Competitiveness, FDI and Technological Activity in East Asia

Edited by

Sanjaya Lall

Professor of Development Economics at the International Development Centre, Queen Elizabeth House and a Fellow of Green College, Oxford University

and

Shujiro Urata

Professor of Economics at Waseda University, Japan

IN ASSOCIATION WITH THE INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT/THE WORLD BANK

Edward Elgar
Cheltenham, UK • Northampton, MA, USA

Published by
Edward Elgar Publishing Limited
Glensanda House
Montpellier Parade
Cheltenham
Glos GL50 1UA
UK

Edward Elgar Publishing, Inc.
136 West Street
Suite 202
Northampton
Massachusetts 01060
USA

A catalogue record for this book
is available from the British Library

Library of Congress Cataloguing in Publication Data

Competitiveness, FDI and technological activity in East Asia / edited by Sanjaya Lall and Shujiro Urata.
p. cm.
"In association with theInternational Bank for Reconstruction and Development/The World Bank."
Includes index.
1. Research, Industrial–Economic aspects–East Asia. 2. Technological innovations–Economic aspects–East Asia. 3. Investments, Foreign–East Asia. 4. Competition–East Asia. I. Lall, Sanjaya. II. Urata, Shujiro, 1950-

HC460.5.Z9R43 2003
338′.064′095–dc21 2003048851

ISBN 1 84376 114 9

Printed and bound in Great Britain by MPG Books Ltd, Bodmin, Cornwall

Contents

Figures

Tables

Contributors

Dr. Joy V. Abrenica
Society for the Advancement of Technology Management in the Philippines
Room 249, School of Economics
University of the Philippines Diliman
Diliman, Quezon City 1101
Philippines
Tel: 63-2-435-6313/16
Fax: 63-2-435-6313; or 63-2-921-3359
Email: satmp@skyinet.net

Dr. Peter Brimble
President
The Brooker Group Limited
2 Floor, Zone D, Room 201/2
Queen Sirikit National Convention Center,
60 New Rachadapisek Road
Klongtoey, Bangkok 10110, Thailand
Tel: 66-2-229-3111
Fax: 66-2-229-3127
Email: peterb@Lox1.Loxinfo.co.th

Professor Akira Goto
Research Center for Advanced Economic Engineering (AEE)
University of Tokyo
Email: agoto@aee.u-tokyo.ac.jp

Professor Hiroki Kawai
John F. Kennedy School of Government
Harvard University
Belfer 315, 79 JFK Street
Cambridge, MA 02138, USA
Tel: 1-617-495-1397
Fax: 1-617-495-1635
Email: hk@econ.keio.ac.jp

Professor Linsu Kim
Professor of Management
College of Business Administration
Korea University,
Seoul, Korea 136-701
Tel: 82-2-3290-1919
Fax: 82-2-921-7246
Email: linsukim@unitel.co.kr

Professor Sanjaya Lall
Queen Elizabeth House
University of Oxford
21 St. Giles
Oxford OX1 3LA, UK
Tel: 44-1865-559614
Fax: 44-1865-559614
Email: sanjaya.lall@economics.ox.ac.uk

Professor Hiroyuki Odagiri
Graduate School of Economics
Hitotsubashi University
Kunitachi
Tokyo 186-8601
Japan
Tel: 81-42-580-8813
Fax: 81-42-580-8882
Email: odagiri@econ.hit-u.ac.jp

Professor Yumiko Okamoto
Graduate School of International Development
Nagoya University
Furo-cho, Chikusa-ku, Nagoya
Japan 464-8601
Tel: 81-52-789-5096
Fax: 81-52-789-4951
Email: p1okamotoy@M.Gsid.nagoya-u.ac.jp

Professor Rajah Rasiah
Professor and Senior Research Fellow
Institute for New Technologies
United Nations University
6211-TC Maastricht
Netherlands
Tel: 31-43-3506330
Fax: 31-43-3506399
Email: Rasiah@intech.unu.edu

Professor Bee-Yan Aw
Department of Economics
501 Kern Graduate Building
Pennsylvania State University
University Park, PA 16802, USA
Tel: 1-814-863-1996
Fax: 1-814-863-4775
Email: byr@psu.edu

Professor Fredrik Sjöholm
Email: fredrik.sjoholm@hhs.se

Professor Gwendolyn R. Tecson
School of Economics
University of the Philippines
Diliman, Quezon City 1101
Philippines
Tel: 63-2-920-5481
Fax: 63-2-920-5462
Email: gtecson@pacific.net.ph

Professor Shujiro Urata
School of Social Sciences
Waseda University
1-6-1 Nishiwaseda, Shinjuku-ku
Tokyo, 169-8050, Japan
Tel: 81-35-286-1414
Fax: 81-33-208-1032
Email: surata@mn.waseda.ac.jp

Professor Poh Kam Wong
Director
Center for Management of Innovation & Technopreneurship (CMIT)
Associate Professor
Department of Business Policy
Business School
National University of Singapore
Singapore 117591
Tel: 65-874-6323
Fax: 65-775-3955
Email: fbawpk@nus.edu.sg

Professor Yang Yao
Associate Professor
China Center for Economic Research
Beijing University
Beijing 100871
China
Tel: 86-10-6275-3103
Fax: 86-10-6275-1474
Email: yyao@ccer.pku.edu.cn

Preface and acknowledgements

This study on competitiveness, FDI and technological activity in East Asia is the outcome of a research project organized by the World Bank Institute under the Brain Trust Program which is financed by the government of Japan through its Policy and Human Resources Development Trust Fund. The principal objective of the Brain Trust Program is to conduct studies on the Japanese and East Asian development management experience and to disseminate the lessons of this experience to developing and transition countries. The current study is one of a series of such projects undertaken over the past decade.

The objective of this study is to examine the degree to which foreign direct investment (FDI) and technological activity have contributed to export competitiveness and economic growth in East Asia. The links between export competitiveness and its main contributory factors, namely FDI and domestic technological effort – which include R&D, learning-by-doing, adaptation and copying – have not yet been fully explored. The ways in which these links are forged differ among countries. Some countries have placed less emphasis on FDI and the presence of transnational companies (TNCs), relying instead on building domestic technological capacity through R&D efforts, adaptation and so on. Some others have depended largely on TNC presence for their technology development and upgrading.

These differences in the strategies adopted by countries in their technology development pose two important questions. They are: (i) what are the most effective ways in which technology transfer could take place through FDI? and (ii) how to adopt alternative ways of technology development in lieu of FDI?

The *first alternative* – where technology transfer and market information are imported through FDI – has several forms. These forms include inward FDI, or externalized methods such as licensing, subcontracting, original equipment manufacturing (OEM) arrangements and so on. Inward FDI transfers take place between TNCs and their overseas affiliates and are called *intra-firm technology transfers*. The externalized methods come under *technology spillover* where technology transfer takes place between TNCs' overseas affiliates and local firms. In the case of Japanese multinational corporations (MNCs), intra-firm technology transfer was quite common, while in the case of countries like Indonesia and Malaysia, spillover was the predominant form of technology transfer from TNCs.

The *second alternative* is to place more emphasis on domestic technological effort. This involves building R&D capabilities, adaptation of new technology, copying and so on. Korea, for instance, took the path of building domestic R&D capabilities instead of relying on FDI for its technological growth. Its total R&D budget as a percentage of GDP has been quite high. Some other countries have taken an informal approach to technology transfer by relying mostly on incremental improvements, learning-by-doing, adaptation and copying. There is, however, little correlation between successful technology development and the existence of a strong domestic technological base. A number of countries have been able to undertake highly sophisticated export activity – such as exporting electronic equipment – by specializing in the final assembly of products by foreign affiliates even when they lacked a strong domestic technological base. Some others have encouraged affiliates to undertake advanced processes and design the products locally and even launch advanced R&D. A third category of countries has embarked on the path of developing local capabilities and networks which allow them to keep up with fast-moving technologies without having to rely on FDI.

The alternatives chosen by each country depend on a number of factors. These include, *inter alia*, the prevailing policy environment, domestic technological capacity, development objectives and the institutional framework. While these factors are unique to each country, it is possible to distill some general lessons and policy guidelines by looking at some of the country experiences in East Asia. For this reason, a number of countries have been identified for case studies. They include Japan, Korea, Taiwan, Singapore, Malaysia, Thailand, the Philippines and China.

Technological progress is achieved through a continuous upgrading of technology, information and skills. The process becomes more complex in an environment where both export competition and technical change take place simultaneously and at very high levels. Depending on how this process of technological progress is managed, each economy develops a distinctive pattern of exports over time. These export patterns differ in terms of the product, market and technological specialization. The significant differences in the levels of technology transferred, upgrading of local content over time, and R&D undertaken by affiliates are influenced by the prevailing export patterns and vice versa. Similarly, the main agents responsible for technology transfer are also, to a large extent, influenced by these patterns. For instance, in Singapore, China, Malaysia, Thailand and Indonesia, TNCs have been the main agents of technology transfer whereas in Korea, Taiwan and Hong Kong, domestic firms have played the central role in this regard.

In spite of the different strategies used, there is a rapid convergence in policy objectives as a result of the intensifying competitive pressures and changing 'rules of the game' on trade and investment. Countries which have labour-intensive TNCs are beginning to find that it is difficult to sustain their export growth without deepening local content, skill upgrading and increasing local R&D activity. The others with strong indigenous technological bases are also realizing that as technological innovation becomes more expensive and specialized it is imperative to form alliances with technology leaders or rely more on FDI. The most common response by countries to these emerging trends is to encourage labour-intensive processes to relocate to cheaper areas and thereby to undertake outward FDI of their own.

A study such as this cannot be completed without incurring a heavy debt of gratitude. All those who participated in the two workshops in Bali, Indonesia and Sapporo, Japan have made immense contributions to this study at various stages. We owe special gratitude to Mr Farrukh Iqbal who was the manager of the Brain Trust Program at the time when this study was conceptualized. He helped organize the study and provided valuable guidance in the two workshops as well as in subsequent discussions. We are grateful to Ms Vasumathi Rollakanty for providing assistance with the organization of the workshops and for attending to all other logistical matters in the management of this project. We would be remiss if we failed to acknowledge the support of Ms Valentina Kalk of the External Affairs Office of the World Bank and the publisher, Edward Elgar Publishing Ltd, UK, without whose encouragement and support, it would not have been possible to publish this study in such a short time. Needless to say, all of those who are associated with this study owe special gratitude to the two editors, Professor Sanjaya Lall of Oxford University and Professor Shujiro Urata of Waseda University, whose relentless effort, good judgement, vast experience and knowledge helped shape this study from its inception.

TSUTOMU SHIBATA (Program Manager and WBI Representative for Japan)
K. MIGARA O. DE SILVA (Team Leader)
Brain Trust Program
World Bank Institute (WBI)

1. Introduction and overview

Sanjaya Lall and Shujiro Urata

East Asia is by practically any measure the most competitive and dynamic industrial region in the developing world. This is universally acknowledged but it is not fully understood, despite the industry that has grown up around the analysis of East Asian competitiveness. It is widely known that the successful countries used very different strategies to build their industrial competitiveness, but the ingredients of these strategies still need further analysis. In particular, the means that the 'Tiger' economies used to access and absorb new foreign technologies over time – this process is the very lifeblood of industrial success – have useful lessons for other countries. As the intensity of international competition mounts and as developing countries open their economies more widely to global market forces, all policymakers and analysts need to know how the most dynamic countries 'did it'.

This book deals with one aspect of competitiveness strategies in East Asia: the interaction between foreign direct investment (FDI) and local technological activity in building export competitiveness. It highlights different strategic approaches at the national level and looks at capability development within industrial enterprises.

ISSUES

These differences in the strategies adopted by countries to promote technology development pose important questions. How, for instance, are foreign technologies most efficiently transferred from industrial to developing countries? Does the mode of technology transfer matter for subsequent technology development? What is the need for local technological effort in developing countries that are 'latecomers' to the industrial scene and can draw upon the vast cornucopia of technological knowledge in the developed world? Are TNCs essential for export competitiveness in technology-intensive industries today? And so on. Not all these questions can be addressed in this book but many are.

Some of the points that emerge in the analysis of country experiences are as follows.

- The transfer of technology and market information from foreign companies can take several forms. These include 'internalized' modes like inward FDI (where transfers take place within the company), or 'externalized' modes like licensing, subcontracting, original equipment manufacturing arrangements (where transfers take place across companies). While all countries use both methods to access foreign technologies, the balance between them varies greatly.
- Having accessed foreign technology, the developing country has to learn to use it effectively, adapt it to local conditions and improve it over time to keep up with competition and the international technology frontier. Simply importing new technology does not mean that it can be used competitively: there is always a need for local effort to create the capabilities to use new knowledge.
- The mode of technology transfer affects the need for, and the extent of, domestic effort.
- Reliance on internalized technology transfer reduces the need for independent local effort (though *some* learning is always involved). It also often provides access to state-of-the-art technologies along with established brand names and entry into global markets. FDI is thus a very effective way to transfer and operationalize new technologies for export competitiveness.
- Externalized technology transfer entails greater effort and risk on the part of the recipient country, and may not allow access to the most valuable new technologies (which are closely held by the innovators). Exploiting externalized technologies in world markets is also more difficult because of the need to build export marketing capabilities and channels. Where externalized transfers are not managed effectively, with the considerable local investment in capability development, they can result in technological inefficiencies, lags and subsequent uncompetitiveness.
- Yet there may be sound reasons for encouraging the development of local technological capabilities. In most medium to large sized economies, local enterprises account for the bulk of industrial activity, and their competitiveness depends on externalized technology transfers. Externalized transfers involve greater effort – and yield greater learning benefits. With industrial diversification and deepening, countries have to undertake more advanced technological functions, such as design, development and research. Internalized modes of technology transfer may not lead to the same pace of upgrading as externalized modes: there are good economic reasons for multinational companies to keep advanced technological effort centralized in a few industrialized countries.

- Technology development strategies have a large element of cumulativeness and path-dependence: once launched, they tend to persist along particular trajectories for long periods. At the same time, there are forces making for greater convergence. The international 'rules of the game' are changing, constraining the use of certain government interventions (such as protection, subsidies, local content rules and exclusion of FDI) in promoting technology development. The external environment is also changing, making externalized modes more costly and risky. At the same time, countries relying heavily on internalized modes are seeing the need for greater domestic capability development to sustain export competitiveness.

The East Asian countries have chosen different combinations of internalized and externalized modes of technology transfer, and are converging towards a more uniform set of policies at different rates. Korea, for instance, has taken the path of building domestic R&D capabilities instead of relying on FDI for its technological growth. Taiwan is rather similar, but has been slightly more open to FDI and less interventionist in building domestic industrial champions. Both are now more open to inward FDI while becoming major direct investors on their own.

The Philippines and Thailand have chosen to rely heavily on the import of internalized technology and have invested relatively little in domestic R&D effort. This has not prevented them from entering highly sophisticated and dynamic areas of export activity, but it is seen as a constraint on sustaining competitiveness in the longer term. Singapore has relied on FDI but has made strong efforts to induce foreign investors to deepen into local design and development. China combines the Korean and Singaporean strategies. Its total R&D budget as a percentage of GDP has been quite high. And so on.

The choice of strategy has, of course, depended on many country-specific factors. These include, *inter alia*, the prevailing policy environment (in turn reflecting history, culture and political economy), domestic technological and human capital, development objectives and the institutional framework. As noted, however, there is considerable policy convergence between Asian economies. Countries that have built competitiveness by specializing in labour-intensive segment of MNC activities are finding that they can sustain export growth only by deepening local content, skills and technological activity. Those with strong indigenous technological bases are realizing that innovation is becoming expensive and specialized, and that production is being increasingly organized in internalized MNC systems spanning several countries. It thus becomes necessary to form alliances with technology leaders and participate more fully in global production systems.

This is a highly simplified picture of a complex and dynamic scene, with many variations within and across East Asian countries. The chapters that follow adopt different approaches to the analysis of technology strategy and competitiveness. We have not sought to impose a uniform format or approach on the studies, encouraging authors to explore aspects of technology development and FDI from their own perspectives.

CHAPTERS IN THIS BOOK

Lall (Chapter 2) sets the scene for the country studies by analysing the general relations between technology transfer, FDI and local technology development. He describes the nature of technological learning and effort in developing countries, and the possibility of a divergence between the private interests of the multinational company and the social interests of the host economy in terms of long-term technology development. He goes on to trace recent patterns of export growth and competitiveness in manufactured products, noting the rising share of technology-intensive products and the growing competitiveness of East Asia. The advantage of East Asia over other developing regions is greatest in technology-intensive products, and the most dynamic exporters (including China) have rapidly moved up the technology ladder as they have expanded exports.

The burgeoning competitiveness of East Asian economies draws upon quite distinct strategies. Lall distinguishes between four broad approaches. The first is 'autonomous' (the building of domestic technological capabilities, restricting FDI entry and investing heavily in domestic skills and capabilities), as in Korea and Taiwan. The second is 'strategic FDI dependent' (relying heavily on FDI but using industrial policy extensively to induce it to deepen into advanced activities and functions), as in Singapore. The third is 'passive FDI dependent' (also heavily FDI reliant but without the use of industrial policy to deepen the technological structure). The fourth is 'ISI restructuring' (inducing domestic market-oriented activities to restructure for export markets), as in China.

Each of these policies has been successful in its own way in boosting export competitiveness, though each faces different strategic challenges. Lall shows with some comparative data the varying implications or consequences of the strategies in terms of skills, R&D and FDI. Cluster analysis is used to supplement the descriptive statistics and illustrate graphically the differences in FDI dependent and autonomous strategies.

Kawai and Urata (Chapter 3) examine the performance of East Asian economies in terms of per capita GDP and total factor productivity (TFP) growth for 1970–97. They also investigate statistically the determinants of per capita GDP and TFP growth for 137 countries with a focus on domestic technological capability and inflows of foreign technologies.

They find that East Asian economies as a group perform better than other developing countries (despite some variations among the individual Asian economies). Improvements in domestic technological capability and greater inflows of foreign technology both contribute to increases in per capita GDP and TFP in East Asia. High educational attainment plays an important role in improving domestic technological capability while capital goods imports and FDI inflows are the main sources of foreign technologies. In some cases, foreign technologies are used most effectively when combined with high domestic technological capability.

Though East Asian economies in general perform better than do other developing economies, there are wide variations among them. Many are facing difficult challenges in upgrading technological levels because of increased competition and rapid technological progress. Kawai and Urata argue for a business-friendly environment for foreign and domestic firms by pursuing open policies, improving hard and soft infrastructure, and maintaining stable macroeconomic performance.

Goto and Odagiri (Chapter 4) analyse how Japan acquired foreign technologies in the manufacturing sector during the period from 1945 to the early 1970s. The most striking feature of Japan's strategy was the limited use of FDI and the reliance on technology licensing and purchase of capital goods for the acquisition of foreign technologies. The reasons for its competitive success lie in accumulated technological capability, a rapidly growing market, intense competition from domestic rivals and potential foreign entrants and government policies. There was a 'virtuous circle' between the import of foreign technology and domestic R&D, resulting in the development of technological capability. The measures used by the Japanese government included the protection of domestic industries and promotion of R&D.

Goto and Odagiri draw two policy implications from Japan's experience. The first is that the acquisition of foreign technology requires strong technological capabilities and enormous efforts on the part of the acquiring country. The government played two important roles in technology acquisition. First, it nurtured technological absorptive capabilities by promoting general education and R&D spending. Second, it opened the economy to trade and FDI gradually and with careful preparation. It announced liberalization in advance and in a policy environment in which Japanese firms could raise technological levels in order to compete effectively with anticipated competition from foreign countries.

The second implication concerns FDI policy. While accepting the potential benefits of FDI for technology transfer, they identify some potential drawbacks, such as the domination of domestic industries by foreign firms. Goto and Odagiri argue that restrictive FDI policy contributed to the development of local firms by providing high profits and so allowing them to invest in capacity and capabilities. However, they warn that such restrictions have to be short term: domestic firms must face a potential entry threat. In the globalized economic environment and taking account of the wide technological gap between developed and developing economies, Goto and Odagiri question the advisability of restrictive FDI policy for developing economies today.

Urata and Kawai (Chapter 5) deal with overseas R&D and intra-firm technology transfer by Japanese MNCs. They distinguish between two types of MNC technology transfers: intra-firm (from the parent to overseas affiliates) and spillovers (from affiliates to local firms). Both can contribute to upgrading technological capability in host economies. Urata and Kawai find that Japanese affiliates transfer technology to affiliates and also undertake R&D in host developing economies (mainly to support production). The determinants of affiliate R&D include strong dependence on local sources for intermediate inputs and long operational history in a given location. The determinants of successful intra-firm technology transfer are the availability of educated personnel and R&D resources, the size and development of the local manufacturing sector and accumulated Japanese FDI.

Urata and Kawai draw the implications of their analysis for developing host economies. First, it is important to build strong supplier industries to promote R&D by foreign firms. Second, developing economies should improve the quality of human capital, on the shop-floor, in engineering and in research activity, in order successfully to assimilate technology from foreign firms. Finally, developing economies should provide the economic environment, legal system, infrastructure and so on that attracts FDI.

Kim (Chapter 6) argues that rapid technological learning by Korean firms was the most important factor in its phenomenal industrial and export growth. Korea relied heavily on the inflow of new technology via licences, capital goods and original equipment manufacture (OEM) contracts rather than FDI. Domestic efforts and capabilities were essential in assimilating foreign technology in these externalized forms, since foreign firms were reluctant to transfer key technologies and capabilities. Kim warns that FDI reduces the efforts on the part of domestic firms and increases their dependence on foreign firms. In Korea domestic technological capability was nurtured by both supply and demand factors. The main supply-side factors were the availability of strong human resources, active R&D by private firms and the creation of large firms, supplemented by credit provided on favourable terms. The main demand-side factor was the very competitive environment facing Korean firms, engendered by the strong emphasis on exports which offset the protection offered on the domestic market in terms of providing incentives for capability building.

Kim derives four policy implications for developing countries. The first is the importance of skill building. The second is the role of strong export orientation in creating an intensely competitive environment. The third is the use of the 'brain drain' as an input into domestic capability building: high calibre nationals abroad can be important sources of technical knowledge and skills. The fourth is the role of government research institutes (GRIs) in providing a supply of capable researchers and engineers.

The Korean experience is, however, difficult to emulate, in part because of the new international environment. For example, tightened intellectual property right protection has made it difficult for developing economies to 'reverse engineer' foreign products, one of the main methods of acquiring foreign technologies by Korean firms. Restrictions on FDI are more difficult, and the protection of infant industries is now impossible.

Bee-Yan Aw (Chapter 7) analyses econometrically the effect of different modes of technology acquisition on total factor productivity growth in Taiwan, using firm-level data for the electronics industry in 1986 and 1991. She distinguishes between the following modes: exporting, FDI, R&D, employee training, subcontracting and technical cooperation. The results suggest that exporting, R&D and FDI had positive effects on TFP. In terms of technology spillovers (the acquisition of technology through informal interaction between firms) FDI and exports have a significant impact in the same geographical region and in the same industry. This points to the importance of contacts with foreign firms through exports and FDI, particularly in the electronics industry, where the technology frontier shifts rapidly.

Aw also finds that R&D and training improve technological ability, allowing local firms to assimilate technology more effectively. In Taiwan, the role of the government and industry associations in linking foreign investors with local firms, and in establishing an efficient system of subcontracting, was vital to technology transfer and absorption. All this required human capital, and policies to improve education and R&D manpower were also critical. The impact of technological activity and spillovers greatly contributed to the competitiveness of the small and medium-sized enterprises which formed the bedrock of Taiwan's economic development.

Wong (Chapter 8) traces Singapore's rapid economic growth and structural transformation since independence in 1965. This remarkable economic performance was, according to him, made possible only by the upgrading of technological capability. Singapore underwent four distinctive phases in technology development. The first was the industrial take-off phase, with high dependence on technology transfer by foreign firms. The second phase involved deepening local process technological capabilities, both within MNC affiliates and in supporting local firms. In the third phase foreign and local enterprises and research institutions expanded applied R&D activity. The fourth phase is that of high-tech entrepreneurship and basic R&D. This evolution has moved Singapore from being a technology user to becoming a technology creator.

The technology development of Singapore is to a large extent attributable to effective government policies. These include sound macroeconomic management, open trade and FDI policies (including effective promotion and targeting of MNCs), active science and technology policy and strong emphasis on education and training. One noteworthy feature of technology development in Singapore has been the willingness of MNCs to invest in R&D, partly in response to the strong incentives and enabling conditions offered by the government. Wong also notes the effectiveness of government measures in creating technological linkages between MNCs and local firms.

Wong draws several implications from this experience for other economies. First, it is important to combine a long-term commitment to upgrade technological capability with the institutional capability for flexible and rapid policy change in response to changes in the global environment and the changing needs of the national innovation system. Second, a proper sequencing should be followed in building and deepening technological capabilities: operational and adaptive capabilities should be built before investing in basic research. Third, success in technology development depends not only on effective science and technology policies but also on a variety of other factors, including an open trade and investment environment, sound macroeconomic performance, political and social stability, a corruption-free public service sector and good infrastructure. Fourth, there is no universal set of technology development policies that can be applied to all the countries. One country cannot copy the system that worked in another without modifying it to suit its own conditions. This modification itself needs significant government capabilities.

Yao (Chapter 9) describes China's remarkable industrial growth since the start of liberalization in the late 1970s. He attributes it partly to improvements in technological levels, revealed by rapid increase in total factor productivity and by a shift in the export structure from resource-based products to labour-intensive and simpler technology-intensive products. He describes several characteristics of the technology system in China, such as the dominance of central and local government and public research institutes in R&D activity and the important (even excessive) role of basic research. The acquisition of foreign technologies has shifted from licensing to FDI, particularly in the 1990s.

Yao assesses the effectiveness of the government, private firms and foreign firms in Chinese technology by descriptive and econometric analysis. He finds several interesting patterns. First, collective, private and foreign firms (excluding those from Hong Kong, Macao and Taiwan) are more efficient than state-owned enterprises. Second, foreign firms seem to be reluctant to transfer state-of-the-art technology, but they have beneficial spillovers by training personnel and stimulating competition. Third, R&D by public research institutes has no significant impact on firms' technological levels.

Yao draws policy implications for China and other developing economies. First, he argues for a shift in emphasis in technology development from the public to the private sector and for close ties between basic research in public laboratories and the private sector. Second, he notes the importance of technology development in labour-intensive industries, in which countries like China have a strong comparative advantage. This entails a shift away from the current emphasis on high-tech. Third, he remarks on the importance of integrating foreign firms into the domestic economy.

Abrenica and Tecson (Chapter 10) provide a provocative analysis of technology development in the Philippines. They contrast its very high-tech export specialization (the Philippines has one of the most technology-intensive export structures in the world) with its weak technology base. They describe the various channels of technology transfer – FDI was the most important – and go on to explain the sharp divergence between the export structure and the technology base. They note that the high-tech export structure is due solely to the predominance of the electronics industry, and within it to semiconductors. In this activity, the Philippines is confined to the labour-intensive end of assembly and testing, with very low local content and little upgrading over time. The apparently high endowment of human capital is also slightly misleading once the quality of education is taken into account.

While MNCs have transferred considerable production technology to the Philippines, they have not invested much in local R&D. Neither have local industrial firms. The bulk of R&D takes place within government laboratories, most of it de-linked from the productive sector. Technology strategy has not been coherent, and its implementation has been weak. The main science and technology body has a low status in the government. Trade liberalization has not stimulated a change in the technology culture in industry, and without this the country is exposed to considerable risk by its narrow specialization and low local content in export activity.

Rasiah (Chapter 11) deals with technology development in Malaysia, which was, to an even greater extent than Thailand, dependent on foreign investors to drive industrial and export growth. As with Thailand, local technology development lagged; Rasiah notes the contrast between Malaysia's experience and those of Japan, Korea and Taiwan, where technology development and industrial competitiveness were largely driven by domestic effort. However, the government did play an important role in attracting FDI and providing good infrastructure and a conducive business environment for export-oriented industrialization.

FDI has provided considerable benefit to the Malaysian economy, going beyond its direct contribution to exports, employment and manufacturing production. It has raised local content over time, and so helped the growth of supplier industries. However, rising costs and the emergence of cheaper sites in China and Indonesia place Malaysia under increasing pressure to upgrade its production structure and capabilities to higher value activities. Rasiah finds that Malaysia has not been very successful in meeting this challenge, largely because of its failure to make the requisite institutional changes in such areas as tertiary education and technological activity. While the public sector has actively supported R&D activities, the private sector has not responded adequately. In addition, there is insufficient co-ordination between such technology support activities as finance, training, technical extension and R&D. Rasiah emphasizes the need for a comprehensive policy addressing all these issues.

Brimble, in his analysis of Thailand in Chapter 12, draws a rather different picture of technology development in another dynamic and competitive economy. Thailand's rapid economic growth was based on the growth of labour-intensive, low-tech industries, with foreign investors playing a very important role. However, the development and deepening of local technological capabilities lagged. Indeed, Thailand lags behind many other Asian economies in terms of technological development; this is borne out by international comparison of such things as the quality of technology, management and labour. It is also shown by low R&D spending, the small number of scientists and engineers and the small number of students specializing in science and technology.

Brimble attributes weak technology development in Thailand to a lack of awareness in the public and private sectors of the economic importance of science and technology. This is attributable to a tradition of passive reliance on off-the-shelf technology import, with little subsequent effort to absorb and improve upon it. Thai entrepreneurs tend to display a short-run commercial orientation, which deters them from investing in the long-term development of technological capability. Yet the phase based on low wages and skills is coming to an end, and Thailand's future growth and competitiveness depend on its ability to develop significant new technological capabilities. This calls for substantial changes in its science and technology policies. Such changes extend well beyond the narrow scope of S&T, and cover manpower development, technological upgrading of small and medium-sized enterprises and the development of support industries.

Brimble stresses the need to allocate more resources to training, R&D and other innovation activities with a particular emphasis on applied technology. He also points to the importance of the creation and use of linkages – between the government and the private sector, between foreign firms and public intervention and between foreign and local firms – to improve technological capabilities. All this also needs greater awareness on the part of the Thai government, business and the population at large of the importance of technology development and the role of FDI in development.

Okamoto and Sjöholm (Chapter 13) treat the case of Indonesia, which made enormous economic strides before it was struck by the financial crisis in 1997. Despite rapid industrialization, however, Indonesia still lags behind other East Asian countries in technological development. Analysing the results of other studies of Indonesia's experience, Okamoto and Sjöholm draw four lessons for technology development. First, in the early stage of industrial development agents like foreign buyers, trading companies and experts are important sources of technology; thus, it is important to have an open trade and FDI regime. Second, FDI can contribute to development not only by introducing new technology but also by generating employment, expanding production and exports. However, the host economy has to build local skills and R&D capabilities if it is to benefit fully from MNC presence. Third, the government can play an effective role in acquiring, upgrading and disseminating technology, especially in an environment where private industrial linkages are deficient. Specifically, government can provide better education and training, and improve the technology infrastructure (standards, quality and testing). Fourth, technology policies targeting high-technology industries (like aircraft in Indonesia) can be wasteful, unless backed by the prior development of skills and a technological, managerial and institutional infrastructure.

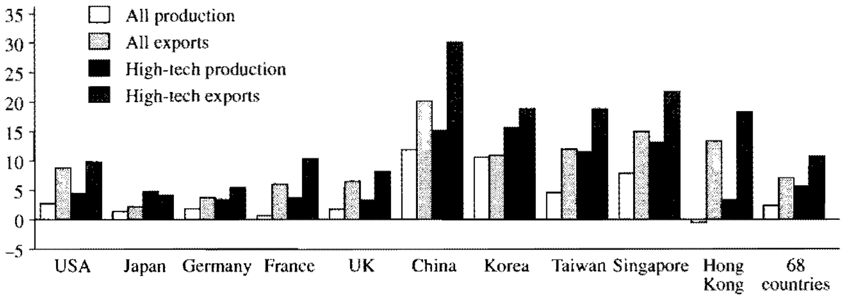


Figure 2.1 Total and high-technology manufacturing: annual growth rates, 1985–97

faster than those that do not. Figure 2.1 shows the growing significance of high-tech activities in production and trade (based on NSF, 2000). The 68 countries in the total sample apparently account for 95 per cent of global productive activity. Note two features of the table: exports in general grow faster than production, and high-tech production and exports grow much faster than overall production and exports.

The speed, spread and nature of technical change pose difficult challenges for achieving competitiveness. Unlike a few decades ago, policy liberalization makes it difficult to insulate tradable industrial activities from global technical pressures. In addition, the traditional buffers provided by high transport and information costs are diminishing in significance as new information technologies force all countries into the same competitive arena. Some analysts note that the nature of competition itself is changing in response to new technologies. What Best (1990) calls the 'new competition' entails flexible response, networking, customization and new forms of inter-firm organization (in clusters) rather than classic cost/price competition dominated by hierarchicallyorganized firms. Small enterprises and networks are establishing competitive niches in many activities, including those with high rates of innovation. At the same time, however, with growing trade and investment flows, the role of multinational corporations (MNCs) is rising in importance.

2. TECHNOLOGY AND CAPABILITY BUILDING – ANALYTICAL FRAMEWORK

Technological effort is vital to developing countries, even though they do not innovate. 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 to handle the tacit elements of technology. Received theory assumes that technology mastery and diffusion in developing countries are relatively easy, knowledge is not tacit, and the markets involved 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.[3]

This approach is over-simplified. The international technology market is far from perfect.[4] 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; Westphal, 2002).

Some important features of the capability building process are described in Box 2.1. 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.[5] Technology development can thus face market failures (Stiglitz, 1996).

In sum, learning to use new technologies (new, that is, 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)

BOX 2.1 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 that 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 satisficing 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 to 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 (2000b).

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. This has always been true, but the new technological paradigm means that the challenges are greater.

Continuous access to new technologies is essential to sustaining competitiveness. While internalized modes necessarily involve MNCs, externalized ones may also involve MNCs selling technologies on contract (MNCs are the largest sellers of licensed technology). However, there are also 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.

3. ROLE OF FDI IN TECHNOLOGY TRANSFER AND LEARNING

The MNCs 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 2 per cent (representing the largest employers) of manufacturing companies undertaking R&D in the USA accounted for nearly 80 per cent of industrial R&D spending (calculated from table 2-8, NSF, 2000). Such concentration is even higher in small OECD industrial countries (UNCTAD, 1999). It does not seem to have declined over time.

As the major innovators, MNCs are the main sources of international technology transfer. Their role is naturally larger in high-technology activities where they possess the strongest advantages. Before considering transfers to developing countries, let us highlight features of recent FDI (Box 2.2).

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

BOX 2.2 SALIENT FEATURES OF RECENT FDI

- FDI flows are growing faster than other economic aggregates like national gross fixed capital formation, world trade and GDP. International production (by MNCs and affiliates) is steadily increasing its share in global production.
- MNCs increasingly dominate world trade: around two-thirds of visible trade is handled by MNCs, and the share is growing particularly in activities with significant scale economies in production, marketing or innovation.
- Of the visible trade handled by MNCs, between 30 and 40 per cent is within MNC systems, between affiliates and parents or among affiliates. Such internalized trade contains the most dynamic exports today, moving within integrated international production systems, where MNCs locate different functions or stages of production to different countries. Affiliates participating in such systems produce at 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, the Philippines and Mexico). The globalization of the value chain is likely to spread across many other industries, and linking local production chains to global chains will become a major source of growth, technology transfer and skill development.
- Some MNCs are locating non-production functions like 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 has termed '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 that of production, particularly in developing countries. Over 90 per cent of overseas R&D by US MNCs is in other industrial countries. MNCs from smaller countries are more international in terms of relocating R&D overseas, but MNCs from economies like the UK are also conducting very substantial amounts 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 MNCs need 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 USA) account for 90 per cent, the USA 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.
- MNCs 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 Korea and Taiwan is sold to MNCs on an OEM (original equipment manufacture) basis. The significance of OEM for Korea is shown by the following statistics. In 1985, over 40 per cent of Korean exports were in the form of OEM. In 1989, around 50–60 per cent of VCR and TV exports and about 80 per cent of PC exports by Korea were under OEM. In 1990, 70–80 per cent of total Korean electronics exports were under OEM. MNCs are also active in *exports of low-technology products* where factors like scale economies, branding, distribution and design are important.
- MNCs can help *restructure and upgrade competitive capabilities* in import-substituting activities. Where the facilities are already foreign owned, MNCs 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, MNCs 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 constitutes 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 MNCs can provide rapid improvements in the productivity and efficiency to host economies, not only in their industries but also to their customers (many of which are important exporters).

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 transferrer 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 transfer may also have costs (Pack and Saggi, 1997). Profits are realized by the MNC on the package as a whole rather than just the innovation component. If the host country already possesses other elements of the package, it is cheaper to buy the technology separately (countries like Korea and Taiwan 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 such activities, reliance on foreign investment can shorten the learning period but reduce the other benefits of technology transfer and capability building.

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.

The advantage of internalized forms 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, MNCs 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 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. MNCs 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 scope for a clash between the social interests of the host economy and the private interests of MNCs. 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 MNCs to transfer more advanced technological functions.

4. PATTERNS OF EXPORT COMPETITIVENESS IN EAST ASIA

The pattern of manufactured exports reflects the underlying structure of and competitive advantages in manufacturing. A sophisticated export structure, with growing world market shares, generally suggests that the exporting economy has built the production and innovative capabilities to use advanced technologies and, over time, keeps abreast of new technologies. This is not, however, always the case. The rise of integrated production systems means that developing countries can enter sophisticated export activities at the simple labour-intensive end: FDI can introduce a wedge between indigenous capabilities and export structures. East Asia has examples of both kinds of competitive bases. Some countries have built strong domestic capabilities in technology-intensive activities, generally by restricting or manipulating FDI to boost local innovation. Others have enjoyed rapid export growth and technological upgrading by plugging into high-tech TNC production systems. This section shows how both strategies have led to dynamic competitiveness in East Asia.

Both strategies have advantages and drawbacks. The domestic capability building strategy has many long-term advantages, but it is costly, risky and prolonged. And over time, as innovation accelerates and the structure of international production changes, it has to move towards greater reliance on MNCs. The FDI dependent strategy allows countries to raise exports and technological structures rapidly, but it faces the problem of sustainability. MNCs can dynamize competitiveness in countries in which they locate integrated systems, but such activity may not allow the exporting country to maintain a competitive edge as wages rise, technologies grow more demanding or there is greater need for local suppliers. Thus, domestic capability building becomes necessary to retain the base set up by export-oriented MNCs.

While the two strategies move towards some convergence, however, there is considerable path-dependence once countries get launched along particular trajectories. This is clearly the case in East Asia, as the country studies in this book show. But let us paint a broad comparative picture here by analysing the export data.

Technological Classification

The analysis separates primary from manufactured exports and groups manufactures into four technology levels: resource-based (RB), low-technology (LT), medium-technology (MT) and high-technology (HT) (Lall, 2000a). All such classifications suffer from data and definition

Table 2.1 Technological classification of exports

Primary products	Fresh fruit, meat, rice, cocoa, tea, coffee, wood, coal, crude petroleum, gas
Manufactured products	
Resource-based manufactures	
Agro/forest-based products	Prepared meats/fruits, beverages, wood products, vegetable oils
Other resource-based products	Ore concentrates, petroleum/rubber products, cement, cut gems, glass
Low-technology manufactures	
Textile/fashion cluster	Textile fabrics, clothing, headgear, footwear, leather manufactures, travel goods
Other low-technology	Pottery, simple metal parts/structures, furniture, jewellery, toys, plastic products
Medium-technology manufactures	
Automotive products	Passenger vehicles and parts, commercial vehicles, motorcycles and parts
Medium-technology process	Synthetic fibres, chemicals and paints, fertilizers, plastics, iron, pipes/tubes
Medium-technology engineering	Engines, motors, industrial machinery, pumps, switchgear, ships, watches
High-technology manufactures	
Electronics and electrical	Office/data processing/telecommunications equipment, transistors, turbines, generating equipment
Other high-technology	Pharmaceuticals, aerospace, optical/measuring instruments, cameras
Other transactions	Electricity, cinema film, printed matter, 'special' transactions, gold, art, coins, pets

problems. It is not possible to capture an important aspect of technical change: upgrading *within* given product categories.[6] The categories are highly aggregated and can conceal differences within each category.[7] They do not show the processes involved in making a given product: the spread of integrated production systems mean that these differ substantially between countries.[8] Nor do they show local physical and technological content in exports: one country may be assembling imported components and another manufacturing the product from scratch. Nevertheless, some disadvantages can be overcome indirectly. For instance, we can use qualitative information on local content and processes to allow for differences in technology content in export activity in different locations.

Table 2.2 Growth rates and market shares of exports (% per annum)

	All products	Primary	All mfg.	RB	LT	MT	HT
Growth 1985–98							
World	8.6	3.4	9.7	7.0	9.7	9.3	13.1
Developed	8.4	4.4	8.8	7.0	8.5	8.5	11.3
Developing	8.7	1.3	12.5	6.0	11.7	14.3	21.4
Growth 1985–90							
World	13.1	5.6	14.9	11.4	16.3	15.1	17.4
Developed	14.0	7.9	14.7	12.7	15.4	14.7	16.2
Developing	9.1	1.3	15.4	4.9	18.4	19.3	26.7
Growth 1990–95							
World	8.2	4.4	8.9	7.4	8.3	7.8	13.2
Developed	7.0	4.9	7.2	6.2	6.2	6.6	10.1
Developing	12.0	2.7	15.3	10.3	11.3	16.6	25.4
Growth 1995–98							
World	2.1	−1.9	2.7	−0.4	1.8	2.5	6.1
Developed	1.7	−2.3	2.2	−0.9	1.4	2.0	5.6
Developing	2.8	−1.1	3.5	0.9	2.2	3.1	7.0
Shares of products in world exports, 1985 and 1998							
1985	100	21.7	73.8	21.1	13.7	30.2	12.4
1998	100	11.5	84.2	14.5	15.8	32.8	21.1
Shares of developing countries in world exports, 1985 and 1998							
1985	24.3	52.1	16.4	26.3	26.7	8.3	10.7
1998	25.0	39.7	23.3	23.7	34.5	15.3	27.0

Global and Regional Patterns

We start with the major categories for four sub-periods between 1985 and 1998.[9] Table 2.2 gives growth rates and market shares for exports by the world, developed and developing countries.[10]

Table 2.3 shows manufactured exports by main developing regions.[11] SSA and LAC are shown with and without their major exporters – South Africa and Mexico, the 'outliers' in their regions.[12] The figures show large, and generally increasing, disparities in export performance across the developing world, with enormous concentration of competitive capabilities in East Asia.

Table 2.3 shows that with nearly 70 per cent of total manufactured exports by developing countries, East Asia is not just the dominant player, its share is rising over time. The largest loss of share is by LAC2 (excluding

Table 2.3 Regional shares of developing countries' manufactured exports (% of developing world total)

	Year	East Asia	South Asia	MENA	LAC1 (incl. Mexico)	LAC2 (exc. Mexico)	Mexico	SSA1 (incl. S Africa)	SSA2 (exc. S Africa)
All manufactures	1985	56.9	4.5	12.9	23.1	16.9	6.2	n/a	2.6
	1998	69.0	3.8	6.0	19.3	8.9	10.4	1.8	0.8
RB	1985	34.6	3.8	23.8	32.9	30.7	2.2	n/a	4.9
	1998	47.5	4.7	15.0	28.0	24.0	4.0	4.8	1.4
Agro-based	1985	55.1	2.2	4.5	32.0	30.4	1.6	n/a	6.2
	1998	55.1	1.7	4.9	33.1	28.3	4.6	5.3	2.4
Other RB	1985	25.6	4.5	32.3	33.3	30.8	2.5	n/a	4.3
	1998	41.4	7.2	23.1	23.1	20.6	2.5	4.4	0.6
LT	1985	71.7	8.3	7.3	11.9	10.2	1.7	n/a	1.8
	1998	70.2	8.5	7.2	12.6	5.4	7.2	1.5	0.2
Textile cluster	1985	69.9	11.6	8.1	9.5	8.5	1.0	n/a	0.9
	1998	67.3	12.1	9.1	10.4	4.9	5.5	1.1	0.8
Other LT	1985	75.2	1.7	5.7	16.6	13.5	3.1	n/a	0.8
	1998	74.9	2.9	4.2	16.0	6.3	9.7	2.0	0.3

MT	1985	63.4	2.0	7.1	25.8	17.5	8.3	n/a	1.8
	1998	63.8	1.8	4.4	28.1	10.2	17.9	1.9	0.2
Auto	1985	40.6	2.7	5.9	50.3	32.9	17.4	n/a	0.4
	1998	39.8	1.4	2.9	54.2	16.9	37.3	1.7	0.1
Process	1985	53.4	2.3	13.8	28.2	25.2	3.0	n/a	2.3
	1998	65.6	3.3	8.4	19.9	13.0	6.9	2.8	0.5
Engineering	1985	73.0	1.7	3.5	20.1	10.4	9.7	n/a	1.7
	1998	72.5	1.1	2.6	22.4	5.8	16.6	1.3	0.1
HT	1985	81.0	1.1	1.8	14.8	6.6	8.2	n/a	1.3
	1998	85.5	0.6	0.7	12.9	2.1	10.8	0.4	0.0
Electronic	1985	84.7	0.5	0.7	14.0	5.1	8.9	n/a	0.1
	1998	87.2	0.3	0.6	11.8	1.2	10.6	0.2	0.1
Other HT	1985	60.3	4.5	8.2	19.2	15.2	4.0	n/a	7.8
	1998	66.9	4.2	1.9	25.0	12.2	12.8	0.0	0.3

Source: Lall (2000a).

Mexico, which shows a healthy increase). It is followed by MENA, which retains second position but after a hefty fall; its performance is strongly influenced by Turkey. South Asia, despite its substantial industrial sector, suffers a diminution of its small share, the continuing legacy of decades of import-substitution. Sub-Saharan Africa starts from a marginal position and deteriorates further. The share of SSA2 falls to below 1 per cent (only 0.2 per cent of the world total); even including South Africa only brings the figure to below 2 per cent (0.4 per cent of the world total).

Table 2.4 shows the *technology composition* of manufactured exports by region. The world and the developed countries shift from RB to HT products. In the developing world, there is a more marked shift away for 'simple' (RB and LT) to 'complex' (MT and HT) products, but with a massive increase in HT. East Asia has the most high-tech export structure (more than developed countries) and the largest upgrading; its reliance on LT products falls over time, particularly in the textile group. LAC has a complex export structure but mainly because of MT products (particularly autos). The Mexican presence is very significant, driven in turn by its *maquiladora* export activities. Both MENA and SSA2 reduce their heavy dependence on RB, but remain specialized in simple manufactured products, especially in the fashion cluster (led by Turkey and Morocco in MENA and Mauritius in SSA2). While MENA raises its share of HT and MT, SSA2 does the reverse. South Asia shows a similar trend to MENA, but with a much heavier reliance on LT products. Thus, East Asia emerges as the most competitive, dynamic and technologically advanced region in the developing world.

Country-level Performance in East Asia

Manufactured exports by developing countries are concentrated not just at the regional but also at the country level. In 1998, for instance, the leading five exporters accounted for 60 per cent, and the leading ten for over 80 per cent, of the developing world total. Interestingly, concentration tends to be greater the higher the level of technology, ranging from about 60 per cent for RB to 96 per cent for the top ten HT exporters in 1998. This suggests, as expected, that capability needs (and entry barriers) rise with technological sophistication. Concentration levels also tend to rise over time, indicating growing capability needs. Annex Tables 2A.1 and 2A.2 show values and breakdowns of manufactured exports by technological category for 13 main developing country exporters. All the countries in this study are in this group. Shares of MT and HT products in their 1998 manufactured exports are shown in Figure 2.2.

In MT, the highest share is in Mexico, a result of its MNC dominated

Table 2.4 Distribution of manufactured exports over technological categories, 1985 and 1998

1985	RB	RB1	RB2	LT	LT1	LT2	MT	MT1	MT 2	MT3	HT	HT1	HT2
World	23.7	9.8	13.8	18.6	8.3	10.3	40.9	12.2	9.7	19.0	16.8	10.9	5.9
Developed	21.0	9.6	11.5	16.1	5.8	10.3	44.7	14.3	10.3	20.1	18.2	11.4	6.8
Developing	38.0	11.6	26.5	30.4	20.1	10.3	20.6	2.1	6.7	11.9	11.0	9.3	1.7
East Asia	23.1	11.2	11.9	38.3	24.7	13.6	23.0	1.5	6.3	15.2	15.6	13.8	1.8
South Asia	32.3	5.6	26.7	55.8	51.8	4.0	9.2	1.3	3.4	4.5	2.8	1.1	1.7
MENA	70.1	4.0	66.1	17.1	12.6	4.5	11.3	1.0	7.1	3.2	1.6	0.5	1.1
LAC1	54.2	16.1	38.2	15.7	8.3	7.4	23.1	4.5	8.2	10.4	7.0	5.6	1.4
LAC2	61.1	18.4	42.7	16.2	8.9	7.3	18.9	3.6	8.8	6.5	3.8	2.5	1.3
SSA2	70.7	27.3	43.3	10.1	7.0	3.0	13.8	0.3	5.9	7.6	5.5	0.5	5.0

1998	RB	RB1	RB2	LT	LT1	LT2	MT	MT1	MT2	MT3	HT	HT1	HT2
World	17.3	8.9	8.4	18.8	8.2	10.6	38.9	11.5	8.8	18.6	25.1	18.2	6.9
Developed	16.8	9.1	7.7	15.5	5.2	10.2	43.2	13.6	9.1	20.5	24.5	16.0	8.5
Developing	17.6	7.8	9.8	27.8	17.1	10.8	25.5	5.2	7.6	12.8	29.1	26.6	2.5
East Asia	12.1	6.2	5.9	28.3	16.6	11.7	23.6	3.0	7.2	13.4	36.0	33.6	2.4
South Asia	21.7	3.4	18.3	61.6	53.6	8.0	12.1	1.9	6.5	3.7	4.6	1.9	2.8
MENA	44.3	6.4	37.9	33.7	26.1	7.6	18.8	2.5	10.6	5.7	3.3	2.5	0.8
LAC1	25.4	13.3	12.1	18.1	9.1	8.9	37.1	14.5	7.8	14.8	19.4	16.2	3.2
LAC2	47.2	24.5	22.6	16.8	9.3	7.5	29.1	9.8	11.0	8.3	6.9	3.5	3.4
SSA1	46.0	22.4	23.6	22.6	10.5	12.0	25.8	4.9	11.6	9.3	5.7	3.0	2.7
SSA2	51.3	38.6	12.7	35.0	27.4	7.6	11.5	0.6	7.7	3.2	2.2	0.7	1.5

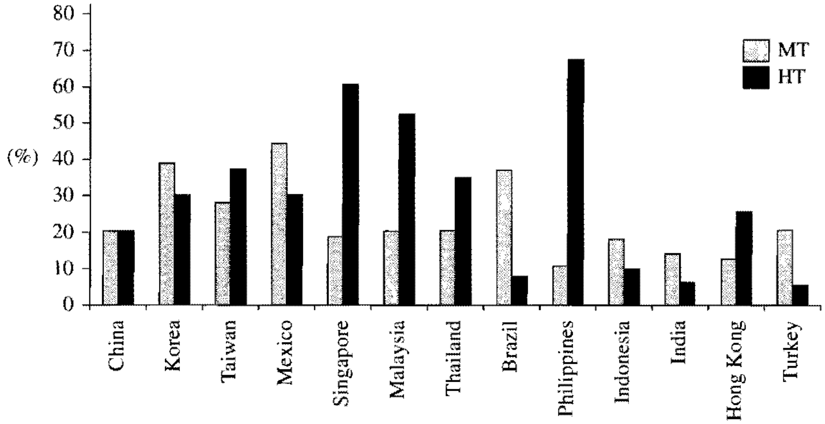


Figure 2.2 Shares of MT and HT products in manufactured exports (1998) for 13 largest exporters

automotive and engineering exports, followed by Korea (dominated by the *chaebol*) and Brazil (mainly MNCs). The highest shares of HT are in the Philippines, Singapore and Malaysia, all dominated by MNC export-oriented operations. Of these countries, local content is highest in Singapore, followed by Malaysia. The Philippines remains at the stage of final assembly and testing operations.

However, Korea and Taiwan have the greatest technological inputs and competence among the large HT exporters. Their domestic firms undertake much of the manufacturing and also provide high levels of physical, design, R&D and engineering inputs (see Hobday, 1995 and Lall, 1996). Because of product differentiation and branding, a large proportion of sophisticated exports have to be sold by MNCs under their own brands (called OEM, or original equipment manufacture). Hong Kong has a weak technology structure, and is the only Asian Tiger to suffer massive de-industrialization in recent years. This may in part be traced to its lack of targeted industrial and technological policies: Singapore, with higher wages and a strong service sector, has a growing industrial sector because it has been able to target and promote higher value-added activities.

Let us now consider *revealed comparative advantage (RCA) by technology categories* for the leading exporters in 1985–98 (Table 2.5).[13] There are several points of note.

China. In 1985 no manufactured export category for China had an RCA of over 1 (at the more disaggregated level, its fashion cluster products had an advantage). Its main advantage lay in primary products (with an

RCA of 1.7, not shown here). In 1998, China showed a revealed comparative advantage only in LT products. Its RCA for HT products also increased strongly over the period, but not sufficiently to give an RCA of over unity. Its weakest RCA was in medium-technology products, while the lowest increase was in RB.

Mature Tigers. Korea started the period with a strong revealed comparative advantage in LT and a slight one in MT. By 1998, while it retained RCAs of over unity in these two groups, it had also developed a strong comparative advantage in HT products offset by a declining RCA in LT (and primary products). Taiwan started in 1985 with a stronger RCA in LT and had a slight advantage in HT. In 1998, it retained this pattern, but like Korea had suffered a large erosion of LT advantages while enjoying an increase in HT. Singapore had a strong comparative advantage in RB (petroleum refining and petrochemicals) and a somewhat lower one in HT products. By 1998, its only area of comparative advantage was HT, the only country in the group to show an increasing RCA in this set of products and declining ones in all others. Hong Kong remained overwhelmingly specialized in LT over the period, far more so than much lower-wage economies in the region. However, it also showed a slight positive comparative advantage in HT products (mainly electronics-based light consumer goods like watches and toys) in both periods. In general, it showed the weakest and least dynamic of industrial structures among the Tigers, accompanying an anaemic export performance.

'New Tigers'. The Philippines started in 1985 with an RB-dominated export structure (with a slight comparative advantage in textile products). It then underwent a dramatic transformation, losing in RB and gaining in HT. However, this was driven almost entirely by semiconductor assembly and belies an otherwise weak competitive performance.[14] Malaysia also started with a strong advantage in RB but it already had an advantage in HT. Over the period, its RB suffered a decline but retained a (slight) advantage, while its HT greatly increased its RCA. Thailand had advantages in RB and LT in 1985, and by 1998 had greatly increased its competitive edge in HT while losing it slightly in RB and LT. Indonesia started, like China, with no RCAs of over unity in any manufactured category (that is, its advantages lay in primary products). Over time, Indonesia acquired advantages in RB and LT products. Its pattern of resource-based and low-technology competitiveness development contrasts with that of most other countries in the region.

Table 2.5 RCAs for leading 13 developing country exporters by technological category, 1985 and 1998

1985	RB Total	RB1	RB2	LT Total	LT1	LT2	MT Total	MT1	MT2	MT3	HT Total	HT1	HT2
China	0.525	0.364	0.639	0.751	1.417	0.219	0.096	0.012	0.322	0.034	0.099	0.019	0.248
Korea	0.471	0.462	0.477	2.890	4.270	1.786	1.183	0.249	1.398	1.673	0.986	1.347	0.318
Taiwan	0.539	0.760	0.381	3.657	4.599	2.904	0.663	0.314	0.764	0.836	1.237	1.794	0.205
Mexico	0.462	0.253	0.610	0.366	0.322	0.401	0.547	0.390	0.267	0.790	0.693	0.987	0.148
Singapore	2.070	0.921	2.888	0.523	0.548	0.502	0.645	0.071	0.654	1.009	1.644	2.127	0.750
Malaysia	1.695	3.521	0.396	0.322	0.489	0.189	0.208	0.015	0.236	0.319	1.195	1.719	0.224
Thailand	1.124	2.009	0.495	1.336	2.279	0.582	0.378	0.022	0.574	0.506	0.197	0.260	0.080
Brazil	1.728	1.914	1.597	1.067	1.305	0.877	0.679	0.558	1.137	0.523	0.272	0.280	0.257
Philippines	1.695	3.142	0.666	0.930	1.258	0.667	0.157	0.051	0.499	0.052	0.467	0.693	0.048
Indonesia	0.893	1.252	0.637	0.234	0.445	0.064	0.044	0.001	0.168	0.009	0.050	0.054	0.042
India	1.610	0.392	2.476	2.289	4.653	0.397	0.231	0.148	0.269	0.266	0.227	0.135	0.398
Hong Kong	0.174	0.231	0.133	4.415	6.953	2.383	0.609	0.001	0.166	1.225	1.146	1.616	0.275
Turkey	0.908	1.021	0.828	2.814	4.402	1.543	0.567	0.144	1.325	0.452	0.093	0.101	0.079
All developing countries	1.0812	0.791	1.288	1.0982	1.633	0.670	0.3398	0.115	0.465	0.420	0.4387	0.571	0.193

1998	RB Total	RB1	RB2	LT Total	LT1	LT2	MT Total	MT1	MT2	MT3	HT Total	HT1	HT2
China	0.619	0.520	0.723	2.883	4.151	1.896	0.563	0.105	0.773	0.745	0.862	1.016	0.455
Korea	0.671	0.479	0.874	1.210	1.493	0.991	1.073	0.889	1.525	0.971	1.288	1.619	0.418
Taiwan	0.362	0.334	0.391	1.839	1.870	1.814	0.804	0.400	1.175	0.877	1.654	2.203	0.208
Mexico	0.409	0.426	0.390	1.070	1.152	1.006	1.187	1.696	0.604	1.151	1.260	1.561	0.469
Singapore	0.912	0.422	1.431	0.417	0.293	0.514	0.537	0.081	0.623	0.778	2.683	3.545	0.414
Malaysia	1.032	1.741	0.282	0.625	0.651	0.606	0.557	0.064	0.571	0.855	2.217	2.876	0.482
Thailand	1.080	1.342	0.803	1.302	1.782	0.928	0.508	0.191	0.596	0.663	1.339	1.729	0.311
Brazil	2.074	2.436	1.690	0.730	0.893	0.603	0.858	0.967	1.201	0.629	0.295	0.189	0.577
Philippines	0.471	0.702	0.227	0.873	1.463	0.414	0.317	0.134	0.158	0.505	3.042	4.133	0.169
Indonesia	1.470	1.957	0.954	1.148	1.630	0.773	0.311	0.066	0.729	0.264	0.252	0.318	0.079
India	1.623	0.343	2.979	2.409	4.363	0.887	0.348	0.231	0.741	0.234	0.244	0.140	0.519
Hong Kong	0.291	0.360	0.219	3.352	6.491	0.908	0.378	0.000	0.393	0.605	1.158	1.306	0.766
Turkey	0.854	1.096	0.598	3.114	5.522	1.239	0.554	0.293	0.997	0.503	0.253	0.281	0.180
All developing countries	0.949	0.816	1.091	1.384	1.937	0.953	0.613	0.421	0.801	0.641	1.083	1.365	0.339

Note: Calculated for all exports, including primary products (not shown here).

5. MAIN DETERMINANTS OF COMPETITIVENESS

Strategic Issues

What were the strategies pursued by these countries to build industrial competitiveness? While a part of export growth was certainly based on the better exploitation of natural resources and unskilled or semi-skilled labour, the most dynamic performers have relied on the creation of *new advantages in complex products*. This has been based, in turn, on new domestic skills and technologies and/or on the attraction of MNC production chains. The exact combination of the two has differed by country: some have relied on attracting FDI, others have built stronger domestic capabilities by intervening in factor and product markets.

To reiterate the *strategic issues*: the development of competitiveness in all activities at all technological levels requires building capabilities in management, production, engineering, design, distribution, marketing and so on. The realization of *existing* advantages (say, in resource-based or unskilled labour-intensive activities) tends to involve less effort, risk and externalities than the development of advantages in complex activities. Sustained export growth needs moving from easy to complex products and processes within activities, and across activities from easy to complex technologies. The choice between modes of technology transfer depends on the existing base of skills and the scale, marketing and technological demands of exporting. It also depends upon the ability of governments and institutions to help local enterprises build capabilities and tap externalities. MNCs and local firms face different factor markets and have to overcome different market failures in learning.

MNCs have advantages over local firms in using new technologies. They have mastered and used the technologies elsewhere; they may have created the technology in the first place. They have large reserves of skill, technical support, experience and finance to design and implement learning. 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 MNC corporate systems.

While MNCs can be a highly effective means of transferring technologies and building production capabilities, they may be less effective in deepening and broadening them. MNCs initially transfer equipment and technologies suited to *existing* skills and capabilities. They do invest in upgrading local skills, technological capabilities and supply chains but only to the extent that it is profitable in commercial terms (to implement production technologies). They will go beyond this, but only if the skill base is growing, local suppliers improving their capabilities, technology institutions can provide more advanced services, and so on. This needs active government policies. Moreover, a policy to induce MNCs to enter more advanced activities by offering such inducements as specialized infrastructure and skills can accelerate the upgrading process. With a completely passive policy, MNC exports can remain at low, technologically stagnant, levels. *Thus, an MNC-dependent export strategy needs a proactive element for dynamic competitiveness.*

More important, depending on FDI is not a substitute for strengthening domestic capabilities. There are many activities that MNCs do not enter, including many localized ones that tend to be populated by SMEs. They also need efficient local suppliers if they are to go beyond the assembly of imported components. Capturing the spillover benefits of foreign presence needs capable local firms. More important, a strong base of national enterprises can lead to broader, deeper and more flexible capabilities, since the technology development process within foreign affiliates may be curtailed as compared to local firms. 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 like advanced engineering, design or R&D, which MNCs tend to centralize in industrial countries. As they mature industrially, it is imperative for developing countries to undertake these functions locally to support their future comparative advantage. This is why some countries choose to promote technology development in indigenous firms.

Different countries make different strategic choices in these respects. Taking our sample of leading developing country exporters, we may distinguish between four:

1. *Autonomous*, based on the development of capabilities in domestic firms, starting in simple activities and deepening 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 setting, with favours granted in return for good export performance. The prime examples are Korea and Taiwan.
2. *Strategic FDI-dependent*, driven by FDI and exports within integrated production networks. There was a strong effort to upgrade

MNC 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.

3. *Passive FDI-dependent*, also driven by FDI but relying largely on market forces to upgrade the structure. The main tools were a welcoming FDI regime, strong incentives for exports, good export infrastructure and cheap, trainable labour. Skill upgrading and domestic technological activity were relatively neglected (though 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, along with the Special Economic Zones of China (and the *maquilas* of Mexico).
4. *ISI restructuring*, with exports growing from 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 and in others they were MNCs. The main difference from the 'autonomous' strategy was the lack of clear and coordinated industrial policy to develop export competitiveness, with haphazard (and 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 exclusive. Countries often combine them and vary the combinations over time. Nevertheless, this typology is useful as an analytical tool. Let us now consider the main supply-side determinants of capability building (skills, technological activity and FDI attraction).

Skills

In the traditional setting, industrial development required improving the quantity and quality of primary schooling and basic technical education, and encouraging all forms of in-firm training. The data do not permit a rigorous comparison of skill formation across countries, particularly for enterprise training. What is possible is to compare educational enrolments.

The most common comparisons are for the three general levels: primary, secondary and tertiary. Given the focus in technology, however, we concentrate on *tertiary enrolments in technical subjects*: science, mathematics and computing and engineering. Note, however, that national rankings are fairly similar even if other measures of skill creation are used (Lall, 1999), so the exact definition of the measure is not that important. Table 2.6 shows enrolments for the mid-1990s for East Asia and its comparator regions and countries, with some advanced industrial countries shown for reference.

Enrolment data are not, as noted, the ideal measure of skills. They ignore on-the-job learning, other forms of training and quality differences in the education provided. Nevertheless, they are the only comparable data available and they do show the national base for skill acquisition. In percentage terms the Asian NIEs enrol over 33 times as many of their population in technical subjects than does SSA (including South Africa). The ratio is twice that of industrial countries, nearly five times that of Latin America and the new NIEs, and over ten times that of South Asia and China. The leading three countries in terms of total numbers of technical enrolments – China (18 per cent), India (16 per cent) and Korea (11 per cent) – account for 44 per cent of the developing world's technical enrolments, the top ten for 76 per cent and the top 20 for 93 per cent.

In terms of the *intensity* of technical skill creation (enrolments as a percentage of the population), however, the picture is quite interesting, particularly at the country level (Table 2.7). The world leader is Korea (1.65 per cent), followed by Finland (1.33 per cent). Taiwan, the next developing country, ranks fifth (1.07 per cent). Singapore comes in much later, in thirty-eighth position, below the Philippines and Hong Kong; however, this is misleading in that the polytechnics provide a great deal of technical education in Singapore and students also study abroad, which is not captured in the UNESCO data. The new NIEs, apart from the Philippines, are well behind: Indonesia (54), Thailand (70) and Malaysia (75). China and India are even further (82 and 78 respectively).

These figures have to be treated with care. The connection between technical enrolments and technological competence is not direct. The quality of the training and the ability of industry to exploit available skills in R&D or other technical effort matter a great deal. The accumulated stock of trained manpower and, more importantly, its base of experience are extremely important.

Technological Activity

Technological activity in developing countries consists less of 'innovation' than of engineering and technical work for learning, adaptation and improvement. Given its diffuse nature, however, it is difficult to measure.

Table 2.6 Tertiary level enrolments and enrolments in technical subjects, 1995

	Tertiary level enrolment		Technical enrolments: numbers and % of population							
	Total no. students	% pop.	Natural science		Maths, computing		Engineering		All technical subjects	
			numbers	(%)	numbers	(%)	numbers	(%)	numbers	(%)
Developing countries	35345800	0.82	2046566	0.05	780930	0.02	4194433	0.10	7021929	0.16
Sub-Saharan Africa	1542700	0.28	111500	0.02	39330	0.01	69830	0.01	220660	0.04
MENA	4571900	1.26	209065	0.06	114200	0.03	489302	0.14	812567	0.22
Latin America	7677800	1.64	212901	0.05	188800	0.04	1002701	0.21	1404402	0.30
Asia	21553400	0.72	1513100	0.05	438600	0.01	2632600	0.09	4584300	0.15
4 mature Tigers	3031400	4.00	195200	0.26	34200	0.05	786100	1.04	1015500	1.34
4 new Tigers	5547900	1.61	83600	0.02	280700	0.08	591000	0.17	955300	0.28
S. Asia	6545800	0.54	996200	0.08	7800	0.00	272600	0.02	1276600	0.10
China	5826600	0.60	167700	0.02	99400	0.01	971000	0.10	1238100	0.13
Others	601700	0.46	70400	0.05	16500	0.01	11900	0.01	98800	0.08
Transition economies	2025800	1.95	55500	0.05	30600	0.03	354700	0.34	440800	0.42
Developed economies	33774800	4.06	1509334	0.18	1053913	0.13	3191172	0.38	5754419	0.69
Europe	12297400	3.17	876734	0.23	448113	0.12	1363772	0.35	2688619	0.69
N. America	16430800	5.54	543600	0.18	577900	0.19	904600	0.31	2026100	0.68
Japan	3917700	0.49					805800	0.10	805800	0.10
Australia, New Zealand	1128900	5.27	89000	0.42	27900	0.13	117000	0.55	233900	1.09

Source: Calculated from UNESCO (1997) and national sources. Blank spaces indicate data was not available.

Table 2.7 Technical tertiary enrolments by country (% population), 1995

1	Korea	1.65	38	Bolivia	0.34
2	Finland	1.33	39	Costa Rica	0.34
3	Australia	1.17	40	Turkey	0.33
4	Taiwan	1.06	41	Ecuador	0.29
5	Spain	0.97	42	Uruguay	0.29
6	Ireland	0.90	43	Venezuela	0.29
7	Austria	0.78	44	El Salvador	0.26
8	Germany	0.77	45	Morocco	0.25
9	UK	0.75	46	Tunisia	0.24
10	Chile	0.73	47	Indonesia	0.23
11	Portugal	0.73	48	Nicaragua	0.22
12	Sweden	0.73	49	Honduras	0.20
13	Greece	0.72	50	Thailand	0.19
14	Canada	0.69	51	Brazil	0.18
15	Israel	0.68	52	S. Africa	0.17
16	N. Zealand	0.68	53	Hungary	0.16
17	USA	0.68	54	Malaysia	0.13
18	Norway	0.67	55	Egypt	0.12
19	Italy	0.64	56	India	0.12
20	Japan	0.64	57	Jamaica	0.11
21	France	0.61	58	Paraguay	0.11
22	Denmark	0.60	59	China	0.10
23	Panama	0.59	60	Zimbabwe	0.09
24	Netherlands	0.56	61	Bangladesh	0.08
25	Philippines	0.55	62	Nepal	0.08
26	Colombia	0.51	63	Sri Lanka	0.08
27	Switzerland	0.51	64	Cameroon	0.06
28	H. Kong	0.49	65	Madagascar	0.06
29	Romania	0.49	66	Pakistan	0.05
30	Argentina	0.47	67	Senegal	0.05
31	Singapore	0.47	68	Mauritius	0.04
32	Peru	0.46	69	Congo	0.03
33	Mexico	0.44	70	Kenya	0.02
34	Belgium	0.43	71	CAR	0.01
35	Jordan	0.42	72	Ethiopia	0.01
36	Algeria	0.41	73	Malawi	0.01
37	Poland	0.39			

Source: Calculated from UNESCO (1997).

What we *can* measure is formal R&D. This is still useful, since R&D becomes an important input into competitiveness in countries at intermediate levels of industrialization. It is necessary to monitor technological developments overseas and select those relevant to local needs. This lowers the cost of technology transfer and captures more spillovers from the operation of TNCs. A growing R&D base permits better and faster technology diffusion within the economy and facilitates greater use of local resources. It makes it feasible and attractive for TNCs to locate their own design and development work there. Most importantly, it permits the industrial sector greater flexibility and diversification, and allows it greater autonomy.

