taiwan Province of China always had a more distant relationship with industry and never promoted the growth of large private conglomerates like the *chaebol*. It started to address the development of local R&D capabilities fairly early, in the late 1950s, when its growing trade dependence reinforced the need to enhance local innovative effort to upgrade and diversify its exports. A Science and Technology Programme was launched in 1979, targeting energy, production automation, information science and materials science technologies for development. In 1982, biotechnology, electro-optics, hepatitis control and food technology were added to this list. In 1986, the S&T Development Plan for 1986–1995 was launched, continuing the targeting of strategic areas of technology. It set a target for total R&D of 2 per cent of GDP for 1995; by 1993, it had reached 1.8 per cent. Today the figure is over 2 per cent.

The Government finances around half of R&D in Taiwan Province of China (much higher than in the Republic of Korea), although the contribution has decreased over time. Private sector R&D has been relatively weak because of the preponderance of SMEs, which cannot afford the large minimum investments involved in much of industrial research. However, enterprise R&D has increased over time as some local firms have grown in size and become transnational. Such R&D has been encouraged over the years by a variety of incentives: provision of funds for venture capital; financing facilities for enterprises that developed "strategic" industrial products (of which 151 were selected in 1982 and 214 in 1987);[15] measures to encourage product development by private firms by providing matching interest-free loans and up to 25 per cent of grants for approved projects;[16] full tax deductibility for R&D expenses, with accelerated depreciation for research equipment; special incentives for enterprises based in the Hsinchu Science Park (with government financial institutions able to invest up to 49 per cent of the capital); and requiring larger firms (turnovers exceeding NT$ 300 million) to invest (0.5–1.5 per cent of sales, depending on the activity) in R&D. The Government also launched large-scale research consortia, funded jointly with industry, to develop critical industrial products such as a new generation automobile engine, and 16M DRAM and 4M SRAM chips.

In sum, the main drive for increasing R&D in Taiwan Province of China came, as in the Republic of Korea, from the export orientation of the economy, combined with measures to reduce dependence on technology imports (below). However, Taiwan Province of China's "lighter" industrial structure constrained the growth of private sector R&D compared with the Republic of Korea. In broad terms, both countries show the strong influence of strategic rather than static interventions on market failures.

Taiwan Province of China started on import-substituting industrialization in the 1950s with a relatively strong base of human capital and a large population of SMEs. Like the Republic of Korea, it switched to export orientation in the 1960s, but retained protection and targeting to promote and guide industrial growth. It combined these with interventions in technology transfer to support technology development by local enterprises. It drew upon the whole gamut of technology imports, but changed the balance and the policy regime over time. In the 1950s, it sought to attract FDI within a liberal regime, with no discrimination by origin, destination (only services were restricted for foreign entry) or degree of ownership. In the 1960s, FDI was sought in labour-intensive industries such as textiles, garments and electronics assembly. In the 1970s, with rising wages and a need to upgrade industry, the Government targeted higher technology, discouraging labour-intensive FDI and favouring investments in automation, informatics and precision instruments. This targeting was strengthened in the 1980s, as high-technology industries were granted five-year tax holidays, accelerated depreciation of equipment, low tax rates for selected activities, and duty-free imports of R&D materials and equipment.

[15]The Government provided NT$ 20 billion in loans at preferential interest rates for buying equipment, of up to 65 per cent of the investment.

[16]By the end of 1992, the Government had granted NT$ 2 billion in matching interest-free loans and NT$ 1 billion in research grants, mostly to the information and communications industries. The provision of grants was limited to products involving "high technology", while loans were available, on approval, to most industries.

Thus, as the industrial sector developed and technologies deepened over time, FDI policy in Taiwan Province of China became more discriminatory. The Government exercised more detailed surveillance (often on a case-by-case basis) to ensure that the technology was in line with changing national priorities. It targeted emerging technologies, and placed strict conditions on investors to benefit the technology development of domestic firms. Where domestic firms were strong, FDI was actively discouraged; where they were weak, foreign firms were made to diffuse technology and contribute to local capabilities. With yet more development of local firms and capabilities, selectivity regarding FDI was relaxed but the guidance and support of technology development continued. In the meantime, Taiwan Province of China firms themselves became major investors overseas, spurred by the need to relocate labour-intensive activities and an enormous balance-of-payments surplus.

The Government sought to maximize benefits from FDI for local firms by promoting local sourcing and subcontracting - an exceptionally successful strategy for enhancing technological and skill linkages with foreign firms. This promotion was done through local content rules, backed by provisions that foreign firms transfer skills and technology to subcontractors and increase the capabilities of local firms.

The Government of Taiwan Province of China also played a *direct* role in developing advanced technologies, where it found that the private sector was unable to develop the necessary capabilities. Take semiconductors. By the 1970s, industry in Taiwan Province of China had fallen behind technologically in this industry, which provided a crucial input into its burgeoning electronics export sector. The lag arose mainly because local firms were too small to set up the capital-intensive facilities involved and to invest in developing the necessary skills. In 1976, the Electronic Research and Service Organization (ERSO), part of the Government's Industrial Technology Research Institute (ITRI), imported and started to develop process technologies for very large integrated circuits (VLSI). By mastering this technology and creating a base of technical skills, ITRI was able to spin off the first integrated circuit manufacturer in Taiwan Province of China in 1982.[17] This firm (UMC) was able to conclude agreements with three Chinese-owned start-ups in Silicon Valley in the United States to develop advanced chip designs. This was successful, and UMC went public in 1985. In 1987, using VLSI technology from UMC, the Government set up a joint venture (the Taiwan Semiconductor Manufacturing Company, TSMC) with Philips of the Netherlands and local private interests for wafer fabrication. TSMC grew rapidly, and supported the development of design and manufacturing capabilities in numerous small electronics firms. This further encouraged the entry of private companies into the production of semiconductors, microprocessors and related electronics products: the Government had been able to catalyse technological development by its critical intervention.

Foreign firms accounted for a relatively small part of Taiwan Province of China’s industrial and export success. Local enterprises, led by SMEs, led the export drive, first by using the “Chinese connection” in Asia and then, as their horizons widened, by tapping Japanese trading companies and American mass-market buyers. In the 1960s, about 60 per cent of textile exports were sold through Japanese trading houses (the *sogo shosha*), and even today these handle a third to half of exports from Taiwan Province of China; such are the economies of scale and information collection in world markets that small firms find it difficult and costly to export alone even after years of experience (this is in contrast to the Republic of Korea case, reviewed below, where the government sought to internalize these functions within local trading houses, part of the giant local conglomerates). United States

[17]Hobday (1995).

buyers became more important over time, with the government facilitating contacts with small suppliers, with aggressive assistance from industry associations and other private organizations. In addition, there emerged many (relatively small) local trading houses, which proved to be valuable sources of technical, design and marketing information for exporters. Large multinational producers, which sourced complex electronic and related products under OEM (original equipment manufacture, where the product is sold under the brand name of the buying company) arrangements in Taiwan Province of China, were even more significant sources of technology transfer.

A more recent example of advanced technology development policy in Taiwan Province of China is its use of innovation consortia. Box 4 describes these.

Box 4. Taiwan Province of China's R&D consortia

A series of collaborative R&D ventures emerged in Taiwan Province of China in the 1990s, within a quite distinctive institutional framework. Unlike in the case of many of the collaborative arrangements between established firms in the United States, Europe or Japan, where mutual risk reduction is frequently the driving influence, in the case of Taiwan Province of China it is technological learning, upgrading and catch-up industry creation that are the object of the collaborative exercises. The Taiwanese R&D alliances were formed hesitantly in the 1980s, but flourished in the 1990s as institutional forms were found which encourage firms to cooperate in raising their technological levels. Most of these alliances have been in the information technology sectors, covering personal computers, workstations, servers and multimedia, as well as a range of consumer products and telecommunications and data switching systems and products. But they have also emerged in other sectors such as automotive engines, motor cycles, electric vehicles, and in the services and financial sector as well. Several such alliances could be counted in Taiwan, Province of China in the late 1990s, bringing together firms and public sector research institutes, with the added organizational input of trade associations, and catalytic financial assistance from government.