Table 2.8 shows R&D scientists and engineers and expenditures in the developing world. The patterns again reflect the technological depth of exports analysed earlier. Productive enterprise-financed R&D as a share of GNP – perhaps the best indicator of *technologically useful* R&D – in the mature NIEs is nearly 400 times higher than in Sub-Saharan Africa, and around 10 times higher than in the new NIEs and Latin America. Asia as a whole accounts for 86 per cent of R&D scientists and engineers in the developing world, Sub-Saharan Africa for 0.3 per cent, and Latin America for 10 per cent. The proportion of enterprise-financed R&D in total R&D spending is highest in the mature NIEs, followed by the new NIEs, and lowest in Sub-Saharan Africa. Latin America and South Asia are similar, with below 10 per cent of national R&D financed by productive enterprises.

The regional averages conceal large variations at the national level. Figure 2.3 shows productive enterprise-financed R&D as a percentage of GNP for selected countries. Korea is again one of the leaders; its figure is the highest, not only in the developing world, but also, apart from Japan, in the world as a whole.[15] Taiwan comes next in the developing world, with a lower ratio than the UK but more than the Netherlands or Italy. Singapore comes next, though much lower in the world scale. While its high dependence on FDI has not held back the growth of private sector R&D (much of it in foreign affiliates), this has needed a strong government push, and the innovation base remains narrow. Hong Kong does not publish R&D data, but reports suggest that total R&D is only 0.1 per cent of GNP (NSF, 2000, table 2-14) and enterprise-financed R&D is a very small proportion of this. The other three Tigers are clearly a class apart in the developing world.

Of the new Tigers, Malaysia leads while Thailand comes in last, surprisingly lower even than Indonesia.[16] This reveals an important weakness in Thai competitiveness, the shallowness of its high-technology export activity (Lall, 2001). Malaysia has succeeded in raising R&D in MNCs (especially in electronics), adopting some of the same strategies as Singapore, but it has a long way to go before it can match the latter in technological competence.

Table 2.8 R&D propensities and manpower in major country groups (latest year available)

Countries and regions (a)	Scientists/engineers in R&D		Total R&D	Sector of performance (%)		Source of financing (% distribution)		R&D by financing (% of GNP)	
	Per mill. pop.	Numbers	(% of GNP)	Productive sector	Higher education	Prod. enterprise	Govt.	Prod. enterprise	Prod. sector
Industrialized economies (b)	1102	2704205	1.94	53.7	22.9	53.5	38.0	1.037	1.043
Developing economies (c)	514	1034333	0.39	13.7	22.2	10.5	55.0	0.041	0.054
Sub-Saharan Africa (exc. S. Africa)	83	3193	0.28	0.0	38.7	0.6	60.9	0.002	0.000
North Africa	423	29675	0.40	n/a	n/a	n/a	n/a	n/a	n/a
Latin America & Caribbean	339	107508	0.45	18.2	23.4	9.0	78.0	0.041	0.082
Asia (excluding Japan)	783	893957	0.72	32.1	25.8	33.9	57.9	0.244	0.231
Mature NIEs (d)	2121	189212	1.50	50.1	36.6	51.2	45.8	0.768	0.751
New NIEs (e)	121	18492	0.20	27.7	15.0	38.7	46.5	0.077	0.055
S. Asia (f)	125	145919	0.85	13.3	10.5	7.7	91.8	0.065	0.113
Middle East	296	50528	0.47	9.7	45.9	11.0	51.0	0.051	0.045
China	350	422700	0.50	31.9	13.7	n/a	n/a	n/a	0.160
European transition economies (g)	1857	946162	0.77	35.7	21.4	37.3	47.8	0.288	0.275
World (79–84 countries)	1304	4684700	0.92	36.6	24.7	34.5	53.2	0.318	0.337

Notes:
(a) Only including countries with data, and with over 1 million inhabitants in 1995.
(b) USA, Canada, West Europe, Japan, Australia and New Zealand.
(c) Including Middle East oil states, Turkey, Israel, South Africa, and formerly socialist economies in Asia.
(d) Hong Kong, Korea, Singapore, Taiwan Province.
(e) Indonesia, Malaysia, Thailand, Philippines.
(f) India, Pakistan, Bangladesh, Nepal.
(g) Including Russian Federation.

Source: Calculated from UNESCO (1997). Regional propensities for R&D spending are *simple* averages.

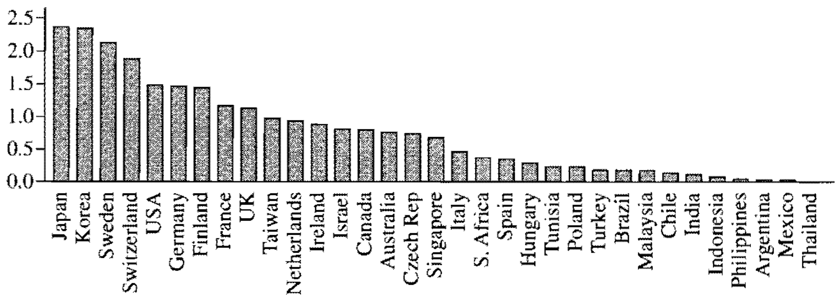


Figure 2.3 R&D financed by productive enterprises, 1995 (% GNP)

MNCs account for substantial portions of technological effort in Singapore, Malaysia, Brazil and Mexico. Interestingly, the latter two countries attract the most US MNC R&D in the developing world (UNCTAD, 1999), but are poor performers in overall terms. In Korea and Taiwan, R&D by local firms takes precedence, driven by strategies to restrict FDI inflows and reverse the passive reliance on foreign technologies that marks most developing countries.

FDI

As noted, trade and competitiveness are increasingly related to MNC activity. MNCs now account for large shares of world trade and their shares are higher in technologically advanced and differentiated products. A very large part of MNC trade is now *intra-firm*. In the USA, for instance, exports by MNCs to their majority-owned affiliates in 1996 comprised 48 per cent of parent company exports, up from 41 per cent in 1977. Half of exports by foreign MNCs in the USA (accounting for 20 per cent of total US exports) were also intra-firm; similar trends are likely in other capital exporting countries. The propensity to engage in intra- as compared to inter-firm trade is higher in technologically complex and novel products. Within the web of intra-firm trade relationships is the emerging network of international production systems, with different stages of production and services located in different countries in accordance with relative costs and strategic considerations.

Entry by developing countries into a large (and dynamic) segment of industrial activity and trade thus increasingly requires direct MNC (that is, equity-based) participation. Arm's length and joint venture relations with MNCs help, but they only provide partial entry into this segment, and only for countries that have strong local technological and innovative capabil-

Table 2.9 FDI as percentage of gross domestic investment (averages)

	1980–85	1994–97
Singapore	18.72	27.81
China	0.87	13.24
Malaysia	11.18	12.47
Hong Kong	6.90	9.93
Philippines	0.37	8.20
Indonesia	1.00	6.60
Thailand	2.41	4.18
Taiwan	1.50	3.05
Korea, Rep.	0.40	1.11
Cambodia	0.00	27.41
Laos	0.00	23.14
Vietnam	0.00	22.88
Pakistan	1.39	6.27
Sri Lanka	3.02	5.54
India	0.14	2.46
Bangladesh	0.00	0.49
Chile	6.23	23.14
Mexico	2.41	12.50
Argentina	2.98	11.39
Brazil	4.19	5.97
Ireland	4.14	15.05
UK	6.53	12.34
France	2.02	8.32
USA	2.74	5.81
Germany	0.60	1.53
Japan	0.09	0.09

Sources: World Bank, (2000), UNCTAD (2002).

ities. Even for such countries, the needs of scale, specialization, and access to new technologies and international marketing makes it imperative to belong to MNC systems rather than stay outside them. This is why world technological leaders encourage interpenetration by each other's MNCs, strategic alliances and cross-border M&As.

However, few developing countries participate in these emerging MNC systems. While FDI in developing countries is rising rapidly (from an average of US$29 billion in 1986–91 to US$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. Table 2.9 shows FDI inflows as a percentage of gross domestic investment in East Asia (including some formerly socialist economies) and comparators in Latin America, South Asia and the OECD, averaged for 1980–85 and 1994–97.

Singapore has been, and remains, the country most reliant on internalized technology transfers by MNCs in the region. Malaysia has traditionally been the second, but in recent years has been overtaken by China (which in absolute terms is the largest recipient of FDI in the developing world). The Philippines has greatly raised its attractiveness to foreign investors, as has Indonesia. Thailand remains a relatively modest player by regional standards. Taiwan, and to a greater extent Korea, have been relatively restrictive on FDI inflows (and have been net exporters of FDI for some time). However, Korea has become far more receptive to inward investments after the financial crisis. In fact, it saw a dramatic upsurge of inward FDI in 1998–99, accounted for by a burst of cross-border M&A activity: inflows thus rose from US$3.1 billion in 1997 to US$10.3 billion in 1999 (UNCTAD, 2000). Thailand has seen a similar spurt, largely into the financial sector but also into manufacturing industries. Indonesia, by contrast, has suffered negative inflows as a result of the political instability following the crisis.

The relationship between reliance on FDI (internalized technology inflows) and domestic R&D effort varies greatly within East Asia. The 'autonomous' countries, Korea and Taiwan, built up strong innovative capabilities by restricting internalized technology inflows and using a battery of promotional measures to encourage technological development and R&D by local enterprises (Lall, 1996). Of the FDI-dependent countries, only Singapore had a coherent and consistent policy for encouraging local R&D, encompassing both foreign and local firms and using tools and incentives to get MNCs to upgrade affiliate technological capabilities. The other economies (China apart) did not have technology promotion policies for MNCs (though Malaysia had a mild and largely ineffective approach along Singaporean lines); for domestic firms they had some general policies but without much 'bite'. As a result, their capabilities were largely confined to production technologies.

This pattern suggests that countries with ambitious technological objectives need to mount coherent and targeted strategies to induce firms to move up the skill and innovation ladder. Building a strong and diverse innovation base in domestic enterprises seems to need selective policies to restrict FDI. Raising R&D in foreign affiliates needs a different set of policies, but it is clearly feasible if the host country is able to provide world-class skills, infrastructure and business environment.

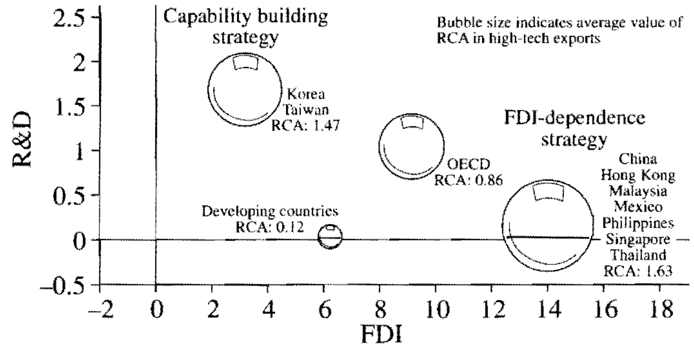


Figure 2.4 RCA in high-technology exports and main industrial strategies, 1995

6. CLUSTER ANALYSIS OF COMPETITIVENESS STRATEGIES

We can illustrate the different strategies for Asian and other countries (73 in total) for 1995. The dependent variable is *competitiveness*, measured by *RCAs in different technological categories*. The independent variables are *FDI* (as a percentage of gross domestic investment) and *technological effort* (R&D by productive enterprises as a percentage of GDP).

The technique used is *K-means cluster analysis*.[17] Cluster analysis groups' observations on the basis of selected characteristics, help in this case to identify groups of countries with similar export patterns and strategies. Strategies in turn are indicated by different degrees of reliance on FDI and domestic R&D. Figure 2.4 is a three-dimensional representation of RCAs and these two determinants of competitive performance. It shows clearly how Korea and Taiwan stand out from the other high performing Asian economies in terms of their higher reliance on domestic R&D rather than R&D. It also shows that FDI-dependent countries in the region have higher RCAs, being able to enter MNC international production systems.

Clearly the growth of these production systems has transformed competitive patterns in some countries very quickly, allowing them to bypass the slow and arduous process of building domestic capabilities. It does not, however, ensure a sustainable base of capabilities in the longer term, as their wages rise and technologies become more complex and skill intensive.

In strategic terms, the data show clearly the differences between what we have termed 'autonomous' and 'FDI-dependent' approaches to building competitiveness. The implications are that countries that wish to pursue autonomous strategies need to mount enormous efforts to compensate for the lack of internalized technology transfers. Those that are unable to do this would be wise to depend on MNCs and direct their efforts towards integration into their international production systems. However, most countries have not been able to do either – the aim of these countries should be to discover what they need to do to follow one pattern or the other. Note, however, that the strategic choices illustrated by these figures relate to the past. The options for the future are much narrower, as the 'rules of the game' change (towards a smaller role for government) and are more rigorously enforced.

7. CONCLUSIONS

The figures on export competitiveness in East Asia are impressive. The region is the best placed in the developing world to sustain export competitiveness. It is a dominant player in developing world trade. It is well positioned in fast growing products and shows great flexibility in adapting to changing patterns of technology and demand. Its specialization in high-technology products points to considerable development of skill and technological capabilities.

These generalizations conceal important national differences. Different Asian exporters base their competitiveness on different agents and factors. At one extreme, Korea and Taiwan have a strong domestic base of enterprises, skills, innovation and institutions. At the other, some very successful exporters have weak domestic enterprises, a shallow technology base, an export sector isolated from local industry, and an inadequate skill creation system.

This is not to say that the former set necessarily has better long-term competitive prospects than the latter. Each group faces its own risks and challenges. For instance, those with autonomous strategies expose themselves to greater risk the more they approach technological frontiers and the more rapid the pace of technical change. Those highly dependent on MNC networks to provide technology do not face the same technological risk. However, looking to the future, we can argue that the requirements of continued competitiveness are likely to be very different from the past. Passive FDI-dependent countries with low levels of skill and R&D may find themselves unable to attract the most advanced or dynamic technologies if their skill and supplier base does not rise to the level needed.

Globalization does not, in other words, reduce the role of local capabilities and innovative activity beyond the short term where an assembly base is established. On the contrary, it raises it because technical efficiency in each location becomes the final determinant of success. As rising wages and technical change force countries into more complex activities, they have to furnish more advanced capabilities. Skill development, industrial specialization, enterprise learning and institutional change are needed to create *cumulative* and *self-reinforcing processes* to promote further learning, regardless of how much countries rely on MNCs.

Autonomous strategies – as demonstrated by Korea and Taiwan – entail a great deal 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. However, such strategies are increasingly difficult and risky on economic grounds – the sheer pace of technical change and the growth of international production systems raise the costs of being left on the outside. They are also increasingly constricted by the new rules of the game being laid down by international agencies and developed countries.

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. The sources of technical change remain largely outside, in the hands of MNCs; there is less need to intervene to promote learning in infant industries for this reason. However, industrial policy is needed to ensure the development of the relevant skills, capabilities and institutions required to ensure that TNCs keep transferring new technologies and higher value functions. Passive strategies involve less industrial policy in export-oriented activities to start with (though there may be intervention in domestic-oriented activity). However, they need to evolve into more targeted strategies if countries are not to lose their competitive positions and momentum.

National technology strategies are now starting to converge. Autonomous countries are becoming more integrated into MNC systems (and have many capable MNCs of their own). FDI-dependent countries are trying to strengthen capabilities in domestic firms and build up the institutional structure for innovation. Those using passive FDI strategies are moving towards more targeted strategies. These changes are driven both by new technologies and globalization as well as by new rules of the game, and are likely to persist into the foreseeable future. This does not, however, mean that countries will converge technologically. There will remain significant differences in technological and competitive performance, even among the successful exporters of East Asia, because of differences in endowments (size, location, resources and so on) and in inherited structures of technological learning. National systems of technology development have elements of path dependence and stability (Lall, 2000a) and can change only as the institutional, technological and human capital base evolves – necessarily a slow process. Inherited structures also influence how flexibly and dynamically countries respond to new competitive challenges: this feedback process can let leaders maintain their advantage for very long periods. FDI can help change national technological systems, but the real driver of change lies within each economy. Government policies and institutional structures play a vital role here, and this role remains even as its form and content evolves.

NOTES

1. I am grateful to Manuel Albaladejo for doing the cluster analysis reported at the end of the paper, and to various members of the World Bank Institute study, in particular Bee-Yan Aw and Rajah Rasiah, for helpful comments. I would like to acknowledge my debt to UNCTAD for classifying the export data at my request. The usual disclaimers apply.
2. See UNIDO (2002) for data on the values and concentration of global and national R&D spending.
3. 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*.
4. 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 (that is, 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.
5. These are explored in 'new economic geography'; see, for instance, Krugman (1995) and Venables (1996).
6. One may compare unit values of exports over time or across countries to get a rough indication of technical change and quality, but this is only possible for a few (relatively homogeneous) products and countries. When the objective is to build up a broad picture of export patterns by technology levels, this procedure cannot be applied.
7. Ideally, the data should distinguish between levels of technology at a fairly disaggregated level, but this is not possible. We use the UN Standard International Trade Classification (SITC) data at the 3-digit level (Revision 2). This level can put together products of different levels of technological complexity in the same category. For instance, telecommunications apparatus includes advanced telephone technology as well as simple telephone receivers. The export data do not distinguish quality differences within categories, such as fashion clothing from mass-produced items.
8. For instance, semiconductor exports can be based on high-tech processes in the USA and simple assembly and testing in the Philippines: both appear as 'high technology'.
9. The export data are all in terms of current US dollars and do not show volume changes. Since the main purpose of the exercise is to compare regions and countries across tech-

nological categories, this does not matter very much, since a general price deflator would apply to all equally. However, it does mean that relative price changes between product categories cannot be taken into account.

10. Transition economies in Eastern Europe and Central Asia are excluded because of the very patchy nature of the data available over the period. Developed economies are defined to include Israel, South Europe but not Turkey (which is included in the Middle East group). Developing countries are defined to include the South Africa, the mature Asian Tigers, China and Asian transition economies (like Vietnam), and all Latin American countries (including Mexico). Data for 1998 have several missing values for developing countries like Bangladesh, Sri Lanka and many African countries, none of which are major exporters in the developing world. Data for 1980 could not be used because they had missing values for major Latin American exporters.
11. 'East Asia' includes all countries in Asia east of Myanmar, including Myanmar and Vietnam (but not Laos or Cambodia) and China, and excludes Japan and Central Asian transition countries. 'South Asia' comprises India, Pakistan, Bangladesh, Sri Lanka, Maldives, Nepal and Bhutan. 'MENA' (Middle East and North Africa) includes Afghanistan and Turkey as well as all Arab countries (Sudan is counted under SSA). 'SSA' (Sub-Saharan Africa) includes South Africa (SSA1) unless specified (SSA2). 'LAC' (Latin America and the Caribbean) includes Mexico (LAC1) and excludes it (LAC2) when specified.
12. Mexico is treated as an outlier because of its proximity to the USA and the unusual nature of its trading relations. Mexico has long been a base for export-oriented assembly by US firms in its border *maquiladoras*, which were allowed to import duty-free inputs and sell the finished product to the USA with tariffs levied only on the value-added. The formation of NAFTA in the mid-1990s gave offshore assembly a new fillip and brought Mexico into a position to challenge Asia. NAFTA allowed significant new privileges like allowing local inputs for duty exemption; this led to dramatic rises across all export categories and to a huge rise in FDI from Asia to use Mexico as an export base for the USA. Mexico now accounts for more manufactured exports than the rest of Latin America put together. South Africa is an outlier in SSA for more obvious reasons. It accounted for 55 per cent of manufacturing value-added in SSA in 1998, and for 45 per cent of its manufactured exports.
13. 'Revealed comparative advantage' is defined as the share of a country's exports of a particular product, say clothing, divided by the share of its total exports in world exports. Thus, an RCA ratio of over 1 for clothing shows that the country has a revealed comparative advantage in clothing: its global share of clothing exports is higher than the share of all its exports.
14. Given its relatively low wages, for instance, the Philippines is performing poorly in traditional labour-intensive exports (Lall, 2001). See Chapter 10 on the Philippines for an analysis of the shallow base of its high-technology exports.
15. However, by 1997 Sweden had overtaken Korea and Japan, see UNIDO (2002).
16. However, this may be due to measurement errors and the real figure is likely to be somewhat higher, taking it ahead of Indonesia but still behind Malaysia. I am grateful to Peter Brimble for this comment.
17. *K-means cluster analysis* is used to cluster large numbers. The number of groups has to be specified in advance: we specified five. Using the squared Euclidean distance (the sum of the squared differences over all of the variables), we identify 'five initial cluster centres' as a reference point for the other cases. Once the cases are classified, we obtain the final cluster centres, which are simply the average values of the variables for cases in the clusters.

REFERENCES

Best, M. (1990), *The New Competition: Institutions of Industrial Restructuring*, Cambridge: Polity Press.

Hobday, M.G. (1995), *Innovation in East Asia: The Challenge to Japan*, Aldershot, UK and Brookfield, US: Edward Elgar.

Krugman, P. (1995), *Development, Geography and Economic Theory*, Cambridge, MA: MIT Press.

Krugman, P. (1996), 'Making sense of the competitiveness debate', *Oxford Review of Economic Policy*, **12**(3), 17–25.

Lall, S. (1992), 'Technological capabilities and industrialization', *World Development*, **20**(2), 165–86.

Lall, S. (1993), 'Understanding technology development', *Development and Change*, **24**(4), 719–53.

Lall, S. (1996), *Learning from the Asian Tigers: Studies in Technology and Industrial Policy*, London: Macmillan.

Lall, S. (1999), 'Competing with labour: skills and competitiveness in developing countries', Geneva: ILO, Issues in Development discussion paper 31.

Lall, S. (2000a), 'The technological structure and performance of developing country manufactured exports, 1985–98', *Oxford Development Studies*, **28**(3), 337–69.

Lall, S. (2000b), 'Technological change and industrialization in the Asian NIEs', in L. Kim and R.R. Nelson (eds), *Technological Learning and Economic Development: The Experience of the Asian NIEs*, Cambridge: Cambridge University Press, pp. 13–68.

Lall, S. (2001), *Competitiveness, Technology and Skills*, Cheltenham, UK and Northampton, USA: Edward Elgar.

Mathews, J.A. and D.S. Cho (2000), *Tiger Technology: The Creation of a Semiconductor Industry in East Asia*, Cambridge: Cambridge University Press.

Nelson, R.R. (ed.) (1993), *National Innovation Systems: A Comparative Analysis*, Oxford: Oxford University Press.

Nelson, R.R. and S.J. Winter (1982), *An Evolutionary Theory of Economic Change*, Cambridge, MA: Harvard University Press.

NSF (2000), *Science and Engineering Indicators 2000*, Washington, DC: National Science Foundation.

Pack, H. and K. Saggi, (1997), 'Inflows of foreign technology and indigenous technological development', *Review of Development Economics*, **1**(1), 81–98.

Radosevic, S. (1999), *International Technology Transfer and Catch-Up in Economic Development*, Cheltenham, UK and Northampton, USA: Edward Elgar.

Stiglitz, J.E. (1996), 'Some lessons from the East Asian miracle', *World Bank Research Observer*, **11**(2), 151–77.

UNCTAD (1999), *World Investment Report 1999: Foreign Direct Investment and the Challenge of Development*, Geneva and New York: United Nations.

UNCTAD (2000), *World Investment Report 2000: Cross-Border Mergers and Acquisitions and Development*, Geneva and New York: United Nations.

UNESCO (1997), Statistical Yearbook 1997, Paris: United Nations Educational, Scientific and Cultural Organization.

UNIDO (2002), *Industrial Development Report 2002*, Vienna: United Nations Industrial Development Organization.

Venables, A.J. (1996), 'Localization of industry and trade performance', *Oxford Review of Economic Policy*, **12**(3), 52–60.
Westphal, L. E. (2003), 'Technology strategies for economic development in a fast changing-global economy', *Economics of Innovation and New Technology*.
World Bank (1993), *The East Asian Miracle*, Oxford: Oxford University Press.
World Bank (1999), *World Development Report 1999*, Oxford: Oxford University Press.
World Bank (2000), *World Development Indicators*, Washington, DC: World Bank.

ANNEX

Table 2A.1 Leading 13 exporters of manufactures in 1998, values of exports in 1985 and 1998 (US$ million)

1985	Total mfrs.	RB total	RB1	RB2	LT total	LT1	LT2
China	6049.2	2349.7	677.7	1672.0	2645.2	2217.4	427.8
Korea	29025.0	2493.6	1016.7	1477.0	12017.6	7892.5	4125.1
Taiwan	29092.5	2883.2	1690.3	1192.9	15381.6	8597.1	6784.5
Mexico	8336.3	1761.4	401.4	1360.0	1097.2	429.3	667.8
Singapore	19014.0	8266.6	1527.8	6738.7	1640.2	764.7	875.5
Malaysia	8626.5	4632.1	3998.9	633.3	692.4	466.6	225.8
Thailand	3657.6	1386.5	1029.8	356.6	1295.1	981.8	313.3
Brazil	17616.8	7744.6	3563.2	4181.4	3757.2	2042.9	1714.4
Philippines	2428.7	1359.1	1047.0	312.0	585.7	352.3	233.4
Indonesia	3856.4	2899.3	1690.4	1208.9	596.2	505.1	91.1
India	6208.9	2518.8	255.1	2263.8	2813.2	2542.2	270.9
Hong Kong	15979.5	504.2	278.1	226.1	10063.3	7045.7	3017.6
Turkey	5790.4	1263.4	590.3	673.1	3075.5	2138.6	936.9
Total above 13	155681.5	37568.9	17766.8	22295.8	43642.7	35976.2	19684.1
Developing world	210244.6	79986.4	24308.2	55678.2	63839.8	42194.1	21645.7
%	74.0	47.0	73.1	40.0	68.4	85.3	90.9

	MT total	MT1	MT2	MT3	HT total	HT1	HT2
China	738.9	28.6	589.5	120.8	315.4	38.6	276.8
Korea	10807.1	678.6	3020.4	7108.1	3706.7	3287.7	419.0
Taiwan	6124.1	865.3	1668.5	3590.4	4703.6	4430.0	273.6
Mexico	3600.7	766.1	415.6	2419.0	1877.0	1736.4	140.5
Singapore	4445.2	146.4	1066.3	3232.4	4662.1	3916.9	745.3
Malaysia	982.1	20.5	262.9	698.7	2319.9	2167.4	152.5
Thailand	803.8	13.9	289.0	501.0	172.2	147.7	24.5
Brazil	5249.6	1287.2	2079.7	1882.7	865.4	578.4	287.1
Philippines	217.8	21.1	163.5	33.3	266.1	256.5	9.6
Indonesia	246.1	0.9	222.2	23.0	114.8	80.9	33.9
India	624.7	118.9	171.5	334.3	252.1	97.4	154.8
Hong Kong	3050.2	1.9	196.4	2851.8	2361.8	2163.1	198.7
Turkey	1359.6	102.8	752.4	504.3	91.9	64.7	27.2
Total above 13	27442.7	4052.2	10897.8	23299.8	18002.2	18965.5	2743.4
Developing world	43369.6	4380.5	14040.5	24948.6	23048.7	19490.7	3558.0
%	63.3	92.5	77.6	93.4	78.1	97.3	77.1

1998	Total mfrs.	RB total	RB1	RB2	LT total	LT1	LT2
China	167681.1	16551.3	7155.4	9395.8	83803.2	52814.7	30988.5
Korea	120700.3	12914.5	4739.6	8175.0	25325.3	13673.1	11652.2
Taiwan	105553.7	5811.3	2761.3	3050.1	32100.7	14291.0	17809.7
Mexico	103681.3	6977.1	3743.6	3233.5	19848.6	9358.2	10490.4
Singapore	103488.5	14588.6	3471.0	11117.6	7254.0	2226.8	5027.2
Malaysia	65940.5	11004.8	9543.2	1461.7	7245.9	3301.7	3944.3
Thailand	44759.5	8657.7	5532.4	3125.3	11345.3	6798.2	4547.1
Brazil	38881.6	15424.7	9319.0	6105.7	5900.6	3158.6	2742.0
Philippines	28118.8	2022.3	1548.6	473.7	4074.3	2988.2	1086.1
Indonesia	26894.8	10447.6	7154.9	3292.7	8868.8	5511.1	3357.7
India	25855.1	7801.8	847.5	6954.3	12583.4	9977.4	2606.0
Hong Kong	23136.7	1041.7	661.4	380.3	13034.7	11049.2	1985.5
Turkey	22885.2	3339.9	2204.1	1135.8	13236.9	10276.1	2960.8
Total above 13	877577.3	116583.5	58681.9	57901.6	244621.8	145424.2	99197.6
Developing world	996967.5	175130.4	77385.7	97744.7	277435.3	169990.4	107444.9
%	88.0	66.6	75.8	59.2	88.2	85.5	92.3

	MT total	MT1	MT2	MT3	HT total	HT1	HT2
China	33853.9	1864.0	10556.4	21433.4	33472.8	28605.5	4867.3
Korea	46443.7	11354.5	14998.0	20091.3	36016.7	32800.6	3216.2
Taiwan	29044.5	4256.5	9644.3	15143.6	38597.2	37259.0	1338.2
Mexico	45598.6	19200.6	5264.1	21133.9	31257.0	28055.0	3202.0
Singapore	19326.2	861.8	5091.3	13373.0	62319.7	59674.4	2645.2
Malaysia	13360.2	455.2	3107.9	9797.0	34329.6	32276.3	2053.3
Thailand	9165.0	1014.8	2438.8	5711.5	15591.5	14593.9	997.5
Brazil	14363.8	4770.0	4563.9	5029.9	3192.5	1476.4	1716.0
Philippines	3058.9	382.2	346.8	2329.9	18963.3	18673.5	289.8
Indonesia	4972.1	310.0	2647.5	2014.6	2606.3	2381.3	225.0
India	3763.5	735.2	1820.4	1208.0	1706.3	708.5	997.8
Hong Kong	3044.5	0.7	717.9	2325.9	6015.8	4920.1	1095.7
Turkey	4870.8	761.5	1992.9	2116.4	1437.7	1156.3	281.3
Total above 13	230865.8	45967.0	63190.3	121708.5	285506.2	262580.8	22925.4
Developing world	254289.1	51537.3	75515.3	127236.4	290112.8	265114.5	24998.3
%	90.8	89.2	83.7	95.7	98.4	99.0	91.7

Table 2A.2 Leading developing country exporters in 1998, distribution by technological category and growth rates, 1985–98

Shares of total manufactured exports by technological categories 1985 (%)

	Total mfrs.	RB total	RB1	RB2	LT total	LT1	LT2
China	100	38.8	11.2	27.6	43.7	36.7	7.1
Korea	100	8.6	3.5	5.1	41.4	27.2	14.2
Taiwan	100	9.9	5.8	4.1	52.9	29.6	23.3
Mexico	100	21.1	4.8	16.3	13.2	5.2	8.0
Singapore	100	43.5	8.0	35.4	8.6	4.0	4.6
Malaysia	100	53.7	46.4	7.3	8.0	5.4	2.6
Thailand	100	37.9	28.2	9.8	35.4	26.8	8.6
Brazil	100	44.0	20.2	23.7	21.3	11.6	9.7
Philippines	100	56.0	43.1	12.8	24.1	14.5	9.6
Indonesia	100	75.2	43.8	31.3	15.5	13.1	2.4
India	100	40.6	4.1	36.5	45.3	40.9	4.4
Hong Kong	100	3.2	1.7	1.4	63.0	44.1	18.9
Turkey	100	21.8	10.2	11.6	53.1	36.9	16.2

Shares of total manufactured exports by technological categories 1985 (%)

	MT total	MT1	MT2	MT3	HT total	HT1	HT2
China	12.2	0.5	9.7	2.0	5.2	0.6	4.6
Korea	37.2	2.3	10.4	24.5	12.8	11.3	1.4
Taiwan	21.1	3.0	5.7	12.3	16.2	15.2	0.9
Mexico	43.2	9.2	5.0	29.0	22.5	20.8	1.7
Singapore	23.4	0.8	5.6	17.0	24.5	20.6	3.9
Malaysia	11.4	0.2	3.0	8.1	26.9	25.1	1.8
Thailand	22.0	0.4	7.9	13.7	4.7	4.0	0.7
Brazil	29.8	7.3	11.8	10.7	4.9	3.3	1.6
Philippines	9.0	0.9	6.7	1.4	11.0	10.6	0.4
Indonesia	6.4	0.0	5.8	0.6	3.0	2.1	0.9
India	10.1	1.9	2.8	5.4	4.1	1.6	2.5
Hong Kong	19.1	0.0	1.2	17.8	14.8	13.5	1.2
Turkey	23.5	1.8	13.0	8.7	1.6	1.1	0.5

Shares of total manufactured exports by technological categories 1998 (%)

	Total mfrs.	RB total	RB1	RB2	LT total	LT1	LT2
China	100	9.9	4.3	5.6	50.0	31.5	18.5
Korea	100	10.7	3.9	6.8	21.0	11.3	9.7
Taiwan	100	5.5	2.6	2.9	30.4	13.5	16.9
Mexico	100	6.7	3.6	3.1	19.1	9.0	10.1

Singapore	100	14.1	3.4	10.7	7.0	2.2	4.9
Malaysia	100	16.7	14.5	2.2	11.0	5.0	6.0
Thailand	100	19.3	12.4	7.0	25.3	15.2	10.2
Brazil	100	39.7	24.0	15.7	15.2	8.1	7.1
Philippines	100	7.2	5.5	1.7	14.5	10.6	3.9
Indonesia	100	38.8	26.6	12.2	33.0	20.5	12.5
India	100	30.2	3.3	26.9	48.7	38.6	10.1
Hong Kong	100	4.5	2.9	1.6	56.3	47.8	8.6
Turkey	100	14.6	9.6	5.0	57.8	44.9	12.9

Shares of total manufactured exports by technological categories 1998 (%)

	MT total	MT1	MT2	MT3	HT total	HT1	HT2
China	20.2	1.1	6.3	12.8	20.0	17.1	2.9
Korea	38.5	9.4	12.4	16.6	29.8	27.2	2.7
Taiwan	27.5	4.0	9.1	14.3	36.6	35.3	1.3
Mexico	44.0	18.5	5.1	20.4	30.1	27.1	3.1
Singapore	18.7	0.8	4.9	12.9	60.2	57.7	2.6
Malaysia	20.3	0.7	4.7	14.9	52.1	48.9	3.1
Thailand	20.5	2.3	5.4	12.8	34.8	32.6	2.2
Brazil	36.9	12.3	11.7	12.9	8.2	3.8	4.4
Philippines	10.9	1.4	1.2	8.3	67.4	66.4	1.0
Indonesia	18.5	1.2	9.8	7.5	9.7	8.9	0.8
India	14.6	2.8	7.0	4.7	6.6	2.7	3.9
Hong Kong	13.2	0.0	3.1	10.1	26.0	21.3	4.7
Turkey	21.3	3.3	8.7	9.2	6.3	5.1	1.2

Annual rates of export growth 1985–98 (%)

	Total mfrs.	RB total	RB1	RB2	LT total	LT1	LT2
China	29.1	16.2	19.9	14.2	30.5	27.6	39.0
Korea	11.6	13.5	12.6	14.1	5.9	4.3	8.3
Taiwan	10.4	5.5	3.8	7.5	5.8	4.0	7.7
Mexico	21.4	11.2	18.7	6.9	24.9	26.8	23.6
Singapore	13.9	4.5	6.5	3.9	12.1	8.6	14.4
Malaysia	16.9	6.9	6.9	6.6	19.8	16.2	24.6
Thailand	21.2	15.1	13.8	18.2	18.2	16.0	22.8
Brazil	6.3	5.4	7.7	3.0	3.5	3.4	3.7
Philippines	20.7	3.1	3.1	3.3	16.1	17.9	12.6
Indonesia	16.1	10.4	11.7	8.0	23.1	20.2	32.0
India	11.6	9.1	9.7	9.0	12.2	11.1	19.0
Hong Kong	2.9	5.7	6.9	4.1	2.0	3.5	−3.2
Turkey	11.2	7.8	10.7	4.1	11.9	12.8	9.3
Total above 13	14.2	9.1	9.6	7.6	14.2	11.3	13.2
All developing	12.7	6.2	9.3	4.4	12.0	11.3	13.1

Table 2A.2 (continued)

Annual rates of export growth 1985–98 (%)	MT total	MT1	MT2	MT3	HT total	HT1	HT2
China	34.2	37.9	24.8	48.9	43.2	66.2	24.7
Korea	11.9	24.2	13.1	8.3	19.1	19.4	17.0
Taiwan	12.7	13.0	14.4	11.7	17.6	17.8	13.0
Mexico	21.6	28.1	21.6	18.1	24.2	23.9	27.2
Singapore	12.0	14.6	12.8	11.5	22.1	23.3	10.2
Malaysia	22.2	26.9	20.9	22.5	23.0	23.1	22.1
Thailand	20.6	39.1	17.8	20.6	41.4	42.4	33.0
Brazil	8.1	10.6	6.2	7.9	10.6	7.5	14.7
Philippines	22.5	25.0	6.0	38.7	38.8	39.1	30.0
Indonesia	26.0	56.7	21.0	41.1	27.2	29.7	15.7
India	14.8	15.0	19.9	10.4	15.8	16.5	15.4
Hong Kong	0.0	−7.5	10.5	−1.6	7.5	6.5	14.0
Turkey	10.3	16.6	7.8	11.7	23.6	24.8	19.7
Total above 13	17.8	20.5	14.5	13.6	23.7	22.4	17.7
All developing	14.6	20.9	13.8	13.4	21.5	22.2	16.2

3. Competitiveness and technology: an international comparison

Hiroki Kawai and Shujiro Urata[1]

1. INTRODUCTION

The economies of East Asia achieved remarkable economic growth in the post-World War II period. Indeed, the World Bank (1993) published a study entitled *The East Asian Miracle* to examine the factors that underlay this export-led growth. It analysed the 1960–89 period and attributed success to several factors including rapid accumulation of physical and human capital, export-oriented trade policy, sound macroeconomic environment and well-functioning institutions. The report also emphasized rapid expansion in productivity as an important factor that contributed to remarkable economic growth.

The World Bank study attracted a lot of attention. Economists and policymakers were particularly interested in the role of government in economic development, because the study acknowledged successful cases of government intervention in the sectoral allocation of resources. This view was quite different from the minimalist view of the government that had been popular earlier. Some observers argued that the success of East Asia was largely due to active government intervention, while others argued that it was attributable to the market mechanism. Consensus has yet to be reached on the issue and the debate on the appropriate role of the government in economic development goes on.

The World Bank study instigated another interesting debate on the sources of economic growth in East Asia. Several researchers questioned the contribution of productivity increase to economic growth in East Asia. The World Bank calculated high total factor productivity (TFP) growth for East Asian economies. Krugman (1994) questioned the validity of these findings by referring to the low TFP growth estimates obtained by Young (1995). Krugman argued that the rapid growth achieved by East Asian economies was largely due to the accumulation of labour and capital inputs, and not to productivity increase. This debate reconfirmed the importance of productivity growth in achieving economic growth; it also brought out the sensitivity of TFP estimates, which depended on the assumptions and the method applied for the analysis.

This chapter examines the factors underlying the growing competitiveness of East Asian economies in the pre-financial crisis period. Recognizing the importance of technology in economic growth, it focuses on technological capabilities in East Asian economies and its relation to the use of foreign technology. Section 2 examines changes in East Asian competitiveness from 1970–97. The analysis of competitiveness uses two indicators, per capita GDP and total factor productivity (TFP). The use of TFP as an indicator of competitiveness is based on the premise that productivity increase is a crucial factor in growth. Per capita GDP is used as a proxy for labour productivity. It is a reasonable proxy because of limited availability of information on labour inputs such as the number of workers or the number of hours worked. It may be added that per capita GDP indicates the stage of economic development, a main concern for the countries striving to achieve economic development. Our analysis covers the period up to the financial crisis, and thus extends the period examined by *The East Asian Miracle*.

Section 3 analyses technological factors in East Asia. The first part of the discussion deals with domestic technological capabilities and the second with inflows of foreign technology. These two aspects are, of course, closely related because assimilation of foreign technology, a major source of building competitiveness, depends crucially on domestic technological capability. We attempt to identify by regression analysis the determinants of competitiveness as measured by the growth of per capita GDP and TFP. Section 4 concludes with policy recommendations.

2. COMPETITIVENESS OF EAST ASIAN ECONOMIES: ECONOMIC GROWTH AND TFP GROWTH

Table 3.1 shows the growth performance of East Asian economies between 1970 and 1997. The average annual growth rate in per capita GDP exceeded 5 per cent in this period.[2] The growth rate accelerated over time, from 5.2 per cent in the 1970s to 6.1 per cent in the 1980s and then to 6.4 per cent in 1990–97. This performance was significantly and consistently better than in other regions.

2.1 Economic Growth

There are wide variations in growth rates within East Asia. The newly industrializing economies (Hong Kong, Korea, Singapore and Taiwan)

Table 3.1 Level and growth of per capita GDP, 1970–97

	Per capita GDP level (1992 US$,PPP)				Annual growth rate (%)		
	1970	1980	1990	1997	1970–80	1980–90	1990–97
Developed countries	13267	16679	20510	22988	2.39	2.12	1.62
Developing countries	4201	5588	5804	7185	3.39	1.90	3.12
1. East Asia & the Pacific	1998	3622	6611	9703	5.13	6.13	6.36
(1) NIEs	3071	5891	11126	16044	6.46	6.58	5.35
Hong Kong	5438	10324	17205	21540	6.41	5.11	3.21
Korea	2509	4367	9240	13831	5.54	7.49	5.76
Singapore	4498	8722	14873	23296	6.62	5.34	6.41
Taiwan	2724	5691	10668	15578	7.37	6.28	5.41
(2) ASEAN4	1547	2389	3378	4728	4.54	3.77	4.69
Indonesia	764	1291	1993	2917	5.25	4.34	5.44
Malaysia	2527	4235	5707	8486	5.16	2.98	5.67
Philippines	2629	3629	3311	3493	3.22	−0.92	0.76
Thailand	1545	2294	4104	5914	3.95	5.82	5.22
(3) China	493	690	1437	2801	3.35	7.34	9.53
2. South Asia	962	1030	1454	1845	0.65	3.43	3.37
3. Latin America and the Caribbean	4626	6515	5966	6971	3.80	−0.73	2.05
4. Europe and Central Asia	3664	4933	5844	6835	2.70	1.89	2.45
5. Middle East and North Africa	11482	12804	7709	7496	2.09	−2.55	−0.37
6. Sub-Saharan Africa	4258	4733	4307	4182	0.96	−0.74	−0.51

Sources: World Bank, *World Development Indicators, 2000*; Republic of China, *Taiwan Statistical Data Book*.

achieved high growth during the 1970s and 1980s, with annual average growth rates of per capita GDP of around 6.5 per cent. Their growth rates declined in the 1990s to 5.3 per cent. Each of the four NIEs had similar growth performance, with the exception of Hong Kong, which recorded relatively low growth rates in 1990–97 (3.2 per cent). The ASEAN4 (Indonesia, Malaysia, the Philippines, and Thailand) performed less well than the NIEs overall. However, their performance was substantially better than other developing countries over the 1970–97 period. Growth rates of per capita GDP for the ASEAN4 declined from 4.6 per cent in the 1970s to 3.8 per cent in the 1980s, before rising to 4.7 per cent in 1990–97. Among the ASEAN4 the Philippines performed the worst, particularly in the 1980s and 1990s. China achieved a remarkable acceleration in growth from the 1970s to the 1990s, with the annual growth rate in per capita GDP rising from 3.4 per cent in the 1970s to 7.3 per cent in 1980s and to 9.5 per cent in 1990–97.

In terms of PPP (purchasing power parity) in 1992 US dollars, average per capita GDP in East Asia increased almost five-fold over the 27 years, from $2000 in 1970 to $9700 in 1997. The comparable increase for developing countries as a whole and for developed countries was only about 70 per cent. Average per capita income in East Asia was only about a half of the average for developing countries in 1970 and was 35 per cent higher in 1997. In comparison with the developed world, per capita income in East Asia rose from 15 per cent of average incomes in 1970 to just over 40 per cent in 1997.

Per capita incomes vary greatly in the East Asian region. In 1997 the NIEs recorded the highest incomes ($16 000), followed by ASEAN4 ($4700), and China bringing up the rear with $2800. Among the NIEs, Hong Kong and Singapore had very high per capita GDP at around $22 000, while the corresponding values for Korea and Taiwan were approximately $14 000. In the ASEAN4, the income ranks in 1997 were: Malaysia, Thailand, the Philippines and Indonesia. Unlike the NIEs, the ranking changed over the 1970–97 period: the Philippines fell from leading place in 1970 to third place in 1997.

2.2 TFP Growth

The level and growth rate of total factor productivity (TFP) are often used to measure the competitiveness of an economy. This is because, given factor inputs such as labour and capital, there is a positive relationship between TFP and output. Table 3.2 presents the results of our estimation of TFP levels and TFP growth rates.[3] To begin with TFP growth, we find that the East Asian economies on average performed favourably compared to other

Table 3.2 Level and growth of total factor productivity, 1970–97

	TFP level (US1980 = 1.0)				Annual growth rate (%)		
	1970	1980	1990	1997	1970–80	1980–90	1990–97
Developed countries	0.83	0.87	0.97	1.02	0.56	0.98	0.81
Developing countries	0.44	0.47	0.48	0.54	0.61	0.22	1.78
1. East Asia & the Pacific	0.29	0.36	0.47	0.55	2.14	2.76	2.19
(1) NIES	0.39	0.48	0.70	0.79	2.14	3.67	1.77
Hong Kong	0.45	0.64	1.02	1.06	3.42	4.69	0.54
Korea	0.43	0.47	0.70	0.75	0.84	3.98	1.11
Singapore	0.48	0.64	0.79	1.00	2.88	2.10	3.44
Taiwan	0.32	0.43	0.59	0.71	3.02	3.14	2.75
(2) ASEAN4	0.22	0.28	0.32	0.35	2.38	1.41	1.17
Indonesia	0.15	0.23	0.27	0.34	4.07	1.72	3.10
Malaysia	0.26	0.34	0.36	0.43	2.58	0.55	2.33
Philippines	0.28	0.35	0.33	0.33	2.37	−0.74	−0.06
Thailand	0.26	0.28	0.36	0.37	0.69	2.77	0.22
(3) China	0.18	0.21	0.21	0.31	1.86	−0.01	5.35
2. South Asia	0.24	0.22	0.28	0.32	−0.50	2.11	2.06
3. Latin America and the Caribbean	0.61	0.62	0.53	0.58	0.08	−1.48	1.26
4. Europe and Central Asia	0.42	0.55	0.49	0.56	2.62	−1.04	1.82
5. Middle East and North Africa	0.49	0.65	0.66	0.76	2.78	0.16	1.93
6. Sub-Saharan Africa	0.35	0.42	0.33	0.32	1.91	−2.48	−0.37

Source: Authors' estimates.

regions, including the developed countries. East Asian TFP growth rates were around 2.1–2.8 per cent per annum from 1970 to 1997. By contrast, TFP growth rates for other regions were low and fluctuated substantially. For example, Latin American TFP growth rates fell from 0.1 per cent in the 1970s to −1.5 per cent in the 1980s and then rose to 1.3 per cent in the 1990–97 period. Similar fluctuations are found for other regions.

Among the East Asian economies the NIEs had higher TFP growth than the ASEAN4: the range is 1.8 to 3.7 per cent per annum in the former and 1.2 to 2.4 per cent in the latter. Although there are variations in TFP growth rates among the NIEs, they are not substantial. This is in contrast to the ASEAN4, among which TFP growth rates differ substantially. Indonesia records relatively high rates of around 1.8 and 4.1 per cent per annum, while the Philippines has negative TFP growth for the 1980–97 period. China shows a V-shaped pattern, with TFP growth rates declining from 1.9 per cent in the 1970s to −0.01 per cent in the 1980s, and rising to 5.3 per cent in 1990–97.

Rapid TFP growth led to rising levels of TFP in East Asia. TFP levels are estimated here by using the TFP level in the USA in 1980 as a base. The estimates indicate that in 1980 the TFP level in East Asia was 36 and 41 per cent of the levels in the USA and developed countries, respectively. Over time, this gap narrowed to 54 per cent of the level in developed countries in 1997.

Among the East Asian economies the NIEs had significantly higher levels of TFP than the ASEAN4 and China. The NIEs as a group had TFP levels of almost 80 per cent of the level for developed countries in 1997; indeed, Hong Kong and Singapore had comparable levels of TFP to that for developed countries. TFP levels in Korea and Taiwan were lower at approximately 70 per cent of the level in developed countries. TFP levels for ASEAN4 and China were substantially lower, less than half of the level in the NIEs in 1997. Malaysia was the exception, with a somewhat higher TFP level than those in the rest of the ASEAN4.

3. FACTORS AFFECTING COMPETITIVENESS: TECHNOLOGICAL CAPABILITY AND IMPORTED TECHNOLOGY

Many factors affect national competitiveness. One of the most important, some would say *the* most important, is technological capability. Even a country richly endowed with natural or labour resources cannot compete in international markets if it cannot use its resources efficiently in combination with appropriate technology. For developing countries the importation of technology from developed countries is a vital source of technology; however, access to foreign technology is not enough – the country needs the capability to absorb and adapt foreign technology. This section examines technological capability and the absorption of foreign technology in East Asia, setting the stage for the statistical analysis of the determinants of competitiveness later.

3.1 Domestic Technological Capability

Educated and well-trained workers are essential for using technologies efficiently and improving them over time. Research and development also plays an important role by producing new technology, new production processes and new products and helping in the absorption of very complex new technologies. We examine these two factors for East Asia.

Education

Although formal education may not constitute technological capability without technical training or experience, it provides the base on which technical skills are developed.[4] Many studies have found a positive impact of education on economic growth, supporting the argument that education plays a role in promoting economic growth. For example, the World Bank (1993) finds that education, particularly primary education, contributed significantly to the increase in per capita GDP in 113 countries in the 1960–85 period. Specifically, it found that a 10 per cent increase in the enrolment ratio in primary and secondary education would lead to a 0.3 per cent increase in the growth rate of per capita GDP.

Let us examine the educational levels of East Asian economies, using the indicator for educational attainment estimated by Barro and Lee (2000). The Barro and Lee data set has at least one observation on school attainment, the highest educational level attained for the population aged 15 or over and for the population aged 25 or over, for 142 economies, of which 107 have complete information at five-year intervals from 1960 to 2000. The data for the period up to 1995 are estimates and those for 2000 are projections. In our analysis we interpolate values for in-between years.

Table 3.3 shows educational attainment and the average years of schooling for developed countries and developing countries. The figures indicate the proportion of population aged 25 or over that attained secondary and higher levels of education. East Asia has higher educational attainments than other developing regions, with the exception of those in Europe and Central Asia, which have longer average schooling and larger shares of the population with higher educational attainment. Educational attainments have improved significantly for all economies in East Asia from 1960 to

Table 3.3 Educational attainment

	Average years of school					Highest education attainment (secondary)					Highest education attainment (higher)				
	1960	1970	1980	1990	1997	1960	1970	1980	1990	1997	1960	1970	1980	1990	1997
Developed countries	7.24	7.82	9.00	9.53	9.97	34.0	36.1	45.2	42.1	41.7	8.4	10.9	17.3	24.9	28.7
Developing countries	1.71	2.37	3.15	4.28	4.90	5.3	9.6	14.9	21.2	23.5	0.9	1.5	2.4	4.1	5.2
1. East Asia & the Pacific	1.75	2.84	3.73	5.16	5.67	6.1	15.0	19.8	31.1	32.4	1.3	1.5	2.0	3.4	4.6
(1) NIEs	3.37	4.64	6.56	8.52	9.55	11.9	20.8	31.7	47.6	47.5	3.1	5.2	8.7	12.5	20.5
Hong Kong	4.74	5.11	6.73	8.37	9.40	17.4	22.3	30.5	43.3	47.3	4.7	3.1	7.1	10.6	14.9
Korea	3.23	4.76	6.81	9.25	10.27	10.9	21.8	36.9	53.9	50.7	2.6	5.6	8.9	13.4	23.5
Singapore	3.14	3.74	3.65	5.52	7.97	23.4	20.9	14.6	31.3	49.5	0.0	2.0	3.4	4.7	9.1
Taiwan	3.32	4.39	6.37	7.44	8.28	11.0	18.1	23.3	37.7	40.7	4.2	5.4	9.3	12.2	17.3
(2) ASEAN4	2.12	3.05	3.88	4.54	5.46	4.5	7.0	11.6	17.9	21.7	1.5	2.5	4.1	6.6	8.9
Indonesia	1.11	2.29	3.09	3.30	4.37	1.9	5.1	9.6	16.8	20.5	0.1	0.5	0.8	2.3	4.3
Malaysia	2.35	3.05	4.49	5.54	7.76	7.2	9.4	19.9	27.1	42.9	1.5	1.5	1.4	2.8	7.2
Philippines	3.77	4.81	6.06	7.07	7.48	10.6	14.2	18.9	27.2	30.2	6.2	9.6	15.2	18.7	21.3
Thailand	3.45	3.54	3.77	5.35	5.91	4.9	4.4	6.8	8.0	9.1	0.6	1.1	2.9	7.8	10.4
(3) China	1.58	2.75	3.61	5.23	5.61	6.2	17.2	21.7	34.4	35.2	1.1	1.0	1.0	2.0	2.5
2. South Asia	1.31	1.77	2.52	3.37	4.03	3.2	4.6	13.3	14.3	16.1	0.1	1.3	2.3	3.7	4.2
3. Latin America and the Caribbean	2.95	3.32	3.97	4.93	5.53	9.4	10.4	12.7	16.5	19.1	1.9	2.5	5.4	8.9	11.1
4. Europe and Central Asia	4.27	4.75	5.62	6.57	7.00	9.9	12.2	19.7	27.1	29.3	1.9	3.4	4.9	6.9	9.0
5. Middle East and North Africa	0.76	1.06	2.00	3.36	4.39	2.3	4.1	7.8	14.8	19.7	0.6	1.2	3.0	5.0	7.2
6. Sub-Saharan Africa	1.18	1.32	1.90	2.78	3.50	3.9	4.4	6.1	10.3	15.3	0.3	0.6	0.6	1.8	2.5

Note: Data for 1997 are interpolated from those on 1995 and 1999.

Source: Barro and Lee (2000).

1997, the average years of schooling rising from 1.8 to 5.7 years. The shares of the population aged 25 and over with primary, secondary, and higher education increased from 25.3, 6.1, 1.3 per cent in 1960 to 39.3, 32.4, and 4.6 per cent in 1997, respectively.

There are wide variations in education among the East Asian economies. On average the NIEs have better performance than the ASEAN4, but there are substantial differences within these groups. Korea stands out among the NIEs with the longest years of schooling and the highest proportion of population with higher education, while Singapore appears to fare the worst. In the ASEAN4, the Philippines outperforms the others, particularly in higher education; one out of every five persons aged 25 and over has higher education there. Indonesia has the lowest years of schooling and also the lowest proportion of population with higher education. Thailand has very low shares of the population with secondary education. Despite a substantial improvement over time, China still trails other East Asian economies in educational attainment, particularly in terms of higher education.

Research and development

The number of researchers in the population can serve as a good indicator of technological capability. Table 3.4 shows the number of researchers per million population for East Asian economies. The average for developing countries was 334 in 1997, compared to 3161 for developed countries. Among the developing countries, the NIEs register much higher figures, comparable to those for developed countries; even more significant is the rapid increase in the number of researchers in the NIEs. In 1970 the number was 198, approximately 10 per cent of the corresponding value for the developed countries; by 1997 the number had increased to 2613, about 80 per cent of the value for developed countries. Within the NIEs, Taiwan has the highest number at 3530 in 1997, higher than the average for developed countries. The ASEAN4 are far behind the NIEs, and they lag even behind China.

R&D is an input for building and improving technological capability. The ratios of R&D to GDP for East Asian and other developing countries are shown in Table 3.4. The picture is fairly similar to that for numbers of researchers per million population. The NIEs perform much better than ASEAN4 or China, spending 2.3 per cent of GDP on R&D compared to 0.14 and 0.66 per cent for the ASEAN4 and China, respectively. Over time, moreover, R&D performance in the ASEAN4 is deteriorating. The NIEs have improved their capabilities greatly over time, and China has also achieved some success. However, ASEAN4 countries are lagging and the gap with the NIEs is likely to widen.

Table 3.4 Researchers and R&D

	Reseachers per million population				R&D/GDP (%)			
	1970	1980	1990	1997	1970	1980	1990	1997
Developed countries	1798	2201	3107	3161	1.99	2.01	2.43	2.39
Developing countries	157	208	278	334	0.31	0.43	0.71	0.79
1. East Asia & the Pacific	178	226	373	486	0.33	0.48	1.04	1.27
(1) NIEs	198	523	1826	2613	0.42	0.62	1.71	2.27
Hong Kong	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Korea	176	484	1645	2195	0.38	0.57	1.88	2.82
Singapore	326	417	1426	2323	0.21	0.27	0.94	1.13
Taiwan	226	620	2260	3530	0.50	0.72	1.66	1.88
(2) ASEAN4	86	104	164	162	0.33	0.35	0.20	0.14
Indonesia	85	102	189	191	0.35	0.35	0.15	0.07
Malaysia	137	165	208	93	0.33	0.34	0.41	0.24
Philippines	93	112	141	153	0.15	0.26	0.20	0.22
Thailand	66	79	94	103	0.39	0.39	0.18	0.13
(3) China	203	243	348	454	0.19	0.37	0.68	0.66
2. South Asia	71	85	132	132	0.32	0.53	0.74	0.69
3. Latin America and the Caribbean	134	203	252	222	0.17	0.27	0.47	0.56
4. Europe and Central Asia	968	1378	798	792	0.71	0.95	0.84	0.56
5. Middle East and North Africa	154	212	296	377	0.24	0.19	0.28	0.32
6. Sub-Saharan Africa	70	109	141	235	0.57	0.56	0.56	0.47

Sources: UNESCO, *Statistical Yearbook*; World Bank, *World Development Indicators, 2000*; Republic of China, *Taiwan Statistical Data Book*.

3.2 Inflow of Foreign Technology

We consider several channels for accessing foreign technology: foreign direct investment, foreign trade and technology imports.

Foreign direct investment

In recent years FDI has become an important means of importing technology for developing countries. Intra-firm technology transfer has been analysed by several studies. Based on a survey of East Asian affiliates of Japanese firms, Urata (1999) finds that relatively simple technologies such as maintenance and repair of production lines were transferred from parent companies to affiliates. He also finds that relatively sophisticated technologies such as development of new technologies and new products were not transferred. Analysing the determinants of the extent of intra-firm technology transfer by Japanese MNCs, Urata and Kawai (2000) find that the capability to absorb technologies reflected in educational level in host countries plays a key role in successful intra-firm technology transfer. Their study also points out that intra-firm technology transfer takes time and experience, suggesting the importance of maintaining a stable economic environment in the host country.

The results of analyses of the presence of technology spillovers are mixed. Using industry-level data, Caves (1974) finds the presence of technology spillover in his study of the Australian manufacturing sector but not in his study of Canadian manufacturing. Using similar methodology, Globerman (1979) finds the presence of the spillover effect of FDI in the Canadian manufacturing sector. Blomström and Persson (1983) and Blomström and Wolff (1994) also detect beneficial technology spillover in their studies of the Mexican manufacturing sector. In contrast, Haddad and Harrison (1993) and Aitken and Harrison (1994) do not find spillover in their studies of Morocco and Venezuela. One possible reason for not detecting technology spillover in these studies may be the limited presence of foreign firms in these countries.

Turning to the impact of FDI on economic growth, one finds that few studies on the subject have been conducted using macroeconomic indicators. Borensztein et al. (1998) find that FDI has a marginally positive impact on economic growth; the impact is significantly positive when FDI is interacted with the educational levels of host countries.[5] Their finding may be interpreted to mean that education becomes more effective when it is associated with foreign knowledge. Given that educational levels in East Asia are relatively high, it is reasonable to argue that FDI inflows have contributed to economic growth in East Asia.

FDI flows have been growing rapidly in recent years. World inward FDI increased more than threefold in eight years from US$203 billion in 1990 to US$680 billion in 1998.[6] This rapid increase is attributable to several factors. Technological progress and deregulation in communication services have reduced the cost of international communication, facilitating the management of far-flung operations by MNCs. Liberalization of FDI policies by many countries has also contributed. East Asia has experienced a remarkably rapid expansion of FDI inflows. It has undertaken considerable liberalization in FDI policies,[7] with several economies offering incentives to foreign investors, such as preferential tax treatment, especially to export-oriented investments. Another factor in East Asia has been favourable growth prospects, driven by past performance.

One notable recent development in Asia has been the rapid increase in cross-border M&As (mergers and acquisitions). The share of M&As in FDI inflows in South, East and South-East Asia increased from around 3 per cent in 1995 to 16 per cent in 1998.[8] Korea and Thailand, hard hit by the financial crisis, liberalized their M&A policies and experienced a large wave of this kind of FDI.

Table 3.5 shows the importance of FDI inflows for East Asian and other economies. The proportion of FDI inflows to GDP in East Asia increased from 1.1 per cent in 1970 to 2.8 per cent in 1997. In 1997 East Asia was behind Latin America in terms of the FDI inflows to GDP ratio, which registered 3.3 per cent. Within East Asia, Singapore had by far the greatest reliance on foreign investors; its ratio of FDI inflows to GDP was 10 per cent in 1997, even after a notable decline from 14.4 per cent in 1990. Malaysia had the second highest ratio at 5.1 per cent, and China was the third at 4.9 per cent in 1997. The increase in the share of FDI inflows in GDP for China was spectacular, since the corresponding ratio for 1990 was only 0.98 per cent. Hong Kong also recorded a relatively high ratio of 3.5 per cent. In contrast to these countries, Korea and Taiwan had ratios of around 0.6–0.8 per cent in 1997. The ratio for Taiwan declined over time, while that for Korea rose steadily.

Imports of capital goods

Foreign trade has been an important source of foreign technologies for developing countries via the importation of intermediate and investment goods that embody new technology. Reverse engineering is one way of assimilating technology from such imports, for countries that have the capability to carry out this complex task. Table 3.6 shows the share of machinery in total imports.[9] East Asia exhibits a significant upward trend in comparison with other developing regions, the share of machinery in total imports rising from 0.30 in 1980 to 0.41 in 1997 compared to 0.31 and 0.35 for other regions. The ASEAN4 consistently have higher shares than

Table 3.5 FDI inflows (gross) (percentage of GDP)

	1970	1980	1990	1997
Developed countries	0.46	0.52	1.06	1.27
Developing countries	0.75	0.78	0.85	2.32
1. East Asia & the Pacific	1.10	1.07	1.59	2.76
(1) NIEs	1.72	1.59	1.59	1.60
Hong Kong	n/a	n/a	2.31	3.46
Korea	n/a	0.01	0.28	0.60
Singapore	5.53	14.00	14.36	10.21
Taiwan	2.45	1.13	0.83	0.79
(2) ASEAN4	0.80	0.91	2.23	2.60
Indonesia	0.86	0.23	0.96	2.17
Malaysia	2.24	3.52	5.45	5.10
Philippines	0.17	0.79	1.20	1.49
Thailand	0.61	0.57	2.86	2.50
(3) China	n/a	n/a	0.98	4.92
2. South Asia	0.08	0.08	0.13	0.83
3. Latin America and the Caribbean	0.82	0.78	0.68	3.25
4. Europe and Central Asia	0.21	0.09	0.85	1.73
5. Middle East and North Africa	0.64	1.15	0.55	1.00
6. Sub-Saharan Africa	0.56	0.41	0.28	1.79

Sources: IMF, *Balance of Payment Statistics*; World Bank, *World Development Indicators, 2000*; Republic of China, *Taiwan Statistical Data Book*.

the NIEs or China. For instance, in 1997 the share for the ASEAN4 was 0.50, while that for the NIEs and China was 0.41 and 0.36, respectively. This may reflect the relatively high value of electronic component imports for export-oriented assembly in the ASEAN4. Singapore and Malaysia have particularly high shares (0.553 and 0.616, respectively) in 1997, again reflecting the strong presence of electronics MNCs in export-oriented activity.

An expansion in imports may lead to improvements in technical efficiency in domestic firms in different ways. One is increased competitive pressure, which to survive firms must introduce new technologies, products, management methods and so on. Several studies have found a positive impact of greater imports on productivity; Lawrence and Weinstein (2000), for instance, found that import expansion was associated with higher productivity in Japan in the post-World War II period. Other studies have not, however, found a clear statistical relationship between import liberalization and productivity.

Table 3.6 Imports of machinery as a share of total imports

	1980	1990	1997
Developed countries	0.256	0.355	0.378
Developing countries	0.310	0.348	0.348
1. East Asia & the Pacific	0.297	0.344	0.406
(1) NIEs	0.254	0.383	0.438
Hong Kong	0.237	0.308	0.371
Korea	0.227	0.351	0.355
Singapore	0.281	0.441	0.553
Taiwan	0.273	0.434	0.474
(2) ASEAN4	0.325	0.421	0.501
Indonesia	0.376	0.411	0.425
Malaysia	0.370	0.525	0.616
Philippines	0.296	0.320	0.487
Thailand	0.260	0.428	0.473
(3) China	0.251	0.351	0.365
2. South Asia	0.257	0.244	0.254
3. Latin America and the Caribbean	0.295	0.339	0.373
4. Europe and Central Asia	0.274	0.320	0.364
5. Middle East and North Africa	0.323	0.341	0.335
6. Sub-Saharan Africa	0.330	0.373	0.325

Sources: World Bank, *World Development Indicators, 2000*; Republic of China, *Taiwan Statistical Data Book*.

An increase in exports may also have a positive impact on productivity. This may be so for several reasons: greater capacity utilization in industries in which the minimum efficient scale is large relative to the domestic market; increasing familiarity with and absorption of new technologies; greater learning-by-doing insofar as this is a function of cumulative output; and the stimulating effects of international competition and the feedback of technical and other information from export markets.[10] Several studies have shown that export expansion, particularly that of manufactured products, results in higher productivity. The World Bank (1993) finds that the high share of manufactured exports in total exports increased the growth rate of TFP in its study of 69 countries for the 1960–89 period.[11] A case study of Korean firms by Rhee et al. (1984) finds that exporting firms achieved higher productivity by obtaining technologies through contact with foreign firms.

Table 3.7 shows the ratio of trade (exports plus imports) to GDP in developing countries. The ratio for East Asia rose sharply over 1970–97, from 47.6 per cent to 91.7 per cent. These values are significantly higher

Table 3.7 Trade (exports + imports) (percentage of GDP)

	1970	1980	1990	1997
Developed countries	28.8	39.2	38.3	42.5
Developing countries	37.4	52.1	53.2	60.8
1. East Asia & the Pacific	47.6	78.6	82.7	91.7
(1) NIEs	76.0	122.0	115.7	118.9
Hong Kong	181.5	180.6	260.1	264.2
Korea	37.5	74.4	59.4	70.5
Singapore	231.6	439.0	397.0	315.6
Taiwan	60.7	106.3	88.5	95.7
(2) ASEAN4	40.1	62.7	74.3	94.9
Indonesia	28.4	54.4	49.9	56.0
Malaysia	79.9	112.6	150.6	185.5
Philippines	42.6	52.0	60.8	108.5
Thailand	34.4	54.5	75.8	94.8
(3) China	3.8	15.5	31.9	41.6
2. South Asia	10.7	19.4	20.5	28.1
3. Latin America and the Caribbean	20.5	26.7	28.9	36.3
4. Europe and Central Asia	29.6	36.1	39.1	60.1
5. Middle East and North Africa	71.9	72.7	68.0	64.8
6. Sub-Saharan Africa	47.2	59.7	51.4	60.1

Sources: World Bank, *World Development Indicators, 2000*; Republic of China, *Taiwan Statistical Data Book*.

than those for other developing regions or developed countries. Within East Asia, Singapore and Hong Kong had very high ratios, 250–300 per cent in 1997, reflecting their role as entrepôt centres and their open trade regimes. Malaysia also had a high ratio, 190 per cent, resulting mainly from the large presence of export-oriented MNCs. By contrast, China, Indonesia and Korea had relatively low ratios, with China having a significant increase and Korea and Indonesia showing fluctuations around the trend. The ratios for Taiwan also fluctuate, but the values are higher than for Korea. The trade–GDP ratios increase steadily for the Philippines and Thailand, but are significantly lower than for Malaysia.

Technology imports

Imports of technology in the form of licences and patents are an important way of obtaining foreign technology. In the past, technology trade was conducted largely by independent firms through arm's length transactions, but in recent years intra-firm transactions (between MNCs and their affiliates)

Table 3.8 Royalty payments (percentage of GDP)

	1970	1980	1990	1997
Developed countries	0.124	0.124	0.178	0.231
Developing countries	0.112	0.086	0.137	0.172
1. East Asia & the Pacific	0.075	0.128	0.259	0.292
(1) NIEs	n/a	0.195	0.472	0.467
Hong Kong	n/a	n/a	n/a	n/a
Korea	n/a	0.195	0.540	0.507
Singapore	n/a	n/a	n/a	n/a
Taiwan	n/a	n/a	0.363	0.405
(2) ASEAN4	n/a	0.098	0.162	0.357
Indonesia	n/a	n/a	n/a	n/a
Malaysia	n/a	0.152	n/a	n/a
Philippines	n/a	0.058	0.086	0.192
Thailand	n/a	0.092	0.200	0.539
(3) China	n/a	n/a	n/a	0.060
2. South Asia	0.016	0.008	0.021	0.034
3. Latin America and the Caribbean	0.158	0.055	0.090	0.115
4. Europe and Central Asia	0.050	0.050	0.050	0.227
5. Middle East and North Africa	0.186	0.177	0.183	0.215
6. Sub-Saharan Africa	0.181	0.155	0.074	0.131

Sources: World Bank, *World Development Indicators, 2000*; Republic of China, *Taiwan Statistical Data Book*.

have grown rapidly. This reflects at least two related developments: rapid FDI expansion and the increased preference on the part of MNEs to use FDI as a means of deploying technology abroad.

Table 3.8 shows patterns of technology trade as measured by royalties and licence fees paid abroad as a percentage of GDP in the East Asian economies. Note, however, that information for Hong Kong, Singapore, Indonesia and Malaysia is not available, and the total for East Asia is understated. The ratio for available countries in East Asia rose from 0.075 per cent in 1970 to 0.292 per cent in 1997, much faster than for other regions, including the developed countries. The increase was particularly large for Thailand, from 0.092 per cent in 1980 to 0.539 per cent in 1997. The ratio for Korea also increased rapidly but not at the pace achieved by Thailand. By 1997 the ratios for Korea, Taiwan and Thailand were more or less comparable at around 0.4 to 0.5 per cent. The ratios for the Philippines and China were significantly lower at around 0.03–0.06 per cent.

4. THE DETERMINANTS OF COMPETITIVENESS

This section presents the statistical analysis of the effect of technological factors on per capita GDP[12] growth and TFP growth. We examined the two technological factors discussed above, domestic technological capability and inflows of foreign technology, using annual panel data for 137 countries over 1970–97. To deal with possible simultaneity problems in the regression analysis, we used instrumental variable estimation. Based on the Hauseman test results, we selected either the fixed effect model or the random effect model for the estimation of the panel data. The statistical analysis was conducted for all the sample countries as well as for subsets of countries. The countries were divided into the following groups: developed countries, developing countries and East Asian developing economies.

Table 3.9 shows the results for per capita GDP growth. Let us start with the whole sample. After controlling for initial per capita GDP (*GDP0*), domestic investment (*INV*), openness (*OPEN*), government expenditure (*GOV*) and inflation (*INF*), we find that domestic technological capability as measured by educational attainment (*HC*) and R&D activities (*RD*), and inflows of foreign technology as measured by inward FDI (*FDI*), capital good imports (*CAP*) and patent and licence payments (*PAT*) have a positive and significant impact. These findings are consistent with expectations, indicating the importance of the technology factor in economic growth. Interaction terms for foreign technology inflows and domestic technological capability suggest that imported patents contribute to growth when combined with a well-educated workforce. Unlike earlier studies, our results do not find a higher impact for FDI when it is combined with high domestic technological capability.

The country groups show interesting differences. To begin with domestic technological capability, we find that both educational attainment and R&D have a positive impact on economic growth for all country groupings but the statistical significance differs: educational attainment has a significantly positive impact for developed and East Asian economies, but not for developing countries. R&D has a significantly positive effect on growth for the developed and developing country groups but not for East Asian economies. In view of the importance of education in economic growth, our findings on the insignificant impact of educational attainment on growth for developing countries is puzzling and needs further investigation.

Turning to the impact of imported technology, the importation of capital goods is found to contribute significantly to growth for all types of countries. FDI has a statistically significant and positive impact for developing countries and East Asian economies but not for the developed countries. However, FDI has a positive impact on growth in developed countries

Table 3.9 The determinants of growth rates of per capita GDP

	Total sample (137 countries, OBS = 3836)				Developing (113 countries, OBS = 3164)			
	coefficient	*t*-value	coefficient	*t*-value	coefficient	*t*-value	coefficient	*t*-value
LGDP0	−6.475	−13.780	−6.604	−13.978	−6.485	−12.380	−6.676	−12.614
INV	0.091	5.137	0.095	5.309	0.094	4.751	0.093	4.678
OPEN	0.020	3.182	0.023	3.477	0.019	2.730	0.022	3.060
GOV	−0.191	−7.566	−0.190	−7.515	−0.186	−6.644	−0.184	−6.554
INF	−0.001	−3.331	−0.001	−3.338	−0.001	−3.041	−0.001	−3.082
RD	1.679	3.350	0.465	1.443	2.061	3.004	1.735	1.083
HC	−0.017	1.028	0.018	0.876	0.019	1.012	0.045	1.193
CAP	12.824	8.098	12.562	5.400	12.795	7.173	10.247	3.693
FDI	0.443	1.956	0.987	1.625	0.449	1.963	0.974	1.937
PAT	0.931	1.657	2.744	1.057	0.229	0.236	2.991	0.389
*CAP**HC*			0.025	0.347			0.030	0.351
*FDI**HC*			0.044	1.162			0.044	−1.036
*PAT**HC*			0.127	2.170			0.133	1.711
*CAP**RD*			3.086	1.225			9.974	2.347
*FDI**RD*			1.701	1.159			2.236	1.203
*PAT**RD*			−2.350	−1.480			−1.249	−0.435
R^2	0.188		0.190		0.182		0.185	
LM het	26.180	[.000]	25.991	[.000]	19.210	[.000]	17.950	[.000]
Hausman	207.870	[.0000]	218.000	[.0000]	161.490	[.0000]	166.910	[.0000]

	Developed (24 countries, OBS = 672)				Developing (E. Asia, 9 countries, OBS = 252)			
	coefficient	*t*-value	coefficient	*t*-value	coefficient	*t*-value	coefficient	*t*-value
LGDP0	−8.832	−8.719	−9.719	−9.475	−0.861	−1.830	−0.099	−1.686
INV	0.064	1.715	0.064	1.738	0.117	2.160	0.068	2.063
OPEN	0.072	5.829	0.077	6.298	0.023	1.486	0.027	1.588
GOV	−0.346	−5.946	−0.424	−6.973	−0.002	−0.023	−0.040	−0.345
INF	−0.012	−2.581	−0.012	−2.542	−0.006	−0.184	−0.003	−0.103
RD	0.506	1.890	3.173	3.218	0.441	0.485	5.359	1.168
HC	0.039	1.861	0.058	1.639	0.081	2.105	0.091	1.720
CAP	15.511	5.610	30.742	5.694	17.623	3.839	37.333	3.356
FDI	0.197	0.090	16.401	1.758	19.015	4.218	11.025	2.020
PAT	1.032	3.166	0.156	1.032	−3.669	−1.063	−20.325	−1.959
*CAP*HC*			0.094	0.859			−0.235	−0.802
*FDI*HC*			0.501	2.781			0.457	1.277
*PAT*HC*			0.076	0.875			0.297	0.972
*CAP*RD*			−5.728	−1.865			−14.272	−1.323
*FDI*RD*			−6.824	−2.386			−12.558	−1.206
*PAT*RD*			−2.378	−1.676			1.214	0.182
R^2	0.323		0.355		0.325		0.352	
LM het	2.857	[.091]	2.296	[.130]	0.410	[.522]	0.215	[.643]
Hausman	64.177	[.0000]	76.257	[.0000]	21.064	[.0070]	25.721	[.0012]

Notes:

1. *GDP0* = In (initial per capita GDP); *INV* = investment/GDP; *OPEN* = (export + import)/GDP; *CAP* = machinery import/import; *FDI* = FDI inflow/investment; *PAT* = Royalities and licence fees payment/GDP; *RD* = R&D expenditure/GDP; *SC* = education attainment rate (secondary [*SC2*] and higher [*SC3*]); *GOV* = government expenditure/GDP; *INF* = inflation rate.
2. Instrument variables are lagged independent variables and population.
3. *T*-values are evaluated by HCV if heteroscedasticity does exist.

Source: Authors' estimation.

when combined with educational attainment. Finally technology imports as measured by payments for patents and licensing have a significant and positive impact on growth for developed countries but not for developing countries or East Asian economies. Our findings suggest that capital goods import and FDI play important roles in acquiring foreign technology by developing countries.

Our findings for the other variables are largely consistent with studies such as the World Bank (1993) and Borensztein et al. (1998). The initial level of per capita GDP (*GAP0*) is significantly negative in many cases, indicating convergence of income levels across countries. The investment ratio (*INV*) has positive and mostly significant effects. Openness (*OPEN*) has a positive impact on growth, supporting the argument that more open trade systems result in better resource allocation. Both high government expenditure (*GOV*) and high inflation (*INF*) reduce per capita GDP growth. The former, often associated with high inflation, tends to crowd out private sector activities and lead to inefficiency in the use of resources. Moreover, inflation discourages investment by increasing uncertainty about future economic prospects.

So far, we have implicitly assumed that technological factors contribute to economic growth by improving productivity. We now investigate this hypothesis directly by looking at the impact of domestic technological capability and foreign technology on TFP growth.

We apply the same methodology as for the analysis of GDP growth. The results for all sample countries suggest that inflows of foreign technology in the form of capital goods and FDI have a significantly positive impact on TFP growth (Table 3.10). The importation of foreign technology through patents and licensing contributes to TFP increase when combined with high educational levels. The estimated coefficients on dometic technological capability are positive, as expected, but not statistically significant. There appears to be convergence of TFP levels among sample countries over time. The effects of investment and openness on TFP growth are positive, but only the effect of investment is statistically significant. Government expenditure and inflation have negative effects, with only the former being statistically significant. These results, very similar to those for growth, are consistent with our expectations.

Turning to the results obtained from different sample groups, we find differences in the impact of domestic technological capability and inflow of foreign technology between developed countries on the one hand and developing and East Asian economies on the other. To begin with domestic technological capability, educational attainment has a significantly positive impact on TFP growth for developing and East Asian economies, while R&D has a significantly positive impact for developed countries.

These findings suggest that innovative capability as reflected in R&D is important in raising TFP levels in developed countries, where TFP levels are already high, while in developing countries it is educational attainment, which improves the capability to absorb and assimilate imported technology, that is the key to improving TFP.

As to the impact of foreign technology, the import of capital goods is found to contribute to TFP growth for all the countries regardless of their levels of economic development. However, the impact of FDI and import of patents differs between developed countries and developing and East Asian economies. For developed countries, the purchase of patents and licences turns out to have a significant and positive impact, while for developing and East Asian economies FDI has a significantly positive impact. These findings suggest that developed countries, with high technological capability, can assimilate foreign technology in forms that do not generally come with much technical support from abroad. In contrast, for developing countries FDI, which brings not only technology but also management know-how, plays a larger role in improving TFP. The import of patents contributes to the improvement of TFP when combined with educational attainment.

The findings for other variables are similar to those for the determinants of economic growth. The results for the TFP gap (*GAP0*) show the intercountry convergence in TFP levels over time. Investment and openness have a positive impact on TFP growth though their statistical significance differs by group. Government expenditure and inflation both have negative impacts on TFP growth, with government expenditure showing statistical significance.

5. CONCLUSIONS

The remarkable growth and TFP performance of East Asian economies has been driven by several factors. Our study shows that important among these are strong domestic technological capabilities and the inflow of foreign technology, particularly in the form of capital goods and FDI. To sustain and promote these assets in the future, East Asian countries have to undertake various policies. To expand trade and FDI, they should further pursue liberalization and participate actively in multilateral and regional efforts to implement liberalization measures. They can also promote trade and FDI by adopting international standards and rationalizing customs procedures, disseminating information on overseas markets to domestic firms interested in exporting and on domestic markets to MNCs interested in undertaking FDI.

Table 3.10 The determinants of TFP growth

	Total sample (68 countries, OBS = 1904)				Developing (44 countries, OBS = 1232)			
	coefficient	*t*-value	coefficient	*t*-value	coefficient	*t*-value	coefficient	*t*-value
GAP0	−0.039	−4.620	−0.039	−4.520	−0.040	−3.629	−0.041	−3.699
INV	0.000	1.829	0.000	1.628	0.000	1.155	0.000	1.077
OPEN	0.000	0.341	0.000	0.267	0.000	1.801	0.000	0.905
GOV	−0.003	−7.330	−0.004	−7.439	−0.004	−5.809	−0.004	−5.850
INF	0.000	−1.464	0.000	−1.492	0.000	−1.164	0.000	−1.221
RD	0.009	1.636	0.014	1.021	0.002	0.252	0.035	0.894
HC	0.001	1.411	0.001	1.209	0.001	2.289	0.001	1.758
CAP	0.106	4.517	0.124	3.551	0.125	3.929	0.105	2.174
FDI	0.069	5.416	0.067	2.908	0.074	4.756	0.081	2.560
PAT	0.005	0.874	0.064	1.024	0.002	0.179	0.087	1.641
*CAP*HC*			−0.001	−0.650			−0.001	−0.386
*FDI*HC*			0.000	0.466			0.000	0.247
*PAT*HC*			0.002	2.245			0.003	1.783
*CAP*RD*			0.007	0.192			0.129	1.368
*FDI*RD*			−0.018	−0.617			−0.071	−1.192
*PAT*RD*			−0.040	−1.933			−0.073	−1.648
R^2	0.146		0.149		0.146		0.150	
LM het	22.295	[.000]	21.600	[.000]	22.295	[.000]	9.846	[.002]
Hausman	77.214	[.0000]	79.907	[.0000]	51.060	[.0000]	57.922	[.0000]

	Developed (24 countries, OBS = 672)				Developing (E Asia, 9 countries, OBS = 252)			
	coefficient	*t*-value	coefficient	*t*-value	coefficient	*t*-value	coefficient	*t*-value
GAP0	−0.022	−1.769	−0.017	−1.328	−0.059	−3.828	−0.099	−3.871
INV	0.000	1.144	0.000	1.309	0.001	1.671	0.002	1.118
OPEN	0.001	4.970	0.001	5.076	0.000	1.964	0.001	1.854
GOV	−0.005	−6.916	−0.005	−7.376	−0.001	−1.199	−0.003	−1.874
INF	0.000	−2.148	0.000	−1.869	0.000	0.176	0.000	0.938
RD	0.013	2.523	0.039	3.297	0.006	0.803	0.078	1.357
HC	0.001	1.402	0.001	1.249	0.001	2.190	0.003	2.000
CAP	0.063	2.213	0.219	3.477	0.062	1.725	0.287	2.280
FDI	0.003	0.135	0.175	0.577	0.237	4.574	0.168	1.275
PAT	0.001	2.215	0.040	1.684	−0.038	−1.086	−0.264	−1.161
*CAP*HC*			−0.001	−0.443			0.000	0.131
*FDI*HC*			0.004	1.724			0.005	1.171
*PAT*HC*			0.001	0.843			0.007	2.002
*CAP*RD*			−0.073	−2.011			−0.211	−1.590
*FDI*RD*			−0.022	−0.649			−0.147	−1.204
*PAT*RD*			−0.010	−0.587			−0.055	−0.713
R^2	0.208		0.225		0.132		0.253	
LM het	0.244	[.622]	0.549	[.459]	3.182	[.074]	1.764	[.184]
Hausman	55.103	[.0000]	59.917	[.0000]	11.551	[.1724]	16.465	[.0362]

Notes:
1. *GAP* = Gap in TFP level vis-à-vis US TFP level; *GDP0* = ln (initial per capita GDP); *INV* = investment/GDP; *OPEN* = (export + import)/GDP; *CAP* = machinery import/import; *FDI* = FDI inflow/investment; *PAT* = Royalities and licence fees payment/GDP; *RD* = R&D expenditure/GDP; *SC* = education attainment rate (secondary [*SC2*] and higher [*SC3*]); *GOV* = government expenditure/GDP; *INF* = inflation rate.
2. Instrument variables are lagged independent variables and population.
3. *T*-values are evaluated by HCV if heteroscedasticity does exist.

Source: Authors' estimation.

The liberalization of FDI policies is a necessary condition for attracting FDI but it has to be supplemented by other measures. Among these are strengthening the infrastructure, both hard infrastructure such as transportation and communication facilities and soft infrastructure such as the governance and legal systems, education and training.[13] Furthermore, one cannot over-emphasize the importance of maintaining a stable macroeconomic environment with low inflation, sound fiscal policy and stable, realistic exchange rates. The reduction of business transaction costs and effective investment promotion are also important in competing for FDI.

To improve technological capabilities, East Asian economies have to improve the quality of human resources and promote R&D. An up-to-date technology infrastructure, with strong institutions for quality, standards, testing and R&D support, as well as for SME extension services, is essential to support capability building. Universities and public R&D institutions have to link up with industry, particularly in countries that are reaching the stage (as in the NIEs) of autonomous innovation.

NOTES

1. The authors are at Keio University, Tokyo, and Waseda University and Japan Center for Economic Research, Tokyo, respectively. An earlier version of the paper was presented at the Workshop on Technology Development in East Asia, sponsored by the World Bank, Bali, Indonesia, December 14–15, 2000.
2. The figures are for East Asia and the Pacific rather than for East Asia alone.
3. TFP growth is estimated by applying the following formula:

$$\ln\{\mathrm{TFP}(t)/\ln\mathrm{TFP}(t-1)\} = \ln\{Y(t)/Y(t-1)\} - \Sigma_i s_i(t)\ln\{X_i(t)/X_i(t-1)\}$$

where Y is value-added, X_i is input and $s_i(t)$ is the factor share, which is computed as a arithmetic mean $(s_i(t)+s_i(t-1))/2$.

TFP levels are estimated by the formula below with the TFP level in the US in 1980 as the reference level.

$$\ln\{\mathrm{TFP}(k)/\ln\mathrm{TFP}(\mathrm{us})\} = \ln\{Y(k)/Y(\mathrm{us})\} - \Sigma_i[s^*_i(k)\ln(X_i(k)/X^*_i) - s^*_i(\mathrm{us})\ln(X_i(\mathrm{us})/X^*_i)$$

where $s^*_i(k)=s_i(k)+s_i$, s_i is the arithmetic mean of factor share defined as $\Sigma_i s_i(k)/K$ and X^*_i is a geometric mean of factor input defined as $X^*_i=\Pi X_i(k)^{vi(k)}$.
4. Lall (2000) provides a detailed discussion of human capital in East Asian economies.
5. United Nations (1999) presents similar findings.
6. United Nations (1996, 2000).
7. Yamazawa and Urata (2000) discuss FDI and trade liberalization by APEC economies.
8. UN (1999, pp. 56–8).
9. Machinery imports are defined as items under SITC 7. These include components for assembly of electronics exports.
10. Pack (1988) presents a good survey of the impact of foreign trade on economic growth and development.
11. A number of studies have found a positive contribution of outward-oriented trade regime to improving productivity. See Pack (1988) for a survey of such studies.

12. Per capita GDP is expressed by 1992 PPP US$.
13. For more detailed discussions of the determinants of FDI, see Urata and Kawai (2000).

REFERENCES

Aitken, B. and A. Harrison (1994), 'Do domestic firms benefit from foreign direct investment? Evidence from panel data', policy research working paper 1248, Policy Research Department, World Bank, Washington, DC.

Barro, R.J. and Jong-Wha Lee (2000), 'International data on educational attainment updates and implications', working paper 7911, New York: National Bureau of Economic Research.

Blomström, M., R.E. Lipsey and M. Zejan (1994), 'What explains developing country growth?', working paper No. W4132, New York: National Bureau of Economic Research.

Blomström, M. and H. Persson (1983), 'Foreign investment and spillover efficiency in an underdeveloped economy: evidence from the Mexican manufacturing industry', *World Development*, **11** (6), 493–501.

Blomström, M. and E. Wolff (1994), 'Multinational corporations and productivity convergence in Mexico', in W. Baumol, R. Nelson and E. Wolff (eds), *Convergence of Productivity: Cross-National Studies and Historical Evidence*, Oxford and New York: Oxford University Press.

Borensztein, E., J. de Gregorio, and Jong-Wha Lee (1998), 'How does foreign direct investment affect economic growth?', *Journal of International Economics*, 45, 115–35.

Caves, R.E. (1974) 'Multinational firms, competition, and productivity in host-country industries', *Economica*, 41 (May).

Globerman, S. (1979), 'Foreign direct investment and "spillover" efficiency benefits in Canadian manufacturing industries', *Canadian Journal of Economics*, **12** (1), 42–56.

Haddad, M. and A. Harrison (1993), 'Are there spillovers from direct foreign investment? Evidence from panel data from Morocco', *Journal of Development Economics*, 42, 51–74.

Krugman, P. (1994), 'The myth of the East Asian miracle', *Foreign Affairs*, 73, 62–8.

Lall, S. (2000), 'Technological change and industrialization in the Asian newly industrializing economies: achievements and challenges', in L. Kim and R. R. Nelson (eds), *Technology, Learning and Innovation*, Cambridge: Cambridge University Press.

Lawrence, R.Z. and D.E. Weinstein (2000), 'Trade and growth: import-led or export-led? Evidence from Japan and Korea', paper prepared for World Bank project 'Rethinking the Asian Miracle'.

Pack, H. (1988), 'Industrialization and trade' in H.B. Chenery and T.N. Srinivasan (eds), *Handbook of Development Economics*, volume 1, Amsterdam: North-Holland.

Rhee, Y.W., B. Ross-Larson and G. Pursell (1984), *Korea's Competitive Edge: Managing Entry to World Markets*, Baltimore: Johns Hopkins University Press.

United Nations (1996), *World Investment Report 1996*, New York: United Nations.

United Nations (1999), *World Investment Report 1999*, New York: United Nations.

United Nations (2000), *World Investment Report 2000*, New York: United Nations.

Urata, S. (1999), 'Intrafirm technology transfer by Japanese multinationals', in D.J. Encarnation (ed.) *Japanese Multinationals in Asia: Regional Operations in Comparative Perspective*, Oxford: Oxford University Press.

Urata, S. and H. Kawai (2000), 'Intra-firm technology transfer by Japanese manufacturing firms in Asia', in T. Ito and A.O. Krueger (eds), *The Role of Foreign Direct Investment in Economic Development*, Chicago: University of Chicago Press for NBER.

Urata, S. and H. Kawai (forthcoming), 'The determinants of the location of foreign direct investment by Japanese small and medium-sized enterprises', *Small Business Economics*.

World Bank (1993), *The East Asian Miracle: Economic Growth and Public Policy*, Oxford: Oxford University Press.

Yamazawa, I. and S. Urata (2000), 'Trade and investment liberalization and facilitation', in I. Yamazawa (ed.), *Asia Pacific Economic Cooperation (APEC)*, London: Routledge.

Young, A. (1995), 'The tyranny of numbers: confronting the statistical realities of East Asian growth experiences', *Quarterly Journal of Economics*, 110, 641–81.

4. Building technological capabilities with or without inward direct investment: the case of Japan

Akira Goto and Hiroyuki Odagiri[1]

> Learning is usually treated as a supply-side matter, thought to follow teaching, training, or information delivery. But learning is much more demand driven. People learn in response to need. When people cannot see the need for what's being taught, they ignore it, reject it or fail to assimilate it in any meaningful way. Conversely, when they have a need, then, if the resources for learning are available, people learn effectively and quickly. (Brown and Duguid, 2000, p. 136)

1. INTRODUCTION

Innovation and learning are, as Cohen and Levinthal (1989) argue, the 'two faces of R&D'. Both indispensable to technological and economic development. They were particularly important for a late-starter like Japan (after the Meiji Restoration of 1867 or after the defeat in World War II), because the acquisition of advanced technology from abroad was essential to help it build technological capabilities of its own.

In this chapter, we examine the process of technology acquisition and the building of technological capability by Japanese manufacturing industries, focusing on the period from the end of World War II to the early 1970s. Post-war Japan imported many advanced technologies and used them to upgrade its level of industrial technology, which in turn contributed to the competitiveness of such industries as automobiles, steel, semiconductors and machine tools. Japan was able to become the world's largest producer in these industries by the 1980s. We concentrate on how Japan acquired foreign technologies; this is probably of most relevance to developing countries today. However, since technology acquisition and domestic innovation are closely linked we will also discuss domestic R&D in Japan (but not in great depth, since there are many other studies on this, including our own, Odagiri and Goto, 1996).

Inward foreign direct investment (FDI) has been a major source of technology transfer in most countries in addition to the import of technology by licensing and the purchase of capital goods embodying new technologies. Inward FDI is considered important for economic growth not only because it brings scarce capital but also because it is a major conduit for flows of foreign technology. Technological spillovers are expected to take place from affiliates of multinational corporations (MNCs) to host countries, contributing to the upgrading of local technological capabilities. However, technology importation by Japan does not conform to this pattern: it is one of the few countries that progressed industrially with very limited inward FDI. Korea and Taiwan are similar, and these are the three countries that experienced rapid growth and attained high levels of per capita GDP. This poses interesting questions on the importance of inward FDI for the accumulation of technological capabilities, and will be discussed in this chapter.

The organization of this chapter is as follows. Section 2 summarizes the current status of R&D activity in Japan. Section 3 examines the process, trends and characteristics of technology importation by post-war Japan, and Section 4 discusses the determining factors, including market conditions and government policies. Section 5 discusses inward FDI as a means of technology transfer, and Section 6 concludes by discussing the implications for developing countries and the challenges facing Japan today.

2. R&D IN JAPAN

Japan spent US$70541 million, nearly three per cent of GDP, on R&D in 1995 (Table 4.1). Of the five leading industrial countries, Japan spent most on R&D relative to GDP, and came second to the USA in terms of absolute amounts. About 80 per cent of Japan's R&D spending was funded and undertaken by the private sector.

The results of R&D can be seen in several ways. First, the number of scientific publications (in natural sciences and engineering) by Japanese scientists is second in the world (Table 4.1), its share increasing from 6.8 per cent in 1981 to 10.3 per cent by 1998 (NISTEP, 2000). The share in citations, supposedly a measure of the quality of scientific papers, has also been increasing. Second, the number of patents taken out in the USA by Japanese citizens is also second only to the Americans (see Table 4.1); 21.5 per cent in 1995, up from just 11.7 per cent in 1980, an impressive rise. Third, Japanese shares in high-technology exports are also high (Table 4.2).

By industry, electric machinery accounts for almost 40 per cent of total manufacturing sector R&D, followed by transportation machinery and general machinery. These three industries together account for over 40 per cent of manufacturing sales and over 80 per cent of overseas sales.

Table 4.1 Indicators of R&D in selected countries, (1995)

	Japan	USA	Germany	France	UK
R&D expenditure (million US$)[a]	70541	160358	31684	24253	19655
R&D expenditure/GDP (%)	2.94	2.52	2.31	2.34	2.02
Government funds (% of total R&D)	22.9	34.5	36.8	41.9	33.2
Number of researchers[b]	658866	987700	231128	151249	146000
Number of researchers/1000 population	5.25	3.75	2.83	2.60	2.49
Share of published scientific papers (%)[c]	9.6	35.1	8.4	6.6	9.0
Share of US patents (%)	21.5	54.8	6.5	2.8	2.5

Notes:
[a] 1990 prices, converted to US dollars by OECD purchasing power parity.
[b] On a full-time-equivalent basis except in Japan.
[c] Calculated from the data in 'National Science Indicators on Diskette' (Institute for Scientific Information).

Source: NISTEP (2000).

Table 4.2 Country share of world exports (by technology)

Technology	United States	Japan	Germany
All technologies	25.2	17.0	11.7
Biotechnologies	37.0	4.3	19.1
Life science technologies	27.5	13.8	20.4
Opto-electronics	13.7	22.8	24.0
Information technologies	18.5	23.0	8.3
Electronics	20.3	25.5	9.4
Manufacturing technologies	16.2	21.5	21.9
Advanced materials	28.6	9.3	15.1
Aerospace	44.2	1.4	11.3
Weapon technologies	34.3	4.6	12.1
Nuclear technologies	20.8	0.2	9.6

Source: DRI/McGraw-Hill, *Special Tabulations*, April 1994, as cited in National Science Foundation, *Science & Engineering Indicators 1996*.

Chemicals and pharmaceuticals together account for more than 16 per cent of total manufacturing R&D, but only for 9.3 per cent of domestic sales and 6.6 per cent of overseas sales. The fact that Japan is competitive in the machinery-related industries but less so in chemical and pharmaceutical industries may be taken to reflect the strength and weakness of Japan's national innovation system (Goto, 2000).

3. THE PROCESS OF LEARNING

3.1 Initial Conditions after the War

The end of World War II left Japan with a large technological gap and assets accumulated from the pre-war and wartime periods, two conditions that not only called for, but were also suited to, the active importation of technology. Since the late nineteenth century, the Japanese economy had grown steadily. Imported technology had played a major role in the process. Aided by indigenous technology and a well-developed education system, imported technology was used effectively to strengthen the domestic technology base and promote economic growth. A number of manufacturing firms, including those in shipbuilding, steel, aircraft and electrical machinery, were near the global technological frontier and had started to produce world-class products. However, even these industries depended heavily on foreign technology and continued to import major technologies even after the outbreak of the Sino-Japanese War in 1937.

World War II forced Japan into technological isolation. Though it tried to fill the resulting gaps with increased domestic R&D, it met with only limited success. When the war ended, Japan found itself lagging well behind technological levels in the West. Since there were also some industries (like petrochemicals and electric appliances) in which Japan was a complete newcomer, it had a huge 'backlog' of technologies to import. Japan also inherited several key 'heavy' industries, such as shipbuilding, steel, machinery and chemicals, which had been strongly promoted by the wartime government. Consumer goods industries, notably textiles, had been converted to the production of military-related goods. As a result, the share in manufacturing production of heavy industries (machinery, metal and chemicals) had risen from 33.9 per cent in 1931 to 79 per cent in 1944 (Miyazaki and Ito, 1989). A large stock of plant and equipment in heavy industries survived the war (around 60–100 per cent, according to Miyazaki and Ito, 1989), along with large numbers of workers who had the experience, if not necessarily with high levels of skill, of working in these plants.

As noted, R&D had increased during the war. According to one (rough) estimate, the share of R&D in GNP went from 0.22 per cent in 1930 to 1 per cent by 1942. There were 1214 research organizations employing 49 560 staff and spending 886 million yen (current price) in 1942 (Hiroshige, 1973). After the war, military spending was virtually eliminated, and the resources accumulated in the heavy industries were converted into the production of civilian goods. As a result, when the war ended, Japan found itself with a widened technology gap and, at the same time, the resource base to fill it: these provided it with the demand as well as the capabilities for active technology importation.

3.2 The Process of Technology Transfer

Technologies travel in many forms. They may be embodied in people – foreign engineers may bring in advanced technologies and Japanese may go abroad to learn them – or they may be embodied in new machinery and equipment, whose deployment can lead to lower costs and new products. In addition, the technological knowledge behind the new machinery can be learned: by taking machines apart, one may learn about new materials, components and designs. Such 'reverse engineering' has been widely used, not only in developing countries but also by firms in developed countries.

Technologies can also be purchased through licensing agreements, the employment of consultants and the purchase of blueprints and other resources. Licensing is the sale of legal rights to the use of a technology. However, technology licensing does not necessarily mean technology transfer if the contract does not provide the underlying engineering or scientific knowledge. FDI is another important channel of technology transfer. Foreign firms often bring not only new technologies but also new management and marketing techniques and production and inventory control methods. Such practice can, in the right conditions, diffuse to local firms. FDI often takes the form of joint venture with local firms, some of which may be induced by conditions imposed by the host government. These conditions are often designed to encourage transfer of technology to local partners and to avoid foreign control of domestic industries. Technology also diffuses when multinationals provide technological assistance to local suppliers.

Other channels for technology transfer include academic and trade journals, exhibitions and trade shows. MNCs now operate research laboratories worldwide, and intra-firm international technology transfer is growing. These overseas laboratories tend to carry out R&D to adapt products to local conditions and to monitor the R&D activities of local firms and research institutions. Gradually, MNCs have been developing global R&D networks, integrating the R&D resources of various countries.

Japan did not, as noted, use all these channels fully. It restricted FDI until the late 1960s and early 1970s, when gradual liberalization began. However, there were exceptions. There were foreign affiliates established before the war. In addition, during 1953–56, the so-called 'yen-based investment system' was adopted and several foreign firms established operations in the Japanese market (Komiya, 1972), including IBM, Esso (Exxon), Mobil, Nestle, Olivetti and NCR. They brought new technologies and new ways of doing business into Japan. These were, however, exceptions. Until liberalization, FDI into Japan was limited; in fact, it grew little even after liberalization. The implications of this process of technology transfer are discussed in the next section.

Japan used other channels of technology transfer extensively. Imported machinery and equipment played a critical role in improving product quality and productivity. The automobile industry used imported machine tools and robots, the steel industry imported converters and rolling machines, electric utilities imported generators, and so on. Domestic machinery and equipment manufacturers used reverse engineering to learn from imported machinery and equipment in order to launch domestic manufacture.

Japanese firms also struck many technological agreements with American and European firms. Most automobile manufacturers, Toyota being the major exception, had technological agreements with Western manufacturers.[2] Among electrical machinery manufacturers, Toshiba, Mitsubishi Electric and Fuji Electric had extensive agreements with GE, Westinghouse and Siemens, respectively. The steel industry introduced the revolutionary LD converter process pioneered by an Austrian firm. Textile manufacturers eagerly sought technological agreements with American and European firms for the production of new synthetic fibres. With these agreements, Japanese firms obtained patent licences and know-how. Foreign engineers from the licensing firms were often invited for advice and instruction. Many consultants were also hired, mostly from the USA, to help modernize the production process. For example, Nissan Motor hired US consultants to help with plans for their advanced Oppama plant, which was completed in 1961.[3]

The purchase of blueprints was also common. In some cases, Japanese firms bought titles to inventions or ideas that had been developed only at the laboratory level. One well-known case is the purchase of a mid-to-low density polyethylene production process by Mitsui Petrochemical from a German scientist. The company is said to have paid US$1.2 million just for two notebooks of experiment data and, based on these data, it managed to build a plant. Japanese firms also sent their engineers abroad to seek promising technologies. Trade associations and institutions like the Japan

Productivity Centre often organized 'missions' to study technological trends and learn business practices.

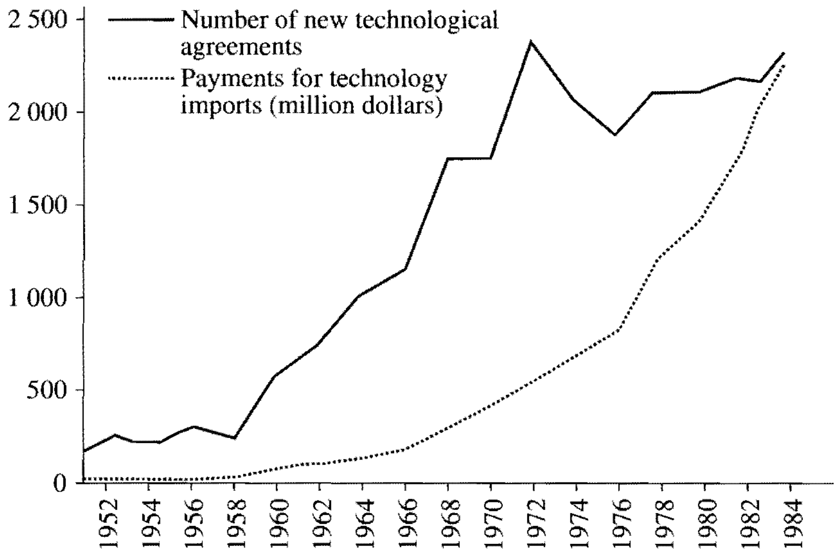
Thus, during the 1950s and 1960s, Japan acquired advanced foreign technology through all channels except for inward FDI. It is important to note the diversity of channels. Discussions of technology transfer or importation tend to be based on technology balance of payments statistics, which covers payments and receipts of patent licences, know-how and associated expenses. However, this only captures a part of technological flows. Learning through reverse engineering, for instance, is not included. Nor is learning through journals, trips and 'missions'. Yet, these means played an important role in the learning of advanced technology by Japanese firms in the post-war years.[4]

3.3 Trends in Technology Transfer

With this important caveat in mind, let us examine post-war trends in technology importation using the technology balance of payment statistics. Figure 4.1 shows the numbers of new technical agreements between Japanese and foreign firms and payments for patent licences, know-how and associated expenses. Although the number of agreements varied with economic conditions and with technology import liberalization, the general trend is that, after remaining rather stable at about 200–300 per year, the number increased rapidly, more than tenfold, during 1958–73, until the first oil crisis hit the Japanese economy.

As shown in Figure 4.1, Japanese technology imports were relatively stagnant until the mid-1950s. During this period, increased demand was met largely through redeployment of unused plant and equipment rather than by new investment. Accordingly, the demand for new technologies remained weak even though the economy had entered the high-growth period. Technology imports accelerated thereafter and the composition of imports also changed gradually. Non-electrical machinery (engines, machine tools and other industrial machinery), electrical machinery and chemicals have been the three largest technology-importing industries throughout the post-war period. However, the shares of electrical machinery and iron and steel dropped sharply from the 1945–65 period to the 1965–72 period, possibly reflecting the rising technological level of these industries.

At the same time, the proportion of technology imports for consumer goods increased. Imports of technology for such goods as air conditioners, colour-television sets, leisure products, cosmetics and clothing designs increased in the late 1960s. This change partly reflects changes in



Source: Science and Technology Agency, *Gaikoku Gijutsu Donyu Nenji Hokoku* (Annual Report on the Import of Foreign Technology), each year.

Figure 4.1 Number of new technical agreements and payments for technology imports, 1952–84

government policy. In the 1950s, the government encouraged the import of technologies that contributed to industrial reconstruction and discouraged those for 'luxuries', but these policies were gradually relaxed. However, we believe that the shift reflected not so much the change in government policy as the changes in demand structure with rising incomes.

4. THE ROLE OF THE MARKET MECHANISM AND GOVERNMENT POLICIES

Three factors explain the active and successful importation of advanced technology by Japanese firms – incentives, capabilities and government policy.

4.1 Incentives: Growing Markets and Intense Competition

From the 1950s, the economy grew rapidly. While investment in plant and equipment by the private sector was only about 10 per cent of GNP during the first half of the decade, household demand, mostly for necessities, underwent rapid expansion. In the mid-1950s, investment in plants and equipment also began to increase, because what was inherited from the war, such as old steel mills, had become obsolete and insufficient to meet new needs. The changing demand structure also created the need to set up new industries, which required new investment.

Entry to this rapidly expanding market was difficult for most foreign firms until at least the mid-1960s. In 1959, the ratio of trade liberalization was only 26 per cent, that is, only 26 per cent of the total value of imports was automatically allowed to enter the country. Trade liberalization proceeded swiftly and the ratio reached 70 per cent by the end of 1961. Subsequently, the import of steel was liberalized in 1961, automobiles in 1965 and computers in 1971. Still, the share of imports grew only slowly, if at all, for many manufactured goods. The liberalization of FDI into Japan followed in the late 1960s and the 1970s. Again, the market share of foreign-owned firms remained low.

Thus, Japanese firms could serve the fast-growing domestic market without foreign competition (before trade and capital liberalization) and despite it (after liberalization). They also exported increasing amounts to world markets, which were growing, but at rates lower than in Japan. This growth created a strong demand for plant and equipment, which, in turn, boosted the demand for advanced technology. Existing firms expanded and new firms entered even existing industries like steel, all seeking plants with state-of-the-art technology. New industries emerged, such as petrochemicals and electrical appliances. The automobile industry, which existed before the war but was limited mainly to producing taxicabs and military vehicles, was also in effect a new industry. These new industries required new investment and new technology on a massive scale.

Under these conditions, the profits of Japanese firms grew and the profitability of the non-financial private sector more than doubled from 1955 to 1970 (Odaka, 1989). Many cases illustrate the high return on investment in imported technology and plant and equipment. Nissan, the second largest automobile manufacturer, made a technology agreement with the British carmaker, Austin, in 1952. At first, it was a knock-down operation where Nissan simply assembled parts provided by Austin, with the technological help provided by the British company. According to a Nissan executive at the time, the company could immediately sell all the cars they assembled at the price of one million yen each, yielding a profit of 200 thousand yen per car (Ekonomisuto, 1984).

These rapidly growing markets clearly provided Japanese firms with the incentive to invest in plant and equipment as well as in technology. However, the market handsomely rewarded firms that succeeded in upgrading their technology, and punished those that failed to do so. The 'Economic Democratization Policy' administered by the Allied powers broke up the pre-war *Zaibatsu* (huge conglomerates). Several dominant firms, such as Japan Steel, Mitsubishi Heavy Industries and Oji Paper, were also split into two to four each. The Anti-Monopoly Law was enacted in 1947. Modelled after the US Antitrust Law, it had several unique provisions, such as the prohibition of holding companies, and was more stringent in many ways than the original. These policy measures helped to create and maintain a competitive environment.

Perhaps more importantly, rapidly growing markets attracted new entrants that further intensified competition. Sony and Honda are among the well-known examples. In steel, aluminium and petrochemicals the number of firms increased and in many cases surpassed the number of firms in the USA, where markets were much larger. In some cases, existing firms and the government tried to discourage further entry, citing the waste caused by 'duplicate investment' and 'excessive competition' and stressing the importance of economies of scale. These efforts, however, met with little success. Though the share of imports and foreign direct investment did not increase rapidly even after liberalization, liberalization pressured domestic firms to upgrade technologies to remain competitive with the much larger firms of the USA and Europe (discussed in more detail in Section 5). In addition, partly due to the Japanese government's concern over the balance of payments, Japanese firms intensified their efforts to export.

Thus, even if direct foreign competition in the domestic market was not intense, domestic firms faced intense competition among themselves, from potential competition from foreign firms in the domestic market and from Japanese and foreign firms in world markets. They were under strong pressure to upgrade their technology and the import of advanced technology was essential.

4.2 Absorptive Capacity

The profit and growth incentives were a necessary condition for active technology importation: domestic capability to select, import, adapt and implement new technology (*absorptive capacity*) was equally indispensable. Japan had inherited a strong technology base, and further investment in

R&D and education during the post-war period promoted not only indigenous innovation but also its capacity to use imported technology efficiently. R&D data, available from 1953, indicate that R&D expenditures began to grow rapidly in the latter half of the 1950s.[5] From 1955 to 1961 they grew by more than 20 per cent annually. As a percentage of national income, they rose from 0.84 in 1955 to 1.73 in 1961. The increase in the latter half of the 1950s coincides with the increase in technology imports, which began in 1958. Over time, domestic R&D and technology importation grew together. Firms and industries that spent large amounts on R&D also tended actively to import technology.

There are many possible explanations for this correlation. One is that rapid technological change will raise both domestic R&D and technology imports because of growing technological opportunity. Another is that sellers of technology often require remuneration not only in financial terms but also in new technology. Thus, in order to buy new technology, a firm must have its own technology to offer, forcing technology-importing firms to do their own R&D. However, these two factors do not fully explain the correlation. The positive relationship between domestic R&D and technology imports is significant only for a few countries (Blumenthal, 1979). In Japan, the number of technology importation contracts involving cross-licensing was small in the 1960s, though it rose over time. In 1965, there were only 3; in 1968, 37; and in 1982, 98.

A more relevant explanation may be the willingness of Japanese firms to invest in assimilating and applying imported technologies. Since FDI was not an important mode of technology import, firms had to carry out R&D to master and adapt the imported technologies. Japan also imported several technologies at a commercially untested stage (e.g. Mitsui Petrochemical's purchase of the mid-to-low density polyethylene process) or some intended for military or other non-commercial uses (e.g. transistors and VCRs). These had to be tested, upgraded and adapted for commercialization, requiring considerable R&D effort. Thus, only with the presence of a technological base inherited from the earlier periods and of entrepreneurship that fostered active R&D could technology import be successfully carried out without FDI. Imported technologies, in turn, helped to enhance and enlarge the technology base and induce further R&D. Domestic R&D and technology imports expanded together through this process.

4.3 Government Policies to Promote R&D and Technology Importation

Four sets of government policies helped Japanese technology imports.[6] First, the government controlled commercial technology imports with the Foreign Exchange and Foreign Trade Control Law of 1949 and the Foreign

Investment Law of 1950. Since technology imports required payments in foreign currency, the Foreign Investment Board reviewed each application, apart from technologies that cost little and could be imported with Bank of Japan approval. Screening by the Board was carried out in consultation with government ministries, particularly the Ministry of International Trade and Industry (MITI). These restrictions were gradually liberalized and the number of technologies to be reviewed decreased rapidly (Sekiguchi, 1986). Major liberalization measures were implemented in 1961, 1968 and 1972. Finally, in 1980, all technology importation was opened up except for twelve designated technologies; even among these, the import of technologies costing less than 100 million yen was liberalized.

With this regulation, the government could influence the choice of the technology to be imported and the firm that imported it. Balance of payments consideration dominated the choices in the 1950s, along with a preference for 'important' industries and public utilities. The criteria changed over time and were sometimes rather vague. It was not clear that the government had the capacity to choose the best technologies and companies. While it may have had superior information-gathering and processing abilities, especially in the early post-war years, there were cases where it apparently made poor decisions because of incompetence or for political considerations.

Second, tax preferences were used to encourage technology import (Goto and Wakasugi, 1988). There were two such measures. The first was introduced to reduce tax withholdings on payments to foreign corporations in exchange for imported technology. The second was to grant tariff exemptions on machines considered necessary for economic development and not produced domestically. Both measures were introduced in the early 1950s: tax savings due to these measures peaked in 1961 at 9.9 billion yen. These measures were abolished in the mid-1960s, as the emphasis of technology policy shifted from technology development through importation to that through domestic R&D.

Third, international technology agreements were reviewed by the Fair Trade Commission (FTC). If foreign firms licensed technology to Japanese firms on conditions considered unreasonable, or involving restraints of trade or unfair trade practices, the FTC requested a revision to the contract or voided the agreement. Conditions which were considered as violations of the Anti-Monopoly Law included: restrictions by licensor on export price, quantity, geographical area or buyer of the product manufactured using the technology in question; grant back clause mandating the licensee to provide adapted, improved technology based on the originally licensed technology to licensor; and restrictions that dealt with competing technologies or products of the licensor. The FTC also strove to prevent 'excessive' royalties being demanded by licensors. There was no such review system for agreements among Japanese firms. While FTC intervention on these grounds was intended to prevent unfair trade practices, it may have also enhanced the bargaining position of Japanese vis-à-vis foreign firms in negotiating licensing agreements.

More indirectly, policies on trade and FDI had a profound impact on technology importation. Until trade and FDI liberalization, foreign firms had little choice in exploiting their technologies in Japan other than by selling them to Japanese firms. Needless to say, these policies must have had a welfare cost by limiting foreign competition and reducing the inflow of capital; however, the intense competition among domestic firms and in export markets, and Japan's high savings rate, meant that these costs did not become too large. At the same time, the policies encouraged the rapid broadening and deepening of the Japanese innovative base.

Technology imports alone were insufficient to raise Japanese technology to levels needed for international competitiveness. The fourth set of policies were designed to encourage R&D activities by Japanese firms. Gradually, policy emphasis shifted from imports to innovation. One such policy was a tax credit for incremental R&D expenditures, started in 1966. This allowed firms to deduct a fixed proportion of their experimental research expenditures in the current year over and above the highest expenditures incurred in previous years. The amount of tax foregone by this credit (and other less important R&D-related credits) reached 19 billion yen in 1970. This type of tax credit for R&D is now widely used throughout the world.

The government also started several subsidy programmes to encourage R&D. The value of subsidies reached 11 billion yen in 1970 and 61 billion yen in 1980 (Goto and Wakasugi, 1988). A large portion of these subsidies was given through *research associations*. The government, citing the fact that the R&D expenditures of the six largest Japanese computer makers combined was a mere fifth of that of IBM in 1970, encouraged collaborative research and provided R&D subsidies through this channel. Research associations, a form of research consortium, also became an important technology policy tool in the 1970s and 1980s. Some of these associations, the VLSI (very large-scale integrated circuits) Association in particular, are generally considered to have been successful. Others were not, and there were probably more cases of failure than success (Odagiri and Goto, 1996).

5. DEVELOPMENT WITH OR WITHOUT FDI

Japan is not unique among fast growing industrializing economies in restricting FDI inflows and relying on other means of technology acquisition. Korea and Taiwan followed similar paths. There are, however, several countries in East Asia, such as Thailand and Malaysia, which have grown fast with a rapid increase in inward FDI. Would Japan, Korea and Taiwan have grown even faster if they had accepted more inward FDI?

Past research on the effects of inward FDI on domestic industry gives mixed results. Tokui et al. (1999) cite three studies that examine the impact of inward FDI on the productivity of domestic industries. In Canada, industries with a higher presence of foreign firms tended to have higher labour productivity (Globerman, 1979). In Morocco, on the contrary, FDI was not associated with any productivity increase in domestic firms (Haddad and Harrison, 1993). Lichtenberg and van Pottelsberghe (1996) show that, among developed countries, inward FDI has not contributed to productivity increase in host countries, while outward FDI has tended to contribute to the productivity of home countries.

As for the impact of inward FDI on the R&D in host countries, Veugelers and Houte (1990) find that in Belgium the presence of foreign firms was negatively correlated with R&D by domestic firms. Bertschek (1995), by contrast, finds that in Germany inward FDI had a positive impact on innovation by domestic firms. Tokui et al. (1999) find that inward FDI in Japan tended to reduce both profits and R&D in Japanese firms in 1987–94. It may also be the case that MNCs do not invest in innovative activity in their affiliates when they reap economies of scale and scope in R&D in their established bases at home or elsewhere.

The impact of inward FDI on domestic technological activity or technological level is therefore complex. There may or may not exist an association between inward FDI and domestic R&D or productivity. Even if there is an association, it may be indirect, from spillovers of MNC activity or from the competition created by their entry. Tokui et al. (1999) argue that inward FDI intensifies competition and reduces the profitability of domestic firms, which discourages their R&D investment. Obviously, foreign firms have an incentive to keep technology from leaking out to competitors to maximize the profits from their superior technological resources.

This argument need not imply that the restriction on inward FDI will always encourage domestic R&D or raise the technological level of domestic firms. Note that, even during the 1960s when FDI was restricted, Japanese firms were aware that capital liberalization was inevitable in the near future. Since many American and European firms, such as Du Pont, US Steel, General Motors and IBM, were huge and technologically advanced in comparison to major Japanese firms at the time, the latter felt a severe potential competitive threat. In many industries, they actually experienced the consequences of this threat in the pre-war period. For instance, Ford and GM had plants in Japan before the war and used to dominate the Japanese automobile market. This dominance of Ford and GM, with their formidable financial and technological clout, remained in the minds of Japanese carmakers. After the war, this potential threat and the inevitability of trade liberalization, prompted Toyota, Nissan and other Japanese manufacturers to improve competitiveness. Fujimoto and Tidd (1993) compare this with the UK and argue that, perhaps ironically, the pre-war dominance of British producers like Morris and Austin in the UK market and Ford's failure to penetrate it may have delayed their introduction of a full-scale American mass-production system. Japanese producers, by contrast, retained a strong memory of Ford as a competitor of superior technology. Toyota tried desperately to learn from the mass-production system of Ford and other car producers, and even from those of other industries, most notably textiles, to come up with its own system, now called the 'Toyota production system'.

Therefore, even if FDI did not play a major role in post-war technology transfer to Japan, it did play an indirect role by making the market more contestable and so stimulating local technology development. The role of inward FDI is indeed complex. The simplistic view that inward FDI contributes to the development of host countries through spillovers may be naive, but so is the view that FDI played no role at all in post-war Japan.

6. CONCLUSIONS

Does the discussion of Japanese technology importation and development provide implications for developing countries today? We examine two such implications.

Firstly, the acquisition of technology from abroad is not a simple matter. To be successful, it requires *deliberate effort on the part of the buyer or receiver*, obviously along with the right environmental conditions. In other words, 'technology transfer' can be a misleading term if it suggests that technology can be transferred automatically; 'technology acquisition' is a better expression, indicating the need for active involvement of the country that intends to acquire the technology.

Imported technologies can only be used effectively if sufficient capabilities exist for a country to master imported technologies fully and adapt them to its own environment. Managers, engineers and workers alike have to strive until the imported technologies bear fruit in the form of smooth production, market penetration and profits. They all have to work hard to understand the technology, learn from it through trial and error, and put it in actual use. Entrepreneurship, in its broadest sense, has to be present to facilitate this process. In post-war Japan, entrepreneurship was abundant, from new start-ups like Sony and Honda to established firms like Nippon Steel and Nissan. What encouraged them was the incentive to invest in physical capacity, imported technologies and building their own technological capabilities given by rapidly growing demand in intensely competitive markets. In essence, the Japanese experience suggests that countries have to build absorptive capabilities, learn from imported technologies and develop their capabilities further, utilizing them to promote local innovation.

The Japanese government helped in various ways. From the beginning of industrialization after the Meiji Restoration of 1867, education, both at the elementary and higher levels, was given top priority in government policy. Before and during World War II, government procurement of military goods gave domestic heavy industries a large market and hence the incentive to invest in R&D. After the war, the government encouraged investment through low-interest loans and various tax exemptions. The protection of domestic markets from imports and inward FDI provided Japanese firms with a large and growing market for their products. This restriction on inward FDI forced American and European firms with advanced technologies to sell their technologies instead of exploiting them via direct investment, thereby enabling Japanese firms to import these technologies separately.

Yet, knowing that the restriction would be eliminated in the near future, Japanese firms were under intense threat of entry by advanced foreign rivals. Moreover, this threat was credible. In the automobile and electrical equipment industries, Japanese firms remembered the advanced technological and managerial capabilities of American and European firms, as rivals (for example, GM and Ford) or as major shareholders (for example, GE was 51 per cent owner of Toshiba, Western Electric 54 per cent owner of NEC, and Siemens 30 per cent owner of Fuji Electric). They were keenly aware that, without catching up technologically, they would be wiped out by foreign entrants.

This leads to the second implication for developing countries: *the role of inward FDI.* Theoretically, FDI is an important channel of technology transfer as MNCs are leading innovators and transfer the latest knowledge to their affiliates. Some of their knowledge and skills spills over to local firms by means of technological advice given to local suppliers, the move of management staff, researchers and workers from foreign to domestic firms, and the emulation by domestic firms of the practices of foreign firms. The presence of foreign firms also makes domestic markets more competitive, giving an incentive for domestic firms to raise their productivity.

However, FDI can also constrain local technology development. Once foreign firms dominate domestic markets, domestic firms may lose the opportunity to expand their operation to attain economies of scale and to accumulate production volume needed to learn by doing. The expected profitability from R&D investment may become too low and the cash flow needed to finance R&D may be insufficient. These tendencies may yield a negative spiral, making domestic firms even less competitive and foreign firms more dominant. Thus, government restrictions on inward FDI, as well as on imports, in post-war Japan made sense. We emphasize again, however, that the restriction has to be short term, providing domestic firms with a potential entry threat. In addition, export by domestic firms should be encouraged not only to earn foreign exchange but also to make them face competition in export markets against foreign firms

Does this suggest that developing countries today should restrict inward FDI? We doubt if there is a clear-cut answer to this question. The political feasibility of such a policy is questionable. Besides, the economic environment and the historical background differ significantly from those of post-war Japan. Initial technological capabilities, management know-how, and worker skills were much higher in Japan than in most developing countries. Technologies at the time were less complex and less science based, and the technological gap between Japan and more advanced nations smaller. In these conditions, restricting FDI may only lead to the deterioration of technological levels rather than to faster development of local capabilities. In addition, infant industry protection may be more difficult. Ordinary citizens can easily access information on other markets, and multinational companies can readily switch production bases across countries.

Nevertheless, under the right conditions, such as an educated and entrepreneurial population, protection of industries in which technological catch-up is possible within, say, a decade or two, may be effective, provided the government fixes (credibly) a time limit for the protection. The cost, if industries fail to catch up, may be high and there are clear risks of fostering undesirable political connections between the government and protected industries.

Let us conclude by noting two challenges that Japan now faces. One is the need for more basic research and its application to industrial purposes. The proportion of national R&D spent for basic research was slightly lower in Japan (14.4 per cent) than in the USA (16.6 per cent) in 1998 and the proportion spent by universities was higher in Japan (20.0 per cent) than in the USA (14.4 per cent), suggesting that industries undertook relatively more basic research in the USA. R&D expenditure in the university sector was 3223 billion yen in Japan and 5313 billion yen in the USA (converted with the OECD purchasing power parity index). Japan's expenditure is smaller than that of the USA but the proportional difference is smaller than for total R&D expenditures. Yet, the number of papers in natural sciences and engineering was more than three times smaller in Japan than in the USA

(301 394 versus 1 048 137) in 1994–98, although the language barrier is undoubtedly one reason for this difference.[7]

Japan also has fewer instances, in comparison to the USA, of university–industry collaboration and of new firms established with technologies invented in universities. It is not that there are no cases of collaboration between universities and industries in Japan; in fact there are many. Yet, institutional rigidity surrounding Japanese universities, mainly because major universities are national, has often forced university researchers to collaborate with the industry only on an informal basis (Odagiri, 1999). This rigidity has been gradually relaxed but there is still much to be improved.

The other challenge is the globalization of Japanese industry. This has two implications. First, in several industries, a major part of the production activity has shifted overseas, most importantly to East Asian countries (including China). Since technology accumulation takes place not only by formal R&D but also through learning at the shop floor level, interaction between these two levels is often essential for efficient innovation and for maintaining high technological capabilities. The disappearance of production facilities from Japan may make this interaction difficult, causing the problem of 'hollowing-out'. Many firms in fact maintain some plants – usually the most advanced ones – within Japan despite higher labour costs, precisely to prevent such hollowing-out of the technological base.

Second, many Japanese firms have established R&D facilities abroad. Some, particularly in East Asia and other developing countries, are small and geared mainly to adapting products and processes to local conditions. Others, particularly those established by automobile, electrical equipment and pharmaceutical producers, have been set up in the USA and Europe to conduct major R&D, often in collaboration with local universities (Odagiri and Yasuda, 1997). Maintaining effective collaboration among these laboratories and headquarters laboratories in Japan has become a difficult issue for many companies.

No doubt, these challenges will loom larger for Japan in coming years. Institutional and organizational innovation to resolve them has to be undertaken by Japanese firms. Whether they succeed will be one of the keys, if not *the* key, to continued technological advance.

NOTES

1. An earlier version of this paper was presented at the workshop on 'Technology Development in East Asia' sponsored by the World Bank Institute in Indonesia, December 2000. We wish to thank Linsu Kim, Sanjaya Lall and other participants of the workshop for helpful comments.

2. Toyota also negotiated a technological agreement with Ford but failed because the US government restricted foreign investment and the sending of engineers abroad after the Korean War broke out (Inoki, 1989).
3. See Ekonomisuto (1984). Case studies of technology import in this section are taken largely from this book.
4. The same can be said about domestic R&D activities. Even when firms do not have formal R&D establishments and researchers, learning often takes place at their production sites and other places. This activity is not captured by R&D statistics.
5. Science and Technology Agency, *Kagaku Gijutsu Hakusho* (White Paper on Science and Technology), various years.
6. For more details, see Goto (1993).
7. All the figures here are taken from NISTEP (2000).

REFERENCES

Bertschek, Irene (1995), 'Product and process innovation as a response to increasing imports and foreign direct investment', *Journal of Industrial Economics*, 63, 341–57.

Blumenthal, T. (1979), 'A note on the relationship between domestic research and development and imports of technology', *Economic Development and Cultural Change*, 27, 303–6.

Brown, John Seeley and Paul Duguid (2000), *Social Life of Information*, Boston, MA: Harvard Business School Press.

Cohen, Wesley M. and Daniel A. Leviathan (1989), 'Innovation and learning: the two faces of R&D', *Economic Journal*, 99, 569–96.

Ekonomisuto (1984), *Shogen Kodo Seicho-ki no Nikon* (Testimony on Japan in the High Growth Era), Tokyo: Mainichi Shinbun-sha.

Fujimoto, Takahiro and Joseph Tidd (1993), 'The UK and Japanese auto industry: adoption and adaptation of Fordism', paper presented at the Tokyo University conference on 'Entrepreneurial Activities and Corporate Systems: The Historical Perspective'. The Japanese translation: 'Ford Shisutemu no Donyu to Genchi Tekiou: Nichi-Ei Jidosha Sangyo no Hikaku Kenkyu', *Keizaigaku Ronshu*, **59**(2), 36–50, and **59**(3), 34–56.

Globerman, Steven (1979) 'Foreign direct investment and "spillover" efficiency benefits in Canadian manufacturing industries', *Canadian Journal of Economics*, 12, 42–56.

Goto, Akira (1993), 'Technology importation: Japan's postwar experience', in Juro Teranishi and Yutaka Kosai (eds), *The Japanese Experience of Economic Reforms*, New York: St Martin's Press, pp. 277–304.

Goto, Akira (2000), 'Japan's national innovation system: current status and problems', *Oxford Review of Economic Policy*, 16, 103–13.

Goto, Akira and Ryuhei Wakasugi (1988), 'Technology policy', in Ryutaro Komiya, Masahiro Okuno and Kotaro Suzumura (eds), *Industrial Policy of Japan*, New York: Academic Press, pp. 183–204.

Haddad, Mona and Ann Harrison (1993), 'Are there positive spillovers from direct foreign investment? Evidence from panel data for Morocco', *Journal of Development Economics*, 42, 51–74.

Hiroshige, Toru (1973), *Kagaku no Shakai-shi* (Social History of Science), Tokyo: Chuo Koron-sha.

Inoki, Takenori (1989), 'Seicho no Kiseki: 1' (Path of growth; 1), in Yasukichi Yasuba and Takenori Inoki (eds), *Nihon Keizai-shi*, vol. 8, Tokyo: Iwanami Shoten, pp. 97–151.

Komiya, Ryutaro (1972), 'Direct foreign investment in postwar Japan', in Peter Drysdale (ed.), *Direct Foreign Investment in Asia and the Pacific*, Toronto: University of Toronto Press, pp. 137–72

Lichtenberg, Frank and Bruno van Pottelsberghe de la Potterie (1996), 'International R&D spillovers: a re-examination', NBER working paper series No. 5668, New York: National Bureau of Economic Research.

Miyazaki, Masayasu and Osamu Ito (1989), 'Senji Sengo no Sangyo to Kigyo' (Industries and firms during and after the war), in Takafusa Nakamura (ed.), *Nihon Keizaishi, 7: Keikakuka to Minshuka*, Tokyo: Iwanami Shoten, pp. 165–235.

NISTEP, (National Institute of Science and Technology Policy) (2000), 'Kagaku Gijutsu Shihyo' (Science and technology indicators), NISTEP report No. 66.

Odagiri, Hiroyuki (1999), 'University–industry collaborations in Japan: facts and interpretations', in Lewis M. Branscomb, Fumio Kodama and Richard Florida (eds), *Industrializing Knowledge: University–Industry Linkages in Japan and the United States*, Cambridge, MA: MIT Press, pp. 252–65.

Odagiri, Hiroyuki and Akira Goto (1996), *Technology and Industrial Development in Japan*, Oxford: Oxford University Press.

Odagiri, Hiroyuki and Hideto Yasuda (1997), 'The overseas R&D activities of Japanese firms', in Akira Goto and Hiroyuki Odagiri (eds), *Innovation in Japan*, Oxford: Oxford University Press, pp. 204–28.

Odaka, Konosuke (1989), 'Seicho no Kiseki: 2' (Path of growth: 2), in Yasukichi Yasuba and Takenori Inoki (eds), *Nihon Keizaishi, 8: Kodo Seicho*, Tokyo: Iwanami Shoten, 153–208.

Sekiguchi, Sueo (1986), 'Gijutsu Yunyu-sha to shiteno Nihon' (Japan as a technology importer), in Sueo Sekiguchi and Tran Van Tho (eds), *Chokusetsu Toshi to Gijutsu Iten*, Tokyo: Japan Center for Economic Research.

Tokui, Joji, Tsutomu Miyakawa and Takehiko Yasuda (1999), 'Tainichi Chokusetsu Toshi to Nihon Kigyo no R&D Katsudo' (Direct investment to Japan and R&D activity of Japanese firms), Gakushuinn University GEM discussion paper series No. 99–3.

Veugelers, Reinhilde and Peter Vanden Houte (1990), 'Domestic R&D in the presence of multinational enterprises', *International Journal of Industrial Organization*, 8, 1–15.

5. Overseas R&D activities and intra-firm technology transfer: the case of Japanese multinationals

Shujiro Urata and Hiroki Kawai[1]

1. INTRODUCTION

The importance of technology in determining competitiveness, for firms as well as for countries, has increased. For developing countries assimilating foreign technology has always been crucial to economic growth. Indeed, many successful cases of economic development, including Japan, Korea and Taiwan in East Asia, indicate that the successful assimilation of foreign technology played a very important role. Various channels exist for developing countries to obtain technology from foreign countries. The import of capital goods and technology through licensing were major channels for obtaining technology for Japan and Korea in the post-World War II period, while foreign direct investment (FDI) was also an important channel for Taiwan. In addition, visits by foreign researchers and engineers were used as channels for obtaining foreign technology for these countries.

The role of FDI in technology transfer has grown greatly in recent years, for several reasons. First, FDI has risen rapidly, faster than other international transactions. Thus, world trade in goods and services increased 1.6 times from 1990 to 1998, while FDI increased 3.2 times. Asia recorded the fastest growth in FDI inflows in the world in this period, growing 4.2 times. Second, firms have come to prefer FDI to exporting products or licensing foreign firms as a mode of exploiting their competitive technologies abroad. This preference stems from possible market failures in the technology market: the more sophisticated technologies are, the more difficult it is to value them appropriately and thus the more difficult it is to trade them in arm's length transactions. Furthermore, it is often difficult to monitor the use or abuse of technology by the licensee. To avoid these problems, and to reap the rewards of increasingly expensive R&D, firms tend to use FDI as the main means of deploying technologies (in particular new technologies) in foreign countries.

FDI transfers technology in two ways. One is intra-firm (technology transfers from a parent company to its affiliates). The other is technology spillover from affiliates to local firms in host countries. Both contribute to upgrading technological capability of host countries. For foreign firms undertaking FDI, intra-firm technology transfer is very important because the success or failure of intra-firm technology transfer affects performance of their affiliates. Given the growing importance of FDI, it is also becoming more important for host countries to maximize the spillover effects of affiliates and effectively assimilate them.

This chapter analyses the R&D activities of Japanese firms and their impact on intra-firm technology transfer to developing countries, particularly in East Asia. We choose Japanese firms for two reasons. One is the large size of Japanese FDI in Asia, which makes the analysis useful and interesting for Asian countries. The other is the availability of detailed firm-level data, derived from a survey conducted by the Japanese Ministry of International Trade and Industry (MITI). An analysis of firm-level data provides interesting insights that are not obtained from more aggregated figures. Section 2 reviews briefly the recent development of Japanese FDI. Section 3 analyses overseas R&D activities by Japanese firms. Section 4 examines intra-firm technology transfer by Japanese firms. Section 5 presents some concluding remarks.

2. RAPID EXPANSION OF JAPANESE FDI IN THE 1980S AND SUBSEQUENT SLOWDOWN IN THE 1990S

Japanese FDI increased rapidly in the latter half of the 1980s, undergoing major changes in its regional and sectoral composition (Figures 5.1 and 5.2).[2] The number of overseas investments each year increased sharply from around 2500 in the early 1980s to more than 6000 in the latter half of the decade. Equally dramatic, however, was the pace at which Japanese FDI declined after peaking in 1989. The decline continued through 1994, when the number of overseas direct investments was less than 40 per cent of the level in 1988. From 1994 through 1997, the year of the financial crisis in East Asia, the number of annual investments remained more or less stable, before recording another large drop in 1998.

Both 'push' and 'pull' factors explain recent trends in Japanese FDI. The push factors are those in the home country (Japan), while the pull factors are those in the host countries. There were several *push factors* behind the rapid growth of Japanese FDI in the latter half of the 1980s.

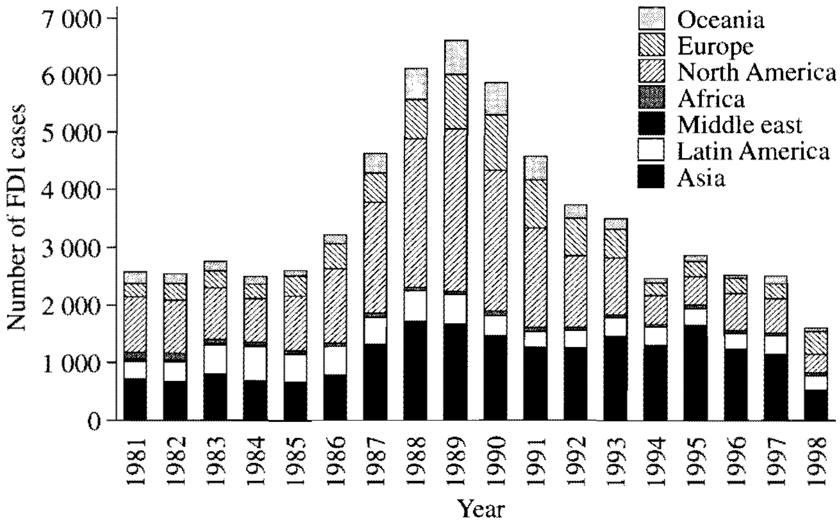


Figure 5.1 Japanese foreign direct investment by region, 1981–98

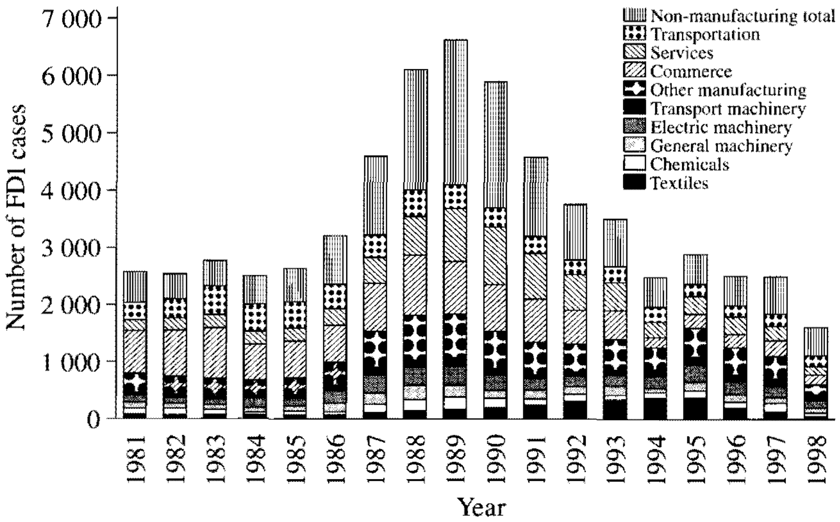


Figure 5.2 Japanese foreign direct investment by industry, 1981–98

- The rapid and steep appreciation of the yen against other currencies was the most important macroeconomic factor; the real effective exchange rate of the yen appreciated by 37 per cent between 1985 and 1988. This stimulated Japanese FDI in two ways: the 'relative price' effect and the 'liquidity' or 'wealth' effect. The former significantly reduced the international price competitiveness of Japanese products, inducing many Japanese firms to relocate production overseas, especially in East Asia where production costs were lower. The yen appreciation also made Japanese firms more 'wealthy' in terms of increased collateral and liquidity, and enabled them to finance overseas investments more cheaply than foreign competitors. Japanese firms undertook many FDI projects in real estate by taking advantage of this liquidity effect.
- Another important push factor was the emergence of the 'bubble' economy in Japan. The liquidity effect was strengthened by the rapid rise in the prices of such assets as shares and land. The average share price in Japan more than doubled between 1985 and 1989, the index of share prices rising from 45.7 in 1985 to 117.8 in 1989.
- The growth of outward FDI also reflected the growing managerial and technological capabilities of Japanese firms, based not just on domestic production but also on export experience.
- Once the largest Japanese firms set up facilities overseas, a number of their suppliers followed them to retain their customers.
- Growing labour shortages and rising wages in Japan forced some firms, especially SMEs, to move their operation abroad.

The decline in Japanese FDI in the early 1990s resulted mainly from the bursting of the bubble economy in 1989, which made it difficult for firms to raise financial resources for FDI. The depreciation of the yen also contributed. In the 1990s the depressed economic situation in Japan, with a consequent poor financial performance by Japanese firms, exacerbated the constraints on FDI.