Taiwan Province of China's high-technology industrial success rests on a capacity to leverage resources and pursue a strategy of rapid catch-up. Its firms tap into advanced markets through various forms of contract manufacturing, and are able to leverage new levels of technological capability from these arrangements. This is an advanced form of "technological learning", in which the most significant players have not been giant firms (as in Japan or the Republic of Korea), but small and medium-sized enterprises whose entrepreneurial flexibility and adaptability have been the key to their success. Underpinning this success is the efforts of public sector research and development institutes, such as Taiwan Province of China's Industrial Technology Research Institute (ITRI), which since its founding in 1973 has acted as a prime vehicle for the leveraging of advanced technologies from abroad, and for their rapid diffusion or dissemination to Taiwan Province of China's firms. This cooperation between public and private sectors to overcome the scale disadvantages of Taiwan Province of China's small firms is a characteristic feature of the country's technological upgrading strategies, and the creation of new high-technology sectors such as semiconductors.

Behind many of these successes lie some remarkable institutional structures favouring collaborative product development, which is Taiwan Province of China's own adaptation of the R&D alliance. Taiwan Province of China's current dominance of mobile PCs for example, rests at least in part on a public-private sector - led consortium that rushed a product to world markets in 1991. Taiwan Province of China's strong performance in communications products such as data switches, which now dominate in PC networks, similarly rests on a consortium which worked with Taiwan Province of China's public sector industry research organization, ITRI, to produce a switch to match the Ethernet standard in 1992/93. When IBM introduced a new PC based on its PowerPC microprocessor in June 1995, Taiwan Province of China's firms exhibited a range of computing products based on the same processor just one day later. Again this achievement rested on a carefully nurtured R&D consortium involving both IBM and Motorola, joint developers of the PowerPC, as external parties (Mathews and Poon, 1995). These successes were followed up by many more such R&D alliances in digital communications and multimedia areas. Taiwan Province of China is emerging as a potentially strong player in the automotive industry, particularly in the expanding China market, driven by its development of a 1.2 litre 4-valve engine; again, this is the product of a public-private collaborative research endeavour involving three companies, which have now jointly created a new Taiwan Engine Company to produce the product. Thus, the R&D consortium is an inter-organizational form that Taiwan Province of China has adapted to its own purposes as a vehicle for catch-up industry creation and technological upgrading. The micro-dynamics of the operation of these consortia are therefore a matter of some substantial interest.

Some of these consortia have been more successful than others - but all seem to have learned organizational lessons from the early cases where government contributed all the funds, and research tasks were formulated in generic and overly ambitious terms for the companies to take advantage of them. The more recent R&D alliances have been more focused, more tightly organized and managed, and have involved participant firms much more directly in co-developing a core technology or new technological standard which can be incorporated by the companies, through adoption and adaptation, in their own products.

The basic model of the Taiwan Province of China alliances is the construction of a process in which R&D costs can be shared, and risks reduced, through bringing many small firms into a collaborative alliance with each other and with ITRI (i.e. with one of its operating laboratories); it is ITRI which provides the anchor for the alliance and the principal technology leverage vehicle. Thus, the Taiwan Province of China R&D alliances differ from their counterparts in the United States, Japan and Europe in that their goal is *rapid adoption* of new technological standards, products or processes developed elsewhere, and their *rapid diffusion* to as many firms as possible. But their organizational form owes much to the R&D collaborative vehicles developed in the leading industrial centres, particularly the way that Japan structured many relatively short-lived R&D alliances with clear technological goals as in the 1976–1979 VLSI project.

One striking feature worthy of immediate notice is the relatively small budgets of these consortia. In all, the 20 consortia have accounted for a budget of no more than NT$4 billion, over 15 years, with government input of no more than NT$2.3 billion -- or these figures reveal just what a "David and Goliath" struggle it has been for Taiwan Province of China to take on US firms in high-technology industries -- and they underscore the significance of the achievements of Taiwan Province of China, which owe as much to organizational finesse and learning as to dollar subsidies.

Source: Mathews (1997).

The China External Trade Development Council (CETRA), set up by the Government in 1970 and funded by a (0.6 per cent) levy on exports, was an important agent of export promotion. CETRA developed sophisticated computerized data banks on foreign markets, buyers and suppliers, providing a one-stop source of information about supply potential in Taiwan Province of China. Its Industrial Design and Promotion Department helped exporters to develop designs and packaging appropriate to different foreign markets. By 1989 the organization had 700 staff and operated 28 branch offices overseas. Ethnic Chinese from Taiwan Province of China living in the United States were also a significant source of technology, investment and skill transfers. In recent years, investment by Taiwan Province of China companies in the developed world has become a growing source of technology, along with strategic alliances with technology leaders (Hobday, 1995).

Taiwan Province of China also developed a comprehensive system for *financing technology activity*. In the early 1980s, the Government found that the financial system was failing to meet the needs of technology-based enterprises. It set up a capital investment fund of NT$ 800 million in 1983, which it augmented in 1991 by a second fund of NT$ 1.6 billion. By mid–1993 it had 23 venture capital companies, which had invested some NT$ 9 billion (US$ 340 million) in nearly 400 companies in high-technology industries (nearly half the funds went into two activities-information and electronics).

Taiwan Province of China's *technology infrastructure*, particularly for SMEs, is one of the best in the world. There are around 700 thousand SMEs in Taiwan Province of China, accounting for 70 per cent of employment, 55 per cent of GNP and 62 per cent of total manufactured exports. The list of different efforts to assist them is impressive. In 1981 the Government set up the Medium and Small Business Administration to support SME development and coordinate the several agencies that provided financial, management, accounting, technological and marketing assistance to SMEs. Financial assistance was provided by the Taiwan Medium Business Bank, the Bank of Taiwan, the Small and Medium Business Credit Guarantee Fund and the Small Business Integrated Assistance Centre. Management and technology assistance was provided by the China Productivity Centre, the Industrial Technology Research Institute and a number of industrial technology centres (for metal industry, textiles, biotechnology, food and information). The Government covered up to 50–70 per cent of consultation fees for management and technical consultancy services for SMEs.

The Medium and Small Business Administration established a fund for SME promotion of NT$ 10 billion. The Centre-Satellite Factory Promotion Programme of the Ministry of Economic Affairs integrated smaller factories around a principal one, supported by vendor assistance and productivity-raising efforts. By 1989 there were 60 networks with 1,186 satellite factories in operation, mainly in the electronics industry.

Several technology research institutes supported R&D in the private sector. The *China Textile Research Centre,* set up in 1959 to inspect exports, expanded to include training, quality systems, technology development and directly acquiring foreign technology. The

Metal Industries Development Centre was set up in 1963 to work on practical development, testing and quality control work in metal-working industries. It later established a CAD/CAM centre to provide training and software to firms in this industry. The *Precision Instrument Development Centre* fabricated instruments and promoted the instrument manufacturing industry, and later moved into advanced areas such as vacum and electro-optics technology. The most important was perhaps the *Industrial Technology Research Institute* (ITRI).

ITRI conducted research and development for technology projects considered too risky. It had seven laboratories, dealing with chemicals, mechanical industries, electronics, energy and mining, materials research, measurement standards and electro-optics, but electronics was the institute's principal focus, with its Electronics Research & Service (ERSO) division accounting for two thirds of the Institute's $450 million budget. ERSO has spun off laboratories as private companies, including the United Microelectronics Corporation (UMC) in 1979 and the Taiwan Semiconductor Manufacturing Company (TSMC) in 1986, Taiwan Province of China's most successful integrated circuit makers. The Institute for the Information Industry (III) was set up to complement ITRI's work on hardware by developing and introducing software technology.

Where the private sector was unable by itself to undertake complex or risky technologies, the Government played a direct lead role. As noted above, the Government (led on the technical side by ERSO) entered into a joint venture with Philips to set up the Taiwan Semiconductor Manufacturing Company, the first wafer fabrication plant in the country. The Government also strongly encouraged industry to contract research to universities, and half of the National Science Council's research grants (about $200 million a year) provided matching funds to industry for such contracts. We have already noted above the use of innovation consortia.

The Taiwan Handicraft Promotion Centre supported Taiwan Province of China's handicraft industries, particularly those with export potential. Its main clients were small entrepreneurs, most with under 20 employees. In addition, the Programme for the Promotion of Technology Transfer maintained close contact with foreign firms with leading-edge technologies in order to facilitate the transfer of those technologies to Taiwan Province of China.

The China Productivity Centre (CPC) promoted automation in industry to cope with rising wages and increasing needs for precision and quality. The CPC sent out teams of engineers to visit plants throughout Taiwan Province of China and demonstrate the best means of automation and solve relevant technical problems, at the rate of approximately 500 visits making some 2,000 suggestions a year. CPC also carried out more than 500 research projects on improving production efficiency and linked enterprises to research centres to solve more complex technical problems.

The Government set up a science town in Hsinchu, with 13,000 researchers in two universities, six national laboratories (including ITRI) and a huge technology institute, as well as some 150 companies specializing in electronics. The science town makes a special effort to attract start-ups and provides them with prefabricated factory space, five-year tax holidays and generous grants. In the 1980s the Government invested US$ 500 million in Hsinchu.

C. SINGAPORE

Singapore, the smallest of the Tigers (with a population of about 3 million), has deepened its industrial and technological structure to sustain impressive growth despite high wages.[18] It started with a strategic location and established *entrepot* facilities (like Hong Kong (China), though with a smaller base of trading and financial activity). Although it had a tradition of shipbuilding and associated skills, Singapore had a weak entrepreneurial base and did not, unlike Hong Kong (China), benefit from an influx of experienced Shanghai businessmen and technologists. Nor did it have access to a large, less-developed but culturally similar, hinterland to which it could sell its services. After a spell of import substitution, the Singapore Government (when it broke away from Malaya) switched to free trade and pursued growth by aggressively seeking and targeting foreign direct investment, deliberately seeking a niche in TNC production networks. The other prong of this strategy was increasing domestic resources by a variety of measures that gave Singapore one of the highest savings rates in the world. The Government realized quite soon that to sustain rising wages with manufacturing growth, industry would have to deepen (i.e. move into more advanced technologies and functions). It set about systematically planning for and achieving such deepening.

Despite its free trade stance, the Singapore Government was highly interventionist, deploying a battery of selective measures to target activities, firms, skills and so on. The aim was consistent and explicit: to combine competitiveness with increasing value-added and rising technology levels. And it was very successful. Singapore has moved steadily from labour-intensive to capital-, skill and-technology-intensive activities, and is now targeting innovation and very high-value service activities. Its technology acquisition policy was directed at consciously acquiring, and subsequently upgrading, the most modern technologies in highly internalized (FDI) forms. This allowed it to specialize in particular stages of production within global systems of TNC production, drawing on the flow of innovation generated by the firms and investing relatively little in its own innovative effort.

How could a small economy with no natural resources or domestic markets attract foreign investment while inducing it to upgrade? The answer lay in skill creation, advanced infrastructure, strategic policy-making and efficient administration. It used incentives and moral suasion extensively, but this would not have worked without the underlying factors that made it a desirable and efficient base for manufacturing and services by TNCs.

Singapore invested heavily in education and training and in physical infrastructure. It transformed its inherited education system into one that was very industrially targeted, able to provide the higher technical skills as well as the worker training needed for high-tech production (Selvaratnam, 1994). Its policies for attracting FDI were based on liberal entry and ownership conditions, easy access to expatriate skills, and generous incentives for the activities that it was seeking to promote. But they were more – they were set within a clear strategic framework and managed by an agency (the Economic Development Board, EDB) that had the vision and the authority to devise and implement industrial policy. Set up in 1961, the EDB was able to coordinate local factor conditions and rules to meet the needs of foreign investors in targeted activities, a status and task that few investment promotion

[18] This section draws upon a previously published paper by the author (Lall, 2000a).

agencies in the world acquire (the exception being the Industrial Development Authority of Ireland). EDB acquired and created industrial estates (box 5). At times it deliberately raised wages to accelerate technological upgrading, although in the mid-1980s a sharp rise in wages was modified to restore competitiveness.

Box 5. Singapore's FDI strategy

The decisions of TNCs about what new technologies to bring into Singapore were strongly influenced by the incentive system and direction offered by the Singapore Government responding (or anticipating through proactive planning and consultation) by providing the necessary skilled manpower in consultation with the TNCs. In many instances, it is the *speed and flexibility* of government response that gave Singapore the competitive edge compared with other competing host countries. In particular, the boom in investment in offshore production by TNCs in the electronics industry in the 1970s and the early 1980s created a major opportunity by ensuring that all the enabling supporting industries, transport and communication infrastructure, as well as the relevant skill development programmes, were available to attract these industries to Singapore. This concentration of resources helped Singapore to achieve significant *agglomeration economies* and hence first-mover advantages got many electronics related industries. An example is the disk-drive industry, where all the major US disk-drive makers have located their assembly plants in Singapore. These industries demanded not only electronics components and PCB assembly support, but also various precision engineering-related supporting industries such as tool and die, plastic injection moulding, electroplating and others. These supporting industries were actively promoted by the Government as part of a "clustering" approach to ensure the competitiveness of the downstream industries.

As labour and land costs rose, the Singapore Government used the opportunity to encourage TNCs to reconfigure their operations on a regional basis, making Singapore their regional administrative headquarters and/or regional marketing/distribution/service/R&D centres to support manufacturing and sales operation in the ASEAN and Asia-Pacific region. To promote such reconfiguration, new incentives such as the regional headquarters scheme, international procurement office scheme, international logistics centre scheme and the approved trader scheme were introduced.

The public sector in Singapore also played an important role in launching and promoting activities chosen by the Government, acting as a catalyst to private investment or entering areas that were too risky for the private sector. While the main thrust of Singapore's technology import policies has been to target FDI, in recent years the Government has also sought to increase linkages with local enterprises by promoting subcontracting and improving extension services (see below).

The success of Singapore's strategy is reflected in the fact that, despite its small size, it remains (in dollar terms) the second largest destination for FDI in Asia after China. Its industrial and manufactured export growth continued at near double-digit rates until the recent recession caused by the global slowdown. Of all the economies plugging into TNC integrated systems, Singapore is the one that has achieved the highest value-added and technological sophistication. It has also induced TNCs to set up R&D facilities locally; although its innovation capabilities do not match those of the Republic of Korea and Taiwan Province of China, they are better than elsewhere in the developing world.

Box 6 describes features of Singapore's human resource development strategy.

Box 6. Skill development for technology-based industrialization in Singapore

The Singapore Government has invested heavily in creating high-level skills to drive the targeted upgrading of the industrial structure. The university system was expanded and directed towards the needs of its industrial policy, its specialization changed from social studies to technology and science. In the process, the Government exercised tight control over curriculum content and quality, and ensured its relevance to the activities being promoted. Apart from formal education, the Government also directed considerable effort towards developing the industrial training system, now considered one of the best in the world for high-technology production.

Singapore is a regional leader in employee training programmes conducted outside the firm. It set up the Skill Development Fund in 1979, along with a Skill Development Fund Levy, which collected a levy of 1 percent of payroll from employers to subsidize the training of low-paid workers. This marked the identification of a technology-intensive and knowledge-intensive industrial structure and high value-added orientation as national objectives with policy thinking focused on the importance of ensuring suitable human resources. The SDF levy is disbursed to firms that send low-paid employees to approved training courses.

Singapore has two national universities, four polytechnics and numerous public or non-profit specialized training institutes, creditable for an economy with less than 3 million people. Of its university graduates in 1996, 41 per cent were in technical subjects. The polytechnics meet the needs for mid-level technical and managerial skills, again with a heavy emphasis on engineering. They cooperate closely with business in designing courses and providing practical training. Numerous Institutes of Technical Education provide blue-collar workers with secondary education with courses to upgrade skills; in 1996 they graduated nearly 6 thousand people in full-time courses, another 17,000 in part-time courses and 29,000 in continuing education courses. An Adult Cooperative Training Scheme, introduced in 1993, provides training for semi- and unskilled workers aged 20 to 40.

The Vocational and Industrial Training Board (VITB) was established in 1979. It is an integrated training structure which has trained and certified over 112,000 individuals, about 9 per cent of the existing workforce, since its inception in 1979. The VITB administers several programmes. The Full-Time Institutional Training Programme provides broad-based pre-employment skills training for school leavers. The Continuing Skills Training Programme comprises part-time skills courses and customized courses. Customized courses are also offered to workers on the basis of requests from companies and are specifically tailored to their needs. Continuing Education provides part-time classes to help working adults. VITB's Training and Industry Programme offers apprenticeships to school leavers and ex-national servicemen to undergo technical skills training while earning a wage. On-the-job training is carried out at the workplace where apprentices, working under the supervision of experienced and qualified personnel, acquire skills needed for the job. Off-the-job training includes theoretical lessons conducted at VITB training institutes or industry/company training centres. Unusually, the Government has collaborated with foreign enterprises (Japanese, French, Indian, German and Dutch) to set up these centres, funding a large part of employee salaries while they are being trained in state-of-the-art manufacturing technologies. The Singapore Government has also worked jointly with foreign governments (Japan, Germany and France) to provide technical training.