Japanese FDI in the second half of the 1980s was directed largely to North America and Europe and focused on non-manufacturing sectors like services and real estate. These two regions together accounted for more than 50 per cent of the number of overseas investments in this period.[3] Although a smaller share of FDI went to Asia, in the 1980s the main focus was on manufacturing. The 1990s saw changes in FDI patterns. First, the share of Asia, particularly East Asia including the NIEs,[4] ASEAN (Association of South East Asian Nations) and China, rose sharply.[5] Indeed, the share of Asia in the number of overseas Japanese investments increased from 25.6 per cent in 1990 to 56.9 per cent in 1995; thereafter, however, this share declined rapidly, reaching 33.6 per cent in 1998. The major *pull factors* in Japanese FDI in East Asia included the region's robust economic growth, low unit labour costs, and trade and FDI policy liberalization.

Since the mid-1980s, the geographical distribution of Japan's FDI in Asia has changed significantly, shifting from the NIEs to the ASEAN4, and then to China and other Asian countries.[6] The NIEs attracted considerable Japanese FDI until the late 1980s; policymakers in Korea, Taiwan and Singapore, in particular, promoted inward FDI in their pursuit of high-tech industrialization. Japanese FDI in the NIEs reached a peak in 1988; the NIEs then started to lose their cost advantages due to rapid wage increases and currency appreciation. Firms in Japan and other advanced economies started to look to other East Asian countries such as the ASEAN4 as hosts for investment. One important factor in attracting manufacturing FDI to the ASEAN4 was the shift in strategy from inward to outward-orientation, carried out through the liberalization of trade and FDI policies.

FDI in China grew quickly after 1990 due to China's economic reforms, liberalization of trade and FDI policies and political and social stability (despite the Tiananmen Square incident in 1989). By 1995, China was the largest recipient of Japanese FDI in Asia. The attractiveness of China as a host country increased as costs in the ASEAN countries rose, with rising wages, material and service costs, in turn reflecting currency appreciation, growing labour shortages, infrastructure bottlenecks and other factors.[7]

Japanese FDI in Asia has been distinguished by its emphasis on manufacturing, with the share of manufacturing around 50 per cent through the 1980s, and reaching over 70 per cent in 1995. Within manufacturing, textiles and electrical machinery increased their share in the 1990s, accounting for 20.8 and 14.0 per cent, respectively, in 1995.[8] Reflecting Japanese FDI as a whole, the geographical distribution of FDI in most manufacturing subsectors shifted from the NIEs to the ASEAN4 and then to China over the period. This shift was most pronounced in the textile sector.

3. OVERSEAS R&D ACTIVITIES

3.1 The Pattern of Overseas R&D by Japanese Firms

The analysis of R&D in overseas Japanese affiliates is based on a 1992 MITI survey of the overseas activities of Japanese firms.[9] Before conducting the analysis, a discussion of the database used for the analysis is in order. Table 5.1 shows the geographical and sectoral distribution of overseas affiliates in the sample. In 1992 there were 7096 overseas affiliates of Japanese firms in the world. Asia was the most popular destination, hosting

Table 5.1 Overseas affiliates of Japanese firms (number)

	North America	Latin America	Asia	East Asia	NIEs	Hong Kong	Korea	Singapore	Taiwan	ASEAN4
Agriculture	8	18	17	15	0	0	0	0	0	14
Mining	17	7	6	6	1	0	0	1	0	5
Manufacturing	707	163	1528	1469	676	109	145	163	259	656
Food	50	13	67	63	27	7	5	8	7	26
Textiles	10	22	129	128	36	19	8	1	8	57
Wood, pulp	11	3	22	22	9	1	1	3	4	11
Chemicals	95	14	225	219	103	9	23	22	49	103
Coal & oil products	3	2	4	4	2	0	0	1	1	1
Iron & steel	36	5	58	56	19	2	4	8	5	33
Non-ferrous metals	30	6	47	47	13	0	3	7	3	33
General machinery	70	15	91	90	60	7	10	19	24	24
Electric machinery	160	45	416	408	208	34	37	65	72	170
Transport machinery	107	20	171	148	51	2	8	4	37	86
Precision machinery	27	2	37	37	24	4	7	4	9	6
Other manufacturing	108	16	261	247	124	24	39	21	40	106
Construction	41	14	114	108	37	8	2	12	15	64
Commerce	531	140	548	543	405	174	7	151	73	133
Services	375	121	304	296	176	78	10	69	19	101
Others	188	42	78	76	46	22	1	17	6	20
Total	1867	505	2595	2513	1341	391	165	413	372	993

	Indonesia	Malaysia	Philippines	Thailand	China	Middle East	Europe	Oceania	Africa	Total
Agriculture	6	1	6	1	1	0	7	8	4	62
Mining	3	0	2	0	0	3	24	29	3	89
Manufacturing	126	210	69	251	137	10	529	78	13	3028
Food	3	6	3	14	10	0	13	13	1	157
Textiles	21	10	3	23	35	0	8	3	1	173
Wood, pulp	5	5	1	0	2	0	9	3	0	48
Chemicals	22	29	12	40	13	3	68	10	1	416
Coal & oil products	0	0	0	1	1	0	3	1	0	13
Iron & steel	7	10	4	12	4	1	2	2	2	106
Non-ferrous metals	5	11	2	15	1	0	7	4	1	95
General machinery	5	6	3	10	6	0	73	5	0	254
Electric machinery	14	90	11	55	30	4	183	9	3	820
Transport machinery	23	11	20	32	11	0	56	15	2	371
Precision machinery	0	3	1	2	7	0	20	2	0	88
Other manufacturing	21	29	9	47	17	2	87	11	2	487
Construction	13	20	8	23	7	7	24	5	2	207
Commerce	10	46	12	65	5	19	730	122	11	2101
Services	18	26	13	44	19	1	241	67	39	1148
Others	1	4	6	9	10	2	96	23	32	461
Total	177	307	116	393	179	42	1651	332	104	7096

Source: MITI, *Kaigai Jigyo Katsudo Kihon Chosa* (Comprehensive Survey of Overseas Activities of Japanese Firms), no. 5, Tokyo, 1993.

2595 affiliates (36.6 per cent). North America and Europe were the next most popular destinations, with 1867 and 1651 overseas affiliates, or 26.3 and 23.3 per cent of total, respectively. Within East Asia, Singapore, Thailand, Hong Kong, and Taiwan hosted similar numbers of Japanese affiliates, around 400 each (5–6 per cent of the total number of affiliates each). These were followed by Malaysia with 307 affiliates (4.3 per cent), and China, Indonesia and Korea with approximately 170 affiliates each (2.5 per cent each).

In terms of the sectoral distribution of affiliates, manufacturing accounted for the largest number at 3028 (42.7 per cent). Trade and services followed with 2101 and 1609 (29.6 and 22.7 per cent). Among manufacturing subsectors, electrical machinery had the largest number of affiliates at 820, far ahead of chemicals, which came second with 416. The share of manufacturing was higher, and that of services lower, in Asia relative to the rest of the world. Among manufacturing subsectors, electrical machinery, chemicals, transport machinery and textiles had high shares.

Table 5.2 shows the geographical and sectoral spread of the overseas R&D units of Japanese MNCs in 1992. There were 291 such units in total, with North America hosting the largest number at 143; this share, 49.1 per cent, was significantly higher than the corresponding share for overseas affiliates (26.3 per cent), indicating the technological strength of the region. Asia was the second most popular region, with 81 R&D units (27.8 per cent). Taiwan accounted for the largest number in Asia, with 34 units (11.7 per cent). Korea came next with 12 units, followed in descending order by Singapore, Malaysia, Thailand, China, Philippines, Indonesia and Hong Kong. By industry, chemicals, electric machinery and food each had large numbers of R&D units throughout the world. In East Asia, food and chemicals had by far the largest number of units; Taiwan hosted as many as 21 and 8 R&D units in food and chemical industries, respectively.

The intensity of Japanese overseas R&D, as measured by the ratio of overseas R&D units to affiliates, was highest in North America (7.7 per cent), compared to 4.1 overall and 3.1 for Asia. These average figures mask substantial variations between countries, with Taiwan at 9.1, higher than North America, and Korea at 7.3, almost comparable to North America.

The position of East Asia for overseas R&D by Japanese MNCs differs by the indicators used to measure R&D activities. In terms of *R&D spending* East Asia had a very low rank, accounting for only 4.2 per cent of total overseas R&D (Table 5.3). By contrast, North America and Europe accounted for 43.5 and 50.6 per cent, respectively. This is also reflected in the R&D/sales ratio of Japanese affiliates: East Asia registers 0.04 per cent, significantly lower than North America (0.19 per cent) or Europe (0.28 per cent).[10] Within Asia, Japanese affiliates in Taiwan and Korea have far higher figures than other economies; Malaysia and the Philippines register relatively high values in the ASEAN4.

The regional R&D gap appears smaller, however, if R&D activities are measured by numbers of researchers (Table 5.4). Japanese affiliates employed the largest number of researchers in East Asia (40 per cent of the world total), while North America and Europe employed 29 and 18 per cent, respectively. The considerably higher expenditure per researcher in the industrialized regions presumably reflected both the higher cost of research staff as well as the more advanced nature of R&D undertaken. Among East Asian economies, Thailand had the largest number of researchers, while the Philippines and China each had a very small number of researchers.

Taking the ratio of the number of researcher to total employees in affiliates, we find that the ratios are higher for North America (4.1%) and Europe (3.8%) than in East Asia (2.9 per cent). Unlike R&D–sales ratios, researcher–employee ratios are comparable across East Asian economies except for Thailand, where the ratio is notably high.

R&D units serve several functions, including information collection, production and sales support and new product development. It is important to recognize the functions of R&D units when assessing their effectiveness in transferring technology. According to Table 5.5, a large number of R&D units in Asia were set up to provide production support,[11] with approximately one out of every two R&D units established for that purpose. There is an interesting pattern in the share of R&D units providing production support in East Asia. Some 71 per cent of Japanese R&D units in China are assigned to production support, while the corresponding share in the ASEAN4 is 47.2 per cent and in the NIEs 39.3 per cent.

The development of products for the local market is the second most important function in East Asia, with 38.8 per cent of units devoted to this purpose, particularly in the NIEs and the ASEAN4. R&D units in East Asia perform two more functions: modification of imported products for local sales and collection of information on the local market, 23.1 per cent and 20.7 per cent by number of R&D units, respectively. The pattern differs from industrialized countries, where R&D units are more focused on new product development and basic research and less on production support.

The geographical allocation and functions of Japanese R&D units are consistent with differences in technological capabilities in the different regions. Most economies in East Asia are competitive in production using standard technologies, and the major role of R&D units is to provide production support. However, it should also be noted that many East Asian economies do possess strong technological capabilities, which are reflected in the relatively high proportion of economies hosting R&D units for the development of new products. In developed countries, with their richer

Table 5.2 Overseas R&D units of Japanese firms (number)

	North America	Latin America	Asia	East Asia	NIEs	Hong Kong	Korea	Singapore	Taiwan	ASEAN4
Agriculture	0	2	0	0	0	0	0	0	0	0
Mining	0	0	0	0	0	0	0	0	0	0
Manufacturing	107	13	77	73	51	0	12	5	34	16
Food	16	0	23	23	22	0	0	1	21	1
Textiles	0	1	1	1	0	0	0	0	0	1
Wood, pulp	0	1	1	1	0	0	0	0	0	1
Chemicals	24	6	20	20	14	0	4	2	8	6
Coal & oil products	0	0	0	0	0	0	0	0	0	0
Iron & steel	4	0	0	0	0	0	0	0	0	0
Non-ferrous metals	5	2	2	2	1	0	1	0	0	1
General machinery	11	3	6	6	6	0	4	1	1	0
Electric machinery	34	0	6	5	2	0	1	1	0	3
Transport machinery	7	0	10	7	4	0	1	0	3	3
Precision machinery	1	0	0	0	0	0	0	0	0	0
Other manufacturing	5	0	8	8	2	0	1	0	1	0
Construction	0	0	0	0	0	0	0	0	0	0
Commerce	11	0	4	4	3	1	0	2	0	1
Services	8	0	0	0	0	0	0	0	0	0
Others	17	0	0	0	0	0	0	0	0	0
Total	143	15	81	77	54	1	12	7	34	17

	Indonesia	Malaysia	Philippines	Thailand	China	Middle East	Europe	Oceania	Africa	Total
Agriculture	0	0	0	0	0	0	1	0	0	3
Mining	0	0	0	0	0	0	0	0	0	0
Manufacturing	2	6	2	6	6	0	34	3	0	234
Food	0	1	0	0	0	0	1	1	0	41
Textiles	0	1	0	0	0	0	0	0	0	2
Wood, pulp	0	0	1	0	0	0	0	0	0	2
Chemicals	1	1	0	4	0	0	4	0	0	54
Coal & oil products	0	0	0	0	0	0	0	0	0	0
Iron & steel	0	0	0	0	0	0	0	0	0	4
Non-ferrous metals	0	1	0	0	0	0	1	0	0	10
General machinery	0	0	0	0	0	0	7	0	0	27
Electric machinery	0	2	0	1	0	0	9	0	0	49
Transport machinery	1	0	1	1	0	0	5	1	0	23
Precision machinery	0	0	0	0	0	0	2	1	0	4
Other manufacturing	0	0	0	0	6	0	5	0	0	18
Construction	0	0	0	0	0	0	0	0	0	0
Commerce	0	0	1	0	0	0	5	0	0	20
Services	0	0	0	0	0	0	5	0	0	13
Others	0	0	0	0	0	0	4	0	0	21
Total	2	6	3	6	6	0	49	3	0	291

Source: MITI, *Kaigai Jigyo Katsudo Kihon Chosa* (Comprehensive Survey of Overseas Activities of Japanese Firms), no. 5, Tokyo, 1993.

Table 5.3 Overseas R&D by Japanese firms (million yen)

	North America	Latin America	Asia	East Asia	NIEs	Hong Kong	Korea	Singapore	Taiwan	ASEAN4
Agriculture	10	6	0	0	0	0	0	0	0	0
Mining	0	60	0	0	0	0	0	0	0	0
Manufacturing	48071	319	6585	5627	4187	15	893	653	2626	1416
Food	130	0	91	91	83	0	1	10	72	8
Textiles	0	2	172	172	43	0	38	0	5	126
Wood, pulp	10	93	130	130	10	0	0	0	10	120
Chemicals	10956	21	827	827	728	0	477	25	226	94
Coal & oil products	0	0	0	0	0	0	0	0	0	0
Iron & steel	764	0	0	0	0	0	0	0	0	0
Non-ferrous metals	477	138	62	62	16	0	12	4	0	36
General machinery	5453	35	209	209	201	0	17	70	114	8
Electric machinery	23664	30	1959	1941	1049	15	309	511	214	892
Transport machinery	3719	0	1157	219	151	0	16	6	129	68
Precision machinery	90	0	151	151	151	0	2	27	122	0
Other manufacturing	2808	0	1827	1825	1755	0	21	0	1734	64
Construction	2	11	1	1	0	0	0	0	0	0
Commerce	631	0	285	285	277	191	0	86	0	8
Services	4737	0	5	5	5	0	0	0	5	0
Others	7088	0	1	1	0	0	0	0	0	1
Total	60539	396	6877	5919	4469	206	893	739	2631	1425

	Indonesia	Malaysia	Philippines	Thailand	China	Middle East	Europe	Oceania	Africa	Total[1]
Agriculture	0	0	0	0	0	0	7	0	0	23
Mining	0	0	0	0	0	0	0	0	0	60
Manufacturing	45	984	162	225	24	0	68974	1291	6	125246
Food	0	0	0	8	0	0	80	25	0	326
Textiles	18	13	0	95	3	0	302	0	2	478
Wood, Pulp	0	0	120	0	0	0	0	0	0	233
Chemicals	1	44	0	49	5	0	1320	0	0	13124
Coal & oil products	0	0	0	0	0	0	0	0	0	0
Iron & steel	0	0	0	0	0	0	0	0	0	764
Non-ferrous metals	4	2	10	20	10	0	45	136	0	858
General machinery	0	0	0	8	0	0	3286	0	0	8983
Electric machinery	0	844	20	28	0	0	54222	66	0	79941
Transport machinery	22	20	12	14	0	0	2403	1046	4	8329
Precision machinery	0	0	0	0	0	0	689	18	0	948
Other manufacturing	0	61	0	3	6	0	6627	0	0	11262
Construction	0	0	0	0	1	0	0	0	0	14
Commerce	0	0	8	0	0	0	307	1	0	1224
Services	0	0	0	0	0	0	19	0	0	4761
Others	0	0	0	1	0	0	1248	57	0	8790
Total	45	984	170	226	25	0	70555	1349	6	139326

Note: [1] The totals ae for North America, Latin America, Asia, the Middle East, Europe, Oceania, and Africa.

Source: MITI, *Kaigai Jigyo Katsudo Kihon Chosa* (Comprehensive Survey of Overseas Activities of Japanese Firms), no. 5, Tokyo, 1993.

Table 5.4 *Researchers at overseas affiliates by Japanese firms (number)*

	North America	Latin America	Asia	East Asia	NIES	Hong Kong	Korea	Singapore	Taiwan	ASEAN4
Agriculture	15	16	6	6	0	0	0	0	0	6
Mining	4	633	0	0	0	0	0	0	0	0
Manufacturing	11147	1692	17184	16161	5613	696	1342	1649	1926	9753
Food	183	3	433	433	145	0	10	29	106	281
Textiles	205	64	4892	4892	113	10	93	0	10	4574
Wood, pulp	92	0	16	16	1	0	0	1	0	15
Chemicals	1393	219	2047	2047	971	40	449	168	314	1022
Coal & oil products	5	0	35	35	30	0	0	0	30	5
Iron & steel	107	0	21	21	3	0	0	2	1	16
Non-ferrous metals	630	109	586	586	81	0	55	22	4	466
General machinery	1047	90	973	973	817	480	52	132	153	154
Electric machinery	3474	570	2733	2592	1258	41	300	405	512	1197
Transport machinery	1688	386	3352	2775	1162	0	212	867	83	1348
Precision machinery	5	0	230	230	210	10	20	18	162	3
Other manufacturing	2318	251	1866	1561	822	115	151	5	551	672
Construction	220	58	1393	1393	451	76	3	131	241	873
Commerce	768	43	774	774	262	196	0	66	0	512
Services	515	69	72	72	26	0	23	0	3	4
Others	1343	4	624	624	468	0	468	0	0	156
Total	14012	2515	20053	19030	6820	968	1836	1846	2170	11304

	Indonesia	Malaysia	Philippines	Thailand	China	Middle East	Europe	Oceania	Africa	Total
Agriculture	6	0	0	0	0	0	19	0	0	56
Mining	0	0	0	0	0	35	7	0	434	1113
Manufacturing	1804	1601	312	6036	795	45	7791	492	1106	39457
Food	61	152	0	68	7	0	112	31	0	762
Textiles	437	195	0	3942	205	0	5	0	1096	6262
Wood, pulp	0	2	13	0	0	0	139	0	0	247
Chemicals	544	137	3	338	54	35	695	10	0	4399
Coal & oil products	0	0	0	5	0	0	0	0	0	40
Iron & Steel	0	6	10	0	2	2	0	0	10	140
Non-Ferrous metals	128	35	25	278	39	0	18	10	0	1353
General machinery	10	93	2	49	2	0	870	0	0	2980
Electric machinery	0	592	216	389	137	8	1618	10	0	8413
Transport machinery	481	51	40	776	265	0	399	430	0	6255
Precision machinery	0	3	0	0	17	0	187	0	0	422
Other manufacturing	143	335	3	191	67	0	3748	1	0	8184
Construction	169	117	57	530	69	16	174	0	0	1861
Commerce	0	100	12	400	0	0	337	317	0	2239
Services	0	1	0	3	42	0	71	38	0	765
Others	0	0	134	22	0	0	276	4	0	2251
Total	1979	1819	515	6991	906	96	8675	851	1540	47742

Source: MITI, *Kaigai Jigyo Katsudo Kihon Chosa* (Comprehensive Survey of Overseas Activities of Japanese Firms), no. 5, Tokyo, 1993.

Table 5.5 Functions of affiliates' research centres (%)

	Information collection	Collaboration with university	Sales support	Production support	Product design	Modification of imports
North America	31.5	8.7	33.7	30.4	21.7	15.2
Latin America	14.3	7.1	14.3	21.4	0.0	21.4
Asia	20.7	0.8	11.6	44.6	2.5	23.1
East Asia	19.8	0.9	11.2	44.8	2.6	13.8
NIEs	21.4	1.8	12.5	39.3	1.8	19.6
Hong Kong	20.0	0.0	20.0	40.0	0.0	20.0
Korea	20.0	6.7	6.7	20.0	0.0	13.3
Singapore	25.0	0.0	25.0	58.3	0.0	16.7
Taiwan	20.8	0.0	8.3	41.7	4.2	25.0
ASEAN4	18.9	0.0	11.3	47.2	3.8	7.5
Indonesia	22.2	0.0	11.1	33.3	11.1	0.0
Malaysia	27.3	0.0	13.6	36.4	0.0	4.5
Philippines	0.0	0.0	0.0	50.0	0.0	16.7
Thailand	12.5	0.0	12.5	68.8	6.3	12.5
China	14.3	0.0	0.0	71.4	0.0	14.3
Middle East	n/a	n/a	n/a	n/a	n/a	n/a
Europe	8.7	0.0	19.6	32.6	10.9	17.4
Oceania	50.0	0.0	50.0	50.0	50.0	0.0
Africa	33.3	0.0	0.0	66.7	0.0	0.0
Total	22.3	3.6	20.5	37.1	10.4	19.1

	Development of local product	Development of new products	Development of exports	Basic research	Others	Sample size
North America	41.3	22.8	18.5	16.3	12.0	92
Latin America	64.3	0.0	7.1	0.0	0.0	14
Asia	38.8	4.1	7.4	4.1	5.0	121
East Asia	38.8	6.0	8.6	2.6	5.2	116
NIEs	41.1	7.1	7.1	3.6	5.4	56
Hong Kong	20.0	20.0	20.0	20.0	0.0	5
Korea	53.3	20.0	13.3	0.0	0.0	15
Singapore	0.0	0.0	0.0	0.0	16.7	12
Taiwan	58.3	0.0	4.2	4.2	4.2	24
ASEAN4	39.6	5.7	11.3	0.0	5.7	53
Indonesia	33.3	22.2	22.2	0.0	11.1	9
Malaysia	40.9	0.0	13.6	0.0	9.1	22
Philippines	50.0	16.7	0.0	0.0	0.0	6
Thailand	37.5	0.0	6.3	0.0	0.0	16
China	14.3	0.0	0.0	14.3	0.0	7
Middle East	n/a	n/a	n/a	n/a	n/a	n/a
Europe	52.2	6.5	8.7	2.2	2.2	46
Oceania	0.0	0.0	0.0	0.0	0.0	2
Africa	66.7	0.0	33.3	0.0	0.0	3
Total	43.2	10.4	11.5	7.6	6.5	278

Source: MITI, *Kaigai Jigyo Katsudo Kihon Chosa* (Comprehensive Survey of Overseas Activities of Japanese Firms), no. 5, Tokyo, 1993.

base of scientists and engineers, competitiveness lies in developing new products and conducting basic research.

3.2 The Determinants of Overseas R&D Activities by Japanese Firms

This section examines the determinants of overseas R&D by Japanese MNCs, starting with previous studies of this subject. Odagiri and Yasuda (1996 and 1997) conduct detailed analyses of overseas R&D by Japanese firms, using industry and firm-level data. They find that Japanese MNCs active in overseas R&D activities have the following characteristics: large size, high export–sales ratios, high overseas to total (parent and affiliates) sales ratios, large numbers of overseas production units, high R&D–sales ratios and low technological advantage. Their findings suggest that R&D activities are subject to economies of scale and scope, and that firms with high sales dependence on overseas markets tend to undertake more R&D in foreign countries. Overseas R&D is conducted to provide support for local manufacturing and firms set up overseas R&D units to acquire technology.

Their analysis of overseas R&D in Asia is broadly similar, except that the relationships are not statistically significant except for one variable, the technological level of the host country. Unlike the finding for the sample as a whole, Japanese firms set up R&D units in Asia in countries where they have a technological advantage. This seems to indicate that Japanese firms set up R&D units to deploy their technology in Asia rather than to acquire new technology.

As far as affiliates are concerned, Odagiri and Yasuda (1996) find that affiliates with R&D have large sales, high dependence on local sales and high local input content. Furthermore, they find that parent firms with high R&D–sales ratios are also active in R&D activities overseas. These findings are consistent with the findings from their firm-level study (1997), where they find that firms with large sales, high R&D intensity, high dependence on local or overseas market for their sales as well as purchase of their inputs tend to be active in overseas R&D.

We now present the result of regression analysis using firm-level data from the MITI survey. One advantage of this data set is that we can link information on parents to overseas affiliates. We first analyse the determinants of the *decision to set up overseas R&D units*, and then the determinants of the *level of R&D activities by affiliates*. For the analysis of the decision to establish R&D units we use a binary variable that takes the value 1 for the presence of an R&D unit and zero otherwise. For the analysis of the determinants of level of R&D activities in overseas affiliates, we use the value of R&D expenditure and the number of researchers as indicators.

For both analyses, we use the characteristics of parent firms and affiliates as explanatory variables. Specifically, we use the following variables as the characteristics of parent firms (with the variable names and expected signs in parentheses): R&D–sales ratio (*PRD*, +), the number of overseas affiliates (*POA*, +), export-sales ratio (*PEX*, +), overseas production ratio (*POP*, +), royalty receipts–sales ratios (*PRS*, +), and worldwide sales (*PWS*, +).

For overseas affiliates we use the following variables: affiliates' sales/worldwide sales (*ASW*, +), local sales ratio (*ALS*, +), local procurement ratio (*ALP*, +), local procurement ratio for investment goods (*ALPI*, +), number of years in operation (*AYR*, +), share of equity held by parent company (*AEQ*, +) and technology transfer requirement (*ATT*, +). The expected signs are derived mainly from Odagiri and Yasuda (1996 and 1997). Basically, firms with large-scale, active R&D and high dependency on overseas sales are assumed to be active in overseas R&D.

An explanation of the expected signs for two of the variables is in order. The share of equity in an affiliate is likely to influence positively the level of affiliate R&D since a parent with high equity participation would spend more on R&D where it can appropriate a larger share of the returns. The parent would also be willing to spend more on transferring technology effectively to such affiliates. Technology transfer requirements imposed by host governments will also tend to raise affiliate R&D, since MNCs would presumably seek to comply with local policies.

In addition to the characteristics of parent firms and affiliates, we include four characteristics of host economies as independent variables: the quality of human capital (*HC*), the level of R&D (*RD*), the share of manufacturing in GDP (*MANF*) and the cumulative number of Japanese investments (*CFDI*). The quality of human capital is measured by educational attainment ratios, taken from Barro and Lee (2000), while the level of R&D is measured by the share of R&D expenditure to GDP. The expected impact of all these variables on R&D by overseas affiliates is positive.

The results of the analysis are shown in Tables 5.6–5.8. On the determinants of the decision to establish overseas R&D, we find that Japanese parents with active R&D (*PRD*), high technological capability (*PRS*) and large worldwide sales (*PWS*) tend to set up R&D units in developed countries (Table 5.6). However, this relationship is not significant for developing countries. Turning to foreign affiliates, we find that affiliates with high local procurement (*ALP*) and long periods of operation (*AYR*) tend to have R&D units in developed countries. In developing countries, affiliates with large shares in worldwide sales (*ASW*) and those subject to technology transfer requirement (*ATT*) are likely to set up R&D units in East Asia. Technology transfer requirements also have positive effects on affiliate

Table 5.6 The determinants of establishment of overseas R&D units (probit estimation)

	Total		Developed countries		Developing countries		East Asia	
	coefficient	*t*-statistic	coefficient	*t*-statistic	coefficient	*t*-statistic	coefficient	*t*-statistic
Characteristics of parent firm								
PRD	1.738	1.227	5.491	2.624***	−6.117	−1.250	−7.323	−1.186
POA	−0.002	−0.742	−0.002	−0.573	−0.001	−0.282	−0.002	−0.417
PEX	−0.269	−0.637	0.497	0.854	−0.407	−0.600	−0.364	−0.426
POP	−0.265	−0.411	−1.463	−1.637	−0.019	−0.017	−1.240	−0.795
PRS	24.473	2.015**	27.746	1.702*	22.900	1.455	40.935	1.015
PWS	0.154	2.793***	0.169	2.201**	0.087	1.000	0.185	1.555
Characteristics of affiliates								
ASW	1.185	1.275	−2.012	−0.995	1.568	1.148	3.159	1.670*
ALS	0.135	0.774	0.073	0.313	0.363	1.150	0.257	0.662
ALP	0.578	3.244***	0.737	3.078***	0.440	1.341	0.024	0.056
ALPI	0.007	1.443	0.009	1.443	0.010	0.923	0.001	0.070
AYR	0.347	2.485**	0.346	1.872*	0.267	1.083	0.373	1.186
AEQ	0.000	−1.566	0.000	−1.241	0.000	−1.067	0.000	−0.271
ATT	0.326	1.888*	−0.130	−0.327	0.715	3.220***	0.662	2.448**

Characteristics of host countries								
HC	0.008	1.518	0.013	1.946*	0.007	1.151	0.069	1.342
RD	0.211	1.078	0.204	0.480	0.041	1.215	0.280	1.770*
MANF	0.102	0.672	1.871	1.227	0.030	0.131	0.080	0.207
CFDI	0.008	0.116	0.295	1.204	0.219	1.835*	0.732	1.310
R^2	0.163		0.176		0.244		0.255	
lnL	−246.616		−145.234		−82.512		−54.131	
OBS	1493		650		843		710	

Notes:
Characteristics of parent firm: *PRD*: R&D/sales ratio; *POA*: number of overseas affiliates; *PEX*: exports/sales ratio; *POP*: overseas production ratio; *PRY*: royalty receipts/sales ratio; *PWS*: ln(worldwide sales).
Characteristics of overseas affiliates: *ASW*: sales/worldwide sales; *ALS*: local sales ratio; *ALP*: local procurement ratio, *ALPI*: local procurement ratio of investment goods; *AYR*: number of years in operation; *AEQ*: equity participation ratio; *ATT*: technology transfer requirement.
Characteristics of host countries: *HC*: education attainment rate; *RD*: R&D expenditure/GDP; *MANF*: log (GDP of manufacturing sector); *CFDI*: log (accumulative FDI); ***, **, and * indicate statistical significance at 1, 5, and 10 per cent, respectively.

Source: Authors' estimation.

Table 5.7 The determinants of R&D expenditure at overseas affiliates of Japanese firms (dependent variable = ln (R&D expenditure in affiliates) (Tobit Estimation)

	Total		Developed countries		Developing countries		East Asia	
Censored	1305		544		761		642	
Unsensored	190		106		84		68	
	coefficient	*t*-statistic	coefficient	*t*-statistic	coefficient	*t*-statistic	coefficient	*t*-statistic
Characteristics of parent firm								
PRD	13.984	2.187**	26.638	2.710***	9.938	0.879	11.267	0.879
POA	−0.027	−2.542**	−0.047	−2.358**	−0.010	−1.059	−0.008	−0.787
PEX	−0.440	−0.261	2.316	0.841	−1.023	−0.577	−0.410	−0.208
POP	−0.739	−0.278	−9.204	−2.108**	4.953	1.651*	3.310	0.977
PRS	61.694	3.014***	92.594	3.115***	26.248	1.052	31.526	1.236
PWS	0.921	3.969***	1.307	3.324***	0.342	1.383	0.380	1.349
Characteristics of affiliates								
ASW	9.012	2.357**	0.721	0.083	3.447	0.937	5.358	1.294
ALS	−0.272	−0.370	−1.192	−1.021	0.240	0.302	0.155	0.165
ALP	4.654	5.747***	6.483	4.991***	3.043	3.367***	2.136	2.130**
ALPI	0.029	1.243	0.045	1.335	0.019	0.678	−0.002	−0.071
AYR	2.639	4.276***	1.599	1.695*	2.892	4.124***	3.658	4.340***
AEQ	−0.001	−1.381	−0.001	−0.614	−0.001	−1.255	−0.001	−0.692
ATT	1.931	2.554**	1.869	1.121	1.732	2.616***	1.931	2.540**

Characteristics of host countries								
HC	0.054	1.975*	0.003	1.049	0.043	1.529	0.189	1.445
RD	0.818	1.631	1.677	1.811*	0.323	1.661*	0.239	1.402
MANF	0.127	0.202	2.824	0.417	0.606	1.025	1.372	1.719*
CFDI	0.053	0.193	1.747	1.447	0.603	1.767*	2.081	2.352**
R^2	0.085		0.076		0.110		0.125	
lnL	−864.170		−488.574		−353.828		−279.097	

Notes:

Characteristics of parent firm: *PRD*: R&D/Sales ratio; *POA*: number of overseas affiliates; *PEX*: exports/sales ratio; *POP*: overseas production ratio; *PRY*: royalty receipts/sales ratio; *PWS*: ln(worldwide sales).

Characteristics of overseas affiliates: *ASW*: sales/worldwide sales; *ALS*: local sales ratio; *ALP*: local procurement ratio, *ALPI*: local procurement ratio of investment goods; *AYR*: number of years in operation; *AEQ*: equity participation ratio; *ATT*: technology transfer requirement.

Characteristics of host countries: *HC*: education attainment rate; *RD*: R&D expenditure/GDP; *MANF*: log (GDP of manufacturing sector); *CFDI*: log (accumulative FDI); ***, **, and * indicate statistical significance at 1, 5, and 10 per cent, respectively.

Source: Authors' estimation.

Table 5.8 *The determinants of the number of researchers at overseas affiliates of Japanese firms (dependent variable = ln (number of researchers in affiliates) (tobit estimation)*

	Total		Developed countries		Developing countries		East Asia	
Censored	1335		556		779		662	
Uncensored	160		94		66		48	
	coefficient	*t*-statistic	coefficient	*t*-statistic	coefficient	*t*-statistic	coefficient	*t*-statistic
Characteristics of parent firm								
PRD	9.091	2.119**	16.583	2.741***	19.359	1.847*	15.034	1.297
POA	−0.015	−2.127**	−0.022	−2.024**	−0.006	−0.716	−0.005	−0.482
PEX	0.012	0.010	1.019	0.616	0.460	0.274	0.193	0.097
POP	−2.069	−1.096	−7.053	−2.674***	2.024	0.708	1.719	0.519
PRS	39.741	2.906***	53.606	3.118***	35.709	1.627	44.686	1.966*
PWS	0.855	4.914***	0.958	3.916***	0.390	1.576	0.503	1.778*
Characteristics of affiliates								
ASW	9.538	3.580***	0.456	0.083	6.299	1.808*	5.776	1.437
ALS	0.364	0.706	0.425	0.608	0.282	0.371	−0.300	−0.337
ALP	2.506	4.339***	3.211	4.138***	1.957	2.226**	0.607	0.596
ALPI	0.024	1.472	0.020	1.009	0.039	1.389	0.020	0.625
AYR	2.127	4.805***	1.377	2.446**	3.020	4.347***	4.421	4.819***
AEQ	−0.001	−1.684*	0.000	−0.198	−0.002	−2.544**	−0.002	−2.242**
ATT	0.734	1.342	−0.630	−0.545	1.458	2.354**	1.787	2.469**

Characteristics of host countries								
HC	0.004	1.206	0.021	1.570	0.010	1.125	0.029	1.250
RD	0.967	2.622***	0.248	1.215	0.492	2.040*	0.287	1.549
MANF	0.549	1.281	1.440	0.376	0.275	0.507	0.002	0.003
CFDI	0.230	1.201	0.991	1.462	−0.014	0.043	0.219	0.311
R^2	0.101		0.086		0.152		0.175	
lnL	−667.499		−387.988		−260.664		−191.916	

Notes:
Characteristics of parent firm: *PRD*: R&D/sales ratio; *POA*: number of overseas affiliates; *PEX*: exports/sales ratio; *POP*: overseas production ratio; *PRY*: royalty receipts/sales ratio; *PWS*: ln(worldwide sales).
Characteristics of overseas affiliates: *ASW*: sales/worldwide sales; *ALS*: local sales ratio; *ALP*: local procurement ratio, *ALPI*: local procurement ratio of investment goods; *AYR*: number of years in operation; *AEQ*: equity participation ratio; *ATT*: technology transfer requirement.
Characteristics of host countries: *HC*: education attainment rate; *RD*: R&D expenditure/GDP; *MANF*: log (GDP of manufacturing sector); *CFDI*: log (accumulative FDI); ***, **, and * indicate statistical significance at 1, 5, and 10 per cent, respectively.

Source: Authors' estimation.

R&D in developing countries. Although this suggests that technology transfer requirements are effective, it should be noted that such a policy may discourage foreign firms from investing in countries with such policies in the first place.[12]

Let us turn to the determinants of the level of overseas R&D by Japanese MNCs (Tables 5.7 and 5.8). The variables affecting the decision to establish R&D, not surprisingly, also affect the level of affiliate R&D. However, for parent firms the level of globalization (the number of overseas affiliates, *POA*) has a negative impact on the level of R&D by affiliates in developed countries. One explanation for this unexpected result may be that R&D is concentrated in a few locations by the parent firm to maximize the benefits of scale economies in R&D activity. In developing countries, we find that, in addition to technology transfer requirements, affiliates with strong dependence on local inputs (*ALP*) and long periods in operation (*AYR*) are more active in R&D.

The characteristics of host countries also significantly affect the R&D activities of Japanese affiliates. The availability of human capital (*HC*) and R&D resources (*RD*) in the host countries are positively related to R&D by affiliates in developed and developing countries, as is the share of the manufacturing sector in the economy (*MANUF*). The presence of Japanese firms in the host country (*CFDI*) similarly promotes R&D by affiliates. These findings suggest that affiliates undertake R&D to meet the demand for high quality products in the host market.

4. INTRA-FIRM TECHNOLOGY TRANSFER

4.1 Patterns of Intra-Firm Technology Transfer by Japanese Firms

FDI has, as noted, become one of the most important means of transferring technology. Governments in host countries have sometimes used policies like technology transfer requirements, to promote such transfers by MNCs. Of course, efficient technology transfer is as important for MNCs as it is for the host country, since the performance of affiliates depends largely on the technological capabilities developed in the affiliates. However, there may be differences between host countries and MNCs on the depth of technology transfer desired.

This section investigates the extent of technology transfer by Japanese MNCs, at least as far as the data allow. We noted earlier the two types of MNC technology transfer: intra-firm (within the MNC) and technology spillovers to local firms. Intra-firm technology transfer is achieved, among other means, by training (on the job, in parent companies and so on).

Technology spillovers take place in various ways: when local workers, who have acquired technology and skills by working at foreign affiliates, move to local companies, when local firms imitate technology and managerial know-how in foreign affiliates, and so on.[13]

We examine intra-firm technology transfer because of data availability. Before conducting an analysis of technology transfer, we investigate training programmes for local employees given by Japanese affiliates, because training programmes are likely to play an important role in technology transfer and also because such programmes tend to indicate the attitude of Japanese affiliates toward technology transfer in that those affiliates with training programmes are eager to undertake technology transfer.

Training programmes in Japanese MNCs vary widely according to the nature of the programmes and the characteristics of participants. We examine the presence or absence of training programmes and the extent of adoption of the four types of programmes: training at the parent firm, training in Japan but not at the parent firm, training in the affiliate, and training in the host country but not in the affiliate. Table 5.9 presents the relevant information.

Some 9 per cent of Japanese affiliates have training programmes. Those in Asia have the highest percentage (13.4 per cent); within the region, the ASEAN4 and China exhibit high shares. In terms of the types of programmes, training in parent firms is the most popular, with three out of four affiliates with training programmes using this method. In the absence of comparable information on other MNCs, it is impossible to judge whether training at parent firms is particularly important for Japanese firms. However, it seems that Japanese firms regard training at parent firms as particularly important for employees to learn the corporate culture. Training in affiliates is the next most popular mode, one out of three firms with training programmes using this mode. Training outside the firm either in the host country or in Japan is less used (one out of five affiliates).

Technology transfer is difficult to measure.[14] Some researchers of Japanese MNCs have used evaluations of the transfer by the personnel involved, like Yamashita (1991) who asked about the extent of the targeted level of technology transfer achieved, that is, 100 per cent, 50 per cent and so on. One of the problems of this approach is the subjectivity of the evaluation. A manager in charge of technology transfer is likely to give a high evaluation, while a person actually engaged in production may give a low evaluation. To overcome this problem, Urata (1999) used information from a questionnaire survey on the nationality of staff given responsibility for such specific tasks as the maintenance of production lines and product development. If local staff, rather than expatriates, are in charge, it is assumed that the technology has been transferred. We

Table 5.9 Training programmes at overseas affiliates (%)

	Total affiliates with training programme	Of the affiliates with training programme				
		Training at parent firm	Training in Japan	Training at affiliate	Training in host country	Others
North America	6.6	67.5	8.3	50.0	29.2	3.3
Latin America	8.5	82.9	36.6	31.7	19.5	0.0
Asia	13.4	85.0	22.4	30.9	13.9	4.6
East Asia	13.3	86.1	21.9	30.7	14.2	4.0
NIEs	9.6	80.3	12.4	35.8	19.0	2.9
Hong Kong	1.8	40.0	10.0	70.0	10.0	0.0
Korea	15.2	82.1	10.7	32.1	17.9	0.0
Singapore	9.2	82.5	12.5	27.5	27.5	5.0
Taiwan	15.9	84.7	13.6	37.3	15.3	3.4
ASEAN4	17.4	89.6	31.9	25.8	11.5	4.9
Indonesia	19.2	81.8	45.5	30.3	3.0	0.0
Malaysia	18.6	90.2	26.2	24.6	23.0	8.2
Philippines	13.8	84.2	31.6	31.6	5.3	0.0
Thailand	16.8	94.2	30.4	23.2	7.2	5.8
China	17.9	90.9	6.1	36.4	9.1	3.0
Middle East	2.4	0.0	0.0	100.0	0.0	0.0
Europe	7.0	69.3	4.4	50.0	41.2	2.6
Oceania	3.3	63.6	9.1	45.5	54.5	0.0
Africa	2.9	50.0	0.0	75.0	25.0	0.0
Total	9.1	78.2	17.2	38.4	22.5	3.7

Source: MITI, *Kaigai Jigyo Katsudo Kihon Chosa* (Comprehensive Survey of Overseas Activities of Japanese Firms), no. 5, Tokyo, 1993.

adopt a similar methodology, one that is admittedly very simplistic and possibly inaccurate. However, in the absence of workable methodology largely because of lack of necessary information, our methodology may be justified.

The MITI survey asked Japanese MNCs whether local staff were responsible for R&D in affiliates; the results are shown in Table 5.10. On average this was the case in one out of every four affiliates, with very small variations between regions except for Africa, where the figure was only one out of ten affiliates. There are variations in the figures among East Asian economies, with a very high share (61.3 per cent) in Korea and lower shares for the affiliates in Singapore, Indonesia, Hong Kong and Thailand. On sectoral patterns, no clear pattern emerges.

There is a clear need to conduct a more detailed analysis of the determinants of technology transfer. The measures used above are very simple and partial, and do not capture the depth of technology transfer and the costs involved. For instance, they do not allow us to judge whether the transfer is 'truncated', with MNCs transferring production know-how rather than innovation capabilities (R&D may, as noted, be largely geared to production support). However, in the absence of better measures and data, this analysis is a useful step forward.

4.2 Determinants of Intra-Firm Technology Transfer

This section analyses the determinants of successful intra-firm technology transfer. As noted earlier, there are very few studies of this subject for Japanese MNCs. One is by Urata (1999), who analysed 133 cases of intra-firm technology transfer by Japanese firms to Asian affiliates. He found a positive correlation between the extent of technology transfer and the share of equity held by the parent company, when the technologies involved were simple (for example, for equipment maintenance). The opposite was found when sophisticated technologies (such as design technologies, development of new machines and development of new technologies) were involved. He concluded that Japanese MNCs were reluctant to transfer sophisticated technologies to affiliates, transferring such technologies only when there was pressure from joint-venture partners. Urata also found that technology transfer was successful only when MNCs adopted specific measures to promote the transfer, such as providing manuals in local languages and seminars in local areas.

Before we take up the determinants of intra-firm technology transfer we should identify the determinants of training programmes, which are important in determining the outcome of intra-firm technology transfers. We use the same explanatory variables as for the determinants of the adoption of training programmes, but we include additional variables for the determinants of successful technology transfer. The variables and expected signs are: presence of R&D units (*ATRU*, +), presence of training programmes (*ATRN*, +), R&D expenditure (*ARDE*, +) and the number of researchers (*ARES*, +). The expected signs are based on the assumption that R&D as well as training programmes are effective in transferring technology. The probit estimation method was used for both analyses, since in both cases the dependent variables are binary.

The results of the analysis are presented in Table 5.11. Parents with high R&D–sales ratios (*PRD*) and low export ratios (*PEX*) tend to have training programmes in overseas affiliates. Parents with high R&D–sales ratios tend to set up training programmes in affiliates in developing countries and

Table 5.10 Technology transfer at overseas affiliates of Japanese firms

	North America	Latin America	Asia	East Asia	NIEs	Hong Kong	Korea	Singapore	Taiwan	ASEAN4
Agriculture	57.1	53.8	63.6	60.0	0.0	0.0	0.0	0.0	0.0	66.7
Mining	11.1	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Food	34.2	71.4	39.2	37.5	33.3	0.0	100.0	28.6	14.3	29.4
Textiles	0.0	23.5	28.9	28.9	60.9	45.5	83.3	0.0	66.7	12.2
Wood, pulp	71.4	0.0	21.4	21.4	14.3	0.0	0.0	0.0	25.0	16.7
Chemicals	47.1	55.6	46.4	45.7	50.0	28.6	91.7	23.5	52.9	41.4
Coal & oil products	0.0	0.0	33.3	33.3	100.0	0.0	0.0	0.0	100.0	0.0
Iron & steel	44.0	75.0	33.3	34.8	37.5	100.0	100.0	25.0	0.0	30.8
Non-ferrous metals	40.7	50.0	21.6	21.6	27.3	0.0	66.7	0.0	33.3	20.0
General machinery	32.0	30.8	24.6	25.0	28.6	0.0	83.3	26.7	16.7	13.6
Electric machinery	40.6	47.8	22.5	21.9	25.0	10.0	44.4	13.2	29.4	14.2
Transport machinery	13.8	43.8	25.4	22.3	35.9	0.0	37.5	33.3	35.7	15.2
Precision machinery	66.7	0.0	33.3	33.3	35.3	0.0	83.3	0.0	16.7	40.0
Other manufacturing	34.1	7.1	25.0	25.8	36.3	43.8	57.1	18.8	22.6	14.8
Construction	17.1	44.4	18.9	18.4	21.4	16.7	100.0	20.0	10.0	17.0
Commerce	17.6	11.5	13.4	13.4	12.4	11.3	20.0	11.2	17.5	16.5
Services	14.4	12.5	28.0	27.3	26.2	19.0	62.5	22.0	41.7	30.0
Others	10.5	6.7	11.8	12.1	15.0	30.0	0.0	0.0	0.0	0.0
Total	24.1	25.3	25.0	24.5	26.6	17.9	61.3	15.8	29.3	20.1

	Indonesia	Malaysia	Philippines	Thailand	China	Middle East	Europe	Oceania	Africa	Total
Agriculture	50.0	0.0	100.0	0.0	0.0	0.0	16.7	40.0	100.0	52.3
Mining	0.0	0.0	0.0	0.0	0.0	0.0	6.3	11.1	33.3	10.9
Food	0.0	0.0	50.0	44.4	71.4	0.0	45.5	75.0	0.0	42.6
Textiles	0.0	20.0	100.0	15.8	32.0	0.0	50.0	33.3	0.0	27.6
Wood, pulp	50.0	0.0	0.0	0.0	100.0	0.0	50.0	0.0	0.0	36.0
Chemicals	30.8	42.1	28.6	48.4	45.5	100.0	57.4	83.3	100.0	50.2
Coal & oil products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7
Iron & steel	0.0	60.0	100.0	0.0	50.0	0.0	0.0	0.0	0.0	39.3
Non-ferrous metals	20.0	22.2	100.0	10.0	0.0	0.0	42.9	0.0	100.0	32.1
General machinery	25.0	16.7	0.0	11.1	50.0	0.0	47.8	50.0	0.0	33.5
Electric machinery	12.5	14.8	25.0	11.6	45.5	100.0	39.8	33.3	33.3	31.2
Transport machinery	21.1	12.5	26.7	4.2	14.3	0.0	45.7	45.5	0.0	26.4
Precision machinery	0.0	33.3	0.0	50.0	20.0	0.0	52.9	50.0	0.0	47.7
Other manufacturing	13.3	8.0	12.5	20.0	27.3	50.0	35.8	44.4	0.0	28.7
Construction	0.0	17.6	20.0	23.8	16.7	25.0	15.4	50.0	0.0	20.0
Commerce	0.0	21.9	37.5	10.0	0.0	0.0	17.1	23.2	0.0	16.1
Services	22.2	35.7	50.0	26.1	25.0	0.0	15.0	7.1	0.0	17.1
Others	0.0	0.0	0.0	0.0	25.0	0.0	15.4	7.1	0.0	9.6
Total	16.1	20.2	30.6	19.1	34.5	25.9	25.7	25.0	9.0	24.7

Note: The figures indicate the percentage share of affiliates where major responsibility in R&D section is taken by local staff.

Source: MITI, *Kaigai Jigyo Katsudo Kihon Chosa* (Comprehensive Survey of Overseas Activities of Japanese Firms), no. 5, Tokyo, 1993.

Table 5.11 The determinants of training programmes at overseas affiliates of Japanese firms (dependent variable = training programme at overseas affliate) (probit estimation)

	Total		Developed countries		Developing countries		East Asia	
	coefficient	*t*-statistic	coefficient	*t*-statistic	coefficient	*t*-statistic	coefficient	*t*-statistic
Characteristics of parent firm								
PRD	1.841	1.960*	0.148	0.114	5.394	2.972***	5.677	2.824***
POA	−0.001	−0.829	−0.003	−1.205	0.000	−0.019	0.000	0.213
PEX	−0.644	−2.959***	−1.166	−3.222***	−0.405	−1.388	−0.357	−1.122
POP	0.046	0.132	0.578	1.062	−0.325	−0.660	−0.200	−0.366
PRS	−6.742	−1.146	−6.328	−0.794	−6.911	−0.800	−8.159	−0.854
PWS	0.003	0.125	0.120	2.451***	−0.073	−2.014**	−0.078	−1.961*
Characteristics of affiliates								
ASW	0.762	1.395	1.661	1.479	0.590	0.849	0.416	0.551
ALS	0.126	1.399	0.537	3.663***	−0.103	−0.857	−0.133	−0.972
ALP	0.248	2.364**	0.390	2.348**	0.158	1.102	0.194	1.220
ALPI	0.007	2.349**	0.011	2.415**	0.006	1.266	0.000	0.019
AYR	0.382	4.611***	0.363	2.949***	0.432	3.698***	0.384	2.990***
AEQ	0.001	5.107***	0.001	4.217***	0.000	2.865***	0.000	2.392**
ATT	0.533	5.176***	0.497	2.049**	0.557	4.798***	0.511	4.034***

Characteristics of host countries								
HC	0.005	1.498	0.000	0.026	0.022	1.627	0.072	1.795*
RD	0.015	1.256	0.556	2.425**	0.032	1.415	0.060	1.707*
MANF	0.200	1.848*	0.755	0.985	0.126	1.461	0.102	1.899*
CFDI	0.003	1.105	0.243	1.917*	0.042	1.770*	0.383	1.597
R^2	0.080		0.116		0.087		0.098	
lnL	−930.804		−378.768		−528.545		−440.639	
OBS	1493		650		843		710	

Notes:
Characteristics of parent firm: *PRD*: R&D/sales ratio; *POA*: number of overseas affiliates; *PEX*: exports/sales ratio; *POP*: overseas production ratio; *PRY*: royalty receipts/sales ratio; *PWS*: ln(worldwide sales).
Characteristics of overseas affiliates: *ASW*: sales/worldwide sales; *ALS*: local sales ratio; *ALP*: local procurement ratio; *ALPI*: local procurement ratio of investment goods; *AYR*: number of years in operation; *AEQ*: equity participation ratio; *ATT*: technology transfer requirement.
Characteristics of host countries: *HC*: education attainment rate; *RD*: R&D expenditure/GDP; *MANF*: log (GDP of manufacturing sector); *CFDI*: log (accumulative FDI); ***, **, and * indicate statistical significance at 1, 5, and 10 per cent, respectively.

Source: Authors' estimation.

East Asia, but not in developed countries. This suggests that Japanese MNCs transfer technology needed for production to developing countries. Parent firms with high export–output ratios are less likely to set up training programmes in affiliates in developed countries, indicating that export-oriented firms do not need to train local staff because exporting from the parent firm is the main means of serving foreign markets. The magnitude of worldwide sales has different impacts on affiliates in developed and developing/East Asian countries. Parents with large worldwide sales tend to train in affiliates in developed countries but not in affiliates in developing and East Asian countries. This is unexpected, and may reflect that Japanese firms with large worldwide sales tend to use affiliates in developing countries as assembly bases where only limited training is needed.

As for affiliates in developing and East Asian countries, those with longer periods in operation (*AYR*), high equity participation by the parent firm (*AEQ*) and subject to technology transfer requirement (*ATT*) tend to have training programmes. In affiliates in developed countries, in addition to these characteristics, high local sales ratio (*ALS*), high local procurement ratio (*ALP*), and high local procurement ratio for investment goods (*ALPI*) are also likely to have training programmes.

These findings are consistent with expectations and suggest the following. Parent firms tend to put greater efforts in transferring technology to affiliates in which they have higher equity stakes. Technology transfer requirements seem to induce affiliates to meet the requirements by training local staff. In developed countries, affiliates with local market orientation in sales and procurement feel the need to improve the quality of local employees by training. This is consistent with the earlier observation that parent firms with strong export orientation were less likely to have training programmes.

Turning to the characteristics of the host countries, we find that host countries with good human resources (*HC*), R&D (*RD*), large manufacturing sectors (*MANF*) and a large presence of Japanese MNCs (*CFDI*) tend to have training programmes. This suggests that both supply and demand-side factors are important in deciding on setting up training programmes. On the supply side, firms set up training programmes in host countries with well-educated populations and strong R&D capabilities. On the demand side, large manufacturing sectors and a strong presence of Japanese firms induce affiliates to improve the quality of local employees to meet their needs.

Table 5.12 presents the results of the analysis of the determinants of successful intra-firm technology transfer. MNCs successful in transferring technology tend to have high R&D–sales ratios (*PRD*) and large numbers of overseas affiliates (*POA*), particularly those with affiliates in developing countries and Asia. Parent firms with high R&D–sales ratios tend to be particularly successful in transferring technology to affiliates in developing countries and Asia. This may indicate that MNCs with a strong technology orientation invest in developing countries to use their technology. The observation that MNCs with many affiliates are successful in transferring technology suggests the importance of accumulated experience. It is somewhat surprising to find that parent firms with large worldwide sales seem to be unsuccessful in transferring technology to affiliates in developing countries or Asia. However, this finding appears consistent with the earlier observation that large Japanese MNCs are not active in conducting R&D nor adopting training programmes in affiliates in developing countries or in East Asia.

As to the characteristics of affiliates in developing countries, the results suggest that those with a strong local market orientation in sales have a good record in intra-firm technology transfer: these affiliates have to improve technological capabilities to modify or develop technology to meet local market needs. A somewhat surprising result is a negative and statistically significant coefficient on equity participation by the parent (*AEQ*) for affiliates in developing and East Asian countries. This may indicate that dependence on high equity participation for the supply of technology by parent companies is characteristic of affiliates that are not able successfully to absorb technology.

The presence of R&D and training programmes has a positive impact on technology transfer to affiliates in developing countries. In developed host countries, affiliates with large worldwide sales, strong dependence on local markets for the purchase of investment goods and active R&D contribute to successful technology transfer. These findings are consistent with our expectations.

Finally, findings on the characteristics of host countries suggest that the availability of skills and R&D resources, and the presence of a large manufacturing sector promote intra-firm technology transfer by Japanese firms in East Asian countries.

5. CONCLUSIONS

Acquisition and assimilation of technology have played an important role in promoting economic development. Among various channels for acquiring technology, technology transfer involving foreign direct investment has increased its importance in recent years. In light of these developments, this chapter has attempted to discern the patterns and the determinants of R&D activities which contribute to technology transfer and intra-firm technology transfer at overseas affiliates of Japanese firms.

Table 5.12 The determinants of the extent of technology transfer achieved (dependent variable = affiliates where local staff takes the main responsibility in R&D) (probit estimation)

	Total		Developed countries		Developing countries		East Asia	
	coefficient	*t*-statistic	coefficient	*t*-statistic	coefficient	*t*-statistic	coefficient	*t*-statistic
Characteristics of parent firm								
PRD	2.161	1.731*	1.920	1.276	4.331	1.975**	6.737	2.613***
POA	0.004	2.865***	0.006	2.801***	0.003	2.063**	0.003	1.995*
PEX	−0.084	−0.340	0.213	0.544	−0.031	−0.093	−0.140	−0.365
POP	−0.893	−2.198**	−2.573	−4.029***	−0.035	−0.060	0.408	0.607
PRS	7.995	1.227	6.060	0.781	9.634	1.101	8.973	0.981
PWS	−0.035	−1.099	−0.019	−0.345	−0.080	−1.861*	−0.135	−2.662***
Characteristics of affiliates								
ASW	1.445	2.404**	2.263	1.768*	0.859	1.120	0.611	0.697
ALS	0.273	2.663***	0.361	2.191**	0.233	1.661*	0.095	0.579
ALP	0.132	1.115	0.083	0.440	0.221	1.349	0.274	1.486
ALPI	0.008	2.266**	0.007	1.302	0.007	1.426	0.005	0.845
AYR	−0.053	−0.560	−0.212	−1.491	0.121	0.893	0.127	0.814
AEQ	0.000	−2.922***	0.000	−2.132**	−0.001	−2.857***	−0.001	−2.680***
ATT	0.008	0.065	−0.656	−2.054**	0.136	1.023	0.135	0.888
ARDU	0.099	0.472	−0.272	−0.916	0.575	1.718*	0.599	1.471
ATRN	0.157	1.892*	0.215	1.620	0.197	1.740*	0.173	1.348
ARDE	0.172	4.331***	0.244	4.802***	0.062	0.731	0.115	1.290
ARES	0.128	1.825*	0.143	1.405	0.082	0.724	0.060	0.468

Characteristics of host countries								
HC	0.011	1.548	0.005	0.583	0.026	1.629	0.048	2.064**
RD	0.311	4.428***	0.148	0.599	0.280	3.114***	0.324	3.343***
MANF	0.082	1.018	1.213	1.398	0.213	2.085**	0.216	1.944*
CFDI	0.046	1.287	0.107	0.806	0.055	0.844	0.244	1.906*
R^2	0.132		0.204		0.129		0.160	
lnL	−678.960		−288.802		−362.847		−280.129	
OBS	1493		650		843		710	

Notes:
Characteristics of parent firm: *PRD*: R&D/sales ratio; *POA*: number of overseas affiliates; *PEX*: exports/sales ratio; *POP*: overseas production ratio; *PRY*: royalty receipts/sales ratio; *PWS*: ln (worldwide sales).
Characteristics of overseas affiliates: *ASW*: sales/worldwide sales; *ALS*: local sales ratio; *ALP*: local procurement ratio; *ALPI*: local procurement ratio of investment goods; *AYR*: number of years in operation; *AEQ*: equity participation ratio; *ATT*: technology transfer requirement; *ARDU*: R&D unit; *ARTRN*: training programme; *ARDE*: R&D expenditure; *ARES*: researchers.
Characteristics of host countries: *HC*: education attainment rate; *RD*: R&D expenditure/GDP; *MANF*: log (GDP of manufacturing sector); *CFDI*: log (accumulative FDI); ***, **, and * indicate statistical significance at 1, 5, and 10 per cent, respectively.

Source: Authors' estimation.

Our analysis revealed a number of useful and important observations. Japanese firms were found to undertake R&D activities at their affiliates in developing and East Asian countries mainly to support production and develop local products. As to the determinants of R&D activities at their affiliates in developing countries, we found that the affiliates with strong dependence on local markets for their procurement of intermediate inputs as well as those with long operation periods actively undertake R&D. Concerning the determinants of successful intra-firm technology transfer at affiliates in developing and East Asian countries, we found that the availability of educated people and R&D resources as well as the large manufacturing sector and a large number of Japanese affiliates contributed to intra-firm technology transfer.

Our findings have several important policy implications for developing countries that are interested in obtaining technology by attracting foreign firms. First, it is important to have supporting industries, which supply parts and components to the assemblers, in order to promote R&D activities by foreign firms. Second, developing countries have to improve quality of labour, engineers and researchers to be able to successfully assimilate technology from foreign firms. Finally, developing countries should be reminded of the importance of having an FDI-friendly environment to attract FDI in the first place, before thinking about R&D by foreign firms or intra-firm technology transfer. An FDI-friendly environment is comprised of various elements including a liberalized economic environment, a well-functioning legal system, a well-developed infrastructure and a sound macroeconomic environment. To achieve these objectives, governments in developing countries are advised to utilize effectively economic and technical cooperation from various sources such as multilateral and regional organizations as well as bilateral schemes.

NOTES

1. Waseda University and Japan Center for Economic Research, Tokyo and Keio University, Tokyo, respectively. An earlier version of this paper was presented at the Workshop on Technology Development in East Asia, sponsored by the World Bank, Bali, Indonesia, 14–15 December 2000. The authors thank the workshop participants for helpful discussions and comments
2. The discussion of Japanese FDI in this section draws on Kawai and Urata (1998).
3. In terms of value, these two regions absorbed more than 60 per cent of Japan's FDI, indicating that the average size of Japanese FDI in terms of value in developed regions is greater than that in developing regions.
4. The NIEs are Hong Kong, Singapore, Korea and Taiwan.
5. The Asian NIEs are Hong Kong, Korea, Singapore and Taiwan, while the members of ASEAN are Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam.

6. The ASEAN4 countries are Indonesia, Malaysia, the Philippines and Thailand.
7. See Urata (1993) for a detailed discussion.
8. The figures for 1995 are not shown in Table 5.2. In terms of cumulative value from 1986 to 1995, electric machinery has the largest share among the manufacturing subsectors, followed by textiles and chemicals.
9. The MITI has conducted a comprehensive survey of overseas activities of Japanese firms every three years starting in 1980. The results of the survey are published under the title of *Kaigai Toshi Kokei Soran (Comprehensive Survey of Overseas Activities of Japanese Firms)*. In the 1992 survey, a questionnaire was sent to 3378 Japanese multinationals, 1594 of whom responded. The respondents covered the activities of 7108 overseas affiliates. The MITI has also conducted an annual survey with the more limited number of questions except for the years of Comprehensive Survey. The results of the survey are published under the title of *Wagakuni Kigyo no Kaigai Jigyo Katsudo (Overseas Activities of Japanese Firms)*. Motives behind FDI are asked for in the comprehensive surveys but not in the annual surveys.
10. The figures shown here refer to R&D ratios for all affiliates including those without R&D expenditure. The R&D-sales ratios for affiliates with R&D expenditure are significantly higher, 1.1 per cent for all affiliates, 1.1, 2.5 and 0.2 per cent for the affiliates in North America, Europe, and Asia, respectively.
11. Our finding is consistent with the findings by Odagiri and Yasuda (1996), who found in their study of Japanese firms' overseas R&D activities that the main purpose of R&D at affiliates in developing countries is to support local manufacturing by transferring technology from Japan, while the main purpose of R&D at affiliates in developed countries is to gain access to the leading scientific and technological knowledge.
12. See Fukao and Yue (1997) for the discouraging impact of performance requirements on Japanese firms' decision on FDI.
13. See Navaretti and Tarr (2000) for a review of studies on technology spillover.
14. There exists a vast amount of literature on international technology transfer. However, the main issue has been the mode and costs of international technology transfer rather than the extent of the transfer. See for example, Reddy and Zhao (1990) for a detailed survey and Urata and Kawai (2000) for a brief survey of recent studies.

REFERENCES

Barro, Robert and Jong-Wha Lee (2000), 'International data on educational attainment: updates and implications', NBER working paper 7911, September.

Fukao, Kyoji and Ximing Yue (1997), 'Foreign direct investment of Japanese firms: an empirical analysis of market and firm specific factors', *Mita Gakkai Zasshi*, The Keio Economic Society, **90**(2), 11–39 (in Japanese).

Kawai, Masahiro and Shujiro Urata (1998), 'Are trade and direct investment substitutes or complements? An empirical analysis of Japanese manufacturing industries', in Hiro Lee and David W. Roland-Holst (eds), *Economic Development and Cooperation in the Pacific Basin: Trade, Investment, and Environmental Issues*, Cambridge: Cambridge University Press.

Navaretti, Giorgio Barba and David G. Tarr (2000), 'International knowledge flows and economic performance: a review of the evidence', *World Bank Economic Review*, **14**(1), 1–15.

Odagiri, Hiroyuki and Hideto Yasuda (1996), 'The determinants of overseas R&D by Japanese firms: an empirical study at the industry and company levels', *Research Policy*, 25, 1059–79.

Odagiri, Hiroyuki and Hideto Yasuda (1997), 'Overseas R&D activities of Japanese

firms', in Akira Goto and Hiroyuki Odagiri (eds), *Innovation in Japan*, Clarendon Press: Oxford, pp. 204–28.
Reddy, N. Mohan and Liming Zhao (1990), 'International technology transfer: a review', *Research Policy*, 19, 285–307.
Urata, Shujiro (1993), 'Japanese foreign direct investment and its effect on foreign trade in Asia', in T. Ito and A.O. Krueger (eds), *Trade and Protectionism*, Chicago: University of Chicago Press for NBER.
Urata, Shujiro (1999), 'Intra-firm technology transfer by Japanese multinationals', in Dennis J. Encarnation (ed.), *Japanese Multinationals in Asia: Regional Operations in Comparative Perspective*, Oxford: Oxford University Press.
Urata, Shujiro and Hiroki Kawai (2000), 'Intra-firm technology transfer by Japanese manufacturing firms in Asia', in Takatoshi Ito and Anne O. Krueger (eds), *The Role of Foreign Direct Investment in Economic Development*, Chicago: University of Chicago Press.
Yamashita, Shoichi (1991), 'Economic development of the ASEAN countries and the role of Japanese direct investment', in Sohichi Yamashita (ed.), *Transfer of Japanese Technology and Management to the ASEAN Countries*, Tokyo: University of Tokyo Press, pp. 3–22.

6. The dynamics of technology development: lessons from the Korean experience

Linsu Kim

INTRODUCTION

No nation has come as far and as fast, from handicrafts to heavy industry and from poverty to prosperity, as the Republic of Korea (Vogel, 1991). Korea has transformed itself from a subsistence agrarian economy into a newly industrialized one in the space of only four decades. In 1961, Korea exhibited most of the symptoms of underdevelopment that poor countries show today. From 1962, the Korean economy grew at an average annual rate of almost 9 per cent, raising GNP per capita in current prices from US$87 in 1962 to US$10550 by 1997 (Kim, 1997a). Despite undergoing the worst economic crisis since the Korea War in 1997, it bounced back impressively in 1999 with a growth rate of 10 per cent, followed in 2000 with 8 per cent.

Korea also achieved phenomenal growth in its exports, which increased from a mere US$40 million in 1963 to US$143 billion in 1999. The structure of manufactured exports changed radically over time (see Table 6.1). The share of primary products fell from 64.4 per cent in 1960 to 2.7 per cent in 1999, and that of manufactures rose from 17.6 per cent to 91.5 per cent. The share of simple manufactures shows an inverted U-shape, rising from 17.3 per cent in 1960 to 54.9 per cent in 1980 and then declining to 28.7 per cent by 1999. Within manufactured exports, the share of simple products decreased steadily from 98.5 per cent in 1960 to 63.7 per cent in 1980, and to 31.4 per cent in 1999. The share of complex manufactures in total exports increased steadily from 0.3 per cent in 1960 to 62.7 per cent in 1999; within manufacturing, their share rose from 1.5 per cent to 68.6 per cent. High-technology products accounted for 52.4 per cent of complex manufactures by 1999, indicating a significant technological upgrading of Korean exports. Moreover, unlike most developing countries, which depend heavily on multinational firms for technology-intensive exports and technological upgrading, in Korea the main agents of change were domestic firms.

Table 6.1 *Korea's exports by technology intensity*

Classification	1960	1965	1970	1975	1980	1985	1990	1995	1999
Primary products	64.42	35.75	21.28	15.34	7.21	5.03	3.51	2.48	2.68
Manufactured products	17.56	61.10	68.68	66.58	86.19	90.11	90.60	91.69	91.47
Simple products	17.30	52.56	62.51	53.60	54.93	43.86	41.07	26.02	28.73
Resource-based	8.17	15.80	12.51	9.16	10.64	6.51	5.24	6.14	9.75
Low-tech	9.12	36.76	50.00	44.44	44.29	37.36	35.83	19.88	18.98
Complex manufact	0.27	8.55	6.16	12.98	31.26	46.25	49.53	65.68	62.74
Medium-tech	0.27	8.55	6.16	12.98	21.63	34.95	29.55	35.55	29.85
High-tech	0.00	0.00	0.00	0.00	9.63	11.30	19.98	30.13	32.89
Others	18.01	3.14	10.04	18.09	6.60	4.85	5.89	5.82	5.84
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Sources: *United Nations, Year Book of International Trade Statistics*; Korean Foreign Trade Association (1999), *Foreign Trade Statistics*.

Such phenomenal growth and structural change may be attributed to many social, economic, and technological factors, but most important is probably rapid technological learning by domestic firms (Kim, 1997a). This chapter addresses the following related issues: (1) the initial conditions, (2) the role of technology transfer and technology spillover effects of multinational corporations (MNCs), (3) domestic technological activities, (4) the role of education and technology institutions, (5) the efficacy of public policies, and (6) lessons of the Korean experience for other developing countries.

THE INITIAL CONDITIONS

Unlike the great majority of developing nations, Korea was a unified, independent state for more than 1200 years since the Silla Dynasty. But surrounded by big powers – China in the west, Mongolia and Russia in the north and Japan in the east – Korea was frequently subject to foreign invasion. The most recent was by the Japanese, culminating in colonial rule from 1910 to 1945.