Under the Industry-Based Training Programme, employers conduct skills training courses matched to their specific needs with VITB assistance. VITB provides testing and certification of its trainees and apprentices as well as trade tests for public candidates. The Board, in collaboration with industry, certifies service skills in retailing, health care and travel services. Using various grant schemes, the Skills Development Fund (SDF) provided one training place per four employees in 1992; by 1995, this had risen to one training place per three employees. The salary ceiling for the SDF levy was raised in 1995 (from S$ 750 to S$ 1,500) to widen its coverage and raise the amounts collected to fund training. National investment in training in Singapore reached 3.6 per cent of annual payroll in 1995, and the SDF plans to raise it to 4 per cent by 1999 (compared with an average of 1.8 per cent in the United Kingdom in 1998). However, this spending comes disproportionately from large firms (with more than 500 employees), which spend close to 6.3 per cent of payroll on training. Small firms (with fewer than 50 employees) spend only 2.3 per cent. The challenge is thus to encourage SMEs to intensify their efforts in training. SDF has introduced a Development Consultancy Scheme to provide grants to SMEs for short-term consultancy for management, technical know-how, business development and manpower training.

The Training Voucher Scheme supports employers in paying training fees. This Scheme enabled the SDF to reach more than 3,000 new companies in 1990, many of which had 50 or fewer employees. The Training Leave Scheme encourages companies to send their employees for training during office hours. It provides 100 per cent funding of the training costs for approved programmes, up to a maximum of $20 per participant hour. In 1990, over 5,000 workers benefited from this Scheme. The success of the Skills Development Fund is due in part to a strategy of incremental implementation. Initially, efforts focused on creating awareness among employers, with ad hoc reimbursement of courses. The policy was then refined to target in-plant training, and reimbursement increased to 90 per cent of costs as an additional incentive. Further modifications were made to encourage the development of corporate training programmes by paying grants in advance of expenses, thus reducing interest costs to firms.

The Economic Development Board (EDB) assesses emerging skill needs continuously in consultation with leading enterprises in the economy, and mounts specialized courses. For instance, in 1998, it offered courses on wafer fabrication, process operation and control, precision engineering, high-end digital media production, and computer networking. The EDB also started an International Manpower Programme in 1991 to help companies based in Singapore to attract skilled personnel from around the world. In 1997, around 2,500 professionals and 10,400 skilled workers and technicians were recruited with EDB assistance. Recently, a blueprint called "Manpower 21" was drawn up to give a further boost to manpower planning in Singapore. Building on past efforts at skill accumulation, Manpower 21 aims to develop Singapore into a "Talent Capital" that will support the transition into a knowledge economy.

There has been a significant shift in the workforce to more highly skilled jobs. The proportion of professional and technical workers rose from 15.7 per cent in 1990 to 23.1 per cent in 1995. Despite these efforts, "there is a chronic shortage of skills of all sorts in Singapore …The MTI [Ministry of Trade and Industry] has projected that given current growth rates, Singapore will be short of some 7,000 graduates annually by the year 2000."

Sources: Lall (1996) and EDB website.

The Singapore Government's early emphasis on relying on TNCs led to a relative neglect of local enterprises and SMEs. The Government was conscious of the risks involved in having a very top-heavy industrial sector dominated by TNCs and sought to promote SMEs. In 1962 the EDB launched a programme to help SMEs modernize their equipment with funds provided by the United Nations Development Programme (UNDP). In the mid-1970s several other schemes for financial assistance were added; of these, the most significant was the Small Industries Finance Scheme to encourage technological upgrading. The 1985 recession induced the Government to take stronger measures, and the Venture Capital Fund was set up to help SMEs acquire capital through low-interest loans and equity. A Small Enterprises Bureau was established in 1986 to act as a one-stop consultancy agency; this helped SMEs with management and training, finance and grants, and coordinating assistance from other agencies. In 1987, a US$ 519 million scheme was launched to cover eight programmes to help SMEs, including product development assistance, technical assistance to import foreign consultancy, venture capital to help technology start-ups, robot leasing, training, and technology tie-ups with foreign companies.

In addition, the Singapore Institute of Standards and Industrial Research (SISIR) disseminated technology to SMEs, and helped their exports by providing information on foreign technical requirements and how to meet them. The National Productivity Board provided management advice and consultancy to SMEs. The Technology Development Centre (TDC) helped local firms to identify their technology requirements and purchase technologies; it also designed technology-upgrading strategies. Since its foundation in 1989, the TDC has provided over 130 firms with various forms of technical assistance. It has also administered the Small Industry Technical Assistance Scheme (SITAS) and Product Development Assistance Scheme to help firms develop their design and development capabilities. It has provided grants of over $1 million for 29 SITAS in the past five years, mainly to local enterprises. Its earnings have risen to a level where its cost-recoverable activities are self-financing.

The EDB encouraged subcontracting to local firms through its Local Industries Upgrading Programme, under which TNCs were encouraged to source components locally by "adopting" particular SMEs as subcontractors. In return for a commitment by the TNCs to provide on-the-job training and technical assistance to subcontractors, the Government provided a package of assistance to the latter, including cost-sharing grants and loans for the purchase of equipment or consultancy and the provision of training. By the end of 1990, 27 TNCs and 116 SMEs had joined this programme.

During 1976–1988, the total value of financial assistance by the Singapore Government to SMEs amounted to S$ 1.5 billion, of which 88 per cent was in the Small Industries Financing Scheme. Grants of various kinds amounted to S$ 23.4 million and the Skills Development Fund for S$ 48.6 million.

In conclusion, we draw on Wong (forthcoming) for a review of Singapore's technological evolution. Wong devides it into four phases, as follows.

(a) *Industrial take-off:* The period from the early 1960s to the mid-1970s, characterized by high dependence on technology transfer from foreign TNCs;

(b) *Local technological deepening:* the mid-1970s to the late1980s, characterized by the rapid growth of local process technological development within TNCs and the development of local supporting industries;

(c) *Applied R&D expansion:* the late1980s to the late1990s, characterized by the rapid expansion of applied R&D by TNCs, public R&D institutions and later local firms;

(d) *High-tech entrepreneurship and basic R&D development:* from the late1990s onwards, characterized by the emerging emphasis on high-tech start-ups and the shift towards technology-creation capabilities.

Wong has some interesting insights into the recent evolution of Singapore's technology.[19] After the economic downturn in 1985, as the manufacturing sector recovered in the second half of the 1980s, new waves of FDI led to the upgrading of manufacturing process technologies. This led to a rapid increase in R&D. From the late 1980s, TNCs started to establish R&D centres in Singapore, alongside new public R&D institutions and the expansion of R&D in tertiary institutions. Some of the more technology-intensive local firms started to invest in applied R&D. In particular, the strong growth of the Singapore Technology Group and other large government-linked companies added impetus to local R&D. Much of this rapid growth in R&D focused on incremental, applied work. For example, much of the R&D in public R&D institutions at this time was to complement and support TNC operations in Singapore, resulting in low intellectual property creation as measured by patenting and technology spin-offs.

At the same time process capabilities continued to deepen, resulting in some major TNCs establishing "lead manufacturing plants" in Singapore (e.g. Glaxo, Seagate and IBM data storage). Many took on *process technology transfer station* roles, to provide the engineering to develop new processes to support product launches and later to transfer them to other countries. Several TNCs (e.g. Philips consumer electronics, Hewlett-Packard ink-jet printers and hand-held computers) also began to locate selected *world product charter* operations in Singapore, with full responsibility for product innovation from R&D, product launch to marketing and sales.

In terms of the development of technological skills, the emphasis shifted from technician training to increasing enrolments in technology courses at local universities. The rate of growth in the number of university graduates began to exceed that of polytechnic graduates. Significant technological development in local supporting industries was generated by the TNCs through increasing outsourcing and intensification of “learning by transacting”. Finally, increasing R&D provided an important training ground for the acquisition of new innovative skills.

Today, another phase is emerging: the beginning of *high-tech entrepreneurial start-ups* similar in spirit and style to Silicon Valley. Whereas earlier local start-ups were mainly in manufacturing and primarily as suppliers and contract manufacturers to TNCs, the new start-ups were based more on product innovation and increasingly focused on information technology, software, Internet applications, biotechnology and life sciences. Venture capital (VC) and "business angels" became increasingly important as a source for funding. The VC industry began to take off rapidly from the mid-1990s, with the funds managed exceeding S$ 10 billion in 2000. In 1999, 71 start-ups received S$ 252 million of VC funding, with 50 per cent in information and communications/media technologies, 15 per cent in electronics, 17 per cent in transportation and logistics, and 12 per cent in industrial products. In particular, spin-offs from universities and public R&D institutions were beginning to increase in frequency.