Under Japanese colonial rule, manufacturing growth averaged 9.7 per cent per annum between 1910 and 1941 (Suh, 1978). Japanese capital accounted for 94 per cent of the authorized capital of manufacturing establishments. There were some 1600 Korean technicians in the manufacturing sector, but they accounted for only 19 per cent of all technicians in Korea. Nearly 300000 Koreans had some experience of mining and manufacturing by the time Korea gained independence in 1945, leaving it with a larger base of industrial experience than in most countries gaining independence around that time. However, most Korean workers had experience of low-level jobs.

Modern education, first introduced to Korea by American missionaries, was expanded by the Japanese colonial government. However, the Japanese limited Koreans mainly to the primary grades, seeking a source of labour for simple tasks in agriculture and industry. At the end of Japanese rule, only 2 per cent of the Korean population over the age of fourteen had completed secondary schools and the illiteracy rate stood at 78 per cent.

The chaos following the end of Japanese rule, the division of the nation into North Korea and South Korea and the ensuing civil war, all between 1945 and 1953, left Korea a 'nation with little left of its past and facing a bleak future' (Mason et al., 1980, p. 58). US aid helped bring Korea back to its pre-war economic level, but the economy suffered from almost all the problems facing most resource-poor, low-income countries today. Korea started on industrial development with a far lower economic and technical base than other newly industrializing economies (NIEs).

THE ROLE OF MNCS

Lacking domestic technological capabilities, Korea had to depend heavily on foreign technology. However, it chose to rely as little as possible on FDI. It encouraged domestic firms to build extensive global networks, with foreign firms providing technology via licensing, capital goods and original equipment manufacture (OEM) contracts. These networks were a major source of technological learning for Korean firms.

Intra-Firm Technology Transfer

Korea restricted inward FDI when technology was not a critical element and the relevant mature technologies could be acquired more easily by other modes than FDI. These arm's length mechanisms included reverse-engineering, OEM, and foreign licensing (FL). There was some FDI in this restrictive policy environment (Table 6.2), rising from a mere US$45.4 million in 1962–66 to over US$8.4 billion in 1992–96. This steady increase indicates a gradual relaxation of FDI policy over the years.

The value of FDI and its share of external borrowing were, however, significantly lower in Korea than in the other NIEs. For example, Korea's stock of FDI in 1983 was only 7 per cent of Brazil, 23 per cent of Singapore, and less than half of Taiwan and Hong Kong. The proportion of FDI to total external borrowing was only 6.1 per cent in Korea, compared with 92 per cent in Singapore, 45 per cent in Taiwan and 21 per cent in Brazil (KEB, 1987). As a result, FDI played a relatively small role in the Korean economy. Thus, the contribution of foreign firms to the growth of Korean GNP was only 1.3 per cent in 1972–80; its share of total value-added was only 1.1 per cent in 1971 and 4.5 per cent in 1980. Its contribution to manufacturing value-added was only 4.8 per cent and 14.2 per cent during the same periods (Cha, 1983).

Manufacturing MNCs set up foreign plants to optimize their global sourcing of inputs and production of outputs. To do this, they transfer the production and management capabilities needed to ensure efficient production. Some MNCs also undertake R&D in host countries, but this is mainly in order to adapt products to local or regional needs. Very rarely do they transfer advanced engineering and innovation capabilities.

A comparative analysis of technological learning and market performance in Hyundai Motor, an independent domestic firm, and Daewoo Motor, a joint venture with GM (the world's largest company, with the highest R&D expenditures), is illustrative. Hyundai licensed technologies from several sources and integrated them into an efficient mass-production system. This was a very risky venture, but it forced and motivated Hyundai

Table 6.2 Foreign technology transfer to Korea, 1962–99

Source	1962–66	1967–72	1971–76	1977–81	1982–86	1987–91	1992–96	1997–99*	Total
Foreign direct investment									
Japan	8.3	89.7	627.1	300.9	876.2	2122.3	1548.3	3260.0	8832.7
USA	25.0	95.3	135.0	235.7	581.6	1477.7	2551.8	9910.5	15012.5
All others	12.1	33.6	117.3	184.0	309.6	2035.9	4305.1	18194.1	25194.3
Total	45.4	218.6	879.4	720.6	1767.7	5635.9	8405.1	31364.6	48859.4
Foreign licensing									
Japan	–	5.0	58.7	139.8	323.7	1383.6	2437.0	1461.7	5809.5
USA	0.6	7.8	21.3	159.2	602.7	2121.9	3687.5	4271.4	10872.4
All others	0.2	3.5	16.6	152.4	258.5	853.9	1193.3	1458.1	3936.5
Total	0.8	16.3	96.6	451.4	1184.9	4359.4	7317.8	7191.2	20618.4
Capital-goods import									
Japan	148	1292	4423	14269	20673	54641	80775	40574	216795
USA	75	472	1973	6219	12434	33098	64681	43129	162081
All others	93	777	2445	7490	17871	33213	75387	50529	187805
Total	316	2541	8841	27978	50978	120952	220843	134232	566781

Note: * The data for 1999 covers only through November.

Source: Ministry of Industry and Energy.

to assimilate foreign technologies as rapidly as possible. In the process, Hyundai invested heavily in R&D in order to build design and innovation capabilities.

That was how in 1975 Hyundai developed its first indigenous car model, the 'Pony', making Korea the second nation in Asia (after Japan) to manufacture its own automobile. The car had 90 per cent local content, and, by dint of R&D, improved rapidly in terms of quality over time. As a result, Hyundai's local market share for passenger cars increased from 19.2 per cent in 1970 to 73.9 per cent in 1979. Hyundai exported nearly 63000 Ponys (to Europe, the Middle East and Asia), accounting for 67 per cent of Korea's total auto exports in 1976–80 and 97 per cent of total passenger car exports in 1983–86. The Pony accounted for 98 per cent of Hyundai's exports in these periods (Kim, 1998).

In contrast, Daewoo, constrained by GM's global objectives, relied solely on the MNC for technology and did relatively little to develop its own technological capability and even less to design its products. Technology transfer by joint venture, where the supplier guarantees the performance of the technology transferred, is apt to lead to a passive technological attitude on the part of the recipient. Investments in product and process improvement by Daewoo in 1976–81 were only 19 per cent of those undertaken by Hyundai, although its production capacity, on average, was approximately 70 per cent as large. As a result, though their products were comparable in engine size and price, in 1982 Daewoo was able to operate only at 19.5 per cent of installed capacity as compared with 67.3 per cent for Hyundai (Table 6.3). The differential in labour productivity was as stark: only 2.61 cars per head at Daewoo compared with 8.55 cars per head at Hyundai. Consequently, Daewoo had only 17 per cent passenger car market share compared to 73 per cent for Hyundai.

Daewoo improved its product/process development and market performance only a year after the local partner took over managerial control from GM in 1983. The management established a fully-fledged R&D department, adopted the Japanese '*kanban*' system, streamlined production, instituted a quality control programme and strengthened its marketing drive. Nevertheless, conflicts between the partners continued to plague the joint venture, giving the smaller Kia a chance to outpace Daewoo. In 1992 the partners finally separated, allowing Daewoo to set its own global strategy and recapture the second position after Hyundai.

The semiconductor industry shows a similar picture: MNCs transferred production capabilities but not design or innovation capabilities. Several MNCs – Signetics, Fairchild, Motorola, Control Data, AMI and Toshiba – began to assemble discrete devices in Korea in the 1960s and 1970s, taking advantage of cheap local labour. The operations involved simple packag-

Table 6.3 Basic parameters and performance between Hyundai and Daewoo, 1982

	Hyundai Motor	Daewoo Motor
A. Capital (million *won*)	64.4	44.5
B. Number of workers	9129.0	5675.0
C. Sales (billion *won*)	4.3	1.9
D. Capacity (cars)	116000.0	76000.0
E. Production (cars)	78071.0	14845.0
F. Exports (cars)	13573.0	114.0
Capacity utilization (E/D)	67.3	19.5
Labour productivity (E/B)	8.55	2.16
Capital productivity (E/A)	1212.0	333.6
Export coefficient (F/E)	17.4	0.8
Market share	73.0	13.0

Source: Adapted from Amsden and Kim (1989).

ing processes in bonded operations by the wholly-owned subsidiaries, with all parts and components imported from the parent companies and re-exported to them. The operations required only about six months' training of unskilled workers, transferring little design or engineering capability to Korea.

The largest *chaebols* – Samsung, Hyundai and LG – marshalled the resources needed to enter into very large scale integrated (VLSI) chip design and production. Leading foreign producers refused to license VLSI technology to the *chaebols*. For instance, Texas Instruments and Motorola in the USA and NEC, Toshiba and Hitachi in Japan, refused to license Samsung 64K DRAM technology. But the *chaebols* were able to find small distressed semiconductor companies in the USA that were ready to sell chip designs and processes to find cash for survival. Samsung licensed 64K DRAM design from financially troubled Micron Technologies, and bought a high speed MOS process for US$2.1 million from Zytrex. To master the licensed technologies, Samsung set up an R&D outpost in Silicon Valley in 1983 and hired five Korean–American PhDs in electronics engineering with semiconductor design experience at IBM, Honeywell, Zilog, Intel and National Semiconductors. The outpost also provided opportunities for Korean engineers to participate in training and research in the USA, enabling them to enhance their learning of VLSI technology (Kim, 1997b).

The Asian crisis, however, forced technologically sound but financially weak Korean firms to invite FDI to cope with pressing cash flow problems. They placed not only peripheral but also core businesses on sale.

Consequently, unlike China and Southeast Asian countries that witnessed sharp falls in FDI (for example, Singapore 24.8 per cent and Taiwan and Malaysia 19 per cent in 1998), Korea had a sudden increase in FDI. Thus, FDI in manufacturing rose from US$2.3 billion in 1997 to US$8 billion in 1998 and to US$15.5 billion in 1999. The lion's share of the new FDI took the form of mergers with and acquisitions of existing Korean firms. Hewlett-Packard purchased a 45 per cent stake in its Korean subsidiary from its joint venture partner, Samsung Electronics, for US$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 US$1.4 billion. Volvo purchased Samsung's construction machinery division for US$730 million.

If assets sales are included, the top five *chaebols* in Korea raised over US$7.4 billion in the year after the crisis. The Korean economy is, therefore, now linked to a far greater extent with foreign multinationals than before. But in most recent cases the FDI transfers neither new processes nor new product technologies. They do transfer managerial capabilities, which introduces transparent and accountable management systems, which Korean firms previously lacked.

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

More recent investors, such as Motorola and Lucent Technologies, have come to Korea to tap Korea's leading edge technologies in semiconductor memory chips, flat panel displays, and code division multiple access (CDMA) mobile telecommunications, in which Korea is ahead of Japan and the USA. Motorola acquired a Korean venture firm, Appeal Technology, to tap its advanced design and innovation capabilities and to source a highly compact mobile telephone set for global markets. Lucent Technologies is in the process of establishing an R&D centre in Korea to tap local capabilities in telecommunications. In this sphere, therefore, FDI in Korea is very similar to that in highly advanced economies.

Inter-Firm Technology Transfer

In contrast to the minimal contribution of FDI to Korea's acquisition of foreign technologies, arm's-length methods such as reverse engineering, original equipment manufacturing (OEM), and foreign licensing (FL) have been critical to transferring technologies and supplementing local efforts.

In the 1960s and 1970s Korea promoted technology transfer through reverse engineering of turnkey plants and capital goods. The rapid growth of the Korean economy required commensurate growth in investment. Government policy favoured the import of turnkey plants and capital goods to strengthen the competitiveness of local industries. This led to the massive import of equipment at the cost of retarding the development of the local capital goods industry. Protection of the machinery industry was relatively low until the mid-1970s. The chemical, cement, steel and paper industries, established in the 1960s and early 1970s, all resorted to the import of turnkey plants and machinery for their initial setup. Such turnkey plants and foreign capital goods served as an important means of technology transfer for two reasons. First, they embodied new technologies. Second, their use led to technological capabilities and to the development of similar products through reverse engineering (Kim and Kim, 1985). Korean firms assimilated the technologies so rapidly that they could undertake subsequent expansions and improvements with little assistance from foreign suppliers (Kim, 1997a).

Of the three categories of technology transfer listed in Table 6.2, capital goods imports far surpassed other means in terms of value. Through 1996, capital goods imports were 24.7 times the value of FDI and 32.2 times the value of FL. The total value of capital goods imports was 14 times that of the other two categories combined. Although the values of different modes of technology transfer are not strictly comparable since they measure different things, they are useful indicators when compared with other countries. Among NIEs, the proportion of capital goods imports to total technology transfer was highest in Korea. Korea clearly acquired more technology through capital goods imports than such NIEs as Argentina, Brazil, India and Mexico (Kim, 1997a). The contribution of reverse engineering cannot be quantified, but in-depth studies reveal that such practice was dominant and widespread in electronics (Kim, 1980), chemicals (Westphal et al. 1985), machinery (Kim and Kim, 1985), computers (Kim et al. 1989) and pharmaceuticals (Kim et al. 1989).

Several other instruments promoted the inflow of foreign equipment. For example, the slight overvaluation of the local currency, tariff exemptions on imported capital goods and the financing of purchases by suppliers' credits (with low rates of interest relative to the domestic market), all worked to increase the attractiveness of these imports. The current account pressures generated were overcome by rapid export expansion based on the efficient use of the imported equipment.

OEM contracts were another major mechanism through which Korean firms accelerated their technological learning. No official statistics are available on OEM, as OEM sales are not separated from other exports, but several studies reveal that OEM accounts for a significant share. According to the Korea Trade Promotion Corporation, OEM accounted for over 40 per cent of Korea's total exports in 1985. The Korea International Trade Association records that 61 per cent of all exports to Europe were on an OEM basis. In electronics, OEM accounted for 70 to 80 per cent of exports in 1990 (Ernst, 1996). In personal computers, OEM accounted for about 80 per cent of exports in 1989, compared to about 40 per cent in Taiwan. In Samsung Electronics, most reverse engineering projects were followed for several years by OEM exports (Cyhn, 1999).

OEM buyers offered various forms of technical assistance to Korean producers to ensure that the products met their technical specifications. The buyers provided not only blueprints but also training for engineers and technicians. They also helped producers improve facilities, manufacturing systems and quality control systems. When a Korean firm provided a prototype to an OEM buyer on the basis of its reverse engineering, the buyer made significant contributions to improving quality to meet its specifications. For instance, when Daewoo undertook OEM manufacture of colour television sets for NEC in Japan, the latter identified over 80 problems ranging from poor sound quality to faulty control knobs – and helped Daewoo correct them. Intensive interactions between engineers of the two sides in ten different meetings (lasting more than 30 days per year) led to the transfer of a significant amount of design, production, packaging, styling and quality control knowledge (Cyhn, 1999).

Such learning allowed Korean firms to progress from OEM to more demanding stages: own design manufacturing (ODM) and own brand manufacturing (OBM) (Hobday, 1995). By the late 1980s, Korean firms had acquired enough capabilities to design their own products. MNCs tested these products and placed large orders. Technology transfer, however, has been far less in ODM arrangements than in OEM.

Korean reliance on FL has increased significantly over time as the economy has approached international technology frontiers. Korean policy on FL was quite restrictive in the 1960s. The 1970s, however, saw a significant change as attempts were made to access sophisticated technologies that were mostly protected by intellectual property rights. As a result, royalty payments for FL increased significantly (Table 6.2) from US$0.8 million during the first Five Year Economic Development Plan (1962–66) to US$451.4 million in the fourth Plan (1977–81). The 1980s and 1990s saw much larger increases. Most foreign licensing in the early years was associated with technical assistance to train local engineers to run turnkey plants (Kim, 1997a).

In sum, Korea restricted FDI but promoted technology transfer through other means such as capital goods imports, OEM and FL in the early years. Capital was acquired through foreign loans. Such a policy, designed to maintain independence from MNCs, was effective in forcing Korean firms to take the initiative in learning from externalized foreign sources such as reverse engineering, OEM and FL. The high debt ratio, however, contributed to the financial crisis in 1997.

DOMESTIC TECHNOLOGICAL ACTIVITIES

As Korea entered progressively more technology-intensive industries, local R&D became more important to sustaining international competitiveness. As a result, R&D investment has seen a quantum jump in the past three decades. Table 6.4 shows that the total R&D increased from US$28.6 million in 1971 to US$3.4 billion in 1990 and to US$9.5 billion in 1998 (1998 was the first year after the Asian crisis and R&D expenditure then was about 13 per cent less than in 1997). Though the Korean economy recorded one of the world's fastest growth rates, R&D rose even faster. R&D as percentage of GDP increased from 0.32 per cent to 2.52 in this period, surpassing many West European countries.

The government launched various programmes to increase private R&D. Spurred partly by these programmes and partly by increasing competition in the international market, the number of corporate R&D laboratories rose from 1 in 1970 to 3760 in 1998 and 4810 in 1999, a clear reflection of the seriousness with which Korean firms pursued high-technology development. There were significant structural changes in R&D, the government dominating in early years but private firms taking an increasing role over time. The private sector accounted for only 2 per cent of the total R&D in 1963 and over 80 per cent in 1994, one of the highest in both advanced and newly industrialized countries.

The growth rate of total R&D as a share of GDP in Korea (24.2 per cent in 1981–91) was the highest in the world, compared to 22.3 per cent in Singapore, 15.8 per cent in Taiwan, 11.4 per cent in Spain and 7.4 per cent in Japan. The annual growth rate of business R&D as a share of GDP was also the highest in Korea (31.6 per cent), compared to 23.8 per cent in Singapore, 16.5 per cent in Taiwan, 14.0 per cent in Spain and 8.8 per cent in Japan (DIST, 1994).

Two factors – the 'reverse brain drain' and the *chaebol* – played an important role in this R&D growth. Korean firms recruited trained scientists and engineers of Korean origin resident in the USA. Many had left Korea over a decade earlier, doing PhDs in leading US universities and rising through

Table 6.4 Research and development expenditures, 1965–98 ($ million and percentage)

	1965	1970	1975	1980	1985	1990	1995	1998
R&D expenditure	2.1	10.5	42.7	282.5	1237.1	3349.9	9440.6	11336.6
Government	1.9	9.2	30.3	180.0	306.8	651.0	1780.9	3051.8
Private sector	0.2	1.3	12.3	102.5	930.3	2698.9	7659.7	8276.4
Govt vs private	61:39	97:03	71:29	64:36	25:75	19:81	19:81	27:73
University R&D	n/a	0.4	2.2	25.9	118.8	244.3	770.9	1265.1
Govt research institutes R&D	n/a	8.9	28.1	104.5	367.2	731.0	1766.7	1979.2
Corporate R&D	0.2	1.3	12.3	81.4	751.0	2374.5	6903.0	8092.3
R&D/GNP	0.26	0.38	0.42	0.77	1.58	1.95	2.51	2.52
Manufacturing sector								
R&D expenditure	n/a	n/a	16.7[a]	76.0	688.6	2134.7	5809.9	6439.2
Percent of sales	n/a	n/a	0.36[a]	0.50	1.51	1.96	2.72	2.64
Number of researchers (total)[b]	2135	5628	10275	18434	41473	70503	128315	129767
Govt research institutes	1671	2458	3086	4598	7542	10434	15007	12587
Universities	352	2011	4534	8695	14935	21332	44683	51162
Private sector	112	1159	2655	5141	18996	38737	68625	66018
R&D expenditure per researcher (W 1000)	967	1874	4152	15325	27853	47514	73574	87361
Researcher per 10000 population	0.7	1.7	2.9	4.8	10.1	16.4	28.6	27.9
Number of corporate R&D centres	0	1[c]	12	54	183	966	2270	3760

Notes:
[a] for 1976.
[b] The figures do not include research assistants technicians and other supporting personnel.
[c] for 1971.

Source: Ministry of Science and Technology.

the ranks of major firms such as IBM, Fairchild, Intel and National Semiconductor. The number of scientists and engineers recruited abroad by corporate R&D centres was substantial, 427 in 1992 alone. The outflow of technical graduates posed a serious problem to Korea in the 1970s, when 97 per cent of scientists and 88 per cent of engineers who received training abroad (mainly in the USA) remained there, compared with 35 and 30 per cent for all countries (Hentges, 1975). However, this helped form an important international technical network and a high calibre pool of skills for Korea's development. It later helped it to become a serious contender in several cutting-edge technologies.

The *chaebols* were key players in technological learning in Korean industry: (1) they were, as noted, in the best position to attract high quality human resources from abroad; (2) they developed the organizational and technical resources to identify, negotiate and finance foreign technology transfer; (3) they had the resources to expand and deepen industrial R&D; and (4) highly diversified *chaebols* applied experience in one field of business to others, resulting in rapid diffusion of technological capabilities across subsidiaries. As a result, the 20 largest *chaebols* now account for 72 per cent of corporate R&D in Korea.

While increasing in-house R&D, Korean firms began to globalize their innovation activity. LG Electronics, for instance, built a network of R&D laboratories in Tokyo, California, Chicago, Germany and Ireland. These laboratories monitor frontier technological change, develop strategic alliances with local firms and develop state-of-the-art products through advanced R&D. LG Technology in California, for instance, plays a pivotal role in designing the latest personal computers, display terminals and high resolution monitors, while the laboratory in Chicago concentrates on HDTV, digital VCR and telecommunications equipment. Samsung, Daewoo and Hyundai Electronics have similar R&D outposts. Samsung has R&D facilities in San Jose, Maryland, Boston, Tokyo, Osaka, Sendai in Japan, London, Frankfurt and Moscow. Daewoo has two in France, one in the UK, and one in Russia. Hyundai has outposts in San Jose, Frankfurt, Singapore and Taipei.

Another indicator of Korea's growth in R&D is patent registrations at home and abroad. Patenting in Korea has grown significantly in the past two decades. It rose by 48 per cent in the 14 years from 1965 to 1978, then almost tripled in the next 11 years (1979–89) and almost tripled again in the next four (1989–93), reflecting the increasing importance of innovation and the declining significance of reverse engineering. There is still a large patent gap in comparison with advanced countries, but the gap is closing rapidly. The share of Koreans in local patent registration increased from 11.4 per cent in 1980 to 69.2 per cent by 1999 (see Table 6.5). Korea ranked fifth in

Table 6.5 Patent applications and patents granted

	1981	1985	1990	1995	1999
Applications					
National	1319	2703	9082	59236	55970
Foreign	3984	7884	16738	19263	24672
Total	5303	10587	25820	78499	80642
Patents granted					
National	232	349	2554	6575	43314
Foreign	1576	1919	5208	5937	19321
Total	1808	2268	7762	12512	62635

Source: Korea National Statistics Office.

the world in 1999 in the number of domestic industrial property applications, after Japan, the USA China and Germany. In terms of industrial property applications by local residents per head of population, Korea ranks second after Japan.

Patent registration in the USA is often used as a measure of international competitiveness. The number of patent registrations in the USA by Koreans is far below that by Taiwanese, let alone that by advanced countries. The cumulative number of patents granted to Koreans by the USA between 1969 and 1992 was 1751 compared to 4978 for Taiwan. However, Korea jumped from thirty-fifth place in the number of patents in the USA (among 36 countries listed in an NTIS report) in 1969 to eleventh in 1992, giving an average annual growth rate of 43 per cent (NTIS, 1993). This growth rate was the highest of the countries in the report. A more recent report shows that Korea jumped to sixth place in 1999, with 3679 patents, after only Japan, Germany, Taiwan, France and the UK. Samsung Electronics, the most R&D-intensive firm in Korea, ranked fourth with 1545 US patents, coming only after IBM, NEC and Canon. These figures again indicate how rapidly Korea has gained in technological competitiveness.

The crisis of 1997 appears to have made a significant dent in Korean R&D. In order to improve liquidity, the large *chaebols* reduced R&D by some 13 per cent in the year following the crisis (Kim, 1999). At the same time, there was a surge of small technology-based firms as well-trained scientists and engineers laid off by *chaebols* set up on their own, with a strong emphasis on technology. The promotion of venture capital by the government also played a role in fostering this surge. As a result, the number of R&D laboratories increased from 3060 at the time of the crisis to 5200 two years later. Small and medium-sized enterprises (SMEs) account for 95 per cent of this increase. This shift may signify a structural change in the skewed Korean industrial structure.

Korea now leads the world in several advanced technologies such as memory semiconductors, flat panel displays and CDMA mobile telephone sets in terms of product development and production. It has the largest world market shares in satellite receiving systems and videotapes. The International Standardization Organization (ISO) has recently adopted fifteen new technologies in the multimedia area developed by Korean firms as global standards. Nine more are under review.

In conclusion, Korean firms acquired mature technologies through imitative reverse engineering in the early years, but then invested heavily in R&D to enhance their competitiveness in the face of rapidly changing technologies. Korea is now one of the most R&D-intensive countries in the world, in terms of the share of GDP devoted to innovation.

THE ROLE OF EDUCATION AND TECHNOLOGY INSTITUTIONS

The government and the private sector invested heavily in order to achieve rapid expansion in the education sector in Korea. Many other developing countries attained an equally rapid growth in elementary education; what was unique in Korea was the well-balanced expansion at all levels. This rapid expansion created short-term unemployment problems among the educated, but the formation of human capital laid the foundations for the acquisition and assimilation of mature labour-intensive technologies in the 1960s and 1970s. As Korea underwent major structural change in the 1980s, three sets of institutions – universities, government-supported research institutes (GRIs) and SME technical extension services – became important for local technology development.

Universities

Universities played a fairly marginal role in the early years of Korean industrialization. They were primarily undergraduate teaching-oriented institutions that undertook little research. University R&D, only US$1.3 million in 1970, constituted about 3.5 per cent of the nation's total R&D while accounting for 35.7 per cent of the number of researchers. Frustrated in its efforts to reform the universities, the government founded a research-oriented S&T school – the Korea Advanced Institute of Science and Technology (KAIST) – in 1975. KAIST played a pivotal role in training a large number of high calibre scientists and engineers.

Another effort to upgrade university R&D capabilities began in the late 1970s and 1980s. The government established the Korea Scientific and Engineering Foundation in 1977, and later the Korea Research Foundation in 1981, to fund basic research in universities. The government also enacted the Basic Research Promotion Law in 1989, explicitly targeting basic research as one of the nation's top technological priorities. As a result, university research has also expanded significantly as shown in Table 6.4, almost tripling in eight years from US$341.2 million in 1990 to US$1.06 billion in 1998. The number of university researchers more than doubled from 21 332 to 51 162 in this period. In addition, emulating the US experience, the government started in 1989 to establish Science Research Centres (SRCs) and Engineering Research Centres (ERCs) in the leading universities. The number of SRCs and ERCs increased from 13 in 1990 to 84 by 2000, each receiving grants from the government for nine years.

There are also encouraging signs on the quality of university research. The number of scientific publications by Koreans cited by the *Science Citation Index* increased slowly from 27 in 1973 to 171 in 1980, then more rapidly to 1227 in 1988, to 3910 in 1994, and to 10918 in 1999. This meant a rise from thirty-seventh place in the world in 1988 to twenty-fourth in 1994 and sixteenth in 1999. The ranking, however, is still low compared with its eleventh place in gross national product.

The financial crisis prompted the government to formulate an ambitious reform programme to transform a dozen leading universities into first-class research-oriented institutions. The government earmarked about US$1.4 billion over seven years for this programme. It is too early to assess the outcome, but if implemented properly the programme is expected significantly to upgrade the quality of scientists and engineers that Korean universities will produce. In addition, leading universities have established techno-parks and business incubators in order to link their research with leading firms and to foster technology-based small enterprises spun off from university R&D laboratories. This means that universities will play an increasingly important role in Korea's pursuit of high-technology industries in the future.

Government Research Institutes

Given the weak research base in universities, the government set up GRIs by recruiting overseas-trained Korean scientists and engineers. GRIs dominated R&D in Korea in the early years, accounting for 83.9 per cent of total R&D expenditures and 43.7 per cent of researchers in 1970. GRIs, however, faced numerous obstacles in the 1970s. They had poor linkages with industry. Most Korean scientists and engineers in the GRIs came from academic institutions or R&D organizations. There was little demand from industry for the services GRIs offered. Expertise was particularly lacking in manufacturing know-how and the development of prototypes, which were in great demand in the early years.

This does not mean that GRIs did not produce any results. The problem was that their usable research output was ignored or distrusted by the private sector, which preferred turnkey plants or licences from experienced foreign firms. Large projects like fertilizer, chemical and cement plants relied completely on turnkey projects, while consumer electronics resorted to licensing. Over time, however, the situation changed. The government set up specialized GRIs (for example in chemical, machinery, electronics, ocean, standardization, nuclear energy, biotechnology, system engineering, aerospace and so on) to serve the increasingly diverse and complex needs of the private sector. GRIs began to play an important role in strengthening the bargaining power of local enterprises in acquiring foreign technologies. For instance, when Corning Glass refused to transfer optical fibre technology to Korea in 1977, two large copper cable producers in Korea entered a joint R&D project with a GRI. After seven years of R&D, the locally developed optical cable was tested successfully on a 35–km route in 1983. Although this effort eventually ground to a halt, due mainly to slow progress in R&D, it helped local firms in bargaining for foreign technology. Four firms entered licensing agreements with multinational enterprises in 1984 (Kim, 1993).

Another important effect on local technology development of GRIs was a sharp cut in import prices. For example, no sooner had a GRI successfully developed Betamethasone in 1979 than its import price went down from Won/30 000/kg to Won/15 000/kg. When the GRI developed Rifamycine in 1982, its import price dropped from Won/1 000 000/kg to Won/450 000/kg (KIST, 1994).

The most important – but unintended – role of GRIs in the early years of industrialization in Korea was the creation of experienced researchers. When the private sector began to invest in R&D in the 1980s, the researchers trained in GRIs moved to corporate R&D centres as well as to new GRIs and universities. For example, over 2800 experienced researchers left from KIST, a leading GRI: 420 went to private R&D centres, 784 to universities, and 1594 to newly-established GRIs (KIST, 1994).

In addition, the government introduced two major sets of national R&D projects: the Industrial Generic Technology Development Project (IGTDP) and the National R&D Project (NRP). IGTDP concentrated on current problems in 'existing' technologies with high externalities. NRP projects focused on future problems in 'new' (to Korea) technologies with a high risk of failure or with high externalities, thus warranting public support.

Although these projects were also open to universities and corporate R&D centres, GRIs played a dominant role in these projects through the mid-1990s.

Nevertheless, in the face of the rapid expansion of private R&D and the increasing intensity of university R&D, the role of GRIs weakened relatively over time. This was so for two reasons. First, GRIs, being under government bureaucratic control, were less dynamic than corporate R&D centres, which responded more dynamically to market signals and technological change. Second, GRIs had difficulties in retaining competent researchers. The best research staff tended to leave for academic institutions for prestige and freedom or for corporate R&D laboratories for higher salaries. The reform of GRIs has been under discussion for some time, but inertia and the labour unions have made it difficult to implement.

SME promotion

The government has been so preoccupied with mission-oriented projects that it has failed to develop an effective infrastructure for SME promotion. The technical extension networks developed in the 1980s have not been adequate to meet the technology development needs of SMEs. A few industry-specific R&D institutes for SMEs were (belatedly) established in the 1990s, but their effectiveness remains to be seen.

In conclusion, despite the rapid growth of demand for technological innovation, Korea's network of technological institutions was not adequate for industrial needs. GRIs played a useful role in some areas in the early decades, but their role needs to be redefined now. The role of universities has become increasingly important, but they have yet to become first-rate research institutions. The incumbent government is determined to reform educational systems and raise R&D capabilities, but it will take a decade or longer before substantial results can be seen.

THE EFFICACY OF PUBLIC POLICIES

The Korean government has adopted an array of policy instruments to facilitate technological learning in industry and so strengthen international competitiveness. This history can be best understood from the perspective of market demand and supply (Kim and Dahlman, 1992). This involves analysing three aspects: (1) policies to create market needs for technology development (demand side); (2) policies to increase S&T capabilities (supply side); and (3) policies to provide effective links between demand and supply (linkage).

Demand Side

Demand-side policies can cover three areas: export promotion, competition policy and government procurement. Export promotion, by pushing firms into highly competitive international markets, has been more influential than other policies in forcing firms to expedite technological learning. Export-oriented industries accounted for the bulk of foreign licensing, capital goods imports and R&D in Korea. Exporters also created capacity in excess of local market needs to achieve economies of scale; this led to crises and forced them to accelerate technological learning to maximize capacity utilization. Export promotion brought in many OEM buyers, who provided valuable help in acquiring capabilities through interactive tutorial processes. As a result, firms in export-oriented industries learned significantly more rapidly and grew faster than firms in import-substituting industries.

Competition policies such as antitrust, trade liberalization and intellectual property protection also increased the need for technological effort. In response to the increasing economic power of the *chaebol*, the government enacted the Fair Trade Act in 1980 to prohibit unfair practices in the market and to restrict the growth of the *chaebols*. At the same time, the government began to liberalize the local market, bringing down tariff and non-tariff barriers, so forcing Korean firms to compete against multinational firms not only in exports but also in the domestic market. In 1986, the government introduced legislation to protect intellectual property rights, pre-empting the reverse engineering of foreign products. These policies forced Korean firms further to intensify technological effort.

Government procurement is often mentioned in the literature as an important tool in creating local demand for technological effort. However, except for significant government procurement of personal computers at the formative stage of the industry in the early 1980s (Kim et al., 1987), this policy did not play a significant role in Korea in creating demand for technological effort.

Supply side

Major supply-side policies cover human resource development, technology transfer and domestic R&D. Given its lack of natural resources, Korea invested heavily in human resource development in the 1950s and 1960s to prepare for industrialization. As a result, given its relative per capita GNP, Korea achieved the highest educational attainment among NIEs. The formation of human resources enabled it to master mature production technologies through reverse engineering in the early years. However, the

Korean government made a critical mistake in neglecting to invest in research-oriented tertiary education in preparation for knowledge-intensive industries, creating a major bottleneck in innovative technological learning in the 1990s.

Foreign technology transfer generally plays a major role in technological learning, providing tacit and explicit knowledge as well as interactions with foreign suppliers. Korea restricted reliance on FDI, enabling local firms to retain managerial independence and allowing them to set the direction of technological learning. The restriction on foreign licensing also enabled Korean firms to strengthen their bargaining power in negotiating the transfer of mature but complex technologies; however, it may have resulted in slow learning owing to the restricted inflow of new foreign technologies. The promotion of capital goods imports forced Korean firms to rely heavily on reverse-engineering foreign goods in early years. Well-trained and hard-working employees were motivated to maximize technological learning from readily available foreign goods; they had sufficient tacit knowledge to reverse-engineer them successfully in the early years.

The government gradually relaxed restrictions on licensing in the 1970s, as Korean industries progressed into more complex technologies. Policies had to adapt to the changing economic environment and to facilitate the inflow of more sophisticated foreign technologies.

The government's role in R&D was small relative to other countries, accounting for only about 20 per cent of total R&D in the 1990s. The government's R&D was largely directed to keeping increasingly weak GRIs afloat (in the mid-1990s over 80 per cent of public R&D expenditures went to GRIs) and to mission-oriented national projects. Some national projects had significant results, such as the development of electronic switching systems and CDMA mobile telephone systems, making Korea the first successfully to commercialize CDMA technology. In general, however, R&D policy neglected diffusion-oriented projects like upgrading the quality of tertiary education and university research. Consequently, Korea tended to produce half-baked human resources while spending heavily on R&D, resulting in relatively low R&D productivity. However, the government's initiative in establishing the first venture capital firm facilitated the growth of the private venture capital industry in subsequent years.

Linkage

Preferential financing and tax incentives are the major instruments that lubricate the linkage process between demand and supply. During the 1970s the interest rate on R&D loans was one of the highest, reflecting the low priority of R&D in government policies. At the same time, preferential financing was largely ignored by industry because of its lack of a felt need to invest in R&D (given the ease of acquisition and assimilation of foreign technologies). It was only in the early 1980s that preferential R&D loans became more important for financing private R&D. The impact of preferential financing on facilitating R&D activities, however, is dubious. Its interest rates, ranging from 6.5 to 15 per cent, were far higher than similar loans in other countries.

Tax incentives were another indirect mechanism for making funds available for corporate R&D. In Korea, tax incentives fell into five categories according to objectives served. The most important were tax incentives for corporate R&D, reduced tariffs on the importation of R&D equipment and supplies, deduction of annual non-capital R&D expenditures and human resource development costs from taxable income, and the exemption of real estate tax on R&D related properties.

In conclusion, preferential financing and tax incentives definitely provided funds for corporate R&D activities and lowered their costs, but were peripheral in promoting R&D in Korea.

IMPLICATIONS FOR OTHER DEVELOPING COUNTRIES

Many political leaders, economic planners and corporate managers in other developing countries have shown a keen interest in learning from the Korean experience. To what extent can and should they emulate the Korean experience?

Many parts of Korea's experience may be emulated. First, the expansion of education, particularly at the secondary and tertiary levels, provides the essential base for subsequent industrialization. Many studies support this argument. For instance, Baumol et al. (1991) conclude that the quantity and quality of education are a major influence on whether an economy can catch up with advanced countries. Many developing countries have achieved parity with advanced countries in terms of enrolments in primary schools: it is the provision of secondary and higher education that explains differences in national wealth. A small cadre of highly-educated elites is not sufficient for industrialization; what is required for rapid industrialization is the provision of quality secondary and tertiary education to the whole population.

Second, countries can emulate the programmes that the Korean government used to facilitate technological learning. Most important of all was the creation of a competitive market, particularly through export promotion. Competing in world markets forces firms to undergo a continuous 'life or death' struggle for survival, for which they have to accelerate learning by importing and rapidly assimilating foreign technologies and deepening local efforts to innovate new technologies. And the government has a decisive role to play in turning an economy into an export-oriented one.

Third, countries can adopt a liberal policy with respect to the brain drain. High calibre human resources abroad can provide valuable overseas technical networks and skill pools for subsequent development. Taiwan's surge in high-technology ventures can largely be attributed to Chinese engineers in Silicon Valley. In Korea, the government offered a very attractive incentive package for Korean–American scientists and engineers to return home through the 1970s. The *chaebols* followed the same strategy after the mid-1980s.

There are also aspects of Korean policies that are difficult to emulate. First, the new rules of international trade under the World Trade Organization (WTO) make it difficult to protect infant industries. The growing pressures to liberalize domestic markets for products, services and investment make it more difficult now to stay independent of multinationals.

Second, stronger intellectual property rights protection restricts the imitation of foreign technologies. China, for instance, faces enormous pressures from the USA to honour intellectual property rights, which Japan, Korea and Taiwan did not face during their early industrialization.

Third, not all developing countries can emulate the cultural and historical conditions that inculcated an entrepreneurial and hard-working spirit in Koreans. These include: (1) a neo-Confucian culture that emphasizes discipline, learning and harmonious interpersonal relations; (2) the Korean War that transformed Korea from a rigid, closed and class-based society into a dynamic, flexible and classless society; (3) the adversity imposed by several climatic conditions; (4) the social competition caused by a dense population; and (5) the adaptability resulting from frequent foreign invasions.

There are also two aspects of Korea's experience that other countries should *not* emulate. The first is Korea's promotion of large conglomerates, which, despite their strengths, stifled the healthy growth of SMEs. It is better to have well-balanced growth of both large and small firms, as in Japan and Germany.

Second, the Korean government was so preoccupied with short-term production and export goals in the 1970s and 1980s that it failed to invest in building the infrastructure needed for the future. One of the most striking examples is under-investment in upgrading the quality of tertiary education. Public policies may be introduced overnight, and technology and capital may be imported relatively quickly, but creating human resources requires long-term investment.

The Korean experience also offers other lessons. Foreign technology transfer should not be viewed as a substitute for in-house efforts or vice versa. The two are complementary. Foreign technology transfer can provide new knowledge and serve as a catalyst for technological change, enabling firms in developing countries to make quantum jumps in technological learning. In-house efforts can, on the other hand, raise local capabilities, strengthen bargaining power in transfer negotiations and enable recipients to rapidly assimilate imported technology.

FDI transfers production capability quickly and efficiently, but does not necessarily transfer design or innovation capability, particularly when the parent company uses affiliates to exploit the local market in host countries. Should firms in developing countries then go independent or enter into joint venture with technology suppliers? When firms in developing countries invest aggressively in technological learning and can deepen their capabilities, it is better to remain independent of foreign equity participation (quadrant 1 in Figure 6.1), particularly when they have a global vision. Even if some equity participation is allowed, management independence should be maintained. Otherwise (quadrant 3) conflicts can arise between the joint-venture partners. When technology recipients are not aggressive in technological learning, a joint-venture arrangement is preferable (quadrant 4); learning is, however, at the pace set by the foreign parent company. As a result, recipients may remain dependent for technology on the parent.

Foreign licensing in a 'packaged' form from a single source involves little risk to the technology recipient, as the supplier guarantees the performance of the transferred technology. However, it leads to a passive attitude by the recipient in the learning process. In contrast, when the recipient unpackages technologies, acquires them from multiple sources and is responsible

Association with foreign firms	Strategy for technological learning: Aggressive	Strategy for technological learning: Not aggressive
Independent	Slow initial learning but dynamic learning in long run (1)	Slow learning throughout (1)
Joint venture	Rapid initial learning but conflicts restrict dynamic learning in long run (3)	Learning at the pace of the parent firm's strategy. Dependency (4)

Figure 6.1 Strategy for technology

for integrating them into a workable system, it undertakes significant risk. This can subsequently force and motivate the recipient to expedite technological learning. In other words, when the recipient has adequate tacit knowledge, it is better to undertake the integration to force technical personnel to expedite learning.

Finally, the Korean experience suggests that the role of GRIs should evolve over time. In the early years of industrialization, GRIs should provide the private sector with technical assistance, strengthening its bargaining power in technology transfer and helping it to assimilate and adapt imported technology rapidly. At this stage, GRIs should not be evaluated in terms of the number of patents or significant research results generated and commercialized, but in terms of the number of experienced researchers created who could play a role in R&D in the private sector. They should also be evaluated in terms of their role in helping the private sector to absorb foreign technologies economically and improve them effectively.

REFERENCES

Amsden, Alice H. and Linsu Kim (1989), 'A comparative analysis of local and transnational corporations in the Korean automobile industry', in Dong-Ki Kim and Linsu Kim (eds), *Management Behind Industrialization: Readings in Korean Business*, Seoul: Korea University Press, pp. 579–96.

Baumol, William J., Sue A. Blackman and Edward N. Wolff (1991), *Productivity and American Leadership*, Cambridge, MA: MIT Press.

Cha, Dong-Sae (1983), *Weja Doipeo Hyogwa Boonsuk (The Effects of Direct Foreign Investment)*, Seoul: KIET Press.

Cyhn, Jin (1999), 'Technological development of the Korean electronics industry: learning through original equipment manufacturing', research paper at Eindhoven Centre for Innovation Studies, The Netherlands.

DIST (Department of Industry, Science and Technology, Australia) (1994), *Australian Science and Innovation Resources Brief 1994*, Canberra: Australian Government Publishing Service, p. 21.

Ernst, Dieter (1996), 'Technology management in the Korean electronics industry: what factors explain the dynamics of change?', BRIE working paper, University of California.

Hentges, H.A. (1975), 'The repatriation and utilization of high-level manpower: a case study of the Korea Institute of Science and Technology', unpublished PhD dissertation at Johns Hopkins University.

Hobday, Michael (1995), *Innovation in East Asia: Challenge to Japan*, Aldershot, UK: Edward Elgar.

KEB (Korea Exchange Bank) (1987), 'Direct foreign investment in Korea', *Monthly Review*, October, 18–19.

Kim, Linsu (1980), 'Stages of development of industrial technology in a developing country: a model', *Research Policy*, 9, 254–77.

Kim, Linsu (1993), 'National system of industrial innovation: dynamics of capability building in Korea', in Richard R. Nelson (ed.), *National Innovation Systems: A Comparative Analysis*, New York, Oxford University Press: pp. 357–83.

Kim, Linsu (1997a), *Imitation to Innovation: The Dynamics of Korea's Technological Learning*, Boston, MA: Harvard Business School Press.

Kim, Linsu (1997b), 'The dynamics of Samsung's technological learning in semiconductors', *California Management Review*, **39**(3), 86–100.

Kim, Linsu (1998), 'Crisis construction and organizational learning: dynamics of capability building in catching-up at Hyundai Motor', *Organization Science*, **9**(4) 506–21.

Kim, Linsu (1999), 'The impact of the Asian crisis on national innovation system: an initial assessment', paper presented at the International Conference on Public Policy, National University of Singapore, September 5–7.

Kim, Linsu and Carl J. Dahlman (1992), 'Technology policy for industrialization: an integrative framework and Korea's experience', *Research Policy*, 21, 437–52.

Kim, Linsu and Youngbae Kim (1985), 'Innovation in a newly industrializing country: a multiple discriminant analysis', *Management Science*, 31, 312–22.

Kim, Linsu, Jangwoo Lee and Jinjoo Lee (1987), 'Korea's entry into the computer industry and its acquisition of technological capability', *Technovation*, 6, 277–93.

Kim, Youngbae, Linsu Kim and Jinjoo Lee (1989), 'Innovation strategies of local pharmaceutical firms in Korea: a multivariate analysis', *Technology Analysis and Strategic Management*, **1**(1), 29–49.

KIST (Korea Institute of Science and Technology) (1994), *KIST 25 Nyunsa (25 Years History of KIST)*, Seoul: Korea Institute of Science and Technology.

Mason, E.S., M.J. Kim, D.W. Perkins, K.-S. Kim and D.C. Cole (1980), *The Economic and Social Modernization of the Republic of Korea*, Cambridge, MA: Harvard University Press.

NTIS (National Technical Information Service) (1993), *Industrial Patent Activity in the United States: Part I Time Series Profile by Company and Country of Origin, 1969–1992*, Washington, DC: Patent and Trademark Office, July, A1–1.

Suh, Sang Chuh (1978), *Growth and Structural Change in the Korean Economy, 1920–1940*, Cambridge, MA: Harvard University Press.

Vogel, Ezra F. (1991), *Four Little Dragons: The Spread of Industrialization in East Asia*, Cambridge, MA: Harvard University Press.

Westphal, Larry E., Linsu Kim and Carl J. Dahlman (1985), 'Reflections on the Republic of Korea's acquisition of technological capability', in Nathan Rosenberg and C. Frischtak (eds), *International Technology Transfer: Concepts, Measures, and Comparisons*, Praeger: New York, pp. 167–221.

7. Technology acquisition and development in Taiwan[1]

Bee-Yan Aw

Like many developing countries, the earliest and most common sources of new technology for Taiwan were foreign direct investment (FDI), joint ventures, licensing agreements and, more indirectly, technology embodied in imports of new capital goods. During the period from 1960 to the mid-1970s, the process of acquiring and using foreign technology was facilitated by the availability of an educated labour force as well as the emphasis on the production of goods using relatively simple technologies. However, over the past two decades, with the rapid growth of real wages, the focus has shifted to new industries characterized by more capital- and technology-intensive processes. This development implies a significant increase in the demand for improved or new local technological capabilities among firms.

In the quest to stimulate private firms to increase R&D and training activities, various government incentives were enacted in 1983 and 1984 to enhance the profitability of such activities and to reduce the risk to investors. The Ten Year Science and Technology Development Plan (1986–95) called for R&D expenditures to rise from 1.04 per cent of GNP in 1986 to 2 per cent by 1995. It also called for an increase in the share of the private sector in total R&D from 40 per cent to 60 per cent in this period (Dahlman and Sananikone, 1990; Hou and San, 1990).

In Section 1 we document the initial conditions of Taiwan's economic development and the role of government policy in the early phases of industrialization. We also analyse the evolving roles of FDI, R&D and export activities in Taiwanese firms, the principal goal being to examine their access to technology from abroad and its interaction with firm-level efforts to learn new technology. In Section 2, firm-level data on nine of Taiwan's manufacturing industries are used to examine the characteristics of firms that invest in the three technology-enhancing activities. This reaction also provides insights into the changing importance of each of these activities on firms' productivity levels. We also review in detail three recent studies that use micro data to examine the technological characteristics of Taiwanese firms and the direct and indirect productivity effects of firms that invest in activities such as R&D, exports and FDI. The final section provides a summary and some policy conclusions.

1. THE HISTORICAL CONTEXT

Initial Conditions

Several historical, political and economic factors have facilitated Taiwan's postwar economic development. The most important of these are the Japanese colonization of Taiwan (1895 to 1945), the immigration of an educated elite from mainland China and the role of US economic assistance.

The Japanese colonial legacy laid the economic foundations for Taiwan's industrial development via the establishment of economic infrastructure such as transportation systems, educational development programmes and subcontracting and trading networks patterned after the ones in Japan. Although these efforts were directed to serve Japan's needs, the result was the gradual development of industrial entrepreneurship adapted to functioning in a market economy. The immigration of skilled professionals from China in the mid-1940s after the end of Japanese occupation was crucial in bridging the skill gap left by the departure of the Japanese administrators, technicians and skilled personnel. Many of these immigrants were wealthy entrepreneurs in the textile and food processing industries on the mainland and they were encouraged to re-establish their expertise in textiles and flour milling, with the assistance of US-financed imports of raw materials.

This early phase of Taiwan's post-war development laid the foundation for the rapid growth of Taiwan's industrial sector, with an emphasis on low capital intensity industries such as textiles, various food processing industries, plastics and electronics assembly. Levy (1988) identifies highly active traders and subcontractors as the primary factor that enabled firms to start production with very low initial investment costs compared to their counterparts in South Korea. This network of small traders and subcontracting relationships, initiated during the regime of Japanese colonization, thrived and grew as the economy expanded to include the lucrative export market during the 1960s and 1970s. By 1973 there were four times as many export traders in Taiwan as in South Korea.

In contrast to South Korea where government policy favoured large firms, the Taiwanese government encouraged the proliferation of small and medium-sized enterprises (SMEs) by requiring foreign investors to hook up with local suppliers and assembly operators. Over time, this relationship between foreign investors and small-scale local suppliers developed into a viable, efficient and dependable network of small subcontractors able and ready to act as local suppliers to foreign investors. Through subcontracting with foreign firms, local SMEs acquired the technology needed to produce goods of internationally competitive quality as well as having a ready market for their output. Thus, the contribution of foreign firms in Taiwan goes beyond making improved technology more accessible to local firms. They fuelled the development of the intricate network of permanent linkages between the local economy and the international economic system.

Foreign Direct Investment

Taiwan's reliance on FDI has been much higher than in Japan or South Korea. Nevertheless, in sheer volume, the direct contribution of FDI to Taiwan's economy has not been significant. Since the first inflows of FDI into Taiwan in the early 1960s, its share of gross investment in the manufacturing sector ranged from 5.56 per cent from 1962–69 and 11 per cent in the period from 1973–94. The bulk of this investment (80–90 per cent) came from foreign (non-Chinese) investors and went into electrical/electronic and the machinery industries. The average annual rate of growth of FDI has fallen from 27.5 per cent in the 1980s to 13.6 per cent from 1990–97 (Table 7.1).

Table 7.1 Foreign direct investment

Year	Value (US$ million)	Average annual growth rate (%)
1952–69	420.33	27.2
1970–79	1832.11	12.7
1980–89	8697.41	27.5
1990–97	18038.56	13.6

Multinational corporations (MNCs) were first attracted to Taiwan because of the cheap and disciplined labour force as well as the well-developed economic infrastructure. Local SME investors entered rapidly growing industries, aggressively seeking out foreign partners or, with government assistance, entered into subcontracting arrangements with MNCs. Hobday (1995) documents that during the start-up phase, many Taiwanese companies learned the art of manufacture by relying heavily on foreign firms for training and licensing agreements.

Policies such as local content requirements were used to generate backward linkages and create a market for a host of small local suppliers and assembly operations. This pattern of foreign investors generating a dense network of small-scale local suppliers took hold over the years, boosting export production and acting as an important channel for the transfer of technology through specification requirements. In addition, the growing numbers of local SME investors constantly competed for orders from foreign firms, resulting in a highly competitive market structure both in the domestic and international markets.

In contrast to the 1960s and early 1970s, when the focus of government policy towards FDI was on labour-intensive industries and processes, after about 1973 Taiwan's overall economic policies towards FDI shifted toward the promotion of more sophisticated, technology-intensive products and processes. The single most striking contrast in the technology development of Taiwan relative to Korea lies in the market structure that evolved. While the major players in the Korean manufacturing sector over the last three decades were large conglomerates, those in Taiwan were predominantly SMEs.

The electronics industry is a case in point. Rather than encouraging the growth of firms to a size at which they would become capable of undertaking serious technology development, the Taiwanese government took three simultaneous steps. First, it encouraged smaller firms to enter into subcontracting arrangements with larger foreign firms. Second, it developed a specialized infrastructure to stimulate the diffusion of technology to small local firms via various state-sponsored institutions such as the factory satellite system, the Industrial Technology Research Institute (ITRI), and the Hsinchu Science and Industry Park. Finally, it empowered industry associations to establish technology links between FDI firms and local producers and suppliers.

Export and local content requirements imposed on foreign firms, coupled with the transfer of foreign expertise in the areas of production, technical know-how, quality control and management assistance to local suppliers led to technological upgrading as well as the necessary backward linkages in the local economy (Schive, 1990). In exchange for their expertise, the government ensured an efficiently run subcontracting network, a ready supply of relatively inexpensive educated workers, and entrepreneurs with the strong potential to reduce the overall cost of production of the foreign enterprises. Most importantly, the creation of the Hsinchu Science and Industrial Park with its proximity to major universities and the leading technology research institute meant that MNCs could benefit from the ready availability of skilled personnel in addition to the generous financial and fiscal incentives within the park. Another purpose of the park was to capture spillovers from the presence of foreign firms in terms of training, technology transfer and direct cooperation with local firms.

The foreign firms' links with local producers were further strengthened by pro-active industry associations. The electronics industry association, TEAMA (the Taiwan Electric Appliances Manufacturers' Association), aggressively recruited members from both foreign and local firms and, with the support of the government, actively promoted the local content programme. This programme was instrumental in establishing the link between local producers and MNCs (Kuo, 1995). Local producers wanted to take advantage of the technology, management skills and sales networks of MNCs. Foreign producers stood to benefit from the local content programme because it reduced labour and transportation costs as long as local supplies met their quality standards. Consequently, the response of MNCs was enthusiastic. They began to train local technicians, provide technical know-how and management skills to suppliers and cooperate with technical schools on internship programmes. These links were further strengthened through the establishment of production satellite systems, which formally connected local producers and MNCs as well as small producers of parts and components and large assemblers.

In sum, anecdotal and case-study evidence indicates that FDI helped upgrade the technological capabilities of the manufacturing sector through subcontracting and technical cooperation agreements between foreign and local producers. In this chapter, we take the existing literature further by quantifying both the direct effects of FDI and the indirect effects, the latter by measuring the spillover to local firms located in the same geographical region as well as in the same industry.

In addition to linkages created with foreign investors, Taiwan formed other important linkages with the wide network of overseas Chinese. These overseas Chinese constitute an important source of foreign direct investment and marketing. The bulk of initial investments into Taiwan came from Asia, and local manufacturers relied on the Chinese network to market their products in those countries. As Taiwan moved into the high-technology sector of development, ethnic Chinese living in advanced industrialized countries began to invest in Taiwan and more importantly, to provide a source of technical manpower as they returned to work in high-tech corporations in Taiwan. The government has been very successful in luring back overseas Chinese with fiscal and financial incentives. Many returning nationals were educated in US and Japanese universities and have assumed positions of leadership in large Taiwanese corporations. Their strategic role is even more apparent at the Hsinchu Science Industrial Park, where the majority of computer companies are owned by overseas Chinese or by Taiwanese who used to work overseas (Dahlman and Sananikone, 1990).

Despite the policy emphasis on developing this system of intricate networks, the dynamism that fuelled Taiwan's economic growth came primarily from the private sector. In particular, small and large, foreign and domestic firms were drawn towards the rapidly expanding export market.

Exports

The government's policy of emphasizing exports in the 1960s and 1970s stimulated local entrepreneurs to export, initially in textiles and processed foods and later in electronics. During this period, as Taiwan's reputation as a low-cost, flexible and efficient supplier grew, foreign buyers from large retail chains in the USA set up offices in Taiwan to deal directly with small manufacturers. Contacts between local producers and foreign buyers were frequent and deepened Taiwan's ties with the international community by linking local producers with foreign customers.

More recent research has revealed that these links with foreign buyers are more than just sources of demand for Taiwanese goods. They are also important sources of foreign technology transfer (Westphal et al., 1984; Pack, 1992). Levy (1994), using detailed field interviews in several developing countries, concludes that foreign buyers and traders are among the most important sources of technological information and support for SMEs. Foreign buyers, eager to purchase from cheaper sources, often provided Taiwanese firms with product designs and technical assistance to upgrade their technology and meet their quality standards and specifications.

This focus on foreign contacts as a conduit for new information on technology is based in large part on the observation that the bulk of Taiwan's exports are made to order and sold under the foreign buyer's brand names (Sease, 1987). In order to ensure better quality, low-cost products, buyers such as Walmart and J.C. Penney's were often willing to transmit knowledge from alternative, often OECD-member suppliers and pass on the information to local suppliers (Evenson and Westphal, 1995; World Bank, 1993; Westphal et al., 1984). According to Evenson and Westphal (1995), 'a good deal of information needed to augment basic capabilities has come from the buyers of exports who freely provide product designs and offered technical assistance to improve process technology in the context of their sourcing activities. Some part of the export-led development must therefore be attributed to externalities derived from exporting' (p. 2264). Through the constant adaptation of their production methods to specifications provided by foreign purchasers, the authors cite evidence of substantial transfer or inflow of non-proprietary technology.

The industry that has been found to gain most from these opportunities and to learn to design new products is electronics (Gee and Kuo, 1998).

According to Westphal (2002), the combination here of continuous and rapid technological change and clearly articulated supply chains among producers has enabled countries like Taiwan to move to higher levels of technological development, progressing to more skill- and technology-intensive activities. Therefore, to the extent that these export-related technology transfers lead to significant and incremental technological change, participation in the export market can be a source of productivity gains for the firm. This hypothesis is tested in the empirical exercise for the Taiwanese electronics industry in Section 2 of this chapter.

Research and Development

The role of R&D in firm-level efficiency was recognized in the early work of Allen (1977) and Mowery (1983). They proposed that firms invest in R&D to maintain their ability to learn, absorb and use new knowledge, achieving a level of technical capability that keeps them abreast of the latest technological developments.

Table 7.2 R&D expenditure indicators

Year	Amount (US$ million)	% of GDP	Ratio of public to private
1986	820	1.01	60:40
1991	3178	1.70	52:48
1996	5040	1.85	42:58

Table 7.2 gives the values of R&D expenditures and their share of GDP in 1986, 1991 and 1996. Although R&D expenditures as a share of GDP rose from 1 per cent in 1986 to 1.85 per cent ten years later, it is considerably lower than the 2.5–3 per cent in industrialized countries. Exploring the efficiency implications of the ways in which firms acquire and effectively appropriate technology has important policy implications in NICs such as Taiwan, where enterprises are heavily dependent on government and foreign sources for new or improved technology. By virtue of their size and limited capital, Taiwanese SMEs have generally ignored the potential value of long-term commitment to research and therefore spend little on R&D. It is the larger firms that undertake R&D or import technology from foreign sources either through joint research or consultancy.

The Taiwanese government's policy has been to compensate for the handicaps faced by SMEs in conducting R&D or buying foreign technology by importing technology on their behalf and establishing the infrastructure to disseminate technological information. The most innovative of these institutions is the Center Satellite Factory system, established in 1984. The purpose of this was to form a subcontracting network between small and medium-sized firms and large firms, linking them to exploit their common interests and mutual benefits. The lead firm would provide technical assistance to satellite SMEs in exchange for dependable and eventually low-cost inputs. By 1988, 50 lead firms with 1015 satellite SMEs had been established.

However, despite the importance of public institutions, recognition of the crucial role played by firms in the development of technological capability is clearly revealed in government policy. Since the early 1980s, policies have been devised to shift the burden of activities related to the upgrading of technology gradually away from the government to firms, and to encourage the latter to expend their own resources in acquiring new technology. Column 3 of Table 7.2 shows that between 1986 and 1996 the share of public expenditure in total R&D fell from 60 to 42 per cent. In addition, in the 1990s government policy to encourage technology development switched from a policy that targeted specific industries such as electronics to one that targeted functions, including conducting R&D or manpower training and environmental compliance.

In a 1987 survey, 1406 firms in various industries were asked to indicate the most effective government policy for promoting technological development (San, 1989). Table 7.3 reports the results of the survey. Only a small percentage of firms considered fiscal incentives the most effective way of advancing their technological capability. The more important forms of government assistance were: educating more R&D personnel (18.8 per cent), coordinating firms to conduct joint research (18.6 per cent), introducing new technology from abroad (17.2 per cent) and transferring technology through

Table 7.3 Firms' views about the most effective ways in which government could promote a satisfactory technology level (%)

Educating more R&D people	18.8
Coordination among firms to do joint research	18.6
Introduction of new technology from abroad	17.2
Transferring technology through government-sponsored research institutions	15.6
Helping firms to establish their own brand names	8.8
Offering low-interest loans for R&D activities	7.6
Tax credits from R&D expenditures	7.8
Standardization of parts and components	n/a
Others	n/a

government-sponsored research institutions (15.6 per cent). These results point to the importance of policies involving investments in education and R&D manpower development, acquiring technology from abroad via formal and informal means, and effective diffusion of technological information and R&D results through well-integrated, government-sponsored research institutions such as the Industrial Technology Research Institute. The overriding goal of investments in R&D, public or private, is to exploit the public good property of investments in R&D and aid firms in capturing the spillovers of these investments.

Technology Spillover

The empirical literature on spillovers falls into several categories defined by the units of observation in the data or the source of spillovers. There are country studies, patent studies and micro-data studies. Country studies such as Coe and Helpman (1995) and Coe et al. (1997) use countries as the basic unit and explore the transmission of knowledge from one country to another. Patent studies such as those conducted by Jaffe (1986) use patent data to determine the 'knowledge distance' between two firms and then estimates the effect that one firm's technology investments has on its neighbours' incentive to invest in additional knowledge. Micro-data studies use firm-level census or survey data to assess the magnitude of knowledge spillovers across firms. Several studies have been done using data on FDI. These empirical models hypothesize that foreign firms bring portions of their stocks of knowledge with them when they invest overseas and that domestic firms are able to learn from their presence. Examples of these studies are Aitken et al. (1997) and Blomstrom and Sjöholm (1998).

Other empirical models test the hypothesis that firms learn by exporting rather than by hosting foreign firms and that their domestic competitors benefit from their knowledge. Learning may occur because firms gain knowledge about foreign markets or because the importers in developed markets share technical knowledge with their suppliers in less developed countries. Examples of such studies are Aw et al. (2001), Clerides et al. (1998) and Bernard and Jensen (1999).

If the knowledge transmission process takes time, access to a large stock of proximate knowledge today is likely to affect future total factor productivity (TFP) or growth in productivity. Several building blocks are needed to specify any testable model of spillovers: a source of spillovers, a measure of the knowledge proximity of two firms, and a measure of firm performance.

Most models of international spillovers can be more precisely illustrated as in Figure 7.1.

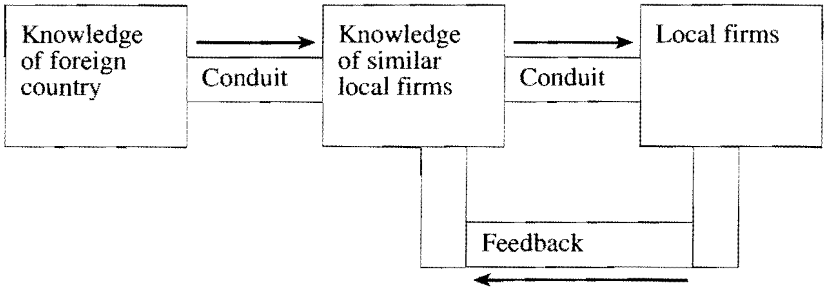


Figure 7.1 *International spillovers*

The knowledge source is a body of knowledge that a firm can access. The conduit is the means by which this knowledge is passed to each firm. Figure 7.1 implies that local firms do not have direct access to the knowledge of foreign firms. Instead, local firms benefit only from the knowledge of similar local firms. The knowledge of foreign firms finds its way into the local knowledge pool through FDI, production for export and so on. Thus the conduit may be something as simple as a firm observing the successful practices of another firm, so that knowledge transmission is facilitated between neighbouring firms. Alternatively, firms within the same industry (narrowly defined) are more likely to benefit from each other's technological activities relative to firms in industries producing very different goods. The literature suggests other possible conduits for knowledge such as intermediate goods and labour movements. A firm that incorporates a new (higher quality) good into its final product may reap some of the benefit of the knowledge used by its supplier. As workers move from one firm to another they may transfer knowledge from their old employer to their new employer.

Access to the source of knowledge generally has two effects. First, a firm may learn from the body of knowledge and therefore improve its performance, and second, it may choose to invest in additional knowledge, the feedback effect. The literature suggests many characterizations of knowledge that could spill over from one firm to another. It may be product design, production techniques, knowledge of domestic or foreign markets, marketing experience, knowledge of financing opportunities and so on. In terms of policy, the presence of spillover effects on other firms producing either for the domestic or export market provides the basis for some form of government action to ensure the socially optimal level of technology development in the economy.

In the next section we describe the technological characteristics of Taiwanese firms in the Census of Manufactures and survey the empirical evidence to date of the links among FDI, exports and R&D expenditure in firm performance.

2. TECHNOLOGICAL CHARACTERISTICS OF TAIWANESE FIRMS

Incidence of FDI, Exports and R&D by Industry

Table 7.4 shows the characteristics of the nine major manufacturing industries in Taiwan for 1986–96. In 1986 and 1996, the electric/electronics industry has the highest share of firms with FDI, at 3.5 and 2.1 per cent, respectively. A close second is the transportation industry. In any given year, the remaining industries have less than 1 per cent of firms with FDI. The variance across industries is smaller for expenditure on R&D, although the percentage of firms involved in R&D in the electrical/electronics industry is 10.6 per cent, a figure at least twice that in other industries. The relatively low proportion of firms that report such expenditures suggests that only formal R&D and training are being captured by these variables, the understatement being most acute in smaller firms where these activities tend to be more informal.

In all industries, a much larger proportion of firms are involved in export activity. Throughout the decade 1986–96, the industry with the highest proportion of exporting firms is electrical/electronics, where the share for all census years has stayed relatively constant at between 20–22 per cent.

Cross-Sectional Evidence of the Links between FDI, Exports, R&D and Productivity

There are two papers in the literature that explore the roles of technology-enhancing activities such as FDI and R&D on productivity using firm-level data for Taiwan. The first paper, Aw and Batra (1998), is based on the 1986 Census of Manufactures while the second paper, Chuang and Lin (1999), uses survey data from large manufacturing firms in 1991.

Using micro-data from the 1986 Taiwanese Census of Manufactures, Aw and Batra (1998) estimate the technical efficiency of firms. Firm-specific characteristics, which include the firm's own investments in R&D and on-the-job training, are used to quantify efforts undertaken by firms to assimilate or modify acquired technology. These characteristics are introduced into a stochastic production frontier model to obtain consistent estimates of the correlations of R&D/training investments and international linkages with firm efficiency. Given the apparent importance of foreign technology in Taiwan, they also include characteristics reflecting the firm's links to the international marketplace in the form of firm-level export sales and the presence of FDI in the firm.

The results of the paper confirm the positive correlations between technology investments and firm-level productivity found in other countries using recently available micro-data (Tybout and Westbrook 1995 for Mexico; Roberts and Tybout 1997 for Colombia and Morocco). Contact with foreign purchasers by itself is associated with higher levels of technical efficiency, particularly in the more modern industries. They also find evidence that firm-level export activities have higher payoffs if accompanied by complementary investments in in-house technological capabilities, although this relationship appears to be industry-specific.

More generally the results suggest that efficiency and firm investments in R&D/training are positively correlated in all industries among both exporters and non-exporters. This correlation is significant in 9 out of 10 industries among non-exporters and in five industries among exporters. Thus, although there appears to be an additional 'bang' to exporters from simultaneous investments in R&D and job training in some industries, investing in R&D and training on its own appears to be significantly correlated with higher technical efficiency.

The results of the Aw and Batra paper suggest that to understand the correlation between efficiency and exports (or foreign linkages more generally) it is important to account for firm-specific investments in R&D and training that increase the capacity to absorb or improve new technology. The cross-sectional nature of the data set used in the Aw and Batra paper does not allow the authors to make conclusive statements on the issue of causality between these technological investments and efficiency. Panel data are essential for this.

Chuang and Lin (1999) also use cross-section data from a random sample of manufacturing firms in Taiwan to examine the spillover effects of FDI and R&D investments on firm productivity. Using the shares of foreign assets (or R&D) at the industry level as their measure of spillover, their regression results indicate that both effects are positive and statistically significant. The authors conclude that the evidence of positive spillover effects from FDI in the industry may therefore serve to reduce the incentives for local firms to strengthen their technical capability by unilateral investments in R&D. In this chapter, we present an alternative measure of spillover that is related more closely with the physical distance between firms undertaking an activity than simply aggregate measures of an activity.

Table 7.4 Mean characteristics of Taiwanese manufacturing industries, 1986

Industry	Number of firms	Size	Age	Capital–labour ratio	Percentage of firms with FDI	Percentage of firms with Exports	Percentage of firms with R&D
Textiles							
1986	7634	37.44	6.44	0.690	0.72	20.0	4.10
1991	7736	26.47	7.88	1.82		14.0	
1996	6276	23.81	10.07	2.81	0.33	10.5	
Clothing							
1986	3262	44.97	5.47	0.432	0.83	30.0	4.54
1991	3603	28.27	7.05	1.15		18.2	
1996	5176	19.79	9.44	1.83	0.43	12.1	
Paper/publishing							
1986							3.91
1991	1151	71.57	10.07	3.18		20.0	
1996	1151	73.34	12.86	4.44		23.4	
Plastics							
1986	10387	29.34	5.29	0.560	0.51	20.1	3.47
1991	13088	17.00	6.63	1.46		12.0	
1996	13648	13.50	9.07	2.26	0.43	10.0	
Iron and Steel							
1986	2837	27.87	6.91	1.23	0.74	12.0	3.56
1991	4788	23.58	7.57	2.43		7.16	
1996	5656	20.59	9.39	4.16	0.85	8.00	

Machinery							
1986	9763	11.54	6.70	0.724	0.51	12.3	3.28
1991	14964	11.30	7.15	1.80		9.64	
1996	18458	10.35	8.90	2.42	0.47	10.1	
Chemicals							
1986	980	67.83	8.10	1.63	4.18	19.0	11.8
1991	3804	18.17	7.84	2.09		5.31	
1996	3981	15.77	10.02	2.45	0.58	4.72	
Electric/electronics							
1986	7504	9.82	0.67	0.600	3.53	2.0	10.6
1991	11619	39.74	6.44	1.51		22.0	
1996	14063	38.07	8.36	2.70	2.12	20.0	
Transport equipment							
1986	4076	29.57	6.70	0.664	1.25	17.3	4.69
1991	5407	24.49	7.76	1.65		13.0	
1996	5955	24.90	9.61	2.23	1.18	9.30	

Panel Data Evidence of Links between FDI, Exports, R&D and Productivity

In this section, we report the results of Aw (2001) where an attempt is made to quantify the direct and indirect (spillover) productivity effects of firm-level investments in R&D, FDI and exports. The objective of this chapter is to see if it is possible to predict higher efficiency or productivity for firms that commit their own resources to enhancing their technological capability, or that have direct access to foreign technology, or both. Details of the empirical model estimated are contained in the appendix.