In summary, Singapore shifted from emphasizing *technology use* to *technology creation* over the last four decades, each phase building upon resources accumulated in earlier phases. New sources of growth were introduced, involving new actors and new forms of linkage among existing actors. In particular, there was a phased building up of TNCs, local manufacturing enterprises (particularly in the electronics supporting industries), public research institutes and university R&D, and local tech start-ups pioneering new products. In

[19] The following paragraphs draw on Wong (forthcoming).

terms of technology capability development, there was a sustained shift from learning to use (with high reliance on internal transfer by TNCs) to learning to adapt and improve (via “learning by doing” within TNCs as well as “learning by transacting” in local firms acquiring external technology), learning to innovate (mainly applied R&D in product or process), and finally, learning to pioneer (creating indigenous intellectual property and commercializing it in the market place).

2. FDI AND TECHNOLOGY POLICIES IN THREE NEW TIGERS

A. MALAYSIA

Malaysia’s export and production performance in technologically sophisticated and high-skill products, and the great weight of these advanced activities in its manufacturing value-added, would normally be associated with a mature industrial economy. Such "maturity" would normally entail a diverse manufacturing base with capital goods manufacturing capabilities, a well-developed local supplier and subcontracting system with large "clusters" of high-technology activities, a well-educated and technically trained workforce, and significant industrial R&D both within and outside enterprises. Such an economy would be expected to have a diverse infrastructure of technology and training institutions, an active technology financing system and a dynamic education system geared to changing technological needs.

Malaysia has succeeded despite having few of these attributes. Its performance is based on high-tech export-oriented FDI that entered more by good luck than by deliberate targeting. The challenge it faces now is to make a transition from this pattern, based on filling the technology "gaps" in its productive base, to one where the base is itself able to support high-technology competitiveness. This transition is needed not just to increase the competitiveness of domestic firms. It is also necessary in order to continue to attract FDI at high levels of skill and technical sophistication, to increase domestic contributions to production and technological activity, and to provide the supplier and service structure that TNCs need for value-added production.

FDI has been critical to the growth of Malaysian manufacturing and exports. [20] Foreign participation has risen continuously in key industries such as electrical machinery. Technology spillovers from FDI – through working experience, employee turnover and increasing domestic capabilities – have spurred local ownership in food processing, furniture and fixtures, petroleum and coal products, non-metal minerals, fabricated metals and transport equipment. Growing domestic demand has stimulated domestic-market-oriented industry. Several of these have built up production capabilities. Paper, publishing and printing, wood and basic metals continue to predominantly locally owned and had developed during colonial rule. Wood-based products have experienced an increase in foreign ownership following investment by Taiwan Province of China and Japanese firms to service their home markets. FDI continues to dominate in electrical machinery, scientific instruments, beverages, tobacco, and textile and garments. TNCs have also increased their role in rubber products, primarily through investments in glove manufacturing. Except for beverages and tobacco, the remaining FDI-dominant industries are export-oriented, with the prime market destinations located in developed economies. FDI participation in these sectors

[20] This section draws upon Rasiah (forthcoming).

is likely to rise further after the removal of foreign ownership conditions following efforts to revive FDI inflows since 1997 and efforts to meet WTO requirements.

FDI has played a critical role in generating employment, capital investment, exports, labour skills and spin-offs (especially in Penang). The integration of the Toyota multi-product single flow line alongside pressures for lean production and quick delivery times has generated substantial synergies. Where strong integrated business networks have emerged, as in Penang, TNCs have generated considerable differentiation and division of labour as large firms opt to source locally rather than import. The number of firms supplying metal and plastic tooling and components to the electronics industry alone rose from around 150 in 1989 to around 455 in 1993.

Weakly integrated business networks restricted the creation of new firms and strong inter-firm links in the other states. TNCs acted not just as potential demand creators, but also as training grounds for entrepreneurs and skilled personnel. A whole range of local suppliers were begun by individuals who gained their professional and entrepreneurial experience working in the TNCs. In addition, the intermediary role of the Penang Development Corporation was important in bringing TNCs and local firms together to support the Penang Skills Development Centre to resolve growing skill problems.

Growth in export-oriented manufacturing and resource-based primary sectors also allowed the Malaysian Government to promote heavy industries as joint ventures with foreign capital. Examples are steel, automobile and cement. Technology tie-ups and foreign acquisitions (e.g. of Lotus by Proton) became the prime source of technology in these industries. However, there is little evidence that these industries have achieved international competitiveness or moved closer to the technology frontier.

Malaysia suffers from a growing shortage of skills, its human capital base being increasingly out of line with its production and export structures. The Government launched several efforts to correct demand-supply shortfalls emerging in the labour market from the late 1980s. A double deduction from tax was introduced in 1988 to encourage in-house training in firms. The Human Resource Development Fund replaced this scheme in 1993; it requires firms to pay a levy of 1 per cent of their payroll, which they can reclaim using approved training expenses. It penalizes firms that do not train in accordance with the criteria defined in the eligible conditions. The main problem here is the absence of proximate training institutions in several locations.

Special directives and incentives were also introduced in the mid-1990s to expand the supply of science and technology graduates. Training suppliers – from low-level technical and vocational trades to engineering degrees – were expanded and modernized. The Private Universities Bill of 1995 helped open the way for the growth of more universities, especially in engineering.

Malaysia’s lags well behind the mature Tigers in terms of R&D and innovative activity. Only 4,052 patents were filed in Malaysia compared with 11,881 in Singapore, 96,557 in the Republic of Korea, 388,957 in Japan and 235,440 in the United States in 1995. A significant number of the patents in Malaysia were filed by non-residents and were not developed locally. This reflects the low level of private sector R&D, which accounted for only 0.17 per cent of GNP in 1992.

The foreign dominated electrical machinery industry has the highest R&D propensity, but foreign firms only undertake the redesign of mature products and minor process improvement. Only a handful of electronics firms undertook product R&D activities in 1996, and all these were locally owned (e.g. OYL Electronics and Sapura). Despite extensive investment in R&D, Proton's capabilities are still largely limited to body design and parts. Malaysian firms are most advanced in oil-palm processing and waste treatment products.

One problem with increasing R&D is the shortage of high-level technical skills. Malaysia only had four R&D scientists and technologists per 10,000 people compared with 22 in the Republic of Korea in 1988–1990. Total R&D in 1992 was only 0.4 per cent of GNP, compared with 2.1 per cent in the Republic of Korea. Foreign firms with high-tech activities in Malaysia depend heavily on their parent companies for innovation. While this is appropriate for certain types of innovation, Malaysia has to develop better design and development capabilities to sustain competitiveness with rising wages.

Let us now look at *institutional support* for technology. This includes the Malaysian Institute of Microelectronics Systems (MIMOS), the National Productivity Corporation, Technology Parks and the Small and Medium Industry Development Corporation (SMIDEC). Complementary institutions such as the Standards and Industrial Research Institute of Malaysia (SIRIM) were established earlier to test and validate products for quality maintenance, and improve productivity. SIRIM's role from the late 1980s has been commendable as it has attempted to infuse the establishment and maintenance of quality into firms. Interviews show that several firms have been certified with ISO 9000.

Efforts have been made since 1983 to improve *government–business coordination*. Government officials were sent to Japan and the Republic of Korea to understand better their operations. Consultative committees were formed between the public and private sectors. The Malaysia Technology Development Corporation was set up in 1992 to commercialize R&D. By the end of 1993, it had invested RM 16 million in 12 firms. A broader collaborative umbrella - the Malaysia Industry–Government Group for High Technology - was launched in 1993 to promote technology prospecting and institute mechanisms to identify new markets, businesses and investment opportunities for R&D and technology development. However, these efforts face drawbacks. First, insufficient effort has been made to involve the private sector, as officials have been appointed as advisers following their retirement from public service. Secondly, there has been little effective participation by governmental officials in the private sector, since their roles have not been clearly defined. Thirdly, most of the public sector officials seconded to the private sector have generally been limited to those from parastatals. Even here, not many have been involved in the business and technical aspects of production.

Technology parks have sprung up in Malaysia since the late 1980s. However, there is little evidence of dynamism in the formation of technology parks. Aggressive promotion by the Government – including direct approaches to identified transnationals – has helped attract a number of firms into the Technology Park at Bukit Jalil and the High Tech Park at Kulim. However, the majority of firms have yet to use it to promote technology development. Unlike the Hsinchu Science Park in Taiwan Province of China, where effective coordination has led to the identification of proven local firms' participation, the rush to fill space in Malaysia seems to have attracted firms only interested in undertaking minor process improvements. Hence, unless a major reorientation takes place, much of the innovation activities in the country will be undertaken outside the technology parks. Local firms, especially those backed by the Government, are likely to operate there, but without significant movement towards the technology frontier.

MIMOS' efforts to build Malaysia's first wafer fabrication plant (Silterra in 1999) were stalled by the financial crisis. Nevertheless, the movement towards fabless manufacturing has inspired the Sarawak State Government to finance the building of 1st Silicon, which was expected to open in 2000. Its success will depend to a large extent on its ability to attract the requisite technical manpower and R&D technologists, and on its ability to coordinate effectively with firms and other supporting institutions.

A major complementary institution launched to enhance technological deepening in the information technology (IT) sector has been the launch of the much-hyped *Multimedia Super Corridor* (MSC). This is envisioned as a cluster of knowledge-rich information technology development organizations and firms that will be located in the corridor between Kuala Lumpur and the new administrative centre of Malaysia in Putra Jaya. The community will be served by a world-class telecommunications and information technology infrastructure, liberal investment incentives for approved projects, and streamlined procedures for both the immigration of skilled technical expertise and the training of local staff. The Government has reviewed legal and administrative barriers, which are often viewed as impediments to new applications of technology to encourage international investment in technology development.

Substantial efforts have been made in communicating the MSC concept to leading-edge IT development transnationals in North America, Europe and Japan, and the interest generated has been considerable. The technologies that have been identified for encouragement within MSC include very focused projects such as telemedicine applications, smart-card technologies and multimedia development that have vast commercial potential. The Government also launched the National Information Technology Agenda (NITA) in 1997 as an effort to focus the energies among private individuals, the corporate sector and the public sector on the tasks ahead.

However, interviews have indicated that not much R&D is undertaken in the MSC because of the lack of high-tech human capital and sufficient innovation synergies. Malaysia would have to complete another major economic restructuring to succeed in using the MSC as a vehicle to propel the nation’s economic base to a sustainable knowledge-based one. Since knowledge generation is critical for stimulating innovations, Universiti Malaysia Sarawak (UNIMAS) and the Multimedia University launched in 2000 knowledge and innovation management centres to coordinate the stimulation and appropriation of knowledge across the country. The entire resources of the nation, with particular emphasis on education, would have to be deployed efficiently and effectively to make the MSC the heart of Malaysia’s innovation engine.

A wide array of institutions have sprung up in Malaysia to stimulate industrial upgrading and technology development. Institutions such as MIDA and the Financing development Corporation (PDC) have managed to stimulate rapid manufacturing expansion in low-value-added EO activities. Growth in domestic demand from expansion in EO manufacturing and primary activities helped stimulate growth in DO industries. Rapid expansion imposed serious limits on factor costs, which forced the Government to launch new institutions to facilitate industrial upgrading and generate innovations. However, the new institutions have yet to successfully transform industrial support to spur firms to make the transition sufficiently to higher-value-added innovative activities.

B. THAILAND

Thailand’s technological positioning lies between the mature NIEs and Malaysia, on the one hand, and low-technology exporters such as Indonesia or India, on the other hand. The country has experienced a very rapid rise in the share of complex exports, which suggests a strong competitive structure. Of the world’s 30 leading high-technology exporters in 1996, Thailand ranked 17th according to market share. Only China, Indonesia and the Philippines exceeded its growth in market share during 1985-1996. Malaysia and the mature Tigers (excepting Hong Kong (China)), with larger shares at the start and end, show slower rates of increase in their shares. However, the emergence of China is going to be a major threat in many industrial activities.

The Government clearly sees a shift from labour-intensive manufacturing into skill - and technology - based activities as the basis of future competitiveness. It also recognizes that its present skill and technological base are not adequate for this purpose. The Thai education system suffers from serious problems of quality. The school system has uneven levels of quality and access. As Middleton and Tzannatos (1998) argue,

> "Relative neglect of secondary and higher education in the 1980s has led to a comparatively low stock of educated workers. In 1994, of the 16 million workers in formal employment, only 40 percent had completed secondary or post-secondary education. As firms are most likely to provide training to more highly educated workers, the low stock acted as a brake on productivity growth. Of particular concern is the small stock of science and engineering skills. In 1995 Thailand had 119 scientists and engineers per million population. The Republic of Korea and Singapore had more than 2,500, and China had 350.
>
> Education has been well financed in the 1990s, reaching 22 percent of public expenditures in 1997. But there are sources of inefficiency. Falling primary school enrolments due to demographic change have led to low and inefficient student-teacher ratios. An important part of public expenditures at the upper secondary level are devoted to expensive vocational education. These schools provide pre-employment training that was appropriate for the early stages of industrialization, but that is increasingly inappropriate for Thailand's dynamic economy" (pp. 4-5).

The tertiary-level educational institutions tend to have outdated curricula, insufficient practical training and little contact with the evolving needs of industry. A high proportion of the university faculty (49 per cent to 64 per cent) have less than a Master's degree. The Government expects a serious skill gap to emerge over the next five years in the supply of engineers and scientists at the Bachelor level — even at current levels of demand. The demand would be even higher if Thai industry were operating with more advanced and skill-intensive technologies.

Thailand has developed considerable capabilities in mastering and using imported technologies at best-practice levels. The industrial base is fairly broad, with a fairly large representation of scale-intensive and differentiated activities. Domestic firms play a dominant role in low-technology activities. These are creditable achievements. However, the growth of production capabilities has *not* led to a similar deepening of capabilities into design, research and new technology development. Such deepening is an increasingly important part of the development process as the industrial sector diversifies and uses more complex and fast-changing technologies. It is particularly important for export-oriented industries that have to constantly upgrade their processes and products. Moreover, deeper local technological capabilities are essential for reducing the costs of absorbing new technologies, and for adapting them to local conditions. Even if all the basic innovation comes from overseas, local design and development capabilities are needed to produce more sophisticated products and take on more advanced manufacturing and other functions.

Although the general policy framework for FDI in the past few years has become more liberal in Thailand, relatively little attention has been paid to the technological features of FDI.[21] Foreign investors have been sought mainly in order to generate employment or exports, or to play a role in the massive restructuring process. The Government is now undertaking a wholesale restructuring of the Board of Investment to make it more proactive and targeted, able to contribute to technological upgrading. TNCs in Thailand are becoming more involved in innovative programmes for training and for undertaking technological activities. While this does not yet constitute a statistically significant quantitative trend, there are a number of interesting stories of such activities.

One good example of a group initiative in training is IDEMA, which is an international non-profit industry organization founded in 1986 in the United States aimed at promoting business networking and facilitating information sharing through education programmes and technical symposiums/conferences. It acts as a forum for the global discussion of technical issues faced by the hard disk drive (HDD) industry. It is an independent institution with membership from the entire HDD value chain. In a more technical area, the Thai-German Institute (TGI), with funding from the Thai and German Governments, has been active in operating a training facility in the eastern seaboard area. German companies that have sent experienced staff to help develop a core group of permanent trainers donate most of the modern equipment used in TGI. The main problem apparently faced by the institute is the difficulty of establishing close relations with other private companies in the area, partly because they are Thai firms that do not yet see the value of advanced technical training.

Some foreign firms have initiated their own programmes for human resources development. For example, Toyota Motor Thailand (TMT) has been very active in the development of corporate training programmes and linkages with local universities. Since 1990, it has provided both instructors and courses for engineering students in Chulalongkorn University's engineering department and helped re-establish the auto-engineering degree programme in 1994. The company has also signed a memorandum of understanding to support the development of an Industrial Engineering Department at Thammasat University, focusing on automotive engineering. In 1996, TMT established its own education and training centre, which can issue certificates to those who pass its courses.

The baht depreciation after the financial crisis has encouraged local sourcing, since domestically produced parts and components have become cheaper than imports. For example, the Australian Submarine Company (ASC), awarded a contract to build surface ships for the Royal Thai Navy in 1994, has been transferring advanced technology developed in Australia to Thailand. Local welders and metal workers have been continually trained in new methods of metalworking that enable them to meet the strict specifications required by production needs. ASC has also assisted with training local subcontractors by sponsoring off-site programmes and the provision of Australian engineers and skilled technicians. Many TNCs have participated in the Government's programme to support SMEs the BUILD programme by allowing potential suppliers to visit their plants and explore the possibility of supplying parts and components to them. Foreign companies have also been very active with other elements of the BUILD programme since its inception in the early 1990s. This interest and initiative in BUILD is a very positive indication of greater technology transfer from foreign firms in the future.