Aw (2001) estimates the empirical model for the Taiwanese electronics industry using a panel data set constructed for 1986 and 1991. Questions regarding the assimilation of foreign technology are especially relevant in this industry for several reasons. First, it is Taiwan's fastest growing and most dynamic export industry. Output growth in the electronics industry skyrocketed after 1985 with exports growing at an average annual compound rate of almost 37 per cent between 1985 and 1988. By the late 1980s it was the largest industrial sector, accounting for over 25 per cent of total exports and over 5 per cent of GNP in 1987. Second, it is the industry with the highest share of exporting firms and firms with FDI and R&D expenditures in the manufacturing sector. Third, the electronics industry has regularly been cited in the literature as possessing the ideal characteristics for export-related technology transfer and has been shown to experience extraordinary technology transfer and assimilation. Finally, the industry's successful development has had a substantial effect on other industries, encouraging new firm entry and the development of foreign market contacts. It has also been the focus of government efforts to stimulate technology diffusion through the rest of the manufacturing sector.

In the empirical model, we also hypothesize that firms located in the same industry or geographical region or county as those that engage in exports, FDI and R&D investments are more likely to benefit from the diffusion of new knowledge associated with these activities. This 'spillover' of foreign technology is obtained by taking the number of firms in a given county (or industry) that are involved in a given activity divided by the total number of firms in the industry.[2]

Table 7.5 contains the results of the TFP growth regressions controlling for a sample selection.[3] Columns 2 and 3 report the results of including the spillover variables expressed as participation rates for SMEs and large enterprises, respectively.

The most striking pattern using the participation measure of spillover is that the coefficient estimates of the R&D, exports and FDI variables as well as two of the six variables used to capture technology spillover are positive

Table 7.5 Coefficient estimates of TFP growth regression by firm size

Variable	Firm size: Small	Firm size: Large
TFP growth equation:	N=3164	N=416
Constant	−0.195*** (0.058)	−0.051 (0.096)
RD	0.071* (0.041)	0.021 (0.035)
Exports	0.039* (0.023)	0.010 (0.063)
FDI	0.143* (0.089)	0.043 (0.039)
County RD	−0.036 (0.026)	−0.031 (0.043)
Industry RD	−0.035 (0.038)	−0.085 (0.058)
County exports	0.015 (0.048)	0.021 (0.070)
Industry exports	0.081** (0.038)	−0.037 (0.070)
County FDI	0.030** (0.016)	0.030 (0.020)
Industry FDI	0.018 (0.024)	−0.051 (0.096)
λ	0.877*** (0.015)	0.828*** (0.045)

Notes:
λ represents the inverse Mill's ratio retrieved from the survival equation estimated in the first step. The estimated coefficients of the survival equation in each separate case do not deviate significantly from the ones reported in the appendix and are therefore not reported here.
*** Statistically significant at 1% level.
** Statistically significant at 5% level.
* Statistically significant at 10% level.

and statistically significant for small firms but not for large firms. For these SMEs, the magnitude of the coefficient for FDI is more than three times that of exports and one-and-a-half times that of R&D. In addition, a 10 per cent increase in the share of firms within the county that has FDI increases firm productivity growth by 3 per cent, while the corresponding figure for exports within each 4–digit industry is much bigger at 8.1 per cent. The coefficients for participation in R&D are negative but not statistically significant.

Given that the three investment activities are generally undertaken by larger firms, the presence of industry spillovers in the case of exports and geographical spillovers in the case of FDI from larger to smaller firms justifies policies that recognize the importance of these activities in technology diffusion. The evidence is particularly true for FDI and export activities since, in addition to the returns to own investments in these activities, benefits are generated within the industry as well as within geographical regions.

Table 7.6 reports the results of the 'pure effects' of the spillover variables for exports and FDI by restricting our observations in the regressions to,

Table 7.6 Coefficient estimates of TFP growth regression for non-exporters and non-FDI firms

Variables	Non-exporters	Non-FDI
TFP growth equation:	$N=2177$	$N=3423$
Constant	−0.342*** (0.078)	−0.191** (0.053)
RD	0.142** (0.072)	0.098** (0.031)
Exports	—	0.048* (0.022)
FDI	0.097 (0.252)	—
County RD	−0.033 (0.033)	−0.044 (0.024)
Industry RD	0.009 (0.047)	−0.023 (0.035)
County exports	−0.038 (0.062)	0.033 (0.044)
Industry exports	0.030 (0.046)	0.059* (0.035)
County FDI	0.024 (0.021)	0.029* (0.014)
Industry FDI	−0.005 (0.030)	0.012 (0.022)
λ	0.906*** (0.015)	0.867*** (0.015)

Notes:
λ represents the inverse Mill's ratio retrieved from the survival equation estimated in the first step. The estimated coefficients of the survival equation in each separate case do not deviate significantly from the ones reported in the appendix and are therefore not reported here.
*** Statistically significant at 1% level.
** Statistically significant at 5% level.
* Statistically significant at 10% level.

first, non-exporters (column 2) and second, firms without any FDI (column 3). A surprising result from examining column 2 is that the spillover benefits from the export activity within 4-digit industries (Table 7.5) do not go to non-exporters. In the case of FDI, there is strong evidence of geographical spillover of county FDI activity to firms without any FDI. Thus, in contrast with the export activity, there are 'pure' geographical externalities from having a larger share of firms that have FDI involvement.

3. SUMMARY AND CONCLUSIONS

FDI is a traditional channel of technology acquisition by firms in developing countries. In Taiwan, it has been widely cited as an important conduit for firms wishing to upgrade their technological capabilities. Much of the transmission of knowledge has been said to occur through subcontracting and technical cooperation agreements between foreign and local producers. In addition, many researchers also stress the importance of private investment in technological capability such as R&D and worker training. These researchers propose that firms invest in R&D or on-the-job training to maintain their ability to learn, absorb and use new knowledge, thus achieving a level of capability that keeps them abreast of the latest technological developments.

However, more recent case studies and anecdotal evidence on the acquisition of foreign technology in NIEs strongly suggests that the most important conduits for technological diffusion are neither formal R&D nor FDI but rather the informal contacts firms have with others in the industry through export activity. Proponents of this view claim that the transfer of technology related to export activity may be an especially crucial means for learning in the SMEs that dominate the Taiwanese manufacturing sector.

Our review of the few empirical papers based on firm-level data in Taiwan reveals several key points. First, the export activity by itself is associated with higher levels of technical efficiency, particularly in the more modern industries. This is consistent with every empirical study that has examined the relationship between exports and productivity. In addition, exports appear to have higher payoffs if accompanied by complementary investments in developing in-house technological capabilities such as R&D and worker training. Second, there is some evidence that there are positive spillover effects of industry-level FDI and R&D investments on firm productivity.

Finally, our examination of electronics firms in 1986 and 1991 indicates that export, R&D and FDI are positive direct sources of growth in productivity. Of the three activities, FDI appears to have the strongest significant and positive direct effect on TFP growth. However, in terms of spillover benefits from these activities, only FDI and exports provide an additional boost to TFP growth. In the case of the export activity, within-industry spillovers are reaped primarily by SMEs and among exporting firms. In the case of FDI, geographical spillovers are positive and have a statistically significant effect on TFP growth of firms without FDI. There is no evidence of any geographical spillover from exporters to non-exporters but some evidence of within-industry spillover. Coupled with the recent finding that it is the 'good' (high productivity) firms that penetrate export markets, rather than exports being the 'cause' of higher productivity, our results indicate that pure spillover effects, if they exist, are far less important than the direct returns to the activity to exporters.

Given Taiwan's status as a technology latecomer, it is not surprising that foreign firms and exporters have higher rates of productivity growth (being more exposed to continuing flows of technical knowledge) than firms with no foreign equity or non-exporters. Moreover, in industries such as electronics where the production frontier is shifting rapidly, such knowledge transfers have a larger impact on productivity growth for firms that have the technical ability and resources effectively to absorb this knowledge

(Pack, 1992). To the extent that R&D expenditures fulfil this role, it explains the positive and significant relationship between R&D and productivity growth.

These results are consistent with the findings of positive spillovers from industry-wide FDI to firm productivity levels in 1991 in Chuang and Lin (1999). The key returns to FDI are likely to be a reflection of the success of efforts of the government and industry associations in linking foreign investors with local producers. Concerted efforts by the government in encouraging and establishing an efficient system of subcontracting networks have contributed significantly to the rapid transfer of technology and the upgrading of technology as well as to backward and forward linkages in the economy.

The lesson for other developing countries is that under certain conditions FDI can facilitate technology transfer within industries and more importantly, within regions. These conditions are likely to be closely related to an economic infrastructure that includes, for Taiwan, a dense network of local producers available to provide the necessary link with the foreign presence. This factor may be just as important as the FDI itself.

R&D by private firms in Taiwan is crucial for building the ability to absorb and use imported technology. Given that the era of low-cost acquisition of non-proprietary information has come to a close, firm-level investments in R&D may assume increasing importance as product cycles become even shorter and markets more competitive. Our results suggesting the lack of any spillover of firm-level expenditures on R&D to other firms in the county or industry may reflect the firm-specific nature of R&D. Alternatively, our R&D measure may be an imperfect reflection of firm investments in technological capability.

Finally, our empirical results provide some insights into the sources of higher productivity growth among SMEs. In contrast to large firms, all three technological activities are positively and significantly correlated to TFP growth in SMEs. We also find evidence of geographical spillovers from FDI and industry spillovers from export activity among SMEs.[4] These results are consistent with the literature on the role of SMEs in the industrial development of Taiwan, as enterprises possessing greater flexibility and having greater contributions to productivity growth (Levy, 1988; Pack, 1992) than their larger counterparts.

APPENDIX

In this appendix, we summarize the methodology and data used to estimate the direct and spillover effects of the three investment activities of exports, R&D and FDI. Further details of the model can be found in a related paper by Aw (2001).

The principal equation of the empirical model is one describing the growth in firm TFP from 1986 to 1991 as a function of firm-level efforts to formally or informally accumulate or assimilate advanced technology. This is written as

$$\text{TFP Growth}_i = Z_i \exists_2 + (_{12}\, N\,(X_i \exists_1)/(1 - M(X_i\, \exists_1)) + \mu_{2i}$$

where the dependent variable is the surviving firm's growth in relative TFP, measured as the difference in the levels of relative TFP in 1986 and 1991. This is regressed on Z_is, which include three separate dummy variables representing the three activities undertaken by firms. These dummy variables take on the value of 1 for firms with positive expenditures on R&D, foreign direct investments and exports. Given the predominance of SMEs in Taiwan, the observations in the estimation work are separated into SMEs (firms with 100 or fewer employees) and large employees (firms with more than 100 employees).

In addition to these three dummies we also include six variables that reflect the 'spillover' effects of R&D, FDI and exports at the county and industry levels. The spillover measures of R&D, FDI or exports are represented by the share of the number of total firms (in the county or 4-digit industry) that record positive values for these variables. These measures are useful in determining if productivity is related to the rate of participation in these activities.

Given that TFP growth rates are not observed for those firms that fail between 1986 and 1991, only survivors remain in the data set and do not represent randomly selected members of the population. The sample selection problem that results is accounted for using the Heckman (1981) two-stage estimation technique. The basic results indicate that firms with higher initial year TFP levels and higher initial year R&D, FDI and exports are more likely to survive into the next period.

$\exists_2$ is the parameter vector estimated from the growth equation, and $(_{12}$ is the covariance between the disturbance terms in the survival equation described below. The expression $N(X_i\, \exists_1)/(1 - M(X_i\, \exists_1))$ is the inverse Mill's ratio, 8, from the survival equation and N and M are, respectively, the density and distribution function for the standard normal random variable. The denominator of the Mill's ratio represents the probability that a population observation with characteristics, X_i is selected into the observed sample. Recall that this is constructed in order to control for the probability of selection into the sample of firms used in the TFP growth regressions. If the disturbances affecting the sample selection are independent of the disturbances affecting the growth equation (($_{12}$ = 0), then 8 may be ommitted as a regressor. That is, $\exists_1$ is an unbiased estimator only if either ($_{12}$ or 8 is zero. In our analysis, all the Z_is, except for exports, are based on initial values of the variables in 1986.

The model estimated above is similar to models estimated by Evans (1987), Hall (1987) and Doms et al. (1994). Unlike the Evans and Hall models, where the X_is are identical to the Z_is, identification of the parameters is achieved through the nonlinearity of the Mill's ratio in X_i and the fact that the variables that influence the survival probability are different from those that enter into the growth equation in the second stage. To control for the likelihood of the problem of heteroskedasticity in the data, standard errors that are consistent under heteroskedasticity are constructed following White (1980).

NOTES

1. I would like to thank the conference participants for very helpful comments and Tor Winston for invaluable research assistance.
2. We also used a second measure of spillover that captures the intensity of an activity by taking the sum of export values (or R&D) of other firms in the same industry or region. In general, our results are not sensitive to the different measures. The only exception is that while the county FDI for large firms is not statistically significant with the participation measure of spillover, it is statistically significant when spillover is measured in terms of intensity.
3. Our estimation of the survival regression indicates that the inverse Mills ratio represented by lambda is large, positive and statistically significant. This suggests that if sample selection was not controlled, the coefficient estimates of the growth equation are likely to be biased.
4. A possible explanation for why the technology variables are not statistically significant for the large enterprises is that large firms in the industry are likely to be more productive because of their greater skills and/or better organizational and management capabilities. Grouping firms by their size is likely to take these (unobservable) factors into account, blurring the productivity effects of the firm's own investments in technological capability. Another possibility is if that firm size is a good proxy for the degree of technological activity and sharing among firms and that this feature may have a more important effect on its productivity growth than the other activities.

REFERENCES

Aitken, Brian, Gordon H. Hanson and Ann E. Harrison (1997), 'Spillovers, foreign investment, and export behavior', *Journal of International Economics*, **43**(1–2) 103–32.

Allen, T.J. (1977), *Managing the Flow of Technology*, Cambridge, MA: MIT Press.

Aw, Bee Yan (2001), 'Accumulating technology and location spillovers among firms in Taiwan's electronics industry', working paper, Department of Economics, Pennsylvania State University.

Aw, Bee Yan and Geeta Batra (1998), 'Technological capability and firm efficiency in Taiwan', *World Bank Economic Review*, **12**(1), 59–79.

Aw, B.Y., X. Chen and M.J. Roberts (forthcoming), 'Firm-level evidence of productivity differential, turnover, and exports in Taiwanese manufacturing', *Journal of Development Economics* **66**(1), 51–86, and NBER working paper No. 6235, Cambridge, MA.

Bernard, Andrew B. and J. Bradford Jensen (1999), 'Exceptional exporter performance: cause, effect, or both?', *Journal of International Economics*, **47**(1) 1–25.

Blomstrom, Magnus and Fredrik Sjöholm (1998), 'Technology transfer and spillovers: does local participation with multinationals matter?', NBER working paper No. 6816, Cambridge, MA.

Chuang, Yih-Chyi and Chi-Mei Lin (1999), 'Foreign direct investment, R&D and spillover efficiency: evidence from Taiwan's manufacturing firms', *Journal of Development Studies*, **35**(4), 117–137.

Clerides, Sofronis K., Saul Lach and James R. Tybout (1998), 'Is learning by exporting important? Micro-dynamic evidence from Colombia, Mexico, and Morocco', *Quarterly Journal of Economics*, **113**(3), 903–47.

Coe, D. and E. Helpman (1995), 'International R&D spillovers', *European Economic Review*, **39**, pp. 859–87.

Coe, David T., Elhanan Helpman and Alexander Hoffmaister (1997). 'North-South research and development spillovers', Centre for Economic Policy Research, discussion paper 1133, 27.

Dahlman, C. and O. Sananikone (1990), 'Technology strategy in the economy of Taiwan: exploiting foreign linkages and investing in local capability', mimeo, The World Bank, Washington, DC.

Doms, M., T. Dunne and M.J. Roberts (1994), 'The role of technology use and the survival and growth of manufacturing plants', University of Oklahoma, working paper.

Evans, D. (1987), 'Tests of alternative theories of firm growth', *Journal of Political Economy*, **95**, 657–74.

Evenson, R.E. and L.E. Westphal (1995), 'Technological change and technology strategy', in J. Behrman and T.N. Srinivasan (eds), *Handbook of Development Economics*, Vol. 3A, Amsterdam: North Holland.

Gee, San and Wen-jeng Kuo (1998), 'Export success and technological capability: textiles and electronics in Taiwan province of China', in Dieter Ernst, Tom Ganiatsos and Lynn Mytelka (eds), *Technological Capabilities and Export Success in Asia*, London and New York, Routledge.

Hall, B. (1987), 'The relationship between firm size and firm growth in the U.S. manufacturing sector', *Journal of Industrial Economics*, **35**, pp. 583–606.

Heckman, James J. (1981), 'The incidental parameters problem and the problem of initial conditions in estimating a discrete stochastic process and some Monte Carlo evidence in their practical importance', in Charles Manski and Daniel McFadden, (eds), *The Structural Analysis of Discrete Data*, Cambridge, MA: MIT Press.

Hobday, M. (1995), *Innovation in East Asia*, Aldershot, UK and Brookfield, MA: Edward Elgar Publishing Limited.

Hou, C.M. and G. San (1990), 'National systems supporting technical advance in industry: The case of Taiwan', mimeo, Taipei, Taiwan.

Jaffe, Adam B. (1986), 'Technological opportunity and spillovers of R&D: evidence from firms' patents, profits, and market value', *American Economic Review*, **76**(5), 984–1001.

Kuo, Cheng-Tian (1995), *Global Competitiveness and Industrial Growth in Taiwan and the Philippines*, Pittsburg: University of Pittsburg Press.

Levy, B. (1988), 'Korea and Taiwan as international competitors', *Columbia Journal of World Business*, Summer, 23(1).

Levy, B. (1994), 'Technical and marketing support systems for successful small and medium-size enterprises in four countries', policy research working paper 1400. Policy Research Department, World Bank, Washington, DC.

Mowery, D.C. (1983), 'The relationship between intra-firm and contractual forms of industrial research in American manufacturing, 1900–1940', *Explorations in Economic History*, **20**, 351–74.

Pack, H. (1992), 'New perspectives on industrial growth in Taiwan', in G. Ranis (ed.), *Taiwan From Developing to Mature Economy*, Boulder, CO: Westview Press.

Roberts, M.J. and J.R. Tybout (1997), 'The decision to export in Colombia: an empirical model of entry with sunk costs', *American Economic Review*, **87**, 545–64.

San, Gee (1989), 'Direct foreign investment and technology transfer in the Republic of China', *Proceedings of Conference on the Industrial Policies of the Republic of Korea and the Republic of China*, conference series 89–01, KDI, Seoul.

Schive, Chi (1990), *The Foreign Factor: The Multinational Corporation's Contribution to the Economic Modernization of the Republic of China*, Stanford, CA: Stanford University Press for the Hoover Institution.

Sease, D. (1987), 'Taiwan's export boom to U.S. owes much to American firms', *Wall Street Journal*, 27 May.

Tybout, James R. and M. Daniel Westbrook (1995), 'Trade liberalization and dimensions of efficiency changes in Mexican manufacturing industries', *Journal of International Economics*, 31, 53–78.

Westphal, Larry E., Y.W. Rhee and G. Pursell (1984), 'Sources of technological capability in South Korea', in M. Fransman and K. King (eds), *Technological Capability in Developing Countries*, London: Pinter.

Westphal, Larry E. (forthcoming), 'Technology strategies for economic development in a fast changing global economy', *Economics of Innovation and New Technology*.

White, H. (1980), 'A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity', *Econometrica*, 48, pp. 817–38.

World Bank (1993), *The East Asian Miracle: Economic Growth and Public Money*, Oxford: Oxford University Press.

8. From using to creating technology: the evolution of Singapore's national innovation system and the changing role of public policy

Poh Kam Wong

1. INTRODUCTION

Singapore has achieved impressive economic growth since independence in 1965 (Table 8.1). In 1999, and despite the impact of the Asian financial crisis, Singapore's per capita GNP stood, on a purchasing power parity (PPP) basis, at over US$27000. This was the highest in Asia, even including Japan, and globally came behind only Luxembourg, the USA and Switzerland (World Bank, 2000). In 1965, Singapore's PPP-adjusted per capita income was less than 16 per cent of that of the USA; as recently as 1980, it was still less than 50 per cent (Wong, 2001a).

The rapid economic expansion of Singapore was achieved through continuous industrial re-structuring and upgrading (Wong, 2001a). In the first decade after independence, growth was led largely by labour-intensive manufacturing. In the two subsequent decades it was propelled by the rapid technological upgrading of manufacturing. The development of Singapore into an increasingly important business, financial, transport and communications services hub in the Asia-Pacific region provided additional engines of growth (Table 8.2). Nevertheless, manufacturing has remained important to the economy, with its share of GDP remaining above 25 per cent for most years in the last two decades.

As in Korea and Taiwan, the growing technology intensity of Singaporean industry was supported by significant government initiatives in technical manpower development and infrastructure investment. The Singapore government was also a lead user of new technologies, especially information technology (IT). However, unlike Korea and Taiwan, Singapore's technology development was, until recently, largely dependent on multinational corporations (MNCs) rather than on indigenous companies (the *chaebol* in Korea (Amsden, 1989) and small and medium-sized

Table 8.1 Aggregate economic growth performance, 1960–2000

	1960–70	1970–80	1980–90	1990–2000	1990–97	1997	1998	1999	2000
GDP	8.7	9.4	7.1	7.5	8.4	8.5	0.1	5.9	9.9
Labour productivity	n.a	4.3	4.8	3.4	3.6	2.3	−2.7	6.3	5.6[p]
(% real growth per annum)									
GNP per capita	1960	1970	1980	1990		1997	1998	1999	2000
(S$ at current prices)	1 330	2825	9941	20090		39 310	38418	39721	42212[p]

Notes:
[p] Preliminary figures.

Sources: Calculated from MTI (1990), *Yearbook of Statistics Singapore* (1993, 1997, 2000), *Economic Survey of Singapore* (1998, 2000). Mid-year population estimate for 2000 obtained from Singstat website, http://www.singstat.gov.sg/FACT/KEYIND/keyind.html.

Table 8.2 Singapore GDP distribution by sectors, 1960–2000 (%)

Industry	1960	1970	1980	1990	1995	1999	2000
Agriculture & mining	3.9	2.7	1.5	0.4	0.2	0.2	0.1
Manufacturing	11.7	20.2	28.1	28.0	26.3	25.0	25.9
Utilities	2.4	2.6	2.1	1.9	1.6	1.9	1.7
Construction	3.5	6.8	6.2	5.4	7.0	7.8	6.0
Commerce	33.0	27.4	20.9	16.3	17.3	17.3	19.1
Transport & communication	13.6	10.7	13.5	12.5	12.4	11.1	11.1
Financial & business services	14.4	16.7	18.9	25.5	25.5	26.2	25.3
Other services	17.6	12.9	8.7	9.9	9.8	10.8	10.9
Total	100	100	100	100	100	100	100

Notes:
Figures may not add up to 100 due to rounding.
Total GDP excludes owner-occupied dwellings and calculations for taxes and duties on imports and imputed bank service charges.

Sources: Calculated from MTI (1990), *Yearbook of Statistics Singapore* (1993, 1997, 2000), *Economic Survey of Singapore* (2000).

firms in Taiwan (Dahlman and Sananikone 1990)). About three-quarters of Singapore's manufacturing output in recent years came from MNCs, and more than 60 per cent of equity in its manufacturing sector was foreign (Wong, 2001a). Technology transfer from MNCs was therefore the major source of technological upgrading in Singapore, not indigenous research and development. Publicly funded R&D was also on a smaller scale than in Taiwan and Korea. As a result, Singapore's R&D as a ratio of GDP lagged behind Korea and Taiwan, let alone most advanced industrial countries (Table 8.3).

Table 8.3 Comparative R&D indicators, Singapore and selected OECD/Asian NIEs

Grouping	Country	Year	R&D/GDP (%)	RSE/10 000 labour force
G-5	Japan	1998	3.1	96
	Germany	1998	2.3	60
	USA	1999	2.8	74 (1993)
	UK	1998	1.8	55
	France	1997	2.2	61 (1996)
Industrialized small countries	Finland	1999	3.1	94 (1998)
	Switzerland	1996	2.7	55
	Sweden	1997	3.9	86
	Ireland	1997	1.4	51
	Netherlands	1996	2.1	46
	Denmark	1998	2.1	59 (1997)
	Norway	1997	1.7	76
	Australia	1996	1.7	66
	New Zealand	1996	0.9	35 (1995)
Asian NIEs	Korea	1998	2.5	48
	Taiwan	1998	2.0	66
	Hong Kong	1996	0.3	na
	Singapore	1999	1.8	70

Sources: National Science & Technology Board, *STI Outlook* (1996, 1998), STI Scoreboard (1999), APEC/PECC Pacific S&T profile (1995), *Far Eastern Economic Review* (14 May 1998), Science & Engineering Indicators (1998), and various national sources.

Since the late 1980s, however, the pace of science and technology development in Singapore has accelerated. The Singapore government has intensified efforts to promote R&D and technology-intensive activities with the establishment of a National Science and Technology Board (NSTB) and the launching of a National Technology Plan (NTP) over 1991–95, followed by a more ambitious second National Science and Technology Plan (NSTP) over 1996–2000. Local companies are beginning to invest more in innovation, while an increasing number of MNCs are investing in R&D activities and in upgrading manufacturing technologies in Singapore. In the new millennium in Singapore, the pace of S&T development is likely to intensify, supported by an increasing policy focus on high technology entrepreneurship and basic research. The national innovation system of Singapore is being transformed from one emphasizing the assimilation and diffusion of technology through leveraging MNCs to one promoting indigenous innovation capability and local high-technology start-ups.

This chapter analyses the changing structure of Singapore's innovation system and S&T policies in response to the needs of global competition. The organization of the chapter is as follows. In Section 2, we introduce a theoretical framework for analysing the structure of the national innovation system (NIS) and its relationship to economic performance. The framework highlights how public policy can shape and influence the system. Section 3 applies this framework to a stylized analysis of the evolution of Singapore's innovation system over four stages of economic development. Section 4 discusses how the role of public S&T policy has changed over time to support NIS development and describes the emerging institutional framework for S&T policy coordination in Singapore. Section 5 highlights the emerging S&T policy challenges facing Singapore. Section 6 provides a brief conclusion.

2. THEORETICAL FRAMEWORK FOR NATIONAL INNOVATION SYSTEM ANALYSIS

2.1 Concept of National Innovation System

The impact of science and technology policy is best examined by looking at innovation systems: how firms and public institutions interact *systemically* in building and using S&T resources. A national innovation system encompasses all innovative activities, not just formal R&D (OECD, 1993). While there is by now a vast literature on NIS in mature industrial countries (Dosi et al., 1988; Nelson, 1993; Lundvall, 1992; OECD, 1997), its emphasis is on elements relevant to advanced than to developing economies. The analysis of NIS in late-industrializing countries is just emerging, and it suggests the need to adapt the NIS framework to their particular conditions (Kim and Dahlman, 1992; Suh, 1998; Wong, 1999a).

2.2 NIS Framework for Small, Late-Industrializing Economies

This chapter builds upon the analytical framework for NIS in late-industrializing countries proposed in Wong (1995a, 1999a). Figure 8.1 provides a summary view of this framework. In essence, it identifies three key groups of innovation actors: the firm, public S&T institutions and the manpower development sector. These groups of actors interact with one another to achieve the two key objectives: efficiently to build the stock of *scientific and technological resources*; and effectively to allocate and deploy these resources to the innovation actors. Technological resources come not only

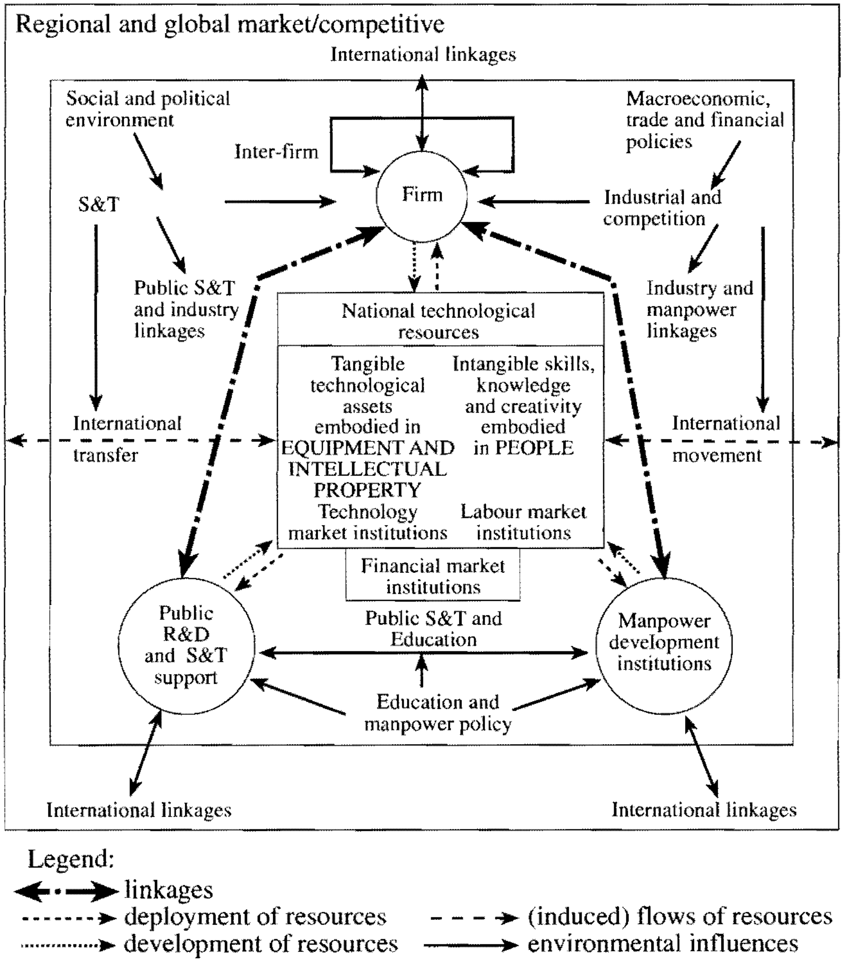


Figure 8.1 Analytical framework for national innovation systems

from technology development within an economy but also from the import or transfer of technology from abroad. Similarly, technologies developed within an economy need not be deployed domestically but also overseas.

Technological resources developed or deployed through innovation can be divided into two broad categories: (i) *tangible* know-how as embodied in capital equipment (hardware as well as software) and *tangible* intellectual property as embodied in patents, copyrights, trademarks and so on; and (ii) *intangible* know-how (skills, tacit knowledge and creativity) as embodied in people ('humanware'). The creation of tangible and intangible assets takes place in all three innovation actors. For example, the development of technical skills does not take place within formal education and training institutions alone; it also occurs within firms and R&D institutions through *learning-by-using* (acquired by utilizing a technology) and *learning-by-doing* (acquired by engaging in R&D).

Both technological resource development and deployment consume technological as well as non-technological resources. The performance of an NIS is thus measured by the effectiveness of *deployment* (*use*) as well as the *development* (*creation*) processes. High development effectiveness is not sufficient by itself: if deployment is not effective, the system is left with under-utilized (or mis-utilized) technological resources, resulting in low returns to development. As termed by Romer (1992), there needs to be a good balance between 'using ideas' and 'producing ideas'.

Figure 8.1 also highlights the importance of effective *linkages* among the three groups of innovation actors. Thus, there has to be close interaction between suppliers and buyers or users, technology alliances between firms, university-industry R&D collaboration, industry involvement in the design of the programmes of training institutions, and so on. Only then can technological resources be properly developed and deployed in the national system.

An important part of NIS, particularly in small, newly industrializing economies, is *international technology linkages* between local and external actors (in other national innovation systems). These linkages can take several forms: intra-firm technology transfer between the parent and affiliates of a transnational company, arm's-length transactions (equipment purchase, technology licensing and so on), or other intermediate forms of technology relationships (for example, international R&D consortia, technical standards coalitions, cross-licensing of technologies or long-term supplier-buyer relationships). Linkages between actors from different national systems provide flows of non-human embodied technological resources across national borders. They are also a major driver for international flows of technical manpower, through such means as intra-company staff transfer among MNC business units and company-sponsored participation in international conferences or trade-shows. The international flow of technical manpower also has a dynamic of its own, through voluntary migration, education overseas and the return of graduates and experienced employees to their home countries.

2.3 The Role of Market Institutions

It is useful to conceptualize technology development and deployment processes as mediated through *market institutions*, using the term to connote the full spectrum of transactional governance mechanisms, from internal hierarchies to relational contracting to arm's-length spot markets (Williamson, 1985). Three interacting sets of markets are critical to the NIS: markets for allocating tangible intellectual property, labour markets for allocating technical skills and talents, and financial markets for allocating risk capital (venture capital, 'business angel' capital and so on) to R&D and new ventures and facilitating their exit (public equity market or private mergers and acquisition market). These markets tend not to be perfectly competitive, even in advanced industrial countries, reflecting the complex nature of technological assets and intellectual property, the non-rivalrous nature of knowledge, the problem of pricing intangible and tacit know-how and the high degree of uncertainty in R&D and venture investments. There has therefore been a strong historical presence of public institutions in each of these markets. This is particularly true for late-industrializing countries, where private market mechanisms are relatively underdeveloped.

2.4 The Role of Public Policies and Institutions in Shaping NIS

Most countries have established government institutions and policy instruments to promote S&T development. However, our analytical framework suggests that the role of government in NIS is not confined to these special institutions and policy instruments. In principle, any government policy or institution that affects the behaviour and performance of any component of the NIS should be taken into account, regardless of whether or not it is aimed explicitly at S&T development. We can divide the role of government into two broad categories:

(i) The *direct role* of operating state-owned enterprises, public R&D institutions and public education and training institutions. Here the government is directly involved in innovation efforts, and its effectiveness may be evaluated in terms of the amount of technological resources created (number of patents and publications or numbers trained). In an NIS framework, however, it may be more useful to assess impact in terms of the eventual *deployment* of the resources generated (the number of patents actually licensed or the actual employment of graduates).

(ii) The *indirect role* of policies and regulatory frameworks that affect the performance of the three markets identified above. The policies and regulations likely to affect NIS performance include not only 'proximate' S&T policies such as R&D grants or tax incentives for innovation, but also more general policies that affect the incentive structure. This includes incentives of firms to innovate or of individuals to train and learn new skills or to start new firms to commercialize knowledge. General policies also relate to the efficient functioning of domestic linkages (for example, university-industry or inter-firm linkages) as well as international ones (MNCs transferring technology to their affiliates). The set of relevant policies and institutions is thus rather broad. It ranges from macroeconomic policies (for example, interest rates or inflation) and financial policies (especially with respect to development of venture capital industry and public equity market for exit) to trade, industrial and competition policies (controls over technology export and import, fiscal incentives, foreign investment policies). It also includes specific technology policies (subsidies for R&D in general or in particular areas, incentives for acquisition of certain technology goods, training grants for specific skills, intellectual property rights protection, and so on).

Although the NIS literature tends to focus on proximate S&T policies, there is no a priori reason to neglect general economic policies that may have a stronger effect. For example, macroeconomic stability and trade orientation (World Bank, 1993) or competition policy (Porter, 1990) may affect innovation more than tax incentives for R&D spending. The phenomenal success of Silicon Valley owes much more to the existence of a vibrant venture capital industry, a liquid public market for initial public offerings (NASDAQ), and a highly mobile labour market than to proximate S&T policy interventions. Our analytical framework therefore incorporates all the important policies that affect the behaviour of innovation actors. In addition, significant political and social changes in the national as well as international environments may also have significant impacts on the behaviour of actors and need to be taken into account (summarized in Figure 8.1). This framework is particularly relevant for analysing NIS in developing countries because these countries have less developed market institutions as well as less stable macroeconomic policies and less open competition and trade policy regimes.

2.5 Summary

Our NIS framework distinguishes three groups of innovation actors (the firm, public R&D and manpower development sectors) and examines how they interact dynamically to create and deploy S&T resources. In this framework, the effect of public and S&T policies on technological development is analysed in terms of three market institutions (intellectual property, skills and risk capital). The framework highlights the need to consider all policies that directly or indirectly affect NIS performance. We adopt this holistic approach to study the dynamics of technological change in Singapore.

3. DYNAMICS OF CHANGE IN SINGAPORE'S NATIONAL INNOVATION SYSTEM

3.1 Phases in the Evolution of Singapore's NIS

The evolution of Singapore's NIS can, like its overall economic development, be analysed as going through four phases in the last four decades (Wong, 2001a).

(a) *Industrial take-off.* The period from the early 1960s to the mid 1970s, characterized by high dependence on technology transfer from foreign MNCs.
(b) *Local technological deepening.* The period from the mid 1970s to the late 1980s, characterized by rapid growth of local process technological development within MNCs and the development of local supporting industries.
(c) *Applied R&D expansion.* The period of the late 1980s to the late 1990s, characterized by the rapid expansion of applied R&D by MNCs, public R&D institutions and, later, local firms.
(d) *High-tech entrepreneurship and basic R&D development.* The period from the late 1990s onwards, characterized by the emerging emphasis on high-tech start-ups and the shift towards technology creation capabilities.

(a) Industrial take-off phase (mid-1960s to mid-1970s)

The decade after independence from Malaysia in 1965 marked a period of rapid industrial take-off based on export-oriented manufacturing by MNCs. The tangible S&T resources of Singapore were built primarily through the transfer of manufacturing technologies by foreign direct investment (FDI) while the intangible (skill) resources were being built through expansion of primary and secondary education and technical training institutions and by 'learning-by-using' among MNC employees. There were few innovation links between MNCs engaged in labour-intensive manufacturing and the rest of the economy in this period. Few local supporting industries existed and the main advantage of Singapore as a production base for MNCs lay in the abundant supply of cheap labour. The main form of technological learning was skill upgrading in the operators and technicians working for MNCs.

(b) Local process technological deepening phase (mid-1970s to late 1980s)
The mid-1970s saw the beginning of rapid growth of indigenous manufacturing process capabilities. The local operators, technicians, engineers and managers working in MNCs were no longer just learning to use the technologies transferred from abroad but were beginning to adapt and improve upon them through learning-by-doing. They were also able to absorb more sophisticated process technologies. A base of local supporting industries began to emerge, and these firms started to invest in acquiring and exploiting imported technologies on their own, in addition to learning from their MNC customers through 'learning by transacting' (Wong, 1992, 2001b). The development of technical skills shifted from operators to more advanced technicians and engineering manpower through the rapid expansion of polytechnics and university engineering courses (Table 8.4). In addition, Singapore started to attract a large number of tertiary-educated manpower from overseas, especially from Malaysia.

Table 8.4 Average output of technical manpower from tertiary education institutions in Singapore, 1970–99 (number of graduates per year)

	1970–79	1980–84	1985–89	1990–94	1995–99
University level[a]	680	1 040	2 162	3 198	4 863
Polytechnic level[b]	1 516	2 463	4 836	6 639	8 493
Total	2 197	3 504	6 998	9 837	13 356
University graduates as percentage of total	31.0	29.7	30.9	32.5	36.4

Notes:
[a] Includes degree courses from SIM.
[b] Includes diploma courses from ISS.

Sources: Calculated from *Singapore Yearbook of Labour Statistics* (various years), *Singapore Yearbook of Manpower Statistics* (1997, 1998).

(c) Applied R&D expansion phase (late 1980s to late 1990s)

After the shock of a severe economic downturn in 1985, the manufacturing sector recovered in the second half of the 1980s. Successive new waves of FDI led to the upgrading of manufacturing process technologies, and there was a rapid rise in R&D from the late 1980s. An increasing number of MNCs started to establish R&D activities in Singapore for the first time, alongside the establishment of new public R&D institutions and the expansion of R&D in tertiary institutions (Tables 8.5–8.7). 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 (GLCs) 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 MNC operations in Singapore, resulting in low intellectual property creation as measured by patenting and technology spin-offs.

Table 8.5 Growth of R&D in Singapore, 1978–99

Year	GERD (S$m)	GERD/GDP (%)	RSEs	RSE/10000 labour force
1978	37.80	0.21	818	8.4
1981	81.00	0.26	1193	10.6
1984	214.30	0.54	2401	18.4
1987	374.70	0.86	3361	25.3
1990	571.70	0.84	4329	27.7
1991	756.80	1.00	5218	33.6
1992	949.50	1.17	6454	39.8
1993	998.20	1.06	6629	40.5
1994	1174.98	1.10	7086	41.9
1995	1366.55	1.13	8340	47.7
1996	1792.14	1.39	10153	56.3
1997	2104.56	1.49	11302	60.2
1998	2492.26	1.76	12655	65.5
1999	2656.29	1.84	13817	69.9
Compound average growth rate per annum (%)				
1978–90	25.4		14.9	
1990–95	19.0		14.0	
1995–99	18.1		13.5	

Notes: GERD is gross expenditure on research and development.
RSE is research scientists and engineers.

Source: *National Survey of R&D in Singapore* (various years), NSTB.

Table 8.6 Number of organizations performing R&D, 1978–1999

Year	Private sector	Higher education sector	Government sector	Public research institutes	Total
1978	63	4	23[a]	–	90
1981	135	4	38[a]	–	177
1984	143	4	20[a]	–	167
1987	191	4	20[a]	–	215
1990	266	5	4	7	292
1991	311	5	9	6	331
1992	331	5	13	5	354
1993	410	6	15	5	436
1994	427	6	16	5	454
1995	440	6	14	10	470
1996	496	6	11	13	526
1997	508	6	14	15	543
1998	571	6	13	14	604
1999	593	6	12	13	624

Notes:
[a] Figures include public research institutes. Definition of government R&D organizations was changed from 1990 onwards, resulting in a smaller number of organizations being counted.

Source: *National Survey of R&D in Singapore* (various years), NSTB.

At the same time local process capabilities continued to deepen, resulting in some major MNCs establishing lead manufacturing plants in Singapore (for example, Glaxo, Seagate and IBM data storage). An increasing number of MNC plants also took on *process technology transfer station* roles, that is, to provide the engineering to develop new processes to support product launches and later to transfer them to other countries. Several MNCs (for example, Philips consumer electronics, HP 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 and 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. As shown in Table 8.4, the rate of growth of university graduates began to exceed that of polytechnic graduates. Significant technological development in local supporting industries was induced by the MNCs through increasing outsourcing and intensification of 'learning by transacting'. Finally, rising R&D provided an important training ground for the acquisition of new innovative skills.

Table 8.7 R&D expenditure by sectors, 1978–99

Year	Private sector (S$m)	Higher education sector (S$m)	Government sector (S$m)	Public research institutes (S$m)	Total (S$m)
1978	25.5	8.2	4.1	–	37.8
1981/82	44.2	24.3	12.5	–	81.0
1984/85	106.7	69.6	38.0	–	214.3
1987/88	225.6	95.4	53.7	–	374.7
1990	309.5	119.7	99.4	43.1	571.7
1991	442.1	147.1	96.8	70.8	756.8
1992	577.6	156.0	105.0	110.8	949.5
1993	618.9	157.3	106.5	115.5	998.2
1994	736.2	179.5	142.1	117.2	1175.0
1995	881.4	193.4	110.4	181.4	1366.6
1996	1133.4	238.7	166.8	253.2	1792.1
1997	1314.5	277.7	216.1	296.2	2104.6
1998	1536.1	305.8	299.8	350.5	2492.3
1999	1670.9	310.0	304.9	370.6	2656.3
1978	67%	22%	11%	–	100%
1984/85	50%	32%	18%	–	100%
1990	54%	21%	17%	8%	100%
1991	58%	20%	13%	9%	100%
1992	61%	16%	13%	12%	100%
1993	62%	16%	11%	12%	100%
1994	63%	15%	12%	10%	100%
1995	65%	14%	8%	13%	100%
1996	63%	13%	9%	14%	100%
1997	63%	13%	10%	14%	100%
1998	62%	12%	12%	14%	100%
1999	63%	12%	12%	14%	100%

Source: *National Survey of R&D in Singapore* (various years), NSTB.

(d) High-tech start-up development & R&D deepening phase (late 1990s onwards)

As the Singapore economy enters the new millennium, another phase appears to be 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 MNCs, the new start-ups were more based on product innovation and increasingly focused on IT, software, internet applications, biotechnology and life sciences. Venture capital (VC) and business angels became increasingly important as a source for funding. As can be seen from

Table 8.8 Growth of Singapore's venture capital industry, 1985–2000

Year	Cumulative funds under management (S$billion)	Government initiatives to promote VC industry
1985	0.16	Launch of EDB VC Programme
1986	0.26	Launch of first major local VC Fund; first Pioneer VC awarded
1988	0.4	Promoted first USVC to set up in Singapore
1989	0.6	–
1990	1.2	Initiated first Seed VC Fund
1991	2.1	–
1992	2.4	–
1993	2.6	Initiated Singapore Venture Capital Association, EDB as patron
1994	3.5	Initiated second Seed Fund and set up Regional Investment Fund
1995	5.3	Initiated first Specialized Communications and Media Fund
1996	6.2	–
1997	7.4	Initiated first Specialized Info Tech Fund, and Pharm Bio Growth Fund
1998	7.7	Set up Life Science Investments
1999	8.8	Initiated third Seed Fund. Set up PLE Investments. Launched US$1 billion Technopreneurship fund
2000	10.2	Launched M-Commerce Fund and launched US$1 billion fund for life sciences

Source: EDB Yearbook 1999/2000.

Table 8.8, the VC industry began to take off rapidly from the mid-1990s, with the cumulative amount of funds managed exceeding S$10 billion in 2000. In 1999, 71 start-ups received S$252 million of venture capital 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. The cumulative number of VC-backed start-ups in Singapore at the end of 1999 was estimated at 375, of which 66 had gone public; the majority were technology-based (EDB, 2000). In particular, spin-offs from universities and public R&D institutions were beginning to increase in frequency.

Another feature is the deepening of R&D in Singapore with a distinct shift towards longer-term, more basic research, away from the prevailing emphasis on short-term applied R&D. As Table 8.9 shows, the number of

Table 8.9 R&D output indicators for Singapore, 1993–99

	1993	1994	1995	1996	1997	1998	1999
No. of patents applied for in the year	142	263	242	316	490	579	673
No. of patents awarded for the year[a]	52	58	51	91	132	136	161
Total no. of patents owned as of 31 December[b]	200	204	256	614	831	847	1,077
Revenue from royalties & licensing of patents/new technologies developed in Singapore (S$ million)[c]	24.34	23.95	27.23	27.34	26.61	50.97	671.89
Sales revenue derived from commercialized products/processes attributable to R&D performed in Singapore (S$ million)				6381.02 (7.2%)[d]	9647.26 (9.6%)[d]	13369.92 (7.6%)[d]	10663.94 (10.2%)[d]
Sales revenue derived from commercialized products/processes attributable to R&D performed in Singapore and launched within the last 2 years (S$ million)				5035.31	6097.24	8026.11	8060.49

Notes:
[a] 1993–95 is awarded to Singapore organizations only.
[b] 1993–95 is for Singapore organizations only.
[c] 1993–95 revenue from royalties and licensing of new technology/products developed in-house (S$m).
[d] Percentage of total sales revenue.

Sources: *National Survey of R&D in Singapore* (various years), NSTB.

patent application doubled in 1996–99, while the number awarded increased by 80 per cent. Although still low in comparison with advanced countries, the growth of basic research is expected to increase very rapidly over the next five years under the new, as yet unpublished National S&T Plan 2001–2005. A new US$1 billion Life Sciences Fund was also announced in 2000 to accelerate the funding of R&D and technology commercialization in the life sciences.

In summary, Singapore has shifted over the last four decades from emphasizing *using* technology to *creating* it (Figure 8.2). Each successive phase has built upon the resources accumulated earlier. The momentum has continued as new forms of growth were introduced, involving new actors and new forms of linkage among existing actors. In particular, there was a phased building up of MNCs, local manufacturing enterprises (particularly in the electronics supporting industries), public research institutes and centres (PRICs) and university R&D, and, in the last phase, local high-tech start-ups pioneering new products. In terms of technology capability development, there was a sustained shift from learning to use (with high reliance on internal transfer by MNCs) to learning to adapt and improve (via 'learning-by-doing' within MNCs 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 marketplace).

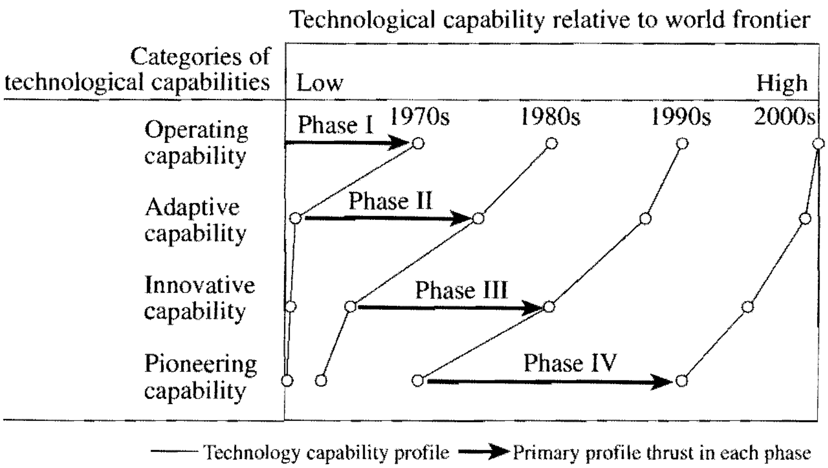


Figure 8.2 Stylized profile of technological capabilities of Singapore over the four phases of NIS development

3.2 The Emerging Characteristics of Singapore's NIS at the Turn of the Millennium

It is useful to look at the emerging structure of Singapore's NIS at the turn of the millennium in terms of the portfolio of technological activities. As indicated in a stylized fashion in Figure 8.2, while Singapore's technology deployment capabilities (to operate and adapt technologies) are now close to the world frontier, its capability to create technologies (to innovate and pioneer new technologies) is still lagging considerably behind this frontier. While precise measures are absent, the stylized interpretation of Figure 8.2 is consistent with the ranking of Singapore in 1999–2000 by the *World Competitiveness Report* and the *Global Competitiveness Report* on a range of technological indicators (Table 8.10). Singapore ranks very high (among the top five to ten countries in the world) in terms of technology-using indicators. These include the quality of school science and technology education, adoption of information and communications technology (ICT), licensing of foreign technologies, use of advanced technologies in production and process management capabilities. In contrast, its ranking is lower in technology-creation indicators like R&D spending and R&D personnel, availability of venture capital and intellectual property protection (ranking between tenth and seventeenth in the world). It is lowest in specific measures of innovation like intellectual property generation, quality of basic research institutions, product design, entrepreneurship and creation of firms (mostly lower than the top twenty).

Supplementing this ranking, Singapore was ranked fourth in the world in 2000 in terms of ICT usage by the Information Society Index (IDC, 2000). It was found to have product/process innovation performance levels comparable to the second half of OECD countries in a recent study by Wong et al. (2001). However, in terms of entrepreneurial propensity, Singapore was ranked nineteenth out of 21 countries covered in the *Global Entrepreneurship Monitor 2000* study (Reynolds et al., 2000). Similarly, although improving rapidly over time, Singapore was ranked outside the top twenty in the world in terms of scientific publications in the *Science Citation Index*.

Thus, while Singapore still lags considerably behind the world leaders in terms of innovation, the structure of Singapore's NIS by the end of the 1990s has become much more balanced, with technology development capabilities catching up with deployment capabilities.

Emerging pattern of technology deployment capabilities

There are no direct statistical measures of how advanced the technologies deployed by organizations in Singapore are. However, indirect indicators of

Table 8.10 Singapore's ranking in technological capability-related indicators

	Ranking
Overall competitiveness ranking	2
Overall technological development indicators	
Overall science and technology competitiveness ranking	9
Technology using capability indicators	
Scientific environment*	
Science and education is adequately taught in compulsory schools	1
Science and technology interests the youth of the country	2
Technology management*	
Technological cooperation is common between companies	8
Technology transfer between companies and universities is sufficient	3
Development and application of technology is supported by the legal environment	1
Qualified engineers are available in your country's labour market	9
Qualified information technology employees are available in your country's labour market	6
Employee training is a high priority in companies	2
Process management is emphasised in your country	1
University education meets the needs of a competitive economy	4
Technology creation capability indicators	
R&D expenditure*	
Total expenditure on R&D per capita 1998	16
Total expenditure on R&D (% of GDP) 1998	14
Business expenditure on R&D per capita	14
R&D personnel*	
Total R&D personnel nationwide per capita 1998	16
Total R&D personnel in business enterprise per capita 1998	17
Intellectual property	
Number of patents granted to residents (average annual number) 1996–97	34
Number of patents secured abroad by country residents 1997	35
Patent and copyright protection is enforced in your country	15
Number of patents in force 1997	12
Creation of firms is common in your country	15
Managers generally have a sense of entrepreneurship	19

Notes:
Ranking is for 2000 unless otherwise stated.
* Only relevant indicators are included.

Source: *World Competitiveness Yearbook 2000*, IMD.

Table 8.10 (continued)

(b) Global Competitiveness Report 1999

		Ranking
Overall competitiveness ranking		1
Overall technological development indicators		
Technological sophistication	Overall, your country is a world leader in technology	9
Technology using capability indicators		
Maths and science education	The school system in your country excels in maths and basic science education	1
Adoption of new technology	The companies are aggressive in absorbing new technology	9
Technology transfer	Foreign direct investment is an important source for technology transfer	2
Licensing of foreign technology	Licensing of foreign technology is a common means to acquire new technology	1
Use of computers	Use of computers is highly sophisticated and widespread	11
Internet use	Do you use the internet at all?	1 (tied)
Computers per 1000 population	1997	10
Production processes	Production processes generally employ the world's best and most efficient technology	9
Management use of computers	Managers personally use computers and information technology extensively	5
Technology creation capability indicators		
Supply of venture capital	Venture capital is readily available for new business development	13
Scientists and engineers	Scientists and engineers are prevalent and of high quality	13
Research institutions	Scientific research institutions in your country are truly world-class	21
Commitment to R&D spending	Substantial public resources are committed to non-military R&D	6
Private sector spending on R&D	The business sector spends heavily on R&D	14
Protection of intellectual property	Intellectual property is well-protected in your country	13
Product design	Product designs are developed locally	23

Source: Global Competitiveness Report 1999, World Economic Forum.

adoption of new technologies strongly suggest that Singapore has become one of the most advanced adopters of new ICTs and manufacturing technologies in the world. For example, Singapore has a very high rate of diffusion by international standards in computer, internet, broadband and wireless technologies (Wong, 1998, 2001c; IDC, 2000). It also ranks quite high in the adoption of advanced manufacturing technologies such as CNC machines and robotics (SIAA, 1996; and UNECE, 1997). The pace of deployment is generally higher among large firms in general and MNCs in particular, with SMEs lagging. However, with the spread of internet technologies and the rapid recent growth of local start-ups, the pace of deployment in SMEs has accelerated.

The public sector has been very aggressive in using new technologies, especially IT. Many of the major statutory bodies in Singapore have become lead users of technology not just locally but probably in the world as a whole. For example, Singapore Airlines, the Port Authority of Singapore and Changi International Airport Services all boast world-class levels of service. Before privatization, Singapore Telecoms was a fast adopter of new telecommunications technologies, resulting in Singapore having one of the most advanced telecommunications infrastructures in the Asia-Pacific region. The recent liberalization of the telecommunications market has further spurred technology adoption in this sector. Although these bodies perform relatively little R&D, they are aggressive investors in deploying new technologies to improve their competitiveness and quality. The same aggressiveness is found in the public sector at large. The Ministry of Environment was among the first in Asia to adopt incineration technology for waste disposal. The Ministry of Communications was also the first in Asia to deploy electronic road pricing. Singapore was among the first in the world to automate trade document submission and approval using electronic data interchange, and has achieved among the highest penetration rates of internet filing of income tax returns.

Emerging patterns of technology development capabilities

Singapore's gross expenditure on R&D (GERD) had increased seven-fold between 1987 and 1999, reaching S$2.66 billion in 1999, or 1.84 per cent of GDP (Table 8.5). The number of research scientists and engineers (RSEs) per 10000 labour force reached 70 in 1999. Although still behind the most advanced OECD countries and Korea, Singapore has overtaken more than a dozen OECD countries and has caught up with Taiwan in terms of the GERD/GDP ratio. While both the public and private sectors had contributed to this impressive performance, Table 8.6 shows that private sector R&D grew faster from the mid-1980s to the mid-1990s; thereafter the two have grown at a comparable pace, with the share of the private sector stabilizing at around 63 per cent. Within the public sector, the share of higher education has declined while that of public research institutes has increased.

In terms of sectors, manufacturing firms account for the lion's share of R&D spending, peaking at 88 per cent of total private R&D in 1996 before declining to 80 per cent by 1999 (Table 8.11). Manufacturing R&D efforts were highly skewed, with over 60 per cent concentrated in the electronics sector in 1999, followed by precision engineering (over 20 per cent) and chemicals (close to 10 per cent). This is consistent with the fact that electronics and IT have been the most important and dynamic sectors since the 1980s, which in turn stimulated the precision engineering industry.

Among private firms, MNCs account for the bulk (56 per cent) of R&D spending, though the share of local firms has grown over time (Table 8.12). Reflecting the concentration of MNCs in electronics and chemicals, the largest share of their R&D is in these two sectors, which accounted for close to two-thirds of their total R&D. The dominance of MNCs in R&D is also most pronounced in these industries: over 69 per cent in electronics and 79 per cent in chemicals (Table 8.13). Unlike MNCs, local enterprises have more diversified R&D activities. While the two largest industries, electronics and precision engineering, together accounted for 58.2 per cent of local enterprise R&D in 1999, there was also sizeable R&D in IT and communications, light industries and transport engineering.

Among the local firms that engage in R&D, we can distinguish three groups. The first consists of the more technically advanced SMEs operating in supporting industries to MNCs, particularly precision engineering. Good examples include Amtek (metal stamping), MMI (precision metal engineering), Meiban and Lixin (precision plastic moulding), Gul technology and Circuit Plus (printed/flexible circuit board), and Venture Manufacturing and Omni Industries (contract manufacturing). The main focus of their R&D is to improve manufacturing process capabilities to meet the stringent quality, cost and delivery demand of their MNC customers, although a small number have also started to diversify into product innovation.

The second group consists of the state-controlled enterprises set up to spearhead local participation in high-tech industries. Called 'government-linked companies' (GLCs), these companies have strong financial backing from holding companies established by the government and have been able to commit significant resources to innovation. The more significant players include companies within the Singapore Technology Group, Sembawang Group, Keppel Group and Natsteel Group. The Singapore Technology Group, for example, has subsidiaries engaged in aerospace repair/maintenance engineering (ST Aerospace), semiconductor fabrication

Table 8.11 Distribution of private sector R&D expenditure by industry, 1993–99

	Total R&D spending by industry (S$m)						
	1993	1994	1995	1996	1997	1998	1999
Manufacturing	502.1	580.0	729.7	1000.2	1110.1	1335.4	1336.0
Electronics	318.1	361.3	433.7	603.1	625.8	741.5	756.1
Chemicals	34.4	54.4	79.6	177.0	202.6	166.4	126.6
Engineering	104.1	123.2	171.7	168.8	208.7	348.7	340.1
Precision engineering	69.5	93.1	131.8	120.6	148.8	295.0	276.1
Process engineering	7.7	6.5	15.2	13.8	12.1	9.6	9.7
Transport engineering	26.8	23.6	24.7	34.4	47.8	44.1	54.4
Life sciences	24.8	38.6	34.4	37.9	58.3	63.8	89.7
Light industries/other manufacturing	20.8	2.4	10.3	13.4	14.6	15.1	53.5
Services	116.7	156.3	151.7	133.2	204.4	200.7	304.8
IT and communications	20.0	23.9	41.6	103.8	134.5	141.1	176.9
Finance & business	26.6	70.1	38.2	14.7	28.4	21.2	31.2
Other services	70.2	62.3	71.9	14.6	41.5	38.4	96.7
All industry groups	618.89	736.2	881.4	1133.4	1314.5	1536.1	1670.9

Table 8.11 (continued)

	Total R&D spending by industry (%)						
	1993	1994	1995	1996	1997	1998	1999
Manufacturing	81.1	78.8	82.8	88.2	84.5	86.9	80.0
Electronics	51.4	49.1	49.2	53.2	47.6	48.3	45.3
Chemicals	5.6	7.4	9.0	15.6	15.4	10.8	7.6
Engineering	16.8	16.7	19.5	14.9	15.9	22.7	20.4
Precision engineering	11.2	12.6	15.0	10.6	11.3	19.2	16.5
Process engineering	1.2	0.9	1.7	1.2	0.9	0.6	0.6
Transport engineering	4.3	3.2	2.8	3.0	3.6	2.9	3.3
Life sciences	4.0	5.2	3.9	3.3	4.4	4.2	5.4
Light industries/other manufacturing	3.4	0.3	1.2	1.2	1.1	1.0	3.2
Services	18.9	21.2	17.2	11.8	15.5	13.1	18.2
IT and communications	3.2	3.2	4.7	9.2	10.2	9.2	10.6
Finance & business	4.3	9.5	4.3	1.3	2.2	1.4	1.9
Other services	11.3	8.5	8.2	1.3	3.2	2.5	5.8
All industry groups	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: *National Survey of R&D in Singapore* (various years), NSTB.

Table 8.12 Foreign companies' share of industry R&D expenditure, 1993–99

Year	Share in total private R&D (%)
1993	67.6
1994	74.5
1995	64.3
1996	67.0
1997	61.2
1998	55.8
1999	55.8

Source: *National Survey of R&D in Singapore* (various years), NSTB.

Table 8.13 Foreign companies' share of industry R&D expenditure, 1999

Industry group	(1) Foreign majority owned companies (S$m)	(2) Local majority owned companies (S$m)	(3) Total R&D spending by industry (S$m)	(1)/(3) %
Manufacturing	780.99	585.1	1366.0	57.2
Electronics	518.32	237.8	756.1	68.5
Chemicals	99.89	26.7	126.6	78.9
Engineering	102.41	237.7	340.1	30.1
Precision engineering	84.13	191.9	276.1	30.5
Process engineering	6.02	3.7	9.7	61.8
Transport engineering	12.26	42.1	54.4	22.6
Life sciences	58.55	31.1	89.7	65.3
Light industries/other manufacturing	1.82	51.7	53.5	3.4
Services	151.84	153.0	304.8	49.8
IT and communications	71.17	105.7	176.9	40.2
Finance & business	18.98	12.3	31.2	60.8
Other services	61.69	35.0	96.7	63.8
All industry groups	932.83	738.0	1670.9	55.8

Source: *1999 National Survey of R&D in Singapore*, NSTB.

(Chartered Semiconductor Manufacturing), electronics systems integration (ST Engineering) and computer software systems (SCS). The Natsteel group has diversified from steel making into electronics contract manufacturing (Natsteel Electronics and Natsteel Broadway).

The third group of local enterprises consists of a small but rapidly increasing number of entrepreneurial high-tech start-up firms that seek to pioneer innovative products through R&D and brand development. Early examples of such firms include PC firms such as IPC and GES, audio-card firms such as Creative and Aztech, industrial electronics firms such as Powermatics, Teledata and Eutech Cybernetics, machine tool makers and industrial machinery makers such as Excel Machine Tools and Falmac, software companies such as CSA and Ednovation, and pharmaceutical/biotech firms such as Genelabs and Zagro. Although most of these are independent start-ups, some are also ventures financed by large local conglomerates trying to diversify into high-tech industries, for example, HawPar Healthcare Products belonging to the HawPar group, and Wearnes Technologies belonging to the Wearnes group. Over time, larger firms have absorbed some of these independent start-ups (for example, Eutech Cybernetics has been acquired by CSA, which in turn has been acquired by an American software giant).

More recently, a second wave of start-ups is emerging, particularly in the IT, telecommunications, internet and e-commerce areas. Unlike the earlier start-ups where the founders had typically worked in industry (especially in MNCs), the new wave of entrepreneurs tend to come from tertiary institutions and public R&D institutions. Examples include more than 10 internet/e-business start-ups by former staff of the National Computer Board (for example, Silkroute, WizOffice and CommerceAsia); a dozen spin-offs from the Kent Ridge Digital Lab (KRDL), a public software R&D institute (for example, Third Voice, Transparity, BuzzCity); and about two dozen high-tech spin-offs by professors from the National University of Singapore (for example, ReasonEdge, iDNS). At the height of the internet boom, many Singaporean entrepreneurs chose to start up in Silicon Valley (for example, ECNet) or to list on the NASDAQ (for example, Interwoven). Although the bursting of the internet bubble and the consequent meltdown of NASDAQ dampened the rate of internet start-ups (as happened worldwide) the number of spin-offs from university and public R&D institutes continues to grow.

The growing technological capabilities of Singapore can also be gauged in terms of patents and revenues from product or process innovation. Table 8.9 shows that the total number of patents filed by Singapore-based organizations (including foreign affiliates) increased from 142 in 1993 to 673 in 1999, while the numbers granted increased from 52 to 161. In 1999, revenue derived from commercialized products and processes attributed to R&D performed in Singapore amounted to 10.2 per cent of total revenues of the R&D-performing companies, up from 7.2 per cent in 1996. Revenues generated from licensing intellectual property to outside parties have also increased steadily over the period 1993–99.

4. THE ROLE OF PUBLIC S&T POLICY IN THE DEVELOPMENT OF SINGAPORE'S NIS

4.1 Historical Overview of Science and Technology Policy in Singapore

Public policies have played a major role in shaping Singapore's NIS. However, until the late 1980s, much of the impact came from general economic policies on industrial growth and upgrading rather than from narrow S&T policy instruments. Indeed, until 1991 Singapore did not have a formal institution to develop and implement science and technology policy. A Ministry of Science and Technology was formed in 1968, but its role was marginal and it was closed down in 1981. Most of the ministry's duties were passed to the Singapore Science Council (SSC), established in 1967 to promote scientific research and public interest in science. However, the role of SSC continued to be quite limited, and mainly of an advisory nature. Most programmes were carried out through implementation agencies in the Ministry of Trade and Industry (MTI) and the Ministry of Education. It was only when the SSC was reorganized in 1991 to form the National Science and Technology Board (NSTB) that an overall organizational framework for integrated science and technology policy implementation was established.

Despite the lack of a formal S&T framework for much of the period, technological upgrading was a central focus of much of economic policy-making in Singapore even if the policy instruments were not labelled as such. The political leadership always displayed a clear understanding of the importance of technological upgrading in sustaining growth, but until the late 1980s, it was believed that Singapore should focus its resources on exploiting available technologies from advanced countries rather than on innovating. This focus was particularly in evidence through the 1970s and 1980s. For example, in the aftermath of the 1985 recession, a high level Economic Committee was formed to chart a strategy for economic recovery. In the strategic document produced by this committee (*The Singapore Economy: New Directions*), the focus on promoting technology deployment was explicitly stated: 'our goal should be to achieve higher value-added, not high technology *per se*' (MTI, 1986, p. 147). Similarly, in the National

Information Technology Plan (NITP) in 1985 and the National Automation Masterplan in 1988, the overriding goal was to promote the diffusion and utilization of IT and advanced manufacturing technologies to boost productivity. Even though both plans called for some modest investment in R&D institutions (establishment of the Information Technology Institute (ITI) as an R&D arm under the National Computer Board (NCB) and expansion of the GINTIC Institute for Manufacturing Technology (GIMT)), they were geared primarily to providing R&D support to the technological upgrading needs of industry.

The strong policy focus on promoting technology deployment did not entirely preclude the promotion of technology creation. Indeed, as early as 1980, the national budget for the first time provided tax incentives for manufacturing companies that undertook R&D in Singapore and for the R&D institutes that worked with them. An Initiatives in New Technology (INTECH) scheme was established in 1984 to make loans for the partial or full funding of research projects, even though its primary objective was to support companies sending their staff for training in high technologies such as robotics, microelectronics, IT, biotechnology, optical and laser technology, engineering science and materials science (Chng et al., 1986). Nevertheless, the level of public commitment to R&D remained low through the 1980s, and was confined largely to scientific research in public universities and defence R&D, both of which had little commercial linkage to industry.

The first significant recognition of the economic importance of R&D came in 1989 when a Committee of Ministers of State was formed to outline the long-term strategy and direction of Singapore's development. The result was 'The Next Lap', which highlighted the need to focus on R&D and specialization in high-tech niches (Government of Singapore, 1991). The importance of innovation gained more recognition in the Strategic Economic Plan formulated in 1991 (MTI, 1991). This new emphasis on S&T led to the formulation of the first Five Year National Technology Plan (NTP) and the establishment of an entirely new statutory board, the National Science and Technology Board (NSTB) in 1991. The intention was to promote industrially relevant R&D, build up S&T manpower, and develop an S&T support infrastructure. A S$2 billion allocation was given. This was followed by the formulation of a second five year plan in 1996, called the Second National Science and Technology Plan (NSTP), where the budget allocation was doubled to S$4 billion, and where the importance of investing in science was recognized in addition to technology.

While the second NSTP intensified public investment in R&D and emphasized the development of scientific research capabilities, there was no real change in strategic direction from the earlier plan. Two major developments in the global environment in the second half of the 1990s prompted the government to introduce more drastic policy changes with respect to S&T development. The first was the financial crisis in mid-1997, which significantly affected investor confidence in East Asia in general and neighbours like Indonesia, Malaysia and Thailand in particular. The severity of the regional economic downturn prompted the government to establish a high-level Committee on Singapore's Competitiveness (CSC) in early 1998 to formulate urgent short-term policy measures as well as long-term strategies. The deliberations of the CSC took into consideration another trend in the global economy: the emergence of the 'New Economy' where growth was seen as increasingly driven by knowledge-based innovations and technology-based entrepreneurship. Thus, by the time the CSC released its report towards the end of 1998, the shift of emphasis towards technological innovation has become central. The acceleration of knowledge-based industrial growth through investing in innovation and promoting 'technopreneurship' (high-tech entrepreneurship) had become the cornerstone of Singapore's economic development strategy.