[21] This draws on Brimble (forthcoming).

Science and Technology concerns in the Eighth National Economic and Social Development Plan (1997-2001) have been integrated into the section on development of economic competitiveness. The Eighth Plan has changed the emphasis from economic development to human resource development and the quality of life. Among other things, this *"means the development of quality and capability of Thai people to be able to initiate ideas and to be creative. This will develop the capability of community, society and finally the nation."* Two key new strategies of the Plan are to build up better relationships between the Government and the people through cooperation and participation, and to reorganize the management system to implement the plans effectively. In fact, this is not just a five-year plan but also a novel approach to national development aimed at achieving the long-term vision of an ideal Thai society.

In parallel and in support of the Eighth Plan, MOSTE has developed a Ten-Year National Science and Technology Development Plan (1997-2006). The Plan identifies four key directions of development: S&T personnel, technology transfer, research and development, and S&T infrastructure. Most recently, a National Science and Technology Council has been established with a view to coordinating S&T policy matters. It is too early to judge how effective this initiative will be. However, despite these efforts, Thailand's S&T institutional structure and policy implementation remain unclear and fragmented. Institutional reform will be a key element of Thailand's innovation strategy, both to improve the existing S&T policy institutions and to involve agencies such as the Ministry of Industry, the Board of Investment, and the Ministries of Education and University Affairs.

Thailand spends a mere 0.13 per cent of its GDP on R&D, according to UNESCO data. However, this may be an underestimate. A recent study by Brookers, a private consulting company, suggests a higher figure, 0.29 per cent. According to this survey, of the total of $358 million spent on R&D in 1999, the manufacturing sector accounted for $147 million, and non-manufacturing firms and SMEs for $26 million. The public sector accounted for another $185 million. Even this more optimistic estimate, however, falls far short of the target of 0.75 per cent of GDP of the 8th National Economic and Social Development Plan. In terms of R&D personnel, despite Thailand's population of 62 million and Malaysia's 22.7 million, the former has only 5,300 R&D workers in business enterprises for a per capita ratio of 0.086 (full-time equivalent per 1,000 people). Malaysia, by comparison, employs 3,500 R&D workers in the private sector for a ratio of 0.16 (full-time equivalent per 1,000 people).

A major factor in Thailand's lagging human resources is the insufficient number and quality of S&T students, particularly at the postgraduate level. Thailand has a paucity of scientists and engineers who can perform high-quality R&D. It had only 119 engineers and scientists per million population before the economic crisis, compared with more than 2,500 each in Republic of Korea and Singapore and 350 in China (UNESCO, 1997). Private firms in Thailand are forced to rely heavily on foreign skilled labour, managers, scientists and engineers. Thailand's higher education system is partly to blame. Thai universities, like those of most other East Asian nations, were established primarily as teaching institutions and research was considered secondary. In addition, the archaic university system and the Government's meagre funding for R&D deter academics from conducting R&D. This makes it very difficult for students to acquire the skills and attitudes needed for R&D.

Most large TNC subsidiaries, some large domestic firms and a few SMEs are generally able to acquire and assimilate technologies reasonably well, and are on the threshold of technology upgrading and reverse engineering. Relatively few such firms have, however, gone into research and technology development. A recent survey of R&D in Thailand finds that only around 15 per cent of medium to large manufacturing firms carry out some form of

R&D. The situation for the remaining large firms and SMEs is more worrying. In many of these firms, even the basic use and operation of technology are found to be weak. They first need to cross the threshold of being able to undertake effective technology acquisition and assimilation. The findings of the R&D/Innovation 2000 Survey (covering the 200 largest firms) point in the same direction. Most sampled firms' technological capabilities are confined to simple quality control and testing. Less than half have capability in design, only one third have reverse engineering capability, and less than 15 per cent have done R&D.

It seems that rapid industrial and export growth has not led to the development of a "technology culture" in Thai industry. This will be a growing handicap to its future competitiveness. While heavy and passive dependence on foreign research, know-how and expertise has worked well in the past, it is not conducive to a continued move up the skill and value-added ladder. The Government does not appear to have an effective strategy to boost enterprise R&D or to strengthen linkages between the official research sector and industry. Unlike in Malaysia, TNC affiliates in Thailand have been slow to increase the technological content of their export activity. Singapore has been able to go further, using grants and other schemes to catalyse technological effort. The Republic of Korea and Taiwan Province of China used pervasive industrial policy to stimulate a local technology culture.

There are thus serious deficiencies on the technology front in terms of Thai industrial competitiveness. This is closely intertwined with its human resource problems, but has other ramifications as well. Thailand needs a clear strategy for improving the technology infrastructure institutions and launching measures to promote in-house technological effort, provide technology finance (which is deficient at this time) and bring about technological collaboration between industry, universities and technology institutions. This strategic challenge assumes considerable urgency with the emergence of China as a major competitor.

C. PHILIPPINES

After decades of relative underperformance, the Philippines has suddenly become a dynamic exporter of manufactured products. Manufactures account for over 80 per cent of Philippine merchandise exports, and in recent years their growth has been higher than for total exports. The growth rate in 1994-1997 was over 11 percentage points higher than in 1991-1993. However, their pattern is highly skewed. During 1991-1997, 84 per cent of the increase in the value of manufactured exports came from *electronics*, with one group of electronics, semiconductors, accounting for 64 per cent. The corresponding figures for the first nine months of 1998 are 113 per cent and 98 per cent. This pace of growth has more than doubled the share of electronics, from below one third to over two thirds. Semiconductors alone contributed over half of the total in 1997 and nearly 60 per cent in January-September 1998. The other major products with substantial (20 per cent plus) growth during 1991-1997 (textiles, machinery and transport equipment) contributed only 5 per cent of the total in 1997.

If we exclude electronics, the Philippines' export performance is rather modest, and deteriorates from 1996 in reaction to the financial crisis. The rate of growth of consumer manufactures falls from 10 per cent in 1991-1993 to negative between 1996 and 1998, mainly owing to the poor performance of *garments*, the Philippines' main traditional export. However, many other consumer products – footwear, toys and leather goods – also did badly. Some fared poorly even before the crisis: the value of garment exports was virtually stagnant during 1994-1997; their growth during (pre-crisis) 1990-1995 was lower than for its ASEAN neighbours and China.[22] Since Philippine wages are lower than in Malaysia and Thailand (though higher than in Indonesia and China), this suggests a weak competitive base in this labour-intensive activity. The recent performance of garment exports in non-quota markets, which face the most intense competition from low-wage countries such as China, Sri Lanka and Bangladesh, has been even worse.

This reinforces the impression that quality and technology upgrading in the Philippines is lagging. Other labour-intensive products such as *footwear, toys* and *leather goods* also perform poorly, with growth rates of below 3 per cent during 1994-1997. The most important resource-based export, processed foods, shows a generally weak and cyclical growth performance. The crisis is only partly to blame for this – the causes must lie in the competitive base of the Philippines.

Let us start with skills. Despite its high enrolments, the Philippine education and training system faces problems of quality and relevance. There is a 40 per cent dropout or failure rate at universities and colleges. The school cycle is one year shorter than in most other countries, so that higher education institutions have to spend more time bringing entrants up to the required levels. The curriculum is not geared to modern technological needs and has few inputs from industry, unlike the NIEs, where there is much more direct and continuous interaction between providers and users of higher education. Standards in many higher education institutions are below international levels. In an exercise ranking 105 state and over 1,000 private colleges into four categories (the highest level, 4, being equivalent to a good foreign university), the Commission for Higher Education found in 1996 that only two institutions in the country achieved Level 4. The vast majority clustered in the two lowest levels. The Commission identified 18 "Centres of Excellence", to be given special assistance to upgrade faculties and equipment. However, the bulk of higher education is turning out graduates of variable, rather indifferent, quality.

Technical education and training for industry also have widespread quality problems. In 1992, the Educational Commission found the technical training system to be ill-managed and underfinanced: it had one of the lowest per capita expenditures in the region (only Bangladesh was lower). There is a significant mismatch between the skills provided by the system and those needed by employers, resulting in large numbers of unemployed trainees. Most large manufacturing firms, especially foreign affiliates, invest significantly in employee training, but to date there has been no systematic survey of industrial training. However, without comprehensive and continuous monitoring of industrial training, the Government cannot systematically encourage it. There is no government levy to promote employee training; such levies exist in most neighbouring countries, together with other schemes to encourage or subsidize firms to invest in upgrading employee skills. SMEs invest little or nothing in formal training of their workforce, and are largely unaware of the need for this: special schemes are needed to upgrade their human capital.

With regard to technological activity, the mismatch between local technological effort and the high-tech structure of exports is even more marked for the Philippines than for the other new Tigers. Overall R&D is very low, especially that financed by enterprises. The public sector dominates R&D, with poor-quality R&D management and institutions de-linked from productive activity. While this is also true of other countries in the region (e.g.

[22] The annual rate of growth of garment exports from the Philippines in 1990-1995 was 7.7 per cent, compared with 11.5 per cent for Malaysia, 12.3 per cent for Thailand, 15.7 per cent for Indonesia and 20.1 per cent for China.

Thailand), it is not typical of the technology-oriented NIEs such as Singapore, the Republic of Korea and Taiwan Province of China.

Such low technological effort would not matter as long as enterprises could remain competitive with heavy reliance on imported technologies. This is adequate when only simple assembly is involved and TNC participation ensures the continuous inflow of new know-how and components. However, the lack of local technological effort constrains competitiveness as wages rise and more complex, value-added activities have to be undertaken. Outside TNCs, R&D capability is increasingly needed to promote the growth and competitiveness of local suppliers and subcontractors. A weak technological support structure, manifested in low public R&D, reduces the ability of smaller enterprises to innovate and increase productivity.

Unfortunately, the Philippine Government has neglected private R&D. Its trade and industrial regimes have failed to foster an autonomous technology culture, and its SME support system is weak. Despite its ambitious Science and Technology Agenda for National Development (STAND), much of the effort remains on paper. Technology finance is weak and there is little effort to raise awareness of the need for technological effort among private enterprises. The *Department of Science and Technology (DOST) system* is large. It encompasses the National Academy of Science and Technology and the National Research Council, as well as five research councils. It also contains seven research institutes, — for industrial technology; the metal industry; nuclear power; textiles; advanced science and technology; food and nutrition; and forest products — and six other institutes, for science education; technology information; technology application and promotion; atmospheric geophysics and astronomy; and seismology, as well as a science high school.

However, its practical relevance for industrial technology development is limited. Only 2 per cent of DOST staff in 1995 had doctorates, and another 9 per cent Master's level qualifications. Staff are poorly paid and tend to be out of touch with international scientific trends and research being done by counterparts overseas. There has been relatively little direct interaction with, or contract research from, the private industrial sector (the whole system had 23 contract research projects from private industry in 1995). Few of the technologies created are in commercial production. R&D on designated "export winners" has yet to yield tangible benefits, and its focus does not seem directly relevant to areas of dynamic competitive advantage to the Philippines.[23] DOST also provides a number of industrial testing and laboratory services, which account for most of its budget and employment.

The *Bureau of Product Standards* provides testing facilities, promotes quality standards and accredits independent laboratories. It has been promoting the spread of ISO 9000 standards in the Philippines, but cannot offer incentives to firms to adopt these standards. This may hold back the spread of an important competitive tool among smaller local enterprises in the country (many countries offer subsidized consultancy services to firms for ISO certification). The Bureau has no financial autonomy and government scales dictate its salaries. This makes it difficult to recruit and retain good technical graduates. Its equipment limits its testing capabilities, and many exporters, in particular smaller companies without in-house facilities, have to have expensive tests done abroad.

[23] The major activities under the "export winners" scheme include glass from processed a "lahar", low-sugar mango product, bamboo products, human identification systems, waxing technology, para-rubber, stripping machinery and calcinated marble dust. See the *DOST 1995 Annual Report*.

In general, therefore, the technology system in the Philippines is of limited effectiveness. There are too many institutions with different programmes and objectives, a major source of weakness. The management and funding system does not conduce to effective operation or to close linkages with industry. Most institutions involved are significantly underfunded for the scale of tasks to be accomplished. Many companies complained of the difficulty and delays involved in obtaining basic services such as equipment calibration. Most institutions are taking a passive role in working with firms rather than proactively seeking opportunities to initiate upgrading programmes. Government programmes to help SME technology suffer from similar problems: they are unorganized, weakly motivated and underfunded, and have too many different objectives. The financing of SME technology upgrading is a serious problem; technology finance for all sizes of enterprises is still in its infancy. The technology information system is not very helpful to private firms that need to locate and buy new technologies from abroad.

Thus, the Philippine technology support system has all the necessary elements on paper, but lacks implementation and coherence. There is no systematic analysis of the technological needs of the country and how to achieve them: current plans are too broad and general. The private sector invests little in technology development, and there is no programme to stimulate technological activity in industry. There is a need for a "technology foresight" exercise to involve industry, technology institutions and academia in evaluating the most pressing technological needs of the Philippines. This would involve all concerned sections of the population in understanding the implications of technological change and gearing up to meet evolving needs effectively.

The technology infrastructure is unable to provide effective support to private industry. Its salary structures and management are not conducive to seeking out and helping enterprises with technical problems and upgrading. Too much attention is paid to routine testing and laboratory services, which could be in the private sector, and not enough to providing real public goods such as basic or contract research, information collection and dissemination, and extension services for SMEs. The large number of institutions needs to be rationalized and better structured and funded. A thorough analysis needs to be carried out of DOST’s functions, structure and management, and measures need to be undertaken to link it more tightly to the productive structure. More generally, there is a need for launching consultancy and productivity-raising measures for industry, using benchmarking techniques and drawing upon the experience of economies such as Taiwan Province of China that cater to large numbers of export-oriented SMEs.

CONCLUSIONS

It is possible to achieve impressive competitive success in manufactured exports by attracting export-oriented FDI on the back of a good location, well-managed macroeconomic policy, and moderate levels of skills and capabilities. None of the three new Tigers considered here has displayed much technological prowess beyond the mastery of simple technologies – and here it is only Thailand that stands out by virtue of its spread and dynamism. Domestic Malaysian and Filipino manufacturing enterprises have shown relatively limited capabilities even in low and medium-technology activities, and the latter have revealed growing weaknesses in what should be their areas of natural strength.

However, the entry of TNCs, particularly in the assembly of high-technology electronics products, allowed each of them to enter very dynamic areas of export activity. With rising wages, the high-tech TNCs have not left but have invested in greater automation and new technologies. They have also invested in creating new skills and some supplier capabilities (they have also attracted their own suppliers overseas to invest). The greatest diversification and deepening of the high-tech export structure has taken place in Malaysia and the least in the Philippines; however, the semiconductor boom in the latter is leading to some increases in local content and even some design activity. Thus, local capabilities have grown and deepened over time – to some extent.

The generic issue is, then, *how far TNC-led capability development can take the upgrading and deepening of the export structure before it becomes uneconomical for private agents*. The countries most pressed for skilled manpower and domestic technological deepening – Malaysia and Thailand – clearly feel that it will not go much further. The Government has to upgrade the skill, technology and supplier structure to allow private enterprises to achieve a new and higher level of competitiveness. Different Governments are adopting different strategies. While all claim to be investing in education and promoting technology development, Malaysia is the most active in terms of proactive industrial policy – the Multimedia Super-Corridor is the most striking example of a strong initiative to take the economy in a particular direction. Thailand is spreading its efforts more widely, and has a much more developed domestic industrial sector to upgrade. The Philippines is doing rather less than the others, apparently coasting on its skill base and the "catch-up" process.

All three economies have much to learn from the mature Tigers. Malaysia is caught between trying to emulate the Singaporean model and the Republic of Korea model, with rather modest success. Given its massive dependence on FDI for competitiveness, the former would seem to be the way to go rather than the latter. However, both strategies need very high levels of skill in the population at large and in the administration; it is not clear that these can be produced in the near future. Thailand probably needs to follow the Taiwan Province of China model: promoting high-tech SMEs to be independent exporters and also suppliers to technology-intensive TNCs, while targeting new technology-based FDI. However, this is again enormously skill intensive and needs strong support institutions (Lall, 1996). The Philippines has to build upon the semiconductor boom but, more important, to strengthen all other export activities. Its relatively strong base of skills may be quickly dissipated if the ability of the productive sector to absorb manpower in more competitive activities is not developed. This entails using bits of strategy from all the mature Tigers. More important, however, it needs the Philippine Government to build up a strategic capability, something it currently seems to lack.

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