Reflecting these strategic thrusts, several new policy initiatives were announced in 1998. These included the Industry21 strategy by the Economic Development Board, the Manpower21 master plan by a newly enlarged Ministry of Manpower (MOM) to promote skills upgrading and accelerate the attraction of foreign talents, and the Technopreneurship21 (or T21 for short) initiative to foster high-tech start-ups. In response to the completion of the Genome Mapping project, the government announced in late 2000 a strategic push to promoting life sciences research and industry development with the launch of a US$1 billion Life Sciences Fund.

The most significant of these initiatives was the T21 strategy, representing a significant departure from the traditional reliance on leveraging foreign MNCs. Several factors prompted the leadership to embark on such a radical change. First and foremost was the Asian financial crisis. This raised concerns about the need to diversify markets and achieve greater penetration of European and North American markets. This clearly required Singapore to have a higher technological competitive edge. Secondly, given currency devaluations by regional neighbours, Singapore would be subject to even greater cost pressures. To stay competitive without lowering standards of living, Singapore needed to sharpen its technological edge with respect to regional competitors. Finally, the leadership had become increasingly impressed by the Silicon Valley model of high-tech innovation (including the successful Israeli and Taiwanese variants) as the key to success in the global knowledge-based economy.

These considerations led to a new consensus in the political leadership that Singapore needed to supplement the leveraging model with the promotion of technopreneurship. First articulated by the deputy Prime Minister, Dr Tony Tan, in late 1998, the T21 initiative was subsequently fleshed out by a high-level inter-ministerial committee (T21 Committee for short) chaired by him. Unlike previous strategic action plans, the T21 initiative did not come in the form of a detailed document. Instead, the T21 committee (together with a private-sector led committee chaired by a very successful local technopreneur, Mr Sim Wong Hoo, the founder of Creative Technology) met regularly and introduced a series of policy changes, directing NSTB or other government agencies to implement them. Although somewhat ad hoc, the T21 initiative led not only to a major restructuring of the NSTB (to become the lead agency implementing T21 programmes) but also to the announcement of changes to a range of business regulations that were thought to stifle start-ups. These included changes to bankruptcy laws, the revision of regulations and taxation governing company stock options and new tax offset provision for losses incurred by investors in high-tech start-ups. A public US$1 billion Technopreneurship Fund was launched in 1999 to stimulate the development of Singapore as a regional venture capital hub.

The breadth and comprehensiveness of the policy changes proposed clearly shows that the government was taking a holistic view of the high-tech entrepreneurship challenge rather than framing the response in narrow S&T terms. Thus, although the government may have come to the realization somewhat late, it appeared to be moving decisively once the decision had been taken to shift direction.

Despite the NASDAQ meltdown in April 2000 and the worldwide decline in venture capital funding for high-tech start-ups thereafter, the Singapore government remained firmly committed to promoting the growth of local high-tech firms. None of the T21 policies had been withdrawn. The bursting of the internet bubble did make policymakers realize the need for start-ups to have truly innovative technologies and defensible intellectual property, and hence the need to raise basic research and innovative capabilities. This is reflected in the new third National S&T Plan 2001–2005, which has not only increased the budget allocation to S&T (from S$4 billion to S$7 billion) but has also allocated a larger proportion to long-term strategic and basic research.

4.2 The Changing Role of Public R&D Institutions

Compared to Korea and Taiwan, public R&D in Singapore has traditionally been small. For a long time, public R&D was concentrated at the National University of Singapore (NUS) – the only university in the country until the early 1990s – and the Singapore Institute for Standards and Industrial Research (SISIR) formed in the 1970s. Other public research institutes were set up only after the late 1980s. Table 8.7 shows the growth of the public research institutes and centres (PRICs) since then in terms of R&D spending. Over 1990–99, R&D spending by PRICs grew nearly ninefold, faster than the growth of private R&D. By 1999, the 13 PRICs accounted for over S$370 million (or 14 per cent) of R&D spending.

The initial mission of the PRICs was to develop the applied technologies deemed critical for the industrial clusters in existence in Singapore. In addition, some institutes had to develop core competencies in the new generic technologies (for example, IMCB in molecular and cell biology, CWC in wireless communications) needed to attract new high-tech industries. The emphasis on applied R&D can be seen in Table 8.14: only 13.6 per cent of R&D in 1999 was in basic research, compared to 36.3 per cent for applied R&D and 50 per cent for experimental development.

Table 8.14 Deepening of Singapore's R&D system

	1993	1996	1997	1998	1999
Percentage of Masters and PhD holders among RSEs (FTE)	39.3	43.5	41.6	44.1	44.1
Percentage breakdown of R&D expenditure:					
Basic research	16.1	11.8	12.8	12.3	13.6
Applied research	39.1	39.6	43.8	34.4	36.3
Experimental development	44.9	48.7	43.3	53.3	50.1

Source: *National Survey of R&D in Singapore*, respective years, NSTB.

The tertiary institutions (two universities and four polytechnics) raised their R&D by nearly three times over 1990–99 to reach S$310 million by the end of the period. While the R&D portfolio of the universities was supposed to be skewed towards basic scientific research, in reality they were under great pressure to do more applied R&D for industry. The key performance criteria for university academic staff was international journal publication, but the extent of technology licensing to the private sector and the number of R&D collaborations with industry were also used to evaluate R&D by tertiary institutions.

The rapid growth of the PRICs met the quantitative targets of public R&D spending and manpower, but it is unclear how effective their activities were. Moreover, their changing role over time may have led to a number of problems. First, PRICs were initially asked by NSTB to spin off high-tech start-ups. This appears to have been hastily implemented without working out the conflict with the objective of licensing existing companies. Some PRICs began to keep technologies they had developed from being licensed and to encourage their staff to start companies to commercialize the technologies, receiving sizeable equity ownership in these start-ups. Secondly, the PRICs did not have incentives to cooperate with each other in research or in technology or market intelligence gathering and intellectual property management.

In response to these problems, the government introduced an institutional restructuring in early 2001. The responsibility for implementing T21 was taken out of the hands of NSTB and transferred to EDB. NSTB was reorganized to focus on promoting research and developing R&D manpower through the formation of two new councils. The Bio-Medical Research Council (BMRC) was set up to award research grants and develop R&D manpower in the life sciences, and the Science and Engineering Research Council (SERC) to do the same in selected scientific and technological fields. In effect, NSTB's role became more like that of the National Science Foundation (NSF) in the USA, focusing on fostering research excellence and R&D manpower. Technology commercialization policies were left to EDB.

4.3 The Changing Role of Manpower Development Institutions

Public policies have played an important role in technical manpower development (see, for example, Soon 1992; Wong, 1995b). Singapore has one of the best systems of industrial and vocational training in the world, transforming its unskilled workforce into a highly skilled one over only two decades. While primary and secondary education was critical to the development of skills, the task of upgrading industrial manpower was performed by vocational and technical training institutions. The early development of industrial vocational training programmes under the Institute for Technical Education (ITE) was an important source for skill upgrading in the take-off phase. In the second phase of industrial development, manpower development policy shifted to more advanced training through a range of specialized industrial training programmes in such areas as computer numeric control (CNCs), precision machining, tool and die making and robotics. A distinguishing feature of many of these programmes was that they were established and run as collaborative ventures between EDB and reputed overseas partners. Some were with well-known MNCs (Philips, ABB and Seiko). Others were collaborations with highly-regarded industrial training institutes: the French-Singapore

Institute cooperated with the French Electrical/Electronic Industry Federation, and the German-Singapore Institute with the German Agency for Technical Cooperation.

In the third phase, some training programmes were upgraded in content (for example, the French and German collaborations were improved and absorbed into the polytechnic system). A number of new specialized technical training programmes were also established, including the Institute of Systems Science (ISS), the Information Communications Institute of Singapore (ICIS), the Japan Singapore Artificial Intelligence Centre (JSAIC) and the Automation Application Centre (AAC).

The changing emphasis of skill development policy can be seen in Table 8.4, which tracks the growth in annual output of tertiary technical manpower. While polytechnic output grew faster than university output in the 1980s, the order was reversed in the 1990s. In addition, there were a large number of part-time tertiary diploma and degree programmes operated by overseas universities on a 'distance learning' basis. However, most of these were in non-technical fields, with the result that the total number of technical graduates from these programmes was relatively small and confined largely to IT-related fields.

To respond to the rapid advances in technology and changing demand for technical skills, local universities and polytechnics had constantly to revise their curricula for degree programmes. This process was facilitated by a strong industry presence on the advisory councils of these institutions, the policy of encouraging competition among them and a growing emphasis on international benchmarking. In addition, the EDB established a new Capabilities Development Division to pro-actively fund new training programmes based on its targeting of new industries and its knowledge of potential new inward FDI. For example, in anticipation of semiconductor wafer fabrication FDI in the second half of 1990s, the EDB funded new programmes for rapid training of wafer fabrication engineers in local universities and by attachment overseas.

To supplement local manpower supply, the government consistently adopted a liberal immigration policy to attract overseas skills. The focus of this policy was initially to allow MNCs to bring expatriate managerial and technical expertise to facilitate the start-up of new operations. Over time, it was broadened to attract a range of professionals to handle subsequent MNC operations. As R&D expanded, the government increasingly focused on attracting foreign scientists and engineers to work in the PRICs. By 1999, 17.3 per cent of the scientists and engineers engaged in R&D in Singapore were foreign. However, this is a gross underestimate: it does not include the sizeable number that had been offered permanent residence and were not counted separately (NSTB Annual Report, 2000). China and the

Indian subcontinent provided the bulk of the foreign experts working in Singapore.

Despite industry concerns about shortages of R&D manpower, the government appears to have played a relatively effective role in increasing the supply of such manpower in a very short period. Nevertheless, as Singapore continues to deepen its R&D efforts, the existing institutions need to undertake even greater changes. NUS has recently revamped its salary and promotion structure to make itself more globally competitive in attracting and keeping star researchers. The university admission system has also been revamped to become less examination results oriented, so as to encourage greater creativity. University curricula are being revised to inject a more liberal arts elements and make students more rounded. Technopreneurship elective courses and business plan competition have been introduced to encourage greater interest in start-ups.

4.4 The Changing Public Policy Roles in Promoting Linkages among Innovation Sectors

Linkages and interaction among innovation sectors are important determinants of the performance of any national innovation system. In Singapore, policy appears to have played a significant role in promoting such linkages, but its effectiveness has been uneven, with evident gaps when compared to the advanced countries. The linkages that were most actively promoted were those between MNC subsidiaries and their parents or associates overseas. The principal device used was investment incentives tied to the introduction of higher value-added operations or to the training of local staff. The government also offered incentives to MNCs to send Singaporean engineers to headquarters to acquire new technical skills.

Linkages between industry and education and training institutions were also quite strong, particularly at the polytechnic and industrial training level. Indeed, close consultation with industry and the anticipatory planning and rapid response of the government to meet industrial skill needs have been important contributing factors to the rapid industrialization of Singapore (Soon and Tan, 1993). The government did not hesitate to recruit expatriates with significant MNC experience to head new training institutes. Indeed, many of the early industrial training institutes were run jointly by MNCs to establish a reputation for their programmes.

Linkages between public R&D institutions and tertiary training institutions also appear to be strong. Academic staff at the universities and polytechnics hold the dual function of R&D and teaching, and much of their research findings can be transferred into the teaching curriculum. Most PRICs are housed in universities and many principal investigators in their

R&D programmes are drawn from the academic staff of the universities. These linkages will be further strengthened under the newly reorganized NSTB.

In contrast, linkages between the universities/PRICs and the enterprise sector were less developed, at least until the late 1990s (Wong, 1999b). To encourage R&D collaboration between industry and PRICs, NSTB set targets for the PRICs to recover a certain proportion of their costs from funding by industry. NSTB also monitored the performance of the PRICs in terms of extent of patenting, licensing of technologies to private industries and joint R&D with private firms. However, because of the gestation time needed for PRICs to establish their core capabilities, the extent of linkages between PRICs and private industries began to increase only in the last 3–4 years. Partly to protect proprietary technologies, many MNCs looked to their headquarters and associate companies for technological needs. They also preferred to tap R&D subsidies offered for in-house R&D, so that they would own the intellectual property generated.

Inter-firm innovation linkages between enterprises have also been rather weak, but have strengthened since the late 1980s. This is particularly so for linkages between local suppliers and MNC buyers. These relationships have contributed significantly to technological development of local firms (Wong 1992, 1999c), less through the deliberate efforts of MNCs to transfer technology than through the exposure to their procedures and technologies in the buyer-supplier relationship. Long-term supply relationships also helped reduce the risk of investing in new technologies to the suppliers, contributing to greater technological effort by local supporting industries.

Various studies (Wong, 1999c; Soon, 1992) indicate that the government played an important role in facilitating links between MNCs and local suppliers through such programmes as the Local Industry Upgrading Programme (LIUP) implemented by EDB. Wong (1999c) documents how the LIUP contributed to the rapid technological development of precision engineering firms supplying MNCs making hard disk drives. More recently, through the Industry Cluster Development strategy, EDB has facilitated joint ventures and technology alliances between Singaporean firms and major MNCs in several high-tech industries, including semiconductor wafer fabrication and chemicals.

In contrast, inter-firm innovation linkages among local firms have been much weaker. There are few reported cases of joint R&D among local firms, and the kind of R&D consortia found in Taiwan and Japan have been largely absent in Singapore. There had also been few reported cases of industry-wide collaboration in technology deployment. There appears to have been inadequate policy attention to promoting innovation collaboration among local enterprises. Despite some recent attempts at promoting

R&D consortia by some PRICs (for example, IME and DSI), the extent of inter-firm collaboration pales in comparison to countries such as Taiwan and Finland.

4.5 Public Policy Role in Promoting the Development of Venture Capital Industry

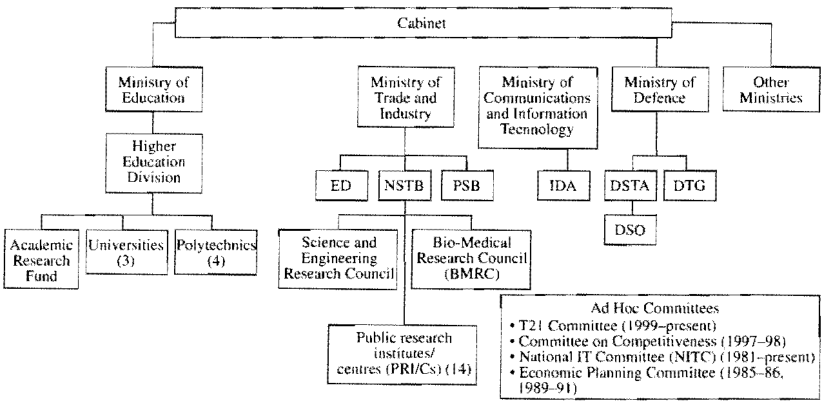
A key component of a national innovation system is institutions providing risk capital for technological activity. As MNCs provided risk capital in the early years of Singapore's development, there was little need to develop financial institutions to support high-technology investment. The financing needs of local SMEs were met mainly through the conventional financial institutions. The government did, however, support SMEs with various subsidized loan-financing schemes, particularly to subsidize investment in new technology and innovation.

It was only from the mid-1980s that the government began to promote the venture capital (VC) industry. Even then, the effort consisted mainly of investment incentives to attract foreign VCs to set up in Singapore, with very small-scale injection of public funds into the industry (unlike the case of Taiwan). It was in the first half of the 1990s that the government began to play a more active and direct role in the VC industry, creating new funds such as Vertex Management and EDB Ventures. The real growth of the VC industry occurred towards the late 1990s (see Table 8.11), with the growing interest of European, American and Taiwanese VC companies in Asia. The establishment of new public VC funds in 1997–98 contributed to the growth, culminating in the US$1 billion Technopreneurship Fund to induce leading VCs to use Singapore as their regional operation hub and train a core of experienced VC professionals. The Fund had been successful in attracting several leading US VCs to Singapore (for example, Draper Fisher Jurvetson, Crimson Ventures).

To encourage start-ups, the government also relaxed listing requirements on the national stock exchange in 1999, making it easier for new ventures to access the market without stringent track records. The flow of Initial Public Offerings (IPOs) by high-tech start-ups increased following this policy change, although several Singaporean start-ups have chosen to list in NASDAQ. NSTB also started a programme of promoting business angels through a tax incentive and co-investment scheme. These initiatives have enabled Singapore to establish itself as the preferred location for VC regional hub operations in Southeast Asia, but in terms of the volume of venture deal flows Singapore still lags considerably behind Taiwan.

4.6 The Changing Institutional Framework for S&T Policy Coordination

One of the key challenges for S&T policy is to ensure coordination between S&T policies and other economic policies on the one hand, and coordination among different S&T policies on the other. The institutional framework for coordinating S&T policymaking and implementation in Singapore has undergone considerable changes over the years. The key principle, which the government appears to have adopted in designing the institutional framework for S&T policy, appears to have stayed constant. This has been to subsume S&T policymaking and implementation largely within the Ministry of Trade and Industry (MTI), the ministry most directly responsible for promoting economic development. This not only simplifies the coordination between S&T and other policies, it facilitates the coordination of policy *implementation*. This arrangement has given strong coherence to policies supporting NIS development in Singapore. However, it may also have delayed the shift towards more upstream, longer-term basic research capabilities.



EDB – Economic Development Board
NSTB – National Science and Technology Board
PSB – Productivity and Standards Board
IDA – Infocomm Development Authority
DSTA – Defence Science and Technology Administration
DTG – Defence Technology Group
DSO – Defence Science Organization

Figure 8.3 Emerging institutional framework for S&T policy in Singapore as of 2001

Figure 8.3 shows the institutional framework for coordinating S&T policies in Singapore at the turn of the millennium. With the exception of the Ministry of Education (MOE), which oversees public education at all levels as well as funding of basic research at universities, the other major agencies responsible for economic development are all under MTI together with the National Science and Technology Board (NSTB). These include EDB, the

Productivity and Standards Board (PSB), the Trade Development Board (TDB) and, until very recently, the National Computer Board (NCB).

Virtually all the major policies to promote the technology development in Singapore fall under one or more of the agencies within MTI. Besides EDB, TDB and PSB, whose functions fall naturally within trade and industry development, MTI also oversaw the National Computer Board (NCB) and the National Science and Technology Board (NSTB). NCB was originally established under the Ministry of Finance in the early 1980s to promote computerization in the public and private sectors. By the mid-1980s, with the formulation of a comprehensive National IT Plan (NITP), NCB became the lead agency to implement the plan. Its role was thus expanded to include the promotion of IT industry, the development and training of IT professionals and the promotion of IT culture and awareness among Singaporeans. In the late 1980s, NCB expanded its mission further by establishing an R&D arm, and its IT industry promotion and manpower development roles also expanded, with the agency transferred to MTI for better coordination. In the early 1990s, another IT plan (called IT2000) was formulated, calling for the establishment of a broadband national information infrastructure (NII) to transform Singapore into an 'intelligent island' by 2000. NCB was put in charge of spearheading the implementation of this plan.

The decision to establish the National Science and Technology Board (NSTB) in 1991 within MTI reflects the strategy of the government to make R&D policies industrially driven. NSTB was established with the mandate to plan and manage the development of PRICs and to design and implement programmes to promote private R&D. In addition, the board was entrusted with R&D manpower development, planning and managing the development of S&T infrastructure such as science parks and incubators, and introducing policies to promote an environment conducive to innovation. In its first five years of operation (1991–95), NSTB was given a S$2 billion R&D fund, doubled to S$4 billion for the second period (1996–2000).

Reflecting the applied orientation of the policies and programmes of NSTB, the first National Technology Plan (NTP) for 1991–95 did not even include the word 'science' in its title. It was only in the second plan for 1996–2000 that NSTB recognized the importance of science. Even then, the key focus remained promoting short to medium-term technological development. As shown in Figure 8.4, the second plan still envisaged the bulk of NSTB funding would go into building short to medium-term technological leadership for Singaporean industries. Funding for longer-term R&D had to be justified on the ground of strategic relevance. In monitoring the performance of PRICs, external financing was used as an important indicator of the relevance of the R&D performed.

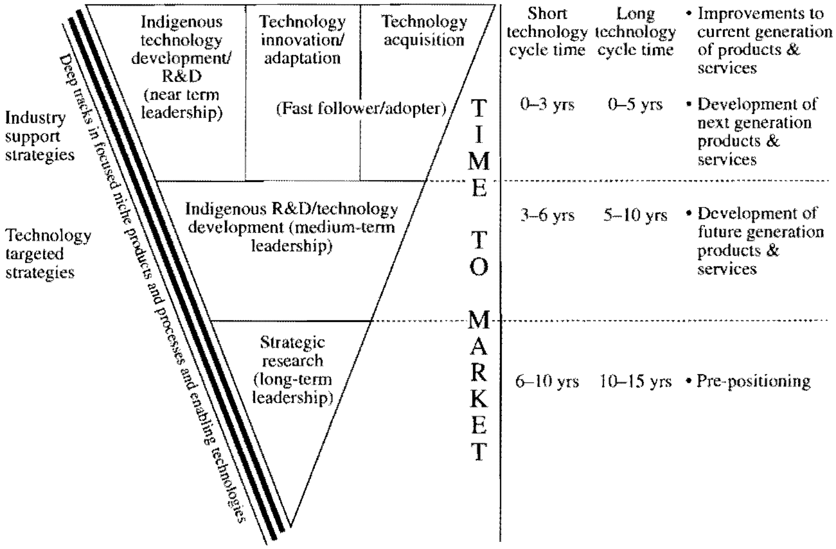


Figure 8.4 *R&D funding priorities according to the National Science and Technology Plan, 1996–2000*

Besides subsuming S&T policy largely within MTI, the Singapore government set up ad hoc high-level inter-ministerial committees from time to time to formulate strategic action plans in response to perceived external challenges or opportunities. The 1986 'New Directions' Action Plan (following the 1985 recession), the 1991 Strategic Action Plan (SEP) (following the formulation of *The Next Lap* vision statement), and the 1998 CSC Action Plan (following the Asian financial crisis) are examples of such action plans. It is through such strategic action plans that the context and impetus for new S&T policies are defined. Singapore is different from most other developing countries in that there are no regular five-year development plans. The system is more flexible, with strategic responses formulated and implemented as the need arises to maximize the speed of reaction to deal with unexpected threats or to capitalize on new opportunities.

This concentration of S&T resources in MTI notwithstanding, there has been some increase in S&T resources given to other ministries over the last three years. A new Ministry of Manpower (enlarged from the old Ministry of Labour) was established in late 1997 to better coordinate manpower development policies. It took over some industrial manpower development functions previously performed by EDB. Three other ministries have also begun to have an influence over S&T development. First, the Ministry of

Defence, which has a large budget for defence-related R&D, has been looking at dual-use technologies. In anticipation of the need to establish linkages with private industry, a Defence Science and Technology Agency (DSTA) was established in 1999 to corporatize defence R&D functions. Second, in 1999, the government recognized, somewhat belatedly, the growing convergence of computers and telecommunications. It transferred NCB to an enlarged Ministry of Information and Communications Technology (MICT) and merged it with the existing telecommunications regulatory authority (Telecommuncations Authority of Singapore or TAS), forming a new entity called the Infocom Development Authority (IDA). Although IDA's primary mission was to promote infocom technology deployment rather than development, its policies will have a strong influence on internet-related innovations. Despite speeding up the pace of telecommunications deregulation in recent years, MICT needs further to liberalize competition policies to stimulate innovation. For example, the government has stopped short of merging the Singapore Broadcasting Authority (SBA) (which regulates the media and broadcasting industry under the Ministry of Information and the Arts) with IDA, despite the growing convergence of broadcasting with telecommunications. Finally, with the growing importance of life sciences and healthcare, the Ministry of Health is expected to play a more important role in promoting life sciences R&D.

The greater involvement of these ministries in S&T development will increase the complexity of coordination in the future. As a step towards a more pluralistic approach, the government, in its Third National Science and Technology Plan (2001–2005), established two new research councils – the Biomedical Research Council (BMRC) and the Science and Engineering Research Council (SERC) in NSTB. These will better coordinate and manage public sector R&D from basic to applied research and across PRICs and institutions of higher learning. NSTB is restructured to play more of an R&D funding role, with greater autonomy from short-term industry concerns, while its previous T21 responsibilities and private R&D incentive functions are being corporatized or transferred to EDB. It is hoped that this restructuring will enable more public resources to be invested in longer-term upstream research capabilities.

Finally, we must mention the role of other ministries and government bodies in promoting technology *deployment*. While the other ministries do not directly shape S&T policies, most have an active policy to deploy new technology in the agencies under their jurisdiction. As mentioned, all government agencies involved in the provision of public infrastructure have been aggressive in deploying new technologies. This is part of the overall 'total business hub' strategy of the government to ensure that the public sector contributes to the productivity of the economy by providing world-class services. All parts of the public sector are constantly benchmarked against global 'best practice' to ensure that the public sector maintains a high level of productivity. While this management philosophy has the beneficial effect of putting pressure on agencies to exploit new technologies, it may have an inherent bias towards conservatism: it encourages public agencies to become fast followers, but not necessarily pioneers in adopting new technologies. In particular, in the classic 'make or buy' choice, the policies of some agencies may be slanted towards procuring proven technologies from foreign suppliers rather than supporting the development of new but unproven technologies by indigenous firms, especially small local start-ups.

To overcome this conservative mindset, the government has started to experiment with new incentive schemes to fund proposals for radical innovations in public services too risky and unproven to be adopted within the normal administrative system. Whether such experiments will become institutionalized remains to be seen.

4.7 Summary Assessment of the Impact of Public Policy

Despite the significant role of policy in Singapore, there have been few systematic empirical studies to assess the impact of these policies on the development of technological capabilities. The rapid advancement in technological capabilities in Singapore relative to other developing countries that were at comparable levels four decades ago suggests that policies were important. However, it is difficult to isolate the contribution of various policies and programmes. Methodologically, any attempt to do this should be based upon a comparative analysis across countries. An attempt of this sort was made by McKendrick et al. (2000), examining the impact of policy on the development of technological capabilities in the hard disk drive industry in Singapore, Thailand and Malaysia. The inadequate attention to external policy evaluation and impact assessment by the government has contributed to the paucity of independent public research.

In the absence of comprehensive evaluation, the finding of Young (1992) that Singapore achieved almost zero total factor productivity (TFP) growth over 1960–80 became very controversial, raising questions about the viability of Singapore's development model. However, Hsieh (1997) has questioned the validity of Young's findings, highlighting problems with the capital data used by Young. Hsieh's estimate of Singapore's TFP (using a different method) was substantially higher. More recent estimates of Singapore's TFP growth in the 1980s and 1990s all yield substantially higher values (Collins and Bosworth, 1996; Rao and Lee, 1996; Singapore

Department of Statistics, 1997; MTI Economic Survey of Singapore, 2001). On balance, empirical evidence appears to support the view that TFP performance in Singapore was low but not zero in the 1980s, adding about 1.5 per cent to annual economic growth (about 20 per cent of the total economic growth of 7.1 per cent over the period). TFP performance improved substantially in the 1990s, adding about 2.5 per cent economic growth per annum, or about one-third of the total growth of 7.5 per cent for the period.

Even if Singapore's growth up to the 1980s can be accounted for largely by growth in inputs, with little TFP contribution, this does not negate the importance of investment in technology absorption capability. Indeed, the rapid growth achieved by Singapore in the 1970s and 1980s (over 7 per cent per annum) required a rate of absorption of new capital and labour inputs that had been rarely witnessed elsewhere. It would not have been possible without absorption capability being developed correspondingly.

The fact that Singapore began to register higher TFP in the 1990s is consistent with the empirical observation that Singapore did not begin to invest substantially in R&D until the later 1980s. Recent econometric estimates by Toh and Wong (2001) show that R&D contributes significantly to TFP growth from the mid-1980s to 1997. Another recent study (Wong and He, 2001) using data from a cross-sectional survey of over 100 manufacturing firms performing R&D, shows that R&D support programmes had a significant impact on innovation performance after controlling for the internal climate for innovation of the firms concerned. While much more empirical research remains to be done, the available evidence does point to a positive role of government policy in technological development.

5. EMERGING S&T POLICY CHALLENGES AND RESPONSES

Singapore's NIS has to be transformed at an even faster pace in the future than in the past. To spur this, the government has to continue to make significant changes to S&T policy. The recent policy shift towards greater emphasis on technopreneurship is a welcome change from the previous focus on technology transfer from MNCs. However, this policy shift by itself is likely to be inadequate. Four supporting S&T policy changes need to be made in the medium term.

First, the government needs to continue to raise investment in R&D to levels found in advanced industrial countries. Second, this must be accompanied by a significant shift in the focus from incremental, applied R&D to basic research. Third, the existing funding and management mechanisms for the PRICs and research at institutions of higher learning need to be fine tuned. Related to this, new policymaking capabilities need to be developed to enable the introduction of new policies and programmes. Fourth, the government needs to play a more pro-active role in promoting international cooperation and networking with other advanced countries in R&D.

5.1 Intensification of R&D investment

Despite the steady growth in R&D in recent years, with the GERD/GDP ratio rising from less than 1 per cent in 1990 to 1.84 per cent in 1999, Singapore's R&D intensity remains lower than in industrial countries and Korea (though, as noted, it has caught up with Taiwan). Given its smaller size and the need to achieve minimum critical mass in most areas of scientific and technological endeavour, it is even more important for Singapore to increase its R&D intensity to the levels of advanced industrial countries. In this regard, it is instructive to look at the rapid growth in R&D intensity in small countries like Finland and Israel, contributing to the recent improvement in their global competitiveness in high-tech industries.

5.2 Shift towards More Basic Research

Besides raising overall R&D, there is an urgent need to shift resources towards the development of basic research capabilities. In contrast to the prevailing emphasis on applied R&D, Singapore needs to emphasize the development of basic research capabilities that can provide more radical or breakthrough solutions, or that anticipate future problems of industry. It is through the tapping of such basic yet economically relevant R&D capabilities that Singaporean companies can hope to achieve more durable competitive advantages. Without a concomitant investment in basic research capabilities, the T21 strategy may run the risk of producing too many 'me too' type of start-ups that lack technological depth and hence are likely to be overwhelmed by global competitors. The leading regions of high-tech entrepreneurial vitality in the world, especially Silicon Valley and Israel, invariably feed on wellsprings of leading edge technologies which are generated by a strong focus on basic research capabilities.

Because private firms are unlikely to invest heavily in basic research, the development of basic research capabilities must remain a major responsibility of the public sector. This is the case worldwide. In Singapore, this means that PRICs need to shift their R&D portfolio towards programmes with longer gestation but greater potential for high pay-offs. More importantly, there is a need to boost the basic R&D budget in local universities. Despite significant progress, the level of basic R&D funding at the two universities in Singapore remains significantly below those of the major state universities in the USA. An increase in the basic R&D budget is also needed to attract top foreign talent, which can then draw good doctoral students and post-doctoral fellows to build critical mass. To ensure that investment in basic research does not become completely 'blue-sky' and unfocused, however, a portfolio management approach needs to be adopted. This will combine a stronger focus on selected areas where Singapore can be a centre of global excellence while allocating funds to novel research. In addition, 'use-inspired basic research' is needed to focus research on problems with significant industrial impact.

5.3 Mechanisms for Funding and Managing Public R&D Institutions

The criteria for selecting R&D programmes for funding and evaluating R&D performance differ, depending on whether the R&D concerned is largely applied or incremental work or with longer-term basic research. With a shift towards basic research, NSTB needs to evolve new funding and management mechanisms and incentive structures. In addition, potential conflicts within PRICs between maximizing technology diffusion and spinning off companies of their own need to be addressed. Better intellectual property management and technology transfer practices need to be established and pooled to avoid unnecessary duplication. Finally, incentives need to be introduced to encourage PRICs and universities to cooperate with one another as well as with industry partners through consortia.

S&T policymaking and evaluation capabilities and accountability mechanisms need to be established within NSTB and MTI. The combination of consultation with industry and international advisers, benchmarking against best practice, setting clear performance objectives and frequent self-monitoring of programme relevance has been effectively used in the past. However, these need to be supplemented by more rigorous policy research and impact studies, as the sophistication of policy instruments increases and the relationship between policy instruments and industry becomes more complex. There is also the need to use more independent researchers to evaluate public policies and programmes.

5.4 Promoting International R&D Cooperation and S&T Networking

To become a viable player in global R&D competition, R&D institutions in Singapore need to develop more collaborative partnerships with leading R&D institutions overseas. This is particularly so in view of the latecomer nature of Singapore in many advanced R&D areas, and the limited pool of domestic R&D talents. The government can play a catalytic role in helping local R&D institutions to establish closer networking and collaboration with carefully targeted partner institutions in Europe, Japan and North America.

6. CONCLUSIONS

If there is one primary lesson to be drawn from Singapore's experience for other small developing countries, it is the need to combine long-term strategic commitment to upgrade technological capability with an institutional capability for flexible and rapid policy change. This apparently paradoxical combination, termed *Strategic Pragmatism* (Schein, 1996), appears best to capture the essence of the success of Singapore in technological development. This institutional capability covers not only implementation but also the ability to transform institutions as circumstances change (Wong, 2001a).

A second important lesson is the need for a proper sequencing of different types of technological capabilities over time. Rather than devoting too many resources to basic R&D at the start, developing countries should focus initially on building operational and adaptive capabilities. It is only after a firm foundation for such capabilities has been laid that investment in R&D becomes viable. A country like China may have overemphasized investment in basic R&D in earlier years when many local enterprises lacked the capabilities and incentives to exploit upstream knowledge. On the other hand, developing countries should not become too complacent in relying on FDI in manufacturing, and delay investing in indigenous innovation for too long. Our analysis suggests that Singapore may have erred in this regard compared to countries like Taiwan and Korea, although the problem may be more serious for other economies with a high reliance on FDI like Malaysia and Hong Kong. A comparative analysis of the NIS characteristics of Singapore with other FDI-dependent countries may be instructive.

A final lesson of Singapore's experience is that the effectiveness of NIS is influenced by not just the proximate S&T policies, but also the wider industrial, trade and competition policy framework. Although this paper has focused on proximate S&T policies, in Singapore these are in a context not often found in developing countries. Singapore has been exceptionally open to trade and investment. It has enjoyed political and social stability and sound macroeconomic policies. It possesses an efficient, relatively corruption-free public service which is professionally run and attracts highly talented staff. It has invested heavily in physical and social infrastructure, education and training. Without these contextual factors, similar S&T policies may not work well, if at all.

Despite its achievements, the path ahead for Singapore is likely to be much more difficult as it competes increasingly against not just regional neighbours and other NIEs but also advanced countries in technologically advanced industries. In seeking to evolve its S&T strategies, Singapore could therefore do well to study the experience of other advanced countries. However, while certain elements of the institutional models that have worked well in places such as Silicon Valley, Finland or Israel can be borrowed and adapted, wholesale duplication is not possible. The national innovation system evolves in a path-dependent manner and needs to respond to the unique endowments and contexts of each country (Nelson, 1993). In the final analysis, therefore, the key S&T policy challenge for Singapore will be to evolve its own unique vision of how a small country can compete in global, knowledge-intensive industries. To borrow the terminology of Romer (1992) once again, the two paths to economic development – using and producing ideas – need to be increasingly integrated in a virtuous cycle.

ACKNOWLEDGEMENT

The author would like to acknowledge the assistance of Ms Annette Singh in the compilation of data for this study.

REFERENCES

Amsden, A. (1989), *Asia's Next Giant: South Korea and Late Industrialization*, Oxford: Oxford University Press.

Chng, M.K., L. Low, A. Tyabji and B.N. Tay (1986), *Technology and Skills in Singapore*, Singapore: Institute of Southeast Studies.

Collins, S. and B. Bosworth (1996), 'Economic growth in East Asia: accumulation versus assimilation', *Brookings Papers in Economic Activity*, 2, 135–204.

Dahlman, C.J. and O. Sananikone (1990), 'Technology strategy in the economy of Taiwan: exploiting foreign linkages and investing in local capability', mimeo, Washington DC: World Bank.

Dosi, G., C. Freeman, R. Nelson, G. Silverberg and L. Soete (1988), *Technical Change and Economic Theory*, London: Frances Pinter.

Economic Development Board (various years), *EDB Yearbook*, Singapore: EDB.

Economic Development Board (2000), *The Singapore Venture Capital Industry Survey 1999*, Singapore: EDB.

Government of Singapore (1991), *The Next Lap*, Singapore: Government of Singapore.

Hsieh, C.T. (1997), 'What explains the industrial revolution in East Asia? Evidence from factor markets', unpublished paper, Department of Economics, University of California, Berkeley.

IMD (2001), *World Competitiveness Report 2001*, Lausanne, Switzerland.

Kim, L. and C. Dahlman (1992), 'Technology policy for industrialization: an integrative framework and Korea's experience', *Research Policy*, 21: 437–52

Lundvall, B. A. (ed.) (1992), *National Innovation System*, London: Frances Pinter.

McKendrick, D.G., R.F. Doner and S. Haggard (2000), *From Silicon Valley to Singapore: Location and Competitive Advantage in the Hard Disk Drive Industry*, Stanford, CA: Stanford University Press.

Ministry of Trade and Industry (various years), *Economic Survey of Singapore*, Singapore: MTI.

Ministry of Trade and Industry (1986), *The Singapore Economy: New Directions*. Singapore: MTI.

Ministry of Trade and Industry (1991), *Strategic Economic Plan: Towards a Developed Nation. The Strategic Economic Plan*, Singapore: MTI.

National Computer Board (1992), *IT2000: Vision for an Intelligent Island*, Singapore: NCB.

Nelson, R.R. (ed.) (1993), *National Innovation Systems: A Comparative Analysis*, New York: Oxford University Press.

National Science and Technology Board (1991), *National Technology Plan*, Singapore: NSTB.

National Science and Technology Board (1996), *National Science and Technology Plan*, Singapore: NSTB.

National Science and Technology Board (various years), *Annual Report*, Singapore: NSTB.

National Science and Technology Board (various years), *National Survey of R&D in Singapore*, Singapore: NSTB.

OECD (1993), *Oslo Manual*, Paris: OECD.

OECD (1997), *National Innovation Systems*, Paris: OECD.

Porter, M.1990. *The Competitive Advantage of Nations*, London: Macmillan.

Rao, B.V.V. and C. Lee (1996), 'Sources of growth in the Singapore economy and its manufacturing and services sectors', *Singapore Economic Review*, **40**(1), 83–115.

Reynolds, P.D., W.D. Bygrave, E. Autio, L.W. Cox, and M. Hay (2000), *Global Entrepreneurship Monitor 2000: Executive Report*, Kauffman Center for Entrepreneurial Leadership.

Romer, P. (1992), 'Two strategies for economic development: using ideas vs. producing ideas', *World Bank Annual Conference on Development Economics*, Washington DC, April 30–May 1.

Schein, E. (1996), *Strategic Pragmatism: The Culture of the Economic Development Board of Singapore*, Cambridge, MA: MIT Press.

Singapore Department of Statistics (1997), 'Multifactor productivity growth in Singapore: concept, methodology and trends', occasional paper on economic statistics.

Soon, T.W. (1992), 'Human resource development and management in Singapore', in P.K. Wong and C.Y. Ng (eds), *Human Resource Development and Utilization in the Asia-Pacific:* A *Social Absorption Capacity Approach*, Singapore: ISEAS, pp. 21–30.

Suh, J. (1998), 'OECD project on NIS in catching up economies', paper presented at the workshop on OECD Project on NIS in Catching Up Economies, Taipei, Taiwan, April 20–22.

Toh, M.H. and P.K. Wong (2001), 'The impact of R&D on Singapore's economy', Singapore: CMIT working paper, National University of Singapore.

United Nations Economic Commission for Europe (1997), *World Industrial Robots*, New York: United Nations.
Williamson, O.E. (1985), *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting*, New York: Free Press.
Wong, P.K. (1992), 'Technological development through subcontracting linkages: evidence from Singapore', *Scandinavian International Business Review*, **1**(3), 28–40.
Wong, P.K. (1995a), *National Innovation System: The Case of Singapore*, Seoul, Korea: Science and Technology Policy Institute (STEPI).
Wong, P.K. (1995b), 'Developing technology managers in Singapore: issues and challenges', in K. Minden and P.K. Wong (eds), *Developing Technology Managers in the Pacific Rim*, New York: M.E. Sharpe, pp. 62–92.
Wong, P.K. (1998), 'Leveraging the global information revolution for economic development: Singapore's evolving information industry strategy', *Information Systems Research (US)*, **9**(4), 323–41.
Wong, P.K. (1999a), 'National innovation system for rapid technological catch-up by small, late-industrializing economies', Singapore: CMIT working paper, National University of Singapore.
Wong, P.K. (1999b), 'University-industry technological collaboration in Singapore: emerging patterns and industry concerns', *International Journal of Technology Management*, **17**(3/4), 270–84.
Wong, P.K. (1999c), 'The dynamics of HDD industry development in Singapore', working paper, San Diego: Globalization of Data Storage Industry Project.
Wong, P.K. (2001a), 'The role of the state in Singapore's industrial development', in P.K. Wong and C.Y.Ng (eds), *Industrial Policy, Innovation & Economic Growth: The Experience of Japan and the Asian NIEs*, Singapore: Singapore University Press
Wong, P.K. (2001b), 'Learning by transacting: A process for accelerated technological learning by late-entrant manufacturing firms?' Singapore: CMIT working paper, National University of Singapore
Wong, P.K. (2002), 'ICT production and diffusion in Asia: digital dividends or digital divide?', *Information Economics and Policy*, 14(2), 167–87.
Wong, P.K., A. Singh, and F. Wong (2000), 'National innovation survey of Singapore manufacturing industry', Singapore: CMIT working paper, National University of Singapore.
Wong, P.K. and Z.L. He, (2001), 'The moderating effect of firm's internal innovation climate on the impact of public R&D support: empirical evidence for Singapore', Singapore: CMIT working paper, National University of Singapore.
World Bank (1993), *The East Asian Miracle: Economic Growth and Public Policy*, New York: Oxford University Press
World Bank (2000), *World Development Report 2000/2001*, Oxford: Oxford University Press.
World Economic Forum (2000), *Global Competitiveness Report 1999*, Geneva: WEF.
Young, A. (1992), 'A tale of two cities: factor accumulation and technical change in Hong Kong and Singapore,' *NBER Macroeconomic Annual 1992*, Cambridge, MA: MIT Press.

9. In search of balance: technological development in China

Yang Yao[1]

China is unique among the developing countries in terms of technological development. Its planning legacy left the economy with a solid industrial and technological foundation as well as with distortions. Even though the role of the planning system has been gradually reduced over some 20 years, this legacy still leaves a clear mark as innovation initiatives still come exclusively from the government. This is both a blessing and a curse. It is a blessing in that it allows China to concentrate its limited resources on the development of the key technologies that it needs to promote economic development. China has a well-trained industrial workforce, a relatively complete education system, a capable research system, and a leading edge in technologies like satellite launching, nuclear power and some areas of biotechnology and new materials. It has grown from being an exporter of primary goods to becoming the developing world's largest exporter of manufactured goods. Yet, the concentration is also a curse. It has resulted in a distorted industrial structure with a relatively highly developed heavy industry and a much less well developed light industry. There is over-investment in the state-owned sector, leading to moral hazard problems and inefficient use of resources. It has created powerful vested interests that are resistant to market-oriented changes.

The 1990s saw tremendous changes in the Chinese economy. The most significant one is perhaps the growth of the non-state sector. Although the state sector is still a significant player, especially in terms of urban employment and tax revenues, its share in China's GDP has been decreasing rapidly, totalling only 37 per cent by 1998. In contrast, the growing private sector (domestic and foreign) contributed 33 per cent of China's GDP in the same year. In terms of industrial output, the domestic private sector's share was close to 35 per cent in 1998, compared to the state sector's share of 33 per cent.[2] However, there is a significant lag between the change of industrial ownership and resource allocation. More than 80 per cent of commercial bank loans, the largest block of resources controlled by the government, still flow to the state sector (SSB, 1999). Although this may have some rationale since the state sector is still the most significant actor in technological terms, the mismatch is likely to take its toll on long-run technological development in China.

The government understands this mismatch and is trying to change the system. However, there are two constraints. First, the government still wants to dominate innovation and dissemination. Second, various levels of government emphasize the need to upgrade technology in their industrial sectors, confusing efficiency with advanced technologies. This is evident in the mushrooming of high-tech industrial parks throughout the country. These factors suggest that the government will continue to dominate technology development even though it may not be the right strategy in an increasingly market-based economy.

In this chapter, we present a general description of technological development in China. We also discuss the adequacy of the strategy to improve China's technological status. Section 1 provides an overview of China's technological development. Section 2 describes China's domestic innovation efforts, concentrating on the role of public institutions and government initiatives. Section 3 surveys the patterns of technology diffusion in China, with special attention to the role of FDI. Section 4 concludes with a brief appraisal of the government's technology development strategy, emphasizing the importance of a balance between technical elevation and proper utilization of China's human and financial resources.

1. HISTORICAL AND CURRENT STATUS OF TECHNOLOGY IN CHINA

We start with an overview and appraisal of China's technology development since 1949. The half-century is divided into three periods, 1949–59, 1960–78 and 1979–99. We then consider China's current technological status, using export composition as the main indicator.

1.1 History

1949–59

China's technological build-up in the early 1950s relied heavily on the Soviet Union. In China's first five-year plan of 1953–58, the Soviet Union provided 156 major industrial projects, predominantly in heavy industry, led by electricity, steel and heavy equipment manufacturing. In addition, China imported 426 sets of equipment and 122 technologies and production lines from the Soviet Union, Eastern European countries and several Western countries (Chen, 1997). These imported technologies laid the foundations of China's modern industry, and their impact can be felt even today. China's economic structure changed swiftly: in 1949, the share of heavy industry in gross national output was only 7.9 per cent and by 1962 it had reached 35.5 per cent. Within the industrial sector, the share of heavy industry rose from 26.4 per cent in 1949 to 53.5 per cent in 1962 (Chen, 1997).

The imported technologies brought not only modern industry to China, but also new knowledge and skills. Thanks to the more than 3000 Soviet experts and many others from the Eastern European countries, China quickly acquired industrial skills and trained a capable workforce. In addition, more than 20000 people were sent to the Soviet Union and Eastern European countries for formal education or training. These people formed the backbone of China's technological capacities until the new generation of college graduates after the Cultural Revolution matured in the late 1980s and early 1990s. The industrial projects were allocated to reduce regional disparities in industrial development, with many located in the central and western regions. Of the 106 completed civil projects, 50 were in the north-east and 32 were in the central provinces. Of the 44 military projects, 21 were in just two western provinces (Bo, 1993). At the same time, thousands of workers, scientists and technicians were mobilized to move from the eastern coast to central and western provinces.

However, some authors have criticized the heavy industry development strategy as the most important deterrent to China's economic development (for example, Lin et al., 1996). To be sure, with a weak industrial base and low national savings, this strategy relied on distorted price signals; the most significant distortion was the suppression of agricultural prices to maintain a low-wage workforce. Another consequence was the suppression of light industry; the result was that the heavy industrial sector found itself with less and less demand. The large-scale movements of the population also caused serious problems. This was especially true for military projects, many of which were deliberately located in mountains for security reasons. In the 1980s, many of these factories had to move out of the mountains. Except for a few exceptional cases (such as Xichang Satellite Launch Centre), the remaining ones now face serious problems due to the loss of skilled workers and technicians and lack of access to markets and information.

It is important to evaluate the heavy industry development strategy from a historical perspective. Import-substitution was the dominant development strategy of the time, even in non-socialist economies. With the strong influence of the Soviet Union, it is not surprising that China undertook the heavy industry development strategy in the 1950s. There was also a certain amount of national pride involved in setting up complex, capital-intensive industries; at the time steel, machinery making and so on were the symbols of a modern country. Perhaps most important was the political situation, which did not allow China to pursue a different development strategy at that time. After the Korean War, China had severed its ties with Western countries. It went into complete isolation after it broke up with the Soviet Union in the early 1960s. Inside the country, several ultra-left political movements mobilized by Mao Zedong flooded the country for 20 years, preventing China from any attempt to adopt a more outward-looking development strategy.

From a historical perspective, we can not only understand why the heavy industry development strategy was adopted, but also reach a balanced appraisal of its achievements and misfortunes. However, dwelling on the past is not useful, we need to focus on this strategy's impacts on today's affairs. The misfortunes of this strategy on the physical side have been corrected by the 20 years of the open-door policy and restoration of the light industrial sector. However, psychologically this strategy lingers on and is manifested by the government's dominance in technological innovations and its determination to concentrate on quick upgrading of China's domestic technologies. We will come back to a discussion of this in later sections.

1960–78

The fast growth of the 1950s ended with the Great Leap Forward, launched in 1958, and the subsequent famine that took at least 20 million lives in just three years (Lin, 1990). In the subsequent 18 years, China was in an abyss of political upheaval and economic stagnation. In the early 1970s, after the frenzy of the Cultural Revolution abated, the government of Zhou Enlai tried to revive China's modernization by proposing 'Four Modernizations' (agriculture, industry, science and the military) to be achieved by the end of the century. This led to a new wave of technological importation. This time the sources were exclusively Western. In the period of 1972–76, US$5.14 billion was spent to equip new factories with imported equipment. The emphasis now was on the the heavy chemical industry. In 1977, the new party chairman, Hua Guofeng, proposed new plans to catch up with the Western world and a new wave of heavy industry development was launched. In 1978 alone, total investment reached 50.1 billion yuan RMB, a 31 per cent increase over 1977. Many technology import contracts were signed hastily, and as a result foreign reserves dropped by nearly US$10 billion that year (Chen, 1997). This wave, subsequently called the 'Foreign Leap Forward', was stopped when Deng Xiaoping took over the government in 1979.

1979–99

After the Third Plenary of the Eleventh Communist Party Congress at the end of 1978, China's economic policy became more pragmatic. Technology imports and technical development went through fundamental changes. Higher education, which had been held back in favour of primary and secondary education, was restored and expanded. Many government research agencies were restored, several new ones were set up. Technology flows from research institutions to firms and inter-firm technical transfers were renewed.

The most significant event in the 1980s was perhaps the emergence of the rural industrial sector and technical transfers from urban industry to this sector. The rural industrial sector is characterized by high labour intensity and has become a major engine for China's economic growth. Two events from the early 1990s are worth mentioning. One is the emergence of private firms and their absorbing of technologies from the state sector. The other is the maturity of the domestic home electronics industry. In the 1980s, foreign home appliances, notably products from Japan, dominated China's market. In the 1990s, domestic firms began to gain ground and by 2000 domestic products almost monopolized the home electronics market. A good example is Changhong, a TV manufacturer located in Sichuan. A military factory before the 1980s, it began to produce colour TV sets in the mid-1980s. After 10 years, it became the largest colour TV maker in China and has maintained a lion's share of 23 per cent in China's domestic market.

The pattern of technology imports after 1978 changed substantially. Equipment imports were curtailed and technology licences became the main mode of technology import. According to a survey of 4302 technological import contracts in the period of 1979–90 conducted by the State Planning Commission, 41.4 per cent were technology licences, 9.3 per cent technical consultation, 5.3 per cent joint production or design and the remaining 44 per cent equipment imports (Chen, 1997). Although equipment imports remained large, the situation was quite different 30 years earlier when over 90 per cent of technology imports consisted of equipment. Import of equipment, especially imports of complete plants, may have been the only alternative for China when its production capacities were weak. However, this alternative involves a large amount of initial investment and has the effect of locking a country into a specific path of technological development. On the other hand, technology licensing has several advantages. It allows a country more room for selection and for mixing foreign technologies with local ones. Therefore, China's shift from equipment imports to technology licensing was a correct choice.

The 1990s also witnessed a boom in China's export of manufactures. In 1990, the five top exports from China were garments, crude oil, cotton fabric, refined oil and silk products; in 1995, they were garments, home electronics, telecommunication equipment, toys and steel (Chen, 1997). This change reflects the rapid technological upgrading of China's competitiveness.

1.2 Contribution of Technological Progress

Although it has many defects, total factor productivity (TFP) is still the most frequently used indicator of a country's technical progress. Table 9.1 shows the TFP growth for China during 1953–95. In this period, China's GDP rose by 8.3 per cent annually while TFP grew by 3.1 per cent, contributing 20.8 per cent to GDP growth. In the period after 1978, GDP grew by 10.1 per cent per year and TFP by 5.1 per cent. In the 1953–59 period, by contrast, GDP grew rapidly but TFP rose by only 1.7 per cent. The average contribution of TFP to growth was negative, and economic growth in this period was driven by capital and labour mobilization. The three years of 1960–62 were the period of famine, with negative GDP growth rate and even more negative growth rate of TFP.

The period 1963–78, despite the Cultural Revolution, witnessed remarkably strong GDP and TFP growth. Indeed, it was not significantly behind

*Table 9.1 TFP in China, 1953–95 (%)**

Year	GDP growth rate	Capital growth rate	Labour growth rate	TFP growth rate	TFP contribution**
1953	13.17	21.88	2.94	4.55	34.53
1954	5.78	17.95	2.60	−1.43	−24.65
1955	6.44	14.37	2.03	0.71	10.99
1956	14.11	16.54	2.40	7.47	52.93
1957	4.50	18.46	3.05	−3.17	−70.51
1958	22.10	24.68	8.75	8.57	38.78
1959	8.06	30.78	5.71	−5.17	−64.16
1960	−1.42	23.26	0.86	−9.00	
1961	−18.43	3.45	−1.07	−18.72	
1962	−6.51	−0.09	−0.73	−5.97	
1963	10.70	2.55	1.59	8.82	82.45
1964	16.95	4.31	3.46	13.24	78.08
1965	16.95	9.08	3.79	11.57	68.28
1966	17.02	8.17	3.71	11.97	70.34
1967	−7.24	4.60	3.62	−11.15	
1968	−6.54	2.33	3.43	−9.64	
1969	19.36	4.20	3.81	15.43	79.72
1970	23.22	9.86	3.95	17.50	75.35

Table 9.1 (continued)

Year	GDP growth rate	Capital growth rate	Labour growth rate	TFP growth rate	TFP contribution**
1971	9.13	9.67	3.76	3.60	39.40
1972	2.85	8.31	2.25	−1.22	−42.74
1973	8.30	9.91	1.55	4.24	51.11
1974	1.15	8.35	2.15	−2.86	−248.70
1975	8.32	8.48	2.23	4.22	50.66
1976	−2.65	7.25	2.18	−6.35	
1977	7.79	8.43	1.78	4.02	51.54
1978	12.27	9.85	1.86	8.01	65.31
1979	7.60	10.91	2.24	2.76	36.30
1980	7.81	8.63	2.89	3.20	40.95
1981	5.26	5.66	3.38	1.20	22.74
1982	0.82	8.20	1.27	−2.53	−308.41
1983	19.90	8.04	5.32	13.76	69.17
1984	15.18	9.09	3.22	10.20	67.19
1985	13.47	12.06	3.73	7.24	53.76
1986	8.86	13.22	2.99	2.80	31.61
1987	11.57	10.40	3.20	6.21	53.67
1988	11.27	10.52	3.01	6.01	53.30
1989	4.07	9.49	2.37	−0.44	−10.71
1990	3.83	8.97	2.17	−0.38	−9.92
1991	9.16	12.00	2.40	3.88	42.36
1992	14.24	14.00	2.21	8.49	59.64
1993	13.50	12.84	2.30	8.04	59.54
1994	12.66	11.47	2.26	7.64	60.32
1995	10.17	11.54	2.20	5.17	50.82
1953–59	10.59	20.67	3.93	1.65	−3.15
1960–62	−8.79	8.87	−0.31	−11.23	
1963–78	8.60	7.21	2.82	4.46	32.37
1979–88	10.17	9.67	3.13	5.08	12.03
1989–90	3.95	9.23	2.27	−0.41	−10.32
1991–95	12.64	12.46	2.24	7.33	57.58
1953–78	6.92	11.07	2.79	1.65	17.55
1979–95	10.09	10.31	2.75	5.06	22.75
1953–95	8.25	10.78	2.76	3.08	20.84

Notes:
* Following Jiang et al. (1998), the share for labour is 0.7, and the share for capital is 0.3.
** Years with negative GDP growth rates are excluded from the calculation.

Source: Data on GDP, capital and labour growth rates are from Li et al. (1998: 246–7). TFP figures are calculated by the author.

1979–88, and even outperformed the later period in terms of TFP contribution. The two years of 1989 and 1990 were special because of the Tian'anmen Square event in the spring of 1989. Although GDP recorded low growth in these two years, TFP growth was negative. The most recent period considered in the table, 1991–95, was the golden age of China's recent economic development, with a GDP growth rate of 12.6 per cent, TFP growth rate of 7.3 per cent and TFP contribution of 57.6 per cent.

There appears to be a positive correlation between TFP growth and GDP growth after 1963. This is remarkable in view of the inefficiency attributed to economic planning. The failure of planning in China was not so much manifested by slow TFP growth as by the lack of incentives (and ultimately the lack of political and economic freedom) and rigidities in the economic structure.

1.3 Current Technological Status

There are many ways to describe a country's technological status. Some will be presented later in this chapter. In this subsection, however, we will first follow Chapter 2 (Lall) in this volume to provide statistics on China's export composition in order to show the dynamics of its competitiveness.

Table 9.2 shows the structural dynamics of China's exports from 1985 to 1999. Until 1990, agricultural goods and resource-based metal and non-metal products were significant in exports. In 1985, these two categories of goods accounted for over 56 per cent of China's total exports, followed by textile products at 22.1 per cent. By 1990, the share of agricultural products had increased from 25.4 per cent to 28.5 per cent, but the share of metal and non-metal products had decreased to 17.6 per cent. In the meantime, textile products had raised their share to 23.9 per cent while other light industrial products had raised theirs to 17.7 per cent (from 6.0 per cent in 1985). By 1995, the share of agricultural product decreased to 12.7 per cent and that of metal and non-metal products to 10.3 per cent. Textiles and other light industrial products had become the two most exported categories of goods, accounting for more than 56 per cent of total exports.

By 1999, the most significant feature of China's export structure was the development of the machinery sector, whose share in total exports had reached 20.5 per cent (from 10 per cent in 1995 and only 2 per cent in 1985). Concomitantly, resource-based goods had declined substantially: agricultural products to 6.2 per cent and metal and non-metal products to 5.7 per cent. The shares of simple labour-intensive products such as textiles and other light industrial goods had also dropped, and machinery had become the second largest export sector, just behind textiles.

Table 9.3 shows China's 10 leading exports from 1985 to 1999. In 1985,

Table 9.2 China's export composition, 1985–98 (9 million US$)

	1985		1990		1995		1999	
	Volume	%	Volume	%	Volume	%	Volume	%
Total exports*	25915.61		52067.32		148769.74		194930.00	
Agricultural products	6595.34	25.45	14820.44	28.46	18920.63	12.72	12147.15	6.23
Textile and related products	5729.43	22.11	12416.66	23.85	37498.37	25.21	43412.18	22.27
Other light industrial products	1564.28	6.04	9192.38	17.65	40141.03	26.98	26772.28	13.73
Metal and non-metal products	8125.62	31.35	9184.86	17.64	15251.75	10.25	11207.44	5.75
Chemical products and medicine	860.97	3.32	2439.17	4.68	7668.33	5.15	10379.88	5.32
Machinery	507.77	1.96	3723.62	7.15	14959.94	10.06	39886.45	20.46

Note: * The total export volume does not equal to the sum of individual categories because of statistical discrepancy. As a result the percentages do not add up to 100.

Source: *China Statistical Yearbook of Foreign Trade and Commerce, 1986–1999,* China Statistical Press.

Table 9.3 The ten most exported products in China: 1985–99 (US$ million)

	1985			1990		
Rank	Items	Volume	% of total	Items	Volume	% of total
1	Crude oil	5451.87	21.04	Crude oil	3817.75	7.33
2	Refined oil	1460.24	5.63	Garment	3425.10	6.58
3	Grain	1350.80	5.21	Cotton fabric	1531.33	2.94
4	Garment	1166.27	4.50	Refined oil	1110.87	2.13
5	Cotton fabric	938.87	3.62	Knitted products	934.88	1.80
6	Cotton	420.03	1.62	Feeds	887.32	1.70
7	Canned foods	382.40	1.48	Home appliances	873.23	1.68
8	Chemical inputs	357.06	1.38	Silk fabric	782.28	1.50
9	Silk fabric	356.78	1.38	Cotton yarn	777.77	1.49
10	Silk	349.76	1.35	Steel	711.43	1.37

	1995			1999		
Rank	Items	Volume	% of total	Items	Volume	% of total
1	Garment	16592.24	11.15	Garment	30057.85	15.42
2	Home appliances	5656.84	3.80	Textile products	12316.88	6.32
3	Comm. equipment	4621.05	3.11	Shoes	8672.70	4.45
4	Toys	3396.54	2.28	Computer products	7922.03	4.06
5	Steel	3219.54	2.16	Plastic products	5174.88	2.65
6	Cotton fabric	3180.03	2.14	Toys	5112.14	2.62
7	Cotton knitted products	2583.82	1.74	Furniture	2707.81	1.39
8	Crude oil	2064.21	1.39	Cable comm. products	2311.50	1.19
9	Wool knitted products	1888.42	1.27	Oil and products	2076.36	1.07
10	Cotton textile products	1877.07	1.26	Integrated circuits	2058.07	1.06

Source: *China Statistical Yearbook of Foreign Trade and Commerce, 1986–1999*, China Statistical Press.

crude oil was China's most exported product with a share of 21 per cent of the total export value in that year. The second most exported product was refined oil, and grain occupied the third place. Textile products occupied the next two positions; cotton and silk were also in the list, showing China's weak manufacturing position at that time. In 1990, while crude oil still occupied the first place, its share dropped dramatically to only 7.3 per cent. Concurrently, garments became the second most exported goods, with a share increasing from 4.5 per cent in 1985 to 6.6 per cent. Home appliances took seventh place, an early indicator of China's improved manufacturing capacities. This trend continued in the second half of the 1990s. While garments constituted the largest export item and most of the items in the list were textile products in both 1995 and 1999,[3] electronic products appeared in the list. This was more prominent in 1999. In that year, computer products became the fourth largest export item; cable communication products and integrated circuits occupied the eighth and tenth positions.

To summarize, in the last 15 years, China has changed from a resource-based exporter to an exporter of labour-intensive and low-end electronic products. This matches the structural changes observed in Taiwan and South Korea in the 1970s and early 1980s, and points to a strengthening of China's technological capabilities and its international competitiveness.

2. PUBLIC INSTITUTIONS AND R&D

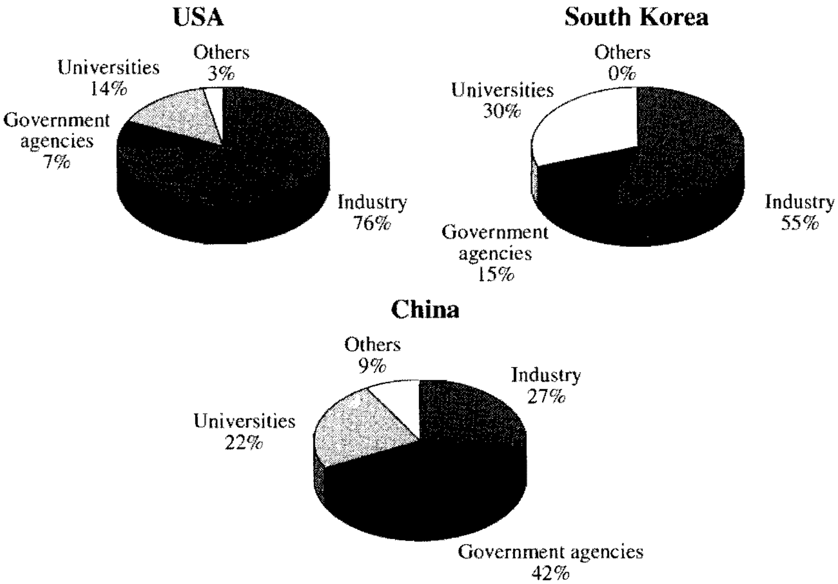
Public institutions and large state-owned enterprises dominate China's domestic R&D. Basic scientific research is mostly carried out in the Chinese Academy of Sciences (CAS), research institutions in government ministries and large research universities. Technological innovations show a similar pattern. We now describe the geographical and sectoral distribution of research, provide an introduction to China's hi-tech industry and key government-supported R&D projects, and present data on R&D achievements in terms of patents and scientific publications.

2.1 Domestic R&D Resources

By the end of 1996, China had 27.6 million professional technical personnel, of whom 407800 were engaged in R&D. This makes it the fourth largest country in terms of R&D personnel, after the USA (962700), Russia (870000) and Japan (526500) (You, 1998: p. 64). However, in terms of R&D personnel per million population, China is well behind the industrial leaders. In 1996, it had 333 R&D personnel per million population, only about one-tenth of the USA. There were 4850 R&D institutes, but 820 did not conduct any meaningful research. In addition, there were 3400 R&D institutes in universities. Many large enterprises also carried out R&D, and in 1996, there were 12033 R&D units at the firm level. This was double the figure in 1985 and equivalent to one R&D unit for every two large and medium firms (You, 1998: p. 46).

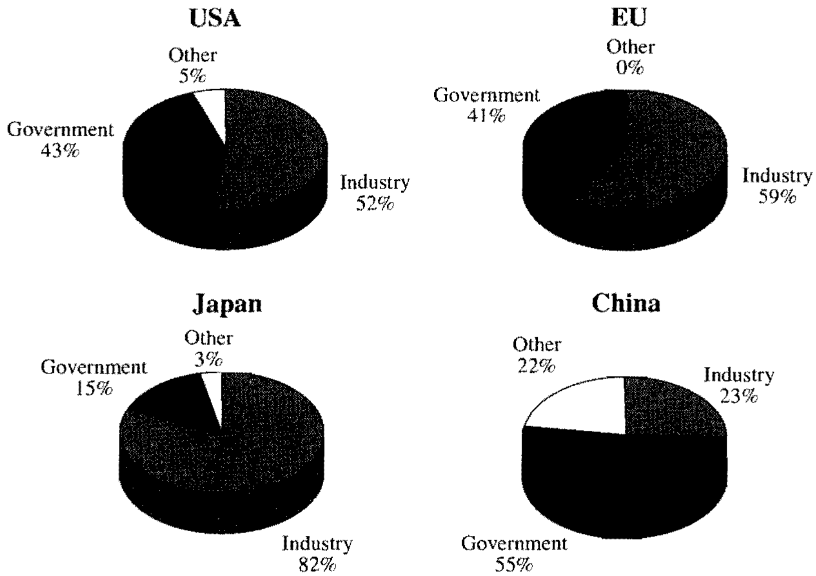
Compared with the developed and newly industrialized economies, China spends relatively little on R&D. Total R&D has been in the range of 0.5–0.7 per cent of GDP, compared to 2.7–3 per cent in the developed economies and 1.8–2.8 per cent in the newly industrialized economies (You, 1998).

In terms of the distribution of R&D personnel, there is a strong concentration in government ministries. As a hangover from the planning period, almost every ministry has its own research institutes. Figure 9.1 compares the distribution of R&D personnel among government agencies, the industry, universities and others in the USA, South Korea and China. China has too many scientists in government-run institutions and too few scientists and technicians in industry. Figure 9.2 compares China with the USA, the European Union and Japan in terms of the distribution of R&D research funds provided by the government and industry. While 82 per cent of Japan's research funds come from industry and some 60 per cent in the USA and EU,



Source: You (1998: 98–9).

Figure 9.1 Comparison of the distribution of R&D personnel in the USA, South Korea and China, 1996



Source: You (1998: 142–3).

Figure 9.2 Comparison of the distribution of R&D expenditure in the USA, EU, Japan and China, 1996

in China the government share is about 55 per cent and that of industry only 23 per cent. Much of the remaining 22 per cent, classified as 'other', may well be channelled from the government because private donations (presumably accounting for the 'other' in the USA and Japan) are rare in China.

Table 9.4 and Table 9.5 show the distribution of R&D personnel and expenditure among central government, the Chinese Academy of Science (CAS) and local provinces in three selected years in the 1990s.[4] Central government's share is about 60 per cent in terms of both personnel and expenditure. Although there has been a weak declining trend in central government's share of personnel, its share of expenditure has remained roughly the same, if it has not not increased.

Turning now to geographical distribution, the contrast between the east and the centre and west is obvious. The nine eastern provinces and municipalities have about half of the country's R&D personnel, and their share of total R&D expenditure is over 60 per cent. This skewed distribution certainly matches the stages of development in the regions, but it is also caused by the concentration of resources in central government, most of whose agencies are located in Beijing.

Table 9.4 Distribution of R&D personnel in Chinese research institutions

	1991		1994		1997	
	No.	%	No.	%	No.	%
By affiliation						
Central government	485431	61.6	430291	52.9	359713	58.2
CAS	48595	6.2	56029	6.9	38104	6.2
Provinces	253852	32.2	327361	40.2	220288	35.6
Total	787878	100.0	813681	100.0	618105	100.0
By region						
East	396326	52.9	420894	55.6	308592	53.2
Central	162855	21.7	175045	23.1	133285	23.0
West	190298	25.4	161703	21.3	138124	23.8
Total	749479	100.0	757642	100.0	580001	100.0

Notes:
East: Beijing, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong.
Central: Heilongjiang, Jilin, Liaoning, Shanxi, Henan, Hubei, Anhui, Jiangxi, Hunan, Guangxi, Hainan.
West: Inner Mongolia, Ninxia, Shaanxi, Gansu, Qinhai, Xinjiang, Sichuan, Chongqing, Guizhou, Yunnan.

Source: Chinese Statistical Yearbook of Science and Technology, 1992–1998, Beijing: China Science and Technology Press.

One remaining issue is the distribution of R&D resources among industries. Table 9.6 and Table 9.7 show the situation in the industrial sector. The sector is divided into three sub-sectors, mining, light industry and heavy industry. The major components of light industry are food, textile, garment and paper production, the major components of heavy industry are steel, chemical, machinery and electronic industries. The shares of heavy industry in both personnel and expenditure are high and increased over the 1990s, and the shares of light industry decreased. The two tables also show the cases of three representative sectors, textiles, medicine and electronics. The shares of the textile sector decreased in the 1990s, which might have been the major force bringing down the share of the light industry sector as a whole. Medicine and electronics are the two industries that are most likely to adopt high technologies. However, the shares of the electronic industry did not increase in the 1990s, and the shares of the medicine industry even showed a tendency of decline. These results are remarkable if we consider the Chinese government's emphasis on developing hi-tech industry. It seems that the research institutions have not responded to the government initiative, rather their behaviour has conformed to more fundamental economic forces.

Table 9.5. Distribution of R&D expenditure in Chinese research institutions (million yuan)

	1991		1994		1997	
	Expenditure	%	Expenditure	%	Expenditure	%
By affiliation						
Central government	13,446.45	61.59	23,560.66	59.69	33,071.66	67.98
CAS	1,397.50	6.40	2,958.41	7.50	3,517.11	7.23
Provinces	6,988.95	32.01	12,950.38	32.81	12,057.33	24.79
Total	21,832.90	100.00	39,469.45	100.00	48,646.09	100.00
By region						
East	12,707.39	62.18	8,352.56	64.50	28,846.37	63.92
Central	3,556.99	17.41	2,593.39	20.03	7,652.41	16.96
West	4,171.02	20.41	2,004.44	15.48	8,630.21	19.12
Total	20,435.40	100.00	12,950.38	100.00	45,128.99	100.00

Note: East, central and west as Table 9.4.

Source: *Chinese Statistical Yearbook of Science and Technology, 1992–1998*, Beijing: China Science and Technology Press.

Table 9.6 Sectoral distribution of institute R&D personnel in the Chinese manufacturing sector

	1991		1994		1997	
Sector	No.	%	No.	%	No.	%
Mining	19112	10.5	14890	6.3	13510	5.3
Light industry	23062	12.7	19183	8.2	15477	6.0
Heavy industry	139334	76.8	200732	85.5	227103	88.7
Total	181508	100.0	234805	100.0	256090	100.0
Selected industries						
Textile	7663	4.2	6135	2.6	4801	1.9
Medicine	10055	5.5	6511	2.8	7816	3.1
Electronics			62568	26.6	62221	24.3

Source: *Chinese Statistical Yearbook of Science and Technology, 1992–1998*, Beijing: China Science and Technology Press,

Table 9.7 Institute R&D expenditure in the Chinese manufacturing sector (million yuan)

	1991		1994		1997	
	Expenditure	%	Expenditure	%	Expenditure	%
Mining	691.02	6.32	923.91	5.62	1578.20	7.57
Light industry	883.32	8.08	1438.41	8.75	972.20	4.66
Heavy industry	9353.05	85.59	14073.76	85.63	18307.39	87.77
Total	10927.40	100.00	16436.08	100.00	20857.79	100.00
Selected industries						
Textile	401.50	3.67	555.83	3.38	434.32	2.08
Medicine	627.06	5.74	1134.28	6.90	1022.14	4.90
Electronics	2131.32	19.50	3143.59	19.13	3989.99	19.13

Source: *Chinese Statistical Yearbook of Science and Technology, 1992–1998*, Beijing: China Science and Technology Press.

2.2 Government Initiatives

The government is consciously using its leverage to stimulate technological advance. In this subsection, we present a description of key government initiatives, including several projects aimed at improving China's technological edge in the hi-tech industry as well as other programmes targeting basic scientific research and the technical capacities of SMEs.

The National Science Foundation (NSF) provides funding for basic research in China. In 1997, 4166 projects obtained a total of 78.8 million yuan (US$9.5 million). In 1991, by contrast, 4196 projects received 17.7 million yuan. Thus in six years, funding per project increased by almost five times. Nevertheless, the funding provided by NSF is still quite limited as the average funding per project was only about US$2200.

The '863' Project was launched in March 1986 with the aim of improving China's education, research and application capacities in the hi-tech area. In 1997, 1087 projects obtained a total funding of more than 505 million yuan (about US$61 million). Of this funding, the government provided 368.6 million yuan, or 72.9 per cent. Table 9.8 shows the distribution of the '863' projects – which were concentrated in the four key areas of information technology, biotechnology, new materials, and automation technology – and the Torch Project (see below).

However, the performance of the '863' project has not been impressive. Table 9.9, adapted from an appraisal report on the project in 1996, shows that only 38.2 per cent of the projects funded in the 1986–96 period had

Table 9.8 Fund distribution of the '863' and Torch projects in 1997 (1000 yuan)

	'863' Project			Torch Project	
	No. of projects	Expenditure	Government funds	No. of projects	Expenditure
Total	1087	505376	368571	1987	14444524
Information technology	341	142401	102262	369	5265957
Biotechnology	271	65382	60247	274	1899482
New materials	202	77352	54825	475	2008300
Energy*	14	126012	110271	243	1320934
Automation	225	86505	33397	486	2423521
Others	34	7724	7569	140	1526330

Note: * Includes environmental technology for the Torch Project.

Source: *Chinese Statistical Yearbook of Science and Technology, 1998*, Beijing: China Science and Technology Press.

Table 9.9 Commercial applications of '863' projects, 1986–96 (%)

	Product in test	Product finalized	Product in production	With substantial profit
Biotechnology	24.2	3.9	32.7	3.9
Energy	3.3	2.0	55.9	1.3
New materials	15.1	12.9	38.4	2.6
Automation	5.3	12.6	11.3	0.0
Information technology	1.4	13.8	49.4	3.8
Light electronics	2.8	15.0	49.1	1.9
Total	8.2	10.7	38.2	2.5

Source: Gu et al. (1998: 364).

gone into commercial application, and only 2.5 per cent had made substantial profits. Although this record can be partially explained by the high risk of hi-tech activities, the very low percentage of projects making substantial profits may indicate a gap between research and commercial applications; this is perhaps not surprising in view of the dominance of government institutions in this programme.

The Torch Project is another government project aiming at improving

China's technical capacities. Compared with the '863' Project, it is more application-oriented and does not support education. Its funding is much larger than the '863' Project, though. In 1997, 1987 projects obtained a total funding of 14.44 billion yuan (US$1.74 billion), with an average funding size of 7.3 million yuan (US$0.88 million).

The Key Technology Project aims to solve key technical issues not only in manufacturing but also in agriculture and social development. The total funding in 1997 was 1.65 billion yuan (US$199 million), the number of projects covered was 1545 (Table 9.10).

Table 9.10 Key Technology Project in 1997 (1000 yuan)

	No. of projects	Expenditure	Government funds
Total	1545	1651838	683382
Agriculture	334	250769	165051
Social development	685	475890	191856
Hi-tech industry	526	925179	326475

Source: *Chinese Statistical Yearbook of Science and Technology, 1998*, Beijing: China Science and Technology Press.

The Star Project aims at improving the technical capacities of small and medium-sized firms, especially rural firms. Table 9.11 shows the sectoral distribution of central government-funded Star projects in 1997. The total expenditure of the project in 1997 was 8.22 billion yuan (US$990 million), a total of 1561 projects were funded, with an average fund per project being 5.3 million yuan. The Star Project has facilitated the development of small and medium-sized firms, but its coverage is limited relative to the population of tens of thousand of SMEs.

Hi-tech zones have been set up to take advantage of the geographic concentration of human capital in certain cities. Since 1988, the central government has approved 52 national hi-tech zones. About the same number of local hi-tech zones have been set up by local governments. Central government provides tax incentives for firms that are qualified to move or set up in the national hi-tech zones and local governments provide specific non-tax incentives (such as preferential land prices) to firms in the local hi-tech zones. Most of the 52 national hi-tech zones are located in the east of the country. In 1998, there were a total of 13681 firms in these 52 hi-tech zones. These firms hired a workforce of 1.47 million employees, their total output value was 338.8 billion yuan (US$40.8 billion), and total profit was 20.7 billion yuan (US$2.5 billion). Of this output, 6.5 billion yuan (US$785 million) were exported. This demonstrates that the export performance of

Table 9.11 The distribution of the Star Project in 1997 (1000 yuan)

	No. of Projects	Expenditure
Total	1561	8217701
Agriculture and fishery	360	1836623
Mining	19	67290
Manufacturing	1070	5570299
Utilities	12	44505
Construction	35	159152
Transportation	9	26520
Wholesale and retailing	3	22600
Finance and insurance	0	0
Real estate	0	0
Social services	9	71190
Health, sports and welfare	16	167094
Education, arts and media	3	26330
Technical services	16	188746
Government agencies	0	0
Others	9	37352

Source: *Chinese Statistical Yearbook of Science and Technology, 1998*, Beijing: China Science and Technology Press.

these hi-tech zones remains weak. Indeed, many of the firms located in the zones are not engaged in hi-tech production at all. One study even shows that a quarter of the hi-tech zones are not qualified in terms of the availability of proper human resources, infrastructure and markets (Gu et al., 1998). Hi-tech zones have also been used by local governments to compete for good firms, no matter whether they are hi-tech or not, by engaging in competitive offers of tax breaks as well as other financial incentives. That is why two neighbouring hi-tech zones (one national, one local) are frequently observed in one city.

2.3 Scientific Publications, Patents and Technology Contracts

From the early 1990s to the late 1990s, the number of scientific publications nearly doubled, the number of patents more than doubled and the number of technology contracts (mainly licensing and technical assistance) more than tripled.

Throughout the 1990s, the structure of the type of contract has been quite stable. About one-third of the contracts were technical development, about 40 per cent of them were technical services, another 16–18 per cent were technical transfers, and the remainder (less than 10 per cent) were technical consultation contracts. This shows that the transfer of ready-to-use technologies constituted only a small portion of the total number of contracts, more frequent subjects of contracts were technical assistance and commissions relating to new technical innovations and developments. In terms of the types of provider, it is evident that research institutes, almost exclusively public, were the most important provider of technologies. However, their share has been decreasing in the 1990s, offset by universities and other providers. The enhanced role of universities was made possible by more R&D funding. In 1991, the total university R&D expenditure was 1.35 billion yuan (US$163.1 million); by 1997, that figure was multiplied by more than four times to reach 5.77 billion yuan (US$694.7 million). Although the amounts are small compared with developed countries, they have contributed to improving the capacity of Chinese universities for innovation and development.

2.4 A Summary Appraisal

We can characterize China's R&D efforts thus. First, the central government controls a disproportionately large share of research resources. Second, firm-level R&D initiatives are weak. Third, central government puts heavy emphasis on hi-tech areas. In terms of the outcomes, we have a mixed picture. On the one hand, the government's emphasis on the hi-tech areas seems to be paying off as China upgrades from a resource-based exporter to a major player in the world's lower-end electronic market. On the other hand, government-sponsored projects have not had matching commercial results. In addition, the weak support to labour-intensive technologies and SMEs may also take a toll on international competitiveness. After all, labour-intensive garment and textile industries are still China's most competitive industries. As pointed out before, the real issue is not whether China should spend on hi-tech industry, but the proper balance between high-tech and other industries.

Some implications are as follows.

- First, government sponsored projects should have better targets, taking commercial viability into fuller consideration. Most public research institutes are not run as profit-making firms but as government departments relying on government support for daily operation. Although a major reform is underway to transform these institutes into independent firms, the process is slow.
- Second, the business infrastructure for technology transfers is weak, creating a gap between R&D and commercial application. Many researchers in research institutes and universities complain that their

inventions cannot find buyers. Although this problem is related to the nature of the institutes and universities as non-profit organizations, it also reflects weak information flows and business intermediaries as well as weak protection of intellectual property rights.

- Third, labour-intensive industry is still a major base for China's international competitiveness. Although it may be proper for the central government to concentrate on financing hi-tech industry, local efforts should support local comparative advantage in less glamorous activities. The proliferation of the hi-tech zones indicates this bias. It diverts precious resources into highly risky and expensive endeavours, crowding out traditional but more profitable industries. However, persuading local government to take this view is difficult because officials do not only consider economic gains but also political status and pride.

3. TECHNOLOGICAL DIFFUSION AND THE ROLE OF FDI

3.1 Regional Technology Transfers

Regional technology transfers are important in narrowing the growing disparities between regions that have attracted considerable attention in recent years. Table 9.12 provides a snapshot of the regional distribution of technology exporters and selected importers in 1993. The technology exporters are the developed coastal provinces and inland provinces with considerable human resources and research capacities (universities, research institutes and so on). The importers are inland provinces and fast growing coastal provinces, especially Guangdong and Jiangsu.

The government has been facilitating regional technology transfers. A major initiative by central government is the one-to-one support of an advanced province for a relatively backward province. This pair-wise arrangement has a comprehensive coverage including poverty alleviation, business connections, cadre exchanges, personnel training and technical assistance. Take the example of the Jiangsu and Guangxi pair. Jiangsu is an advanced coastal province, Guangxi a backward autonomous region in southwest China. Since 1980, government officials from these two provinces have met every year to discuss possible cooperative projects. In the 1980s, more than 1200 projects were implemented, covering almost all economic areas. Jiangsu has a sound textile industry and many projects involved the transfer of technologies in this industry. For example, before 1980, Wuzhou city in Guangxi province only had four textile factories

Table 9.12 Regional distribution of technology exporters and selected importers, 1993 (million yuan)

Exporters						
Province	Beijing	Sichuan	Shanghai	Liaoning	Hunan	Hubei
Net export value	1240	630	488	417	149	115
Selected importers						
Province	Guangdong	Hainan	Shandong	Shanxi	Jiangsu	Guangxi
Net import value	765	437	342	274	244	164

Exporters					
Province	Jilin	Tianjin	Henan	Shaanxi	Heilongjiang
Net export value	101	85	60	52	31
Selected importers					
Province	Inner Mongolia	Zhejiang	Fujiang	Hebei	Guizhou
Net import value	157	152	145	130	102

Source: He et al. (1996: 381).

producing less than 4 per cent of the city's total industrial output. Its partner in Jiangsu, Changzhou, happens to have a large textile industry and an experienced workforce. Changzhou sent more than 300 persons, technicians and managers to help Wuzhou build its textile industry. By 1990, Wuzhou had become capable of producing a large variety of textile products, and the share of the textile industry in the city's industrial output increased to 17.6 per cent (He et al., 1996).

3.2 R&D and Technology Transfers at the Firm Level

R&D in Chinese firms is generally weak. In 1997, the 165080 state-owned and large and medium-sized private firms (with a sales volume of more than 5 million yuan) spent a total of 43.84 billion yuan on R&D, only 0.72 per cent of their sales (265600 yuan per firm). Two surveys show similar results. One by researchers from Tsinghua University found that average R&D spending in China's manufacturing sector was 0.5 per cent of sales, and that smaller firms spent less. R&D by large, medium and small firms as percentages of their respective sales volume came to 0.78 per cent, 0.34 per cent and 0.37 per cent (Fu and Deng, 1994). Another study by the Development Research Centre under the State Council in Fujian and Gansu provinces in 1994 and 1995 showed higher R&D spending but the shares were still small, with similar patterns in relation to firm size. The percentages for the three groups of firm, in the order presented above, were 2.08 per cent, 1.30 per cent, and 1.15 per cent (Fan, 1997).

However, small firms are keener than large ones to adopt suitable technologies and they put more emphasis on profitability. Wang and Yao (2002) identify several interesting patterns from survey studies. First, small firms tend to spend more on acquiring new existing technologies and using them efficiently. In contrast, large firms spend more on buying new equipment and saving on labour input. Second, small firms put more emphasis on obtaining suitable technologies while large firms tend to obtain advanced technologies, especially those embodied in imported equipment. Both may be rational because small firms mainly compete inside China while large ones face competition in the international market. Third, although small firms spend less on R&D, they have a higher success rate in converting technologies into profitable new products. This may have something to do with the different nature of R&D that the two groups of firms are engaged in, but is also related to their different aims, that is, small firms are keen on profitability, large firms on saving inputs.

In terms of the sources of technologies, Wang and Yao (2002) also identify several patterns. First, large firms are more likely to innovate their own technologies; small firms are more likely to buy ready-made technologies. This probably reflects small firms' weaker innovation capacities. Second, small firms seldom buy foreign technologies while large firms do. Third, the most effective channel for small firms to get new technologies is to cooperate with large firms to form joint ventures or to become a large firm's subcontractor. In this way, small firms can quickly obtain large firms' more advanced technologies as well as improve their efficiency by specializing. Fourth, rural firms rely on the city to provide them with technicians. Rural firms hire many urban retirees and a considerable number of urban technicians work in rural firms as a second job. In recent years, many rural and urban private firms have begun to use their improved working and compensation conditions as leverages to compete with large state-owned enterprises for qualified technicians and workers.

3.3 FDI and Technical Diffusion in China

In 1998, realized FDI in China was $45.5 billion, slightly higher than in 1997. The contribution of FDI is evident in areas of employment and export; what is less clear is its contribution to China's technological upgrading. We first provide some statistics on FDI's sectoral distribution, and then discuss how FDI could contribute to improving China's technical stance.

Wang (1997) documented the sectoral distribution of FDI by using the second (1985) and third (1995) national industrial censuses. In 1985, the output of foreign affiliates comprised less than 0.5 per cent of China's industrial output, their sales value was less than 5 per cent in total industrial sales. In 1995, the two figures had increased to 15.9 per cent and 15.8 per cent, respectively. Wang used the FDI concentration index (*FDI_CI*) to show the relative concentration of FDI in Chinese industry, defined as the ratio between its share in total FDI sales and its share in the national sales. Table 9.13 shows the result. In 1985, there were only four sectors where FDI showed strong concentration (*FDI_CI* greater than 2): educational and sports products (including toys), transportation equipment, electronic and communication equipment, and apparatus and other measurement equipment. Electronic and communication equipment had the highest index (10.45). There were three sectors where FDI showed weak concentration (just above 1): foods, beverage, and plastic products. In 1995, there were four sectors with strong FDI concentration. Two of them were the same as in 1985 (educational and sports products and electronic and communication equipment) while two were new (garment and leather products). All the four highly concentrated sectors of 1985 had become much less concentrated in 1995, with the largest decline in electronics and communication equipment. In addition, there were now 11 sectors that had an *FDI_CI* higher than one (the three sectors of 1985 remained).

Two messages can be derived from Table 9.13. First, in the ten years between 1985 and 1995, FDI quickly spread into the Chinese economy, leading to less concentration as well as fuller coverage. In 1985, there were half a dozen sectors that either did not have FDI, or had little presence. In 1995 there was no sector without FDI. Second, while in 1985 FDI was concentrated in relatively capital-intensive and resource-based sectors, in 1995 it had moved to sectors such as garments and leather products.

There are two groups of foreign investors in China. One comprises firms that aim at the domestic market, mostly from developed countries (especially North America and Europe). These firms tend to invest in industries where China's technical capacities are weak. The other group consists of firms that want to use China's cheap labour and export facilities to produce exports. Most of them come from Hong Kong, Taiwan and overseas Chinese communities. Wang (1997) found that more export-oriented foreign firms tended to have lower capital intensity whereas less export-oriented ones had higher capital intensity.

The relationship between FDI and technology transfers in China can be illustrated by the technology import pattern. As reviewed in Section 1, China relied heavily on importing complete sets of equipment as a means of importing technologies before early 1980s, and this practice continued throughout the 1980s and early 1990s, albeit to a lesser extent. However, in

Table 9.13 FDI concentration in the Chinese manufacturing sector (sales volume), 1985 and 1995

	1985			1995		
	All firms (%)	FDI firms (%)	FDI_CI	All firms (%)	FDI firms (%)	FDI_CI
Food	7.37	7.65	1.04	7.65	8.82	1.15
Beverage	1.92	2.43	1.26	2.19	2.83	1.29
Tobacco	2.55	0	0	2	0.06	0.03
Textile	12.94	7.42	0.57	8.58	7.56	0.88
Garment and fabrics	2.21	1.35	0.61	2.71	6.79	2.5
Leather	1.11	0.49	0.44	1.8	4.79	2.66
Wood processing	0.76	0.73	0.96	0.74	0.99	1.34
Furniture	0.58	0.43	0.75	0.41	0.61	1.51
Paper and products	2.04	0.38	0.19	1.94	1.63	0.84
Printing	0.94	0.83	0.88	0.78	0.7	0.9
Educational and sports products	0.49	1.96	3.99	0.71	1.76	2.5
Oil refinery and related products	3.39	0	0	4.13	0.29	0.07
Chemical products	7.36	2.79	0.38	7.24	4.5	0.62
Medicine	1.62	0.5	0.31	1.82	1.64	0.9
Chemical polyesters	1.19	0	0	1.58	0.98	0.62
Rubber products	1.81	0.19	0.1	1.19	1.46	1.23
Plastic products	1.85	1.89	1.03	2.11	3.43	1.63
Non-metal mineral products	5.46	0.36	0.07	5.59	3.14	0.56
Metal refinery and processing	7.06	0.97	0.14	7.59	2.33	0.31
Non-ferrous metal refinery and processing	2.03	1.7	0.84	2.6	1.6	0.62
Metal products	2.99	1.62	0.54	3.06	4.01	1.31
Machinery	10.72	7.06	0.66	7.75	4.63	0.6
Transportation equipment	5.66	18.58	3.28	6.42	7.97	1.24
Electric equipment	4.51	1.28	0.28	5	5.95	1.19
Electronic and communication equipment	3.27	34.11	10.45	4.89	14.63	2.99
Apparatus and measuring equipment	1.31	3.52	2.68	0.84	1.61	1.91
Other manufacturing	1.38	0.87	0.63	1.31	1.98	1.52
Electricity	4.35	0	0	6.2	3.27	0.53

Source: Wang (1997, table 2).

the second half of the 1990s, China no longer imported complete sets of equipment and relied mostly on FDI to acquire foreign technologies (Wang, 1997, table 12).

However, studies show that FDI has not always brought the newest technologies (Wang, 1997). For instance, the first foreign car produced in China, the Volkswagen Santana, used the technology acquired in the early 1980s for nearly 20 years without any substantial improvements. The technologies used by Hong Kong and Taiwan export firms are inferior even to those of many large domestic firms, though they may be appropriate to labour-intensive activities used in exports.

The positive spillover effects of FDI may not come from the spread of 'hard' technologies but from the spread of 'soft' technologies. 'Soft' technologies could include the following. First, the exchange of personnel between foreign firms and domestic firms, which helps to spread better managerial skills as well as production methods. This is particularly significant for export-oriented foreign firms; many employees leave and set up their own factories, usually acting as a subcontractor to the old employers (Liu et al., 2002). Second, the entrance of FDI firms increases domestic competition, which leads to efficiency improvement on the part of domestic firms. Since this improvement is indirect and rather intangible, commentators often ignore it. Third, competition for high quality employees forces domestic firms, especially state-owned enterprises, to improve their utilization of human capital. Lastly, foreign firms set high standards that are quickly recognised and which domestic firms come under pressure to imitate.

4. CONCLUSIONS

There are two unresolved issues regarding China's technological development. One is that China has not found the right balance between advanced technology and appropriate technology, the other is that domestic R&D is dominated by the government (including the public research institutes supported by government funds). This chapter suggests that this dominance does not help China's industrial technical efficiency, and may even harm it (through the crowding-out effect). The policy implication is strong and clear: R&D efforts should be decentralized to firms.

However, this does not imply that China should give up financing public research institutes. At the current stage, it suffices to make the most of the public research institutes profit-seekers instead of pure research units. The Chinese government has begun to head in that direction, and the progress thus far is encouraging. The most significant change has happened to the

CAS, which has initiated a major reform to its research institutes. Except for a few that will remain in the basic research area, most institutes will have to change to profit-oriented applied research. In terms of the limited financial and human resources with which China is currently endowed, this change should focus research where it can serve to improve China's current competitiveness. Of course, it would also be a mistake for China to abandon its basic research. Not least because China has the largest basic research capacity in the developing world and should make good use of it. Linkages between basic research and users should be enhanced.

Another balance that China has to maintain is between advanced and appropriate technologies. On the one hand, it is clear that China will remain a technological follower for some time into the future because it is still capital-constrained and lacks the necessary support of basic scientific research found in developed countries such as the USA. On the other hand, although China's comparative advantage is still in labour-intensive industries, we have seen from its recent export record that exports have moved up the technology scale rapidly in recent years. This trend will certainly continue and in fact is necessary to maintain China's competitiveness in the international market. Indeed, other labour-abundant countries, for example, Vietnam and Bangladesh, have emerged to challenge China's dominance in the world's textile and garment markets. To maintain export growth momentum, it is necessary for China to move up the technological ladder in order to keep its share in the international market.

Therefore, investing in some key technologies in which China currently does not have an apparent comparative advantage may be conducive to sustained growth. However, it is imperative for local governments to realize that only a handful of advanced localities can probably make such an investment, for the majority of cities the only option will be to stick to their current comparative advantage.

This chapter also sheds lights on the role of FDI in disseminating technologies. Analysis shows that the role of foreign firms in disseminating hard technologies is weak or absent, rather, its spillover effect is likely to come from the interchange of personnel between foreign and domestic firms as well as from other kinds of information flow. The transfer of technologies may happen more inside the multinational firms. But this cannot be taken as evidence against FDI – after all, the setting up of an advanced firm by a multinational company is in itself good if the firm's business is well integrated into the local economy.

Corresponding to the above conclusions, the lessons that a developing country can learn from the Chinese experience are also threefold. First, public research institutes are generally much less efficient than firms in utilizing R&D resources. Second, for a large country, a balance between current comparative advantage and catching up with more advanced technologies should be carefully studied and pursued. Third, FDI generally will not disseminate advanced 'hard' technologies in the host country, but through exchange of personnel, the local economy will benefit from the presence of FDI by having a better labour force, more qualified managers, and more able entrepreneurs.

NOTES

1. The author is Associate Professor, China Center for Economic Development, Beijing University.
2. All these figures are from IFC (2000).
3. In 1999 all textile products were grouped into one category.
4. The figures do not include R&D personnel in enterprises.

BIBLIOGRAPHY

Bo, Yibo (1993), *Reflections on Several Major Decisions and Events*, Beijing: The Central Party Academy Press.
Chen, Huiqin (1997), *Technological Imports and Technological Progresses*, Beijing: Economic Management Press.
Chen, Baochun, Jirui Gu and Yinglong Yan (1998), *China's Hi-tech Industry and International Competitiveness*, Dalian: Northeast University of Finance and Economics Press.
Fan, X. (1997), 'A survey of technical innovations at the firm level', *Firm Management*, (3): 22–4.
Fu, J. and X. Deng (1994), 'An analysis of TVEs' adoption of technologies', *Enterprise Technical Progresses*, (11), 21–3.
He, B., J. Gu and Y. Yan et al. (1996), *Technological Transfers and Technical Progresses in China*, Beijing: Economic Management Press, 1996.
Gu, C. (ed.) (1998), *High Technologies and Technical Parks in China*, Beijing: Zhongxin Press.
International Finance Corporation (2000), *China's Emerging Private Enterprises: Prospects for the New Century*, Washington, DC: IFC.
Jiang, Junlu, Ruan Gaofeng and Lin Ren (1998), 'A study on the role of technological progresses in China's economic growth', in *Evaluating the Contribution of Technological Progresses in Economic Development*, Junlu Jiang (ed.), Beijing: China Planning Express.
Jin, Pei (1997), *International Competitiveness of Chinese Industries*, Beijing: Economic Management Press.
Li, Jingwen, Feihong Gong, and Anshu Ming (1998), 'Productivity and economic growth in China', in *Evaluating the Contribution of Technological Progresses in Economic Development*, Junlu Jiang (ed.), Beijing: China Planning Express, 1999.
Lin, Y. Justin (1990). 'Collectivization and China's agricultural crisis in 1959–1961', *Journal of Political Economy*, **98**(4), 1228–52.

Lin, Y. Justin, Fang Cai and Zhou Li (1996), *The China Miracle: Development Strategy and Economic Reform*, Hong Kong: The Chinese University Press.
Lin, Y. Justin and Yang Yao (2001), 'Chinese rural industrialization in the context of the East Asian miracle', in Joseph Stiglitz and S. Yusuf (eds), *Rethinking the East Asian Miracle*, Oxford: Oxford University Press.
Liu, Yigao, Xiaoyi Wang and Yang Yao (2002), *The Chinese Village Inside and Out*, Shijiazhuang: Hebei Renmin Press.
State Statistical Bureau (1999), *China Statistical Yearbook: 1999*, Beijing: China Statistical Press.
Wang, Yueping (1997), 'FDI and Industrial Growth in China', CCER working papers series No. C1997025.
Wang, Yueping and Yang Yao (2002), 'Market reforms, technological capabilities and the performance of small enterprises in China', *Small Business Economics*, 18, 197–211.
You, Guangrong (1998), *A Report on China's Science and Technology*, Changsha: Hunan Renmin Press.

10. Can the Philippines ever catch up?

Joy V. Abrenica and Gwendolyn R. Tecson

1. INTRODUCTION

Post-war industrial development in the Philippines presents a typical portrait of a developing country's struggle to achieve technological competence. However, few countries have squandered their potential with as much profligacy as the Philippines. Despite its rich base of human capital and its early lead,[1] the Philippines has performed poorly, particularly in a region where many other countries have successfully (often spectacularly) overcome similar constraints to development.

Various factors have been held to account for the Philippines' poor performance. One account blames macroeconomic mismanagement. Alternating cycles of crisis and boom are said to have engendered uncertainty and dissuaded the private sector from investing in building technological capabilities. One may, however, argue that no East Asian economy has been spared by the boom-bust cycle, though others have enjoyed longer periods of stability. Other analysts point to the failure of the state to steer the country's technological development along a defined path (as in Korea or Taiwan) because of its liberal approach and over-dependence on market forces. However, policymaking in the Philippines has not always been liberal and market-oriented. There have been ample market interventions in the past, although they may not have been well designed or implemented. Market liberalism is of recent vintage in Philippine policymaking; the country is still in transition from an inward-looking policy environment.[2]

The technological lethargy of a country as well endowed with human capital as the Philippines cannot be easily explained. The boom–bust cycles certainly encouraged the business sector to be more speculative than innovative (Fabella, 1994). The periods of boom were relatively short-lived, and the more frequent periods of crisis wrought deeper economic havoc. It is also true that some advocates of liberalization believe that technology development policies are less important than opening up the market, providing general infrastructure and ensuring macroeconomic stability. The pervasive view is in fact that market liberalization will stimulate FDI inflow and this will suffice to drive the country's technological development (de Dios, 1996). Thus, most attention has been given to stimulating trade and investments while science and technology policies have been largely ad hoc and peripheral.

This chapter traces the roots of Philippine technological underdevelopment by examining the acquisition of industrial technology from various channels. It looks at the institutional setting under which the acquisition took place, and it examines the role of public policy in facilitating technology development. Section 2 is an assessment of Philippine technological capability, presenting evidence of limited upgrading despite the powerful pressures of international competition. Section 3 discusses the sources of technological competence, foreign direct investment (FDI) and local technological effort. The failure of FDI to spur technological development is traced to the shallow linkage of MNC-dominated industries with the rest of the economy. Section 4 examines government policies in trade, industry, human resources and science and technology. It shows that these policies were discordant and bereft of a common long-range vision. The final section pulls together the different strands to offer an explanation of why technological catch-up has been elusive for the Philippines.

2. PHILIPPINE TECHNOLOGICAL CAPABILITY: MYTHS AND FACTS

There are a number of myths about the technological vigour of the Philippines. Most are quite easy to debunk, but the analysis casts doubt on the efficacy of some technology indicators.

Myth 1: The Philippine Manufacturing Sector is Dominated by High-Tech Industries.

The high proportion of high-technology products in Philippine exports has created this myth (Table 10.1). Two-thirds of Philippine manufactured exports are defined as technology-intensive, a share exceeded only by Singapore. Yet what lies behind these figures?

The Philippine export structure has certainly changed radically. Manufactured exports comprised a mere third of total exports in 1980, and by 1999 they accounted for 89%.

Over this period, the composition of manufactured exports also changed, moving up the technological ladder. There was a rapid decline in the export share of natural-resource intensive manufactures like processed food, beverages and wood products, and a concomitant rise in the share of capital and technology-intensive exports from about half in 1980 to over three quarters in 1997.

Table 10.1 Exports of technology-intensive manufactures, selected Asian economies

	Value, 1998 (in US$ million)	Average annual growth 1994–98 (per cent)	Share in total exports (per cent)
Philippines	20034	37	67
Singapore	76628	6	70
South Korea	52951	8	40
Malaysia	39934	11	55
Thailand	22253	12	42
Indonesia	5094	19	10
China	49213	22	27

Source: International Trade Centre, United Nations.

Using Balassa's index of 'revealed' comparative advantage (RCA), the structural change in Philippine exports can be benchmarked against changes in the rest of the world.[3] The shift in the Philippines' pattern of export specialization is evident from the changes in the RCA index over time, as shown in Figure 10.3. The Philippines traditionally specialized in resource-based exports, in particular processed food and other agro-based goods. The pattern started to change from 1975. The RCA index for agriculture-intensive exports fell below 1.0 in 1996, suggesting that the Philippines has started to specialize in other products: manufactured exports, especially labour-intensive goods. There was a sharp rise in the RCA for capital and technology-intensive goods, reaching 1.05 by 1996.

Employing the OECD's classification of exports by technology intensity, Figure 10.4 shows that Philippine manufactured exports until 1995 consisted mainly of low-technology manufactures, led by textiles and clothing, food, beverages and tobacco. As late as 1992, these comprised more than half of manufactured exports. However after 1995, high-technology exports grew rapidly and surpassed all other manufactured export groups. By 1999, they made up 82 per cent of all exported manufactures.

On closer examination, however, high-technology exports are found to be highly concentrated in only two categories: electronics and communications, and computers and office machinery (Figure 10.5).[4] The former makes up about 80 per cent of high-technology exports while the latter accounts for the remaining 20 per cent. Only three items dominate electronics exports: integrated circuits (40 per cent), storage units (16 per cent), and parts and accessories of automated data processing machines (17 per cent). The high concentration in a few products is not only undesirable (it creates

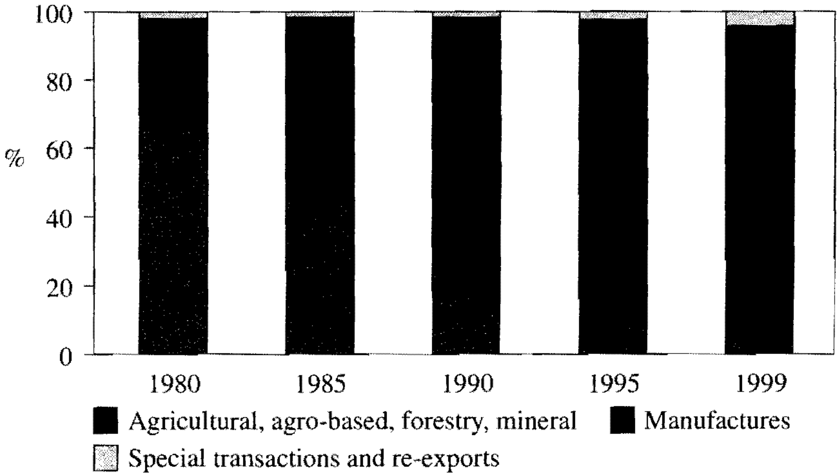


Figure 10.1 *Distribution of Philippine exports, 1980–99*

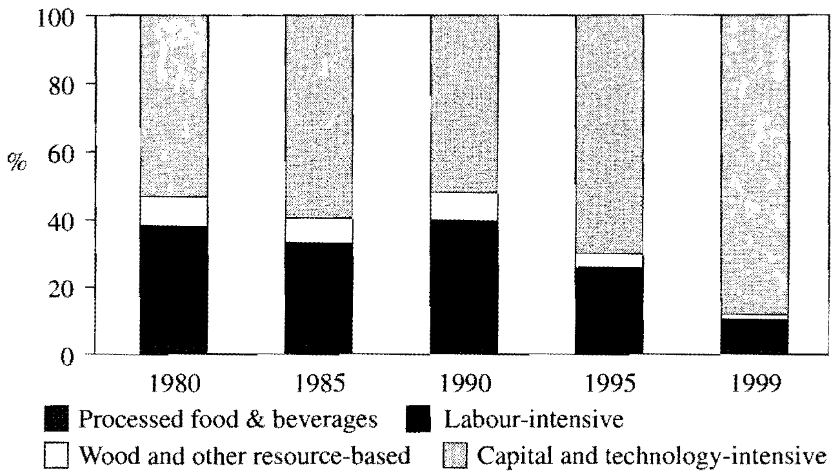


Figure 10.2 *Composition of Philippine manufactured exports, by factor intensity*

extreme vulnerability), it also suggests that resource limitations have constrained diversification.

These figures do not show that the Philippines' high-tech specialization is driven entirely by FDI: foreign investors have concentrated on the electronics industry. Of the eight activities in the electronics industry,[5] the

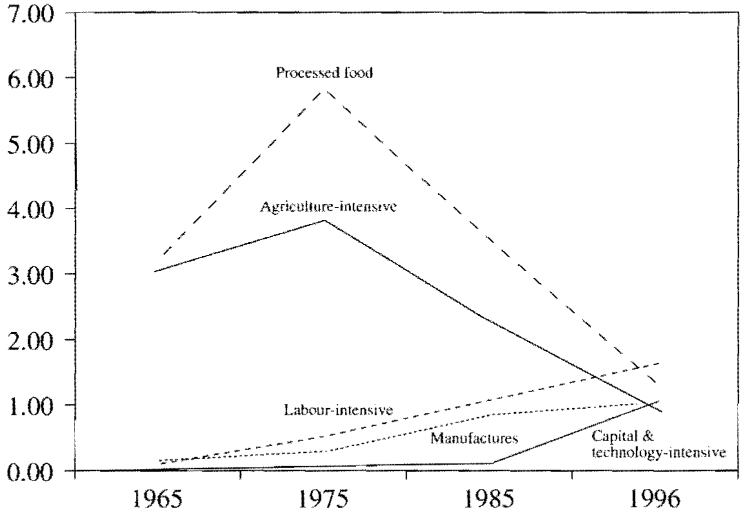


Figure 10.3 RCA of Philippine manufactured exports, 1965–96

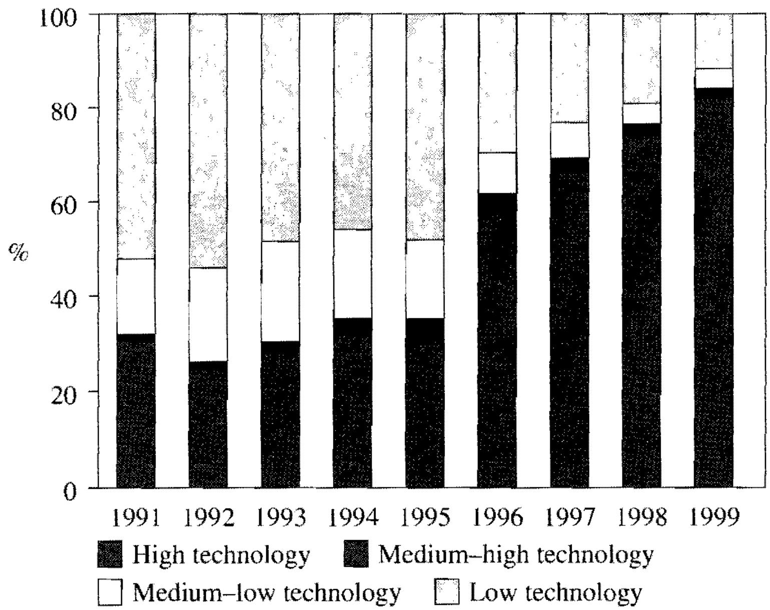


Figure 10.4 Composition of Philippine manufactured exports, by technology intensity

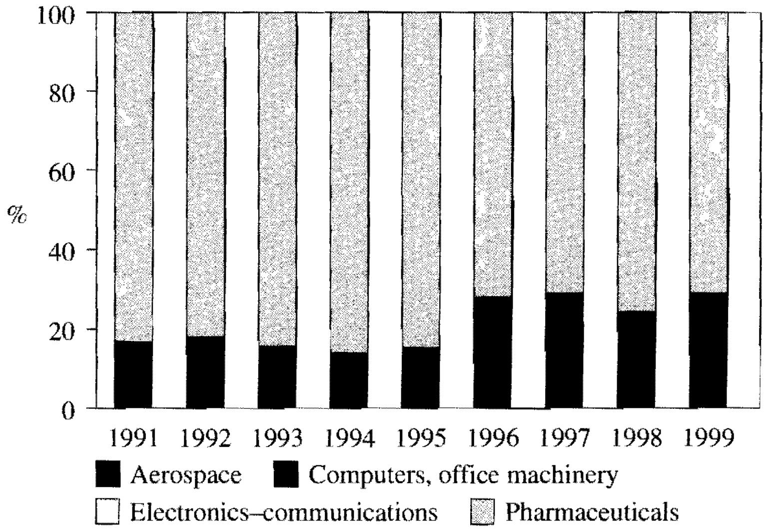


Figure 10.5 Composition of high-technology manufactured exports

largest is components, which made up 42 per cent of the 588 electronic companies registered with the Board of Investments (BOI) and Philippine Economic Zone Authority (PEZA) in 1996, followed by electronic data processing (EDP) and consumer electronics, comprising 17 per cent and 8 per cent of the total, respectively. The components sector is involved mainly in the labour-intensive packaging of integrated circuits and the assembly of transistors, diodes, resistors, capacitors, coils, transformers and printed circuit boards (PCBs). Among the allied industries, the largest category is that of metal casting and stamping.

The share of high-technology exports thus gives a misleading indication on the level of technological sophistication within the economy. Although the final product may have high technological content (such as Intel's Pentium III drives or ball-grid arrays), the Philippines may by confined to the labour-intensive part of the value-added chain. Almost all complex parts and components are imported from the parent company or other foreign sources; wages are practically the only domestic value-added.[6]

Myth 2: The Technological Strength of the Philippines Lies in its Pool of Human Capital

An index most often employed to measure human capital is enrolment rates in formal education (Table 10.2). By this measure, the Philippines compares

Table 10.2 Measures of human capital formation

	Adult literacy rate, 1997	Primary enrolment ratio (% age cohort), 1997	Secondary enrolment ratio (% age cohort), 1997	Tertiary enrolment ratio (% age cohort), 1995	Public expenditures in education as % of GNP, 1997
Philippines	94.6	99.9	77.8	31	2.2
Singapore	91.4	91.4	75.6	—	3.0
South Korea	97.2	99.9	99.9	39	3.7
Malaysia	85.7	99.9	64.0	—	5.2
Thailand	94.7	88.0	47.6	19	4.1
Indonesia	85.0	99.2	56.1	28	1.4
China	82.9	99.9	70.0	37	2.3

Source: UNESCO (1997).

favourably with other countries in the region. It has one of the highest enrolment rates in primary, secondary and tertiary education. However, these rates disguise quality problems that beset the Philippine educational system.[7]

The core of the problem is that while enrolment rates have soared in recent years, stimulated by the policy of compulsory education up to secondary level, the public budget on education has been fluctuating. During the 1950s and 1960s, the share of education in total government spending was about 30 per cent; that share has fallen to about 11–12 per cent in recent years (HDN, 2000). When benchmarked against other East Asian economies, Philippine public spending on education as a proportion of GNP income is among the smallest. Since the Philippines has also a smaller GNP, its spending per pupil in absolute terms compares dismally with its neighbours.[8]

Although no strict correlation has yet been established between spending and quality of education, many indicators (for example, the dwindling supply of textbooks to students) suggest that resource constraints hamper the effective delivery of education.[9] Take the scores obtained by Filipino children in the Third International Mathematics and Science Test of 1995. The Philippines ranked thirty-ninth of 42 countries, and the scores of Filipino students were only better than those from Kuwait, Colombia and South Africa (HDN, 2000).

The supply of science and engineering graduates in the Philippines also needs careful scrutiny. Tan (2000) reports that about half the engineering graduates are in the civil engineering or agriculture fields. There are far fewer graduates in chemical, industrial and electrical engineering fields. In addition, the quality of tertiary education in some 1300 colleges and universities in the country is poor. Only seven of these institutions meet international standards.

In fact, the Philippines has a dearth of scientists and engineers in R&D. The most recent count places the number of scientists and engineers per million at 152 in the Philippines against 326 in Malaysia, 1284 in Singapore and 2576 in Taiwan (UNESCO, 1997). The standard set by UNESCO for industrializing economies is 380. As Table 10.3 shows, the Philippines turns out few innovations. This is expected in view of its small pool of S&T personnel and low spending on R&D.[10]

Myth 3: The Philippines is an Attractive Site for Foreign Investments because of its Strategic Geographic Location, a Large Pool of Educated and English-Speaking Labour and Generous Government Incentives.

The factors that have attracted MNCs to the Philippines can be illustrated by the hard disk drive (HDD) industry. The HDD industry in the Philippines was born in 1988 with the entry of a US firm, Sunward Technologies (eventually taken over by Read-Rite), which started the assembly of magnetic heads. A Japanese firm then entered to assemble floppy and hard disk drives. But the inflow of HDD investments in the Philippines was halted by political and economic instability, and FDI resumed only in 1994 with the entry of Hitachi. At that time, the political crisis had been resolved and major economic reforms were under way.

Three other Japanese major assemblers followed Hitachi in close succession: Fujitsu, Toshiba and NEC. Japanese MNCs came to dominate the HDD industry in the Philippines. Table 10.4 shows the industry players that entered during the period, some with fresh capital infusions into existing or new facilities. It should be noted that American and European MNCs dominated the earlier waves of FDI in the Philippines.

The fact that US HDD majors chose to establish themselves a decade earlier in Singapore, Malaysia and Thailand (rather than in the Philippines), and more recently, in China, is significant on two scores. First, the early half of the 1980s was another politically turbulent period in the Philippines. Because of instability, the Philippines were not only bypassed by American HDD investments, but more substantially, by the Japanese investors that flocked to the rest of Southeast Asia following the yen appreciation. Second, US MNCs had started electronics production in the Philippines as early as the 1950s, and introduced semiconductor assembly in the 1970s. In fact, large electronic MNCs started to invest in the Philippines in the mid-1970s until the early 1980s, primarily to use the country as a manufacturing export base. Examples of large investments

Table 10.3 Comparative S&T performance of selected Asian countries

	Inputs			Outputs			
	Overall productivity, GDP (PPP) per person employed, US$, 1997	Total expenditure on R&D US$ million, 1996	R&D expenditure as % of GDP	Scientists & engineers per million population	Patents granted to residents, average annual no. per 100000 habitants[b]	Patents secured abroad by country residents, 1995	Patents in force (per 100000 inhabitants)
Phillipines	9413	115	0.218	152	0.057	–	1
Singapore	47945	1271	1.370	1284	0.388	96	502
Korea	30856	13522	2.790	1990	13.661	2434	141
Taiwan	45191	5048	1.861	2576[a]	75.981	2486	599
Malaysia	27413	226	0.320	326	0.115	669	29
Thailand	12795	208	0.126	173	0.127	–	1
Indonesia	7947	187	0.092	181	–	–	–
China	6497	3933	0.482	1128	0.129	213	2

Notes:
[a] Authors' calculation using data reported in PECC (1999).
[b] Based on 1994–95 data.

Sources: *World Economic Forum* (1998); *UNESCO* (1997).

Table 10.4 Entry of MNCs in the electronics industry, 1994–96

Year	MNC	Investment (million US$)	Product	Nationality
1994	Read-Rite	58	Magnetic heads	American
	Analogue Devices	60	Semiconductor devices	Dutch
	Cebu Mitsumi	75	Floppy disk drives (FDD)	Japanese
	Amkor Anam	95	Semiconductor devices	British/Korean
	Integrated Microelectronics	143	Magnetic heads & printed circuit boards (PCB)	Filipino
	Intel Manufacturing, Phil.	347	Semiconductor devices	American
1995	Acer Information products	23	Motherboard assemblies	Taiwanese
	Hitachi	57	Hard disk drives (HDD) and parts	Japanese
	Cypress Phils.	64	Integrated circuits	American
	Gateway Electronics	68	Integrated circuits	American
	Fujitsu Computer	124	Optical disk drive; HDD	Japanese
	Amkor Anam Advance Packaging	126	Ball grid array ICs	British/Korean
	Intel Technology	235	Microprocessor – Pentium	American
1996	Daeduck Industries	32	PCBs	Korean
	Automated Technology	38	Electronic devices	Filipino
	Epson Precision	44	Terminal printer	Japanese
	NEC Components	63	Printed wiring board & electronic components	Japanese
	Allegro Microsystem	88	Semiconductor devices	American

Sources: BOI and PEZA files : Department of Trade and Industry.

were Intel Philippines (1974), Temic Telefunken Microelectronics (1974), Motorola (Phil) Inc. (1979), Texas Instruments Philippines (1979), and Philips Semiconductors Philippines (1981). However, the political and economic instabilities of the 1980s deterred fresh FDI.

By the time that FDI inflows resumed in the mid-1990s, HDD production networks were already well established in other East Asian economies. The Philippines had lost the opportunity offered by its early start to build a strong base and attract more high-value activities such as wafer fabrication. Instead, Philippine operations are still limited to the tail-end processes in the value chain. Even though the Philippines is competitive in these processes, its competitive edge remains shallow and can be easily eroded by economies with lower labour costs, such as China (which has, in addition, greater availability of technical skills and potential suppliers).

Export-oriented MNC investments entered the Philippines in a big way after the passage of the Foreign Investments Act in 1991, which liberalized the investment regime. MNCs chose to locate in the export processing zones (EPZs), which, besides allowing tariff-free importation of parts and components, also provided good infrastructure for importing components and exporting the final product. The Philippines also offered other advantages. Interviews with the four leading HDD firms suggest that they chose the Philippines over competing sites because of its proximity to Japan, the relatively abundant supply of engineers and technical graduates, and the pool of relatively cheap English-speaking, semi-skilled and trainable labour.

Locational advantages are, of course, a function of the technological needs of the industry. Physical proximity to Japan is important for Japanese MNCs because all R&D and ramp-up activities take place in the parent company. Benchmarking of productivity levels is undertaken vis-à-vis Japan. Japanese engineers and technicians are brought in to train nationals, and Filipino engineers, technicians and even operators are sent to Japan for training. Because of short product life cycles, it is important that technology be transferred fast, from ramp-up to mass production: hence the need for a constant movement not only of parts and components but also of personnel between Japan, the Philippines, and other countries. Moreover, the short life cycle of the product means that it had to reach the market 'fresh' otherwise it would lose much of its value.

The availability of engineers and technical graduates is important for the HDD industry because of its technology intensity, even at the labour-intensive end undertaken in the Philippines. The country turns out about 30000 engineering graduates yearly. In terms of enrolment in technical subjects that are directly relevant to industrial competitiveness (such as science, mathematics and engineering), the Philippines has 0.33 per cent of its population enrolled in these areas. This is more than double the rates in Malaysia, Indonesia and Thailand (but only a fifth and a third of those in Korea and Taiwan, respectively). Engineers and technicians are also relatively cheap in the Philippines – the lowest cost in ASEAN, even lower than in Indonesia.

The widespread use of the English language in the Philippines was cited as its third advantage over other production sites in Asia. This again reflects the technological demands of the industry: the ability of workers and technicians to understand instructions in English facilitates training and the transfer of technology from Japanese engineers and supervisors. This facility, in turn, is considered essential because flexibility and learning are necessary to cope with short product cycles.

Yet these advantages could be outweighed by other factors such as market size. The Philippines tried hard to attract automotive investments and become the automotive hub in the Southeast Asian region. Despite the incentives offered to global auto assemblers, however, it lost out to Thailand whose vehicle market was five times the size of that of the Philippines (before the financial crisis in 1997).[11]

Investors vote with their feet. In a recent UNCTAD *World Investment Report* (2000), the Philippines ranks among the 10 biggest recipients of FDI in South, East and Southeast Asia. This, however, conceals the fact that FDI in the Philippines shrank during 1999 to a fourth of its value in the previous year. It also conceals that its share of FDI flows in East Asia has been steadily declining since 1990.

Table 10.5 Net foreign investment inflows in selected Asian economies (billion US$)

	1980	1985	1990	1995	1997	1999
Philippines	−0.1	0.0	0.5	1.5	1.2	0.6
Singapore	1.2	1.0	5.6	7.2	8.1	7.0
South Korea	0.0	0.2	0.8	1.8	2.8	9.3
Indonesia	0.2	0.3	1.1	4.3	4.7	−2.7
Malaysia	0.9	0.7	2.3	4.2	5.1	1.6
Thailand	0.2	0.2	2.4	3.1	3.9	6.2
China	–	1.7	3.5	35.8	44.2	38.8
Total of East Asia	–	4.1	16.2	57.9	70.0	66.8
Share of Phil. (%)	–	0	3.1	2.6	1.7	0.1

Sources: UNCTAD (2000) and World Bank (1999).

That the Philippines appears to be losing the competitive battle for FDI can only add to the problem of declining productivity. Various studies, using different approaches for estimating total factor productivity (TFP), are unanimous in finding negative growth rates in TFP. Estimates by Hooley (1985) reveal 1.18 per cent TFP in 1956–60, sliding to −1.90 per cent in 1976–80. Austria and Martin (1992) calculated a −0.6 per cent TFP for the period 1950–87. On a yearly basis, Cororaton and Caparas (1999) found steady decline in TFP, from −1.9 per cent in 1981 to −0.84 per cent in 1996. The contrast of the Philippines' TFP record with those of its neighbours is apparent in Table 10.6. The only consolation is the recent estimates of Austria (2000) that show positive TFP growth, 0.93 per cent, during the period of market liberalization, 1986–96; however, negative TFP (−0.4 per cent) is still obtained for the longer period 1960–96.[12]

Table 10.6 TFP growth rates in selected Asian economies (%)

Period	Philippines	Malaysia	Indonesia	Thailand
1960–73	0.7	1.0	1.1	1.4
1973–94	−1.1	0.9	0.7	2.1
1973–84	−1.3	0.4	0.5	1.1
1984–94	−0.9	1.4	0.9	3.3
1960–94	−0.4	0.9	0.8	1.8

Source: Felipe (1997), cited in Patalinghug (2000).

Nevertheless, a few large and medium-sized firms have made significant technological improvements in response to competitive pressures in the domestic or global markets. This is particularly evident in consumer goods manufacturing, where tariffs were the first to be lowered at the start of trade reforms in the late 1980s. Similarly, local telecommunication carriers are in a close race to introduce new products and services in the deregulated market. What are the sources for technological upgrading? The major sources are foreign direct investment and local technological efforts, considered below.

3. EXPLOITING SOURCES OF TECHNOLOGICAL CAPABILITY

Foreign Direct Investment

We have noted already the role of FDI in the growth of high and medium-high technology exports by the Philippines. Table 10.7 shows the sectoral breakdown of FDI since 1973.

The share of machinery and supplies in FDI in medium-high and high-technology industries has been increasing steadily, from 14 per cent during 1973–88 to 58 per cent by the last half of the 1990s. Except for the lumpy investments in petroleum and coal in 1993[13] and in food in 1999, the picture is one of a steady decline in FDI in low and medium-technology industries and a concomitant rise in medium-high to high-technology industries.

What technology does FDI bring in? MNCs are clearly a major source of new technology and productivity improvements, especially in industries with rapid technological change. Players in these industries continuously introduce new products and processes and improve their management methods.[14] They are at the forefront of raising labour productivity by using

Table 10.7 Inflows of foreign direct investment in the manufacturing sector (US$ million)

	1973–88		1989–94		1995–2000	
	Value	%	Value	%	Value	%
Medium-high/high-technology						
Chemicals & chemical products	394.4	28.7	185.2	10.0	231.2	9.4
Transport equipment	103.6	7.5	118.6	6.4	140.2	5.7
Machinery and supplies	81.3	5.9	443.8	24.0	508.7	20.7
Total	579.4	42.1	747.5	40.4	880.1	35.9
Medium-low technology						
Metal & metal products	169.4	12.3	39.5	2.1	168.6	6.9
Petroleum and coal	82.3	6.0	703.8	38.1	57.7	2.3
Rubber	27.2	2.0	6.1	0.3	61.5	2.5
Non-metallic mineral products	34.6	2.5	43.4	2.3	143.7	5.9
Total	313.5	22.8	792.8	42.9	431.4	17.6
Low-technology						
Food	289.3	21.0	102.0	5.5	1006.4	41.0
Textile and garments	63.2	4.6	102.6	5.5	25.9	1.1
Paper & paper products	26.6	1.9	6.8	0.4	28.7	1.2
Wood, cane & cork	13.3	1.0	24.5	1.3	3.9	0.2
Sugar and tobacco	19.9	1.4	14.3	0.8	0.4	0.0
Leather products	3.4	0.2	12.0	0.6	2.4	0.1
Printing, publishing & allied	5.5	0.4	3.5	0.2	4.1	0.2
Others	62.6	4.5	42.5	2.3	70.7	2.9
Total	483.7	35.1	308.0	16.7	1142.5	46.6
Total manufacturing FDI	1376.6	100.0	1848.4	100.0	2454.0	100.0

Source: Central Bank of the Philippines.

new organizational techniques like worker multi-skilling, small-group activities (for example, quality circles) and innovation sharing plans (Raneses, 2001). Thus, local firms requiring significant technological upgrading tend to form joint ventures or strategic alliances with MNCs. This is commonplace in utility industries, banking, food processing and cement. Outside these partnerships, however, spillovers to the rest of the economy tend to be generally weak. In the electronics industry, for instance, exports are characterized by very low value-added in proportion to output. As Table 10.8 indicates, the value-added to output ratio is only about 30 per cent, and has hardly shown any improvement over time, testifying to the low level of local content.

Table 10.8 Selected ratios in the electronics industry, 1974–1994

Year	VA/output (%)	Output/firm (Pesos 000)	Workers/ firm	VA/worker (Pesos 000)	No. of establishments
1974					
Assembly & parts	23.21	10480	154	25.04	141
1983					
Assembly	38.42	35522	177	76.90	119
Parts/sub-assembly	38.46	135601	981	53.15	32
1988					
Assembly	29.27	69958	132	154.49	163
Parts/sub-assembly	29.69	278925	643	128.87	51
1994					
Assembly	31.29	302725	274	345.49	198
Parts/sub-assembly	31.90	579195	735	251.48	73

Source: NSO, Census of Establishments, various years.

Backward linkages with the domestic economy are established through subcontracting or arm's-length purchases from domestic suppliers. Such linkages not only raise domestic value-added but also transfer new technology and skills to domestic firms, which learn to produce according to the demanding specifications of foreign firms. Supply relationships have, however, remained quite underdeveloped in the Philippines, unlike in such East Asian countries as Korea or Taiwan. The degree of subcontracting in the manufacturing sector, measured by the share of output *done for others* in total industry output, was only 2.6 per cent in 1993, and was even lower than the corresponding figure in 1988 (3.2 per cent).

Subcontracting activity as a share of the total output of an industry is highest in: non-ferrous metals[15] (15.34 per cent), apparel[16] (12.80 per cent), machinery except electric (11.46 per cent), transport equipment (8.84 per cent), while the *electronics industry registered a very low 1.49 per cent subcontracting ratio* in 1993. This is partly on account of the dominance of large firms in the industry. As observed, subcontracting activity tends to decline with size. In the electronics industry, firms employing 1–9 workers showed a 43.85 per cent subcontracting ratio compared with 1.24 per cent for those with 200 and more workers, a figure close to the overall industry subcontracting ratio. Another indication of the degree of subcontracting activity is the extent of contribution to output of work *done by others.* Table 10.9 shows that there is little difference between the subcontracting activity of firms with foreign equity and those without foreign equity.

One reason cited in the explanation of the low degree of subcontracting

Table 10.9 Work done by others as a percentage of total output, 1994 (by size of employment and degree of foreign equity)

Degree of foreign equity participation in manufacturing firms	20–99 workers	100 or more workers
With no foreign equity	6.69	6.44
With less than 10% foreign equity	5.37	4.44
With 10% or more foreign equity	7.58	7.60

Source: NSO (1994).

is that distortions in the macroeconomic and trade policy environment encouraged vertical integration (World Bank, 1993). Specifically, protection and investment incentives engendered biases in favour of large firms (Power and Sicat, 1975). This in turn encouraged greater in-house production at the expense of external sourcing and subcontracting. The chronic overvaluation of the peso and the bias towards capital-intensive production stunted possibilities for growth of a technologically sophisticated and efficient small- and medium-scale sector that had been the wellspring of the industrial dynamism in Japan. Inappropriate foreign exchange policy penalized export production and fragmented the already limited domestic market, resulting in lack of standardization and specialization, as typified by the automotive industry. In addition, as will be elaborated in Section 4, the emphasis on raising local content encouraged in-house production instead of subcontracting (Hill, 1981).

Given the presence of MNCs in export-oriented industries, it can be assumed that most technology transfer is *internalized* by the company (Lall, Chapter 2, this volume). The removal of foreign equity restrictions for firms that export 70 per cent of their output has led to the majority of foreign firms choosing to establish wholly-owned subsidiaries instead of joint ventures. In the hard disk drive industry, the entry of the Japanese majors was almost immediately followed by that of component manufacturers, also mainly Japanese, who have been supplying the majors in Japan. Interviews revealed that the main factor that attracted them to the Philippines was the potential demand from the four HDD assemblers, and possibly other American HDD assemblers in the future, locating in the country. Almost invariably, their answer to the question on why they chose the Philippines was 'to be close to the HDD majors'.

As one respondent noted, the 'majors' included Seagate, which at the time of interview had decided to locate itself in Cebu. This motivation undoubtedly holds for TDK with its recent investment in MR heads as well as other component suppliers (for example, media) in the pipeline. According to the Tokyo-based respondent of Hitachi, many of the available vendors now operating in the Philippines came after the announcement of the relocation decisions of Fujitsu and Toshiba in 1995, a year after Hitachi established itself in the country. Two of its own suppliers with whom the firm had close relationships in Japan – Pretech (precision machining and turned parts) and Sunpino Technology – decided to start operations in the Philippines while Hitachi was still doing its feasibility studies on its relocation.

An interesting upshot of this development is a growing concentration of supply sourcing from two locations: Japan for major components (for example, wafer, media) produced by parent companies, and the Philippines for locally available components and sub-assemblies. This has implications for intra-regional trade. The entry of component manufacturers (for example, Nidec for spindle motors and eventually TDK for magnetic heads) into the country has led to shifts in sourcing away from other ASEAN countries. Indeed, one of the assemblers, Fujitsu, is in the process of recruiting technical personnel for its newest plant designed to produce media which has been previously sourced from Japan. Moreover, assemblers used to import components such as spindle motors from Thailand or certain PCBs from Singapore, but have increasingly turned to local sources once these have come on stream and have been found to be competitive. Even component manufacturers such as Nidec have started to shift to Philippine-based parts (for example, machined or die-cast parts, bearings) as these became available from supplier firms that have relocated from Japan or from other Southeast Asian sites. Respondents also anticipated the components that would become available locally when TDK becomes operational.

If a similar trend is found in other industries, then what appears as increases in value-added of exports may not actually reflect improvements in national technological capability. There are, in fact, apprehensions about the extent to which indigenous firms will be able to establish links with Japanese HDD assemblers and component manufacturers.

The local engineering industry (consisting mostly of SMEs) is unable to exploit the presence of Japanese assemblers because of severe technological handicaps. In 1996, the Metal Institute of Research and Development Centre found that the technology of the local metal casting industry was some 30 years behind Japan's and that the 1995 level of ductile iron in the Philippines had not even reached Japan's 1965 level. Moreover, even the most progressive foundries were still in the 'jolt-squeeze' stage of moulding, that is, producing moulds at the maximum rate of 20 to 25 per hour per machine, while Thai foundries were already producing a minimum rate of 120 moulds. Since this study, some technical assistance (mostly funded by the Japanese) has been given to the industry, but improvements in technological levels are still small and concentrated.

To what extent have FDI and exports contributed to Philippine technological development? Three studies have attempted to measure the contributions of FDI and exports to total factor productivity (TFP). The findings are varied. Austria (2000) found a positive and significant effect of exports on TFP, but the FDI variable was insignificant.[17] Cororaton and Abdula (1997), on the other hand, found both exports and FDI variables to have positive and significant effects. They also obtained a negative coefficient for the tariff variable, suggesting that protection had a perverse impact on technological development. Finally, Okamoto (1999) did not find a significant impact of exports and FDI on TFP, consistent with the qualitative assessment of the weak links between foreign and domestic firms.

Local Technological Effort

While statistical tests do not capture the spillover effects of FDI on domestic firms, it is reasonable to expect that some local technological activities have been spurred by the interaction of local and foreign firms. In the 1970s, for example, the automotive development programme attracted MNCs and gave birth to a machine tool industry in the Philippines, at about the same time as Taiwan and South Korea. At that time, venturing into machine tools was regarded as too ambitious given the level of development of the ancillary sector (machining, metal casting, heat treatment and the like). There were also doubts about the ability of the small domestic market to support an industry. Yet it was also considered 'strategic' to develop a local machine tool industry since a country's capability to produce machines and equipment depended on its stock of machine tools. Unlike Taiwan and South Korea that deftly combined trade and financial instruments to assist machine tool producers and users, the Philippine government left producers to develop on their own. In the end, the local producers were unable to face competition from second-hand imported lathes that (ironically) came from Taiwan (Abrenica, 1994).

A common complaint among inventors and entrepreneurs in the Philippines is the absence of public support for technological start-ups. The Department of Science and Technology (DOST) has supported a number of business incubators like the Institute of Small-Scale Industries at the University of the Philippines, but none has been as successful as counterparts in Taiwan and Korea. There are also no public-sector institutions similar to ITRI in Taiwan or KAIST in Korea, or venture capital institutions that can cooperate with inventors to commercialize local innovations.[18]

It is difficult, in the absence of detailed studies, to pinpoint any sector that has built significant innovative capabilities in the Philippines. Technological activities are limited even in traded goods like electronics that face global competition. A survey of electronic firms by the Department of Trade and Industry shows that four-fifths of electronic firms are engaged in the simple assembly of basic or medium-level technology products such as TVs, video cassette recorders and passive components (resistors, coils, single and double-sided PCBs and so on). Nonetheless, manufacturing capability is judged to be higher in firms that assemble integrated circuits using the latest packaging technology. A few local firms, in particular Ionics Inc. (1982) and Pacific Semiconductors Inc. (1988), undertake substantial subcontracting with MNCs in wafer probe/inspection, die bonding and wire bonding for semiconductor packaging.

In the electronic data processing industry, local firms are active in PCB assembly and module sub-assembly for computer hardware. The more prominent local firms are Integrated Microelectronics Inc. (1980) which has been assembling magnetic heads for US and Japanese MNCs, and Ionics, Inc. which assembles PCs for IBM Corp. But the R&D activities of these firms are mostly directly related to the products that have been subcontracted to them. Ionics is reported to have plans to set up R&D facilities in the Philippines and the USA. In the case of foreign affiliates, Fujitsu (car stereo software), ROHM Megatech (LED and transistor frames), Casio (pagers), Sharp (televisions and karaoke machines), R&D activities are mostly production-related. R&D in new products and processes are still carried out in the parent companies.

Among sectors highly protected in the past, for example, food processing and cement, the import surge following a protracted reform of the tariff structure since 1986 prompted the large firms to source new technologies either through joint ventures or FDI. But there are few local firms with the capacity to attract foreign partners. Government programmes to help SMEs find foreign partners have had limited success.

4. PUBLIC POLICY AND DEVELOPMENT OF TECHNOLOGICAL CAPABILITY

A number of factors explain the Philippines' weak national technological capability. Among these are government policies. We now assess these policies.

Industrial Policy

Like most developing countries, the Philippines embarked on industrialization based on an inward-looking import-substitution and later switched to export-orientation. Unlike the NIEs in the Asian region, protection was protracted, lasting more than three decades. It was only in 1981 that a serious trade reform policy, culminating in a uniform tariff rate of 5 per cent by 2004, was adopted. More importantly, the Philippines was less successful than the Asian NIEs in leveraging policy regimes.[19]

The import-substitution regime

Comprehensive controls on imports and foreign exchange were introduced in the Philippines as early as 1949, four years after Independence, to create an industrial base, first in consumer goods and later in capital goods. The policy attracted tariff-jumping FDI in the consumer durable industry in the 1960s, to assemble cars and 'white goods' (refrigerators, washing machines, air-conditioners, and so on). Aldaba (1994) found the average effective protective rate (EPR) to be a highly significant determinant of Japanese investments in the Philippines, and to a lesser extent of US, European and total FDI in 1973–92. In the automotive industry, import barriers encouraged local assembly from imported CKD (completely knocked-down) kits. However, a local content policy was put in place in order to develop the local parts industry.[20] A number of MNCs producing simple electrical appliances like electric fans, rice cookers, radios, TV sets and air conditioners were also attracted by the protected market. The extent of backward linkage achieved varied by product, ranging from 15 per cent in colour TV to 60 per cent in refrigerators (Morisawa 2000).

How well did the Philippines manage its trade regime to build an industrial base and acquire technological capability? The best illustration is perhaps the automotive industry. In the 1970s, the Philippines was among the first of the Asian economies to launch a vehicle development programme. The programme attracted investments from Japanese, European and US automotive assemblers. Several decades later, unlike Korea, Thailand or Malaysia, the Philippine auto industry remains the smallest and the least advanced in the Southeast Asian region. The failure of the programme can be traced to faulty design and weak implementation (Abrenica, 1994). The experience provides important lessons on industrial strategies anchored in FDI.

One important problem was that the government pushed for the local production of complex parts (engine blocks, axles and transmission) in the belief that this would facilitate greater transfer of technology and generate more export revenues. But the tight specifications required for such sophisticated components only encouraged in-house production: the multinational assemblers raised vertical integration. Subcontracting may have been promoted better if the localization efforts had concentrated on simpler parts such as brake linings, fan belts, radiators, brake drums or seats.

The programme implementers did not enforce localization very strictly. The lack of technical expertise and manpower to monitor compliance in fact rendered the local content regulations largely ineffective. This posed another problem. It had been assumed that the costs of complying with the local content requirements would encourage assemblers to limit the number of brands and frequency of model changes. However, since the enforcement of local content was weak, a large number of brands and models were assembled, depriving local manufacturers of the scale needed for technological development. A more serious shortcoming was the neglect of the small- and medium-sized parts manufacturers. Although some policies were ostensibly directed to support parts manufacturing, the results were not in line with intentions. The incentive structure was biased in favour of capital-intensive and vertically-integrated operations.

The implementers erroneously assumed that the cost penalty of localization would compel the foreign assemblers to assist local parts producers, replicating the tight assembler–parts supplier links that existed in the home bases of the assemblers. The expectation did not materialize. Most of the foreign assemblers elected to bring to the host country their affiliate parts manufacturers; others, as noted, chose to manufacture the parts themselves.

Export-oriented policy regime

By the 1970s, the Philippine economy could no longer bear the burden of costs imposed by import-substitution policies. This prompted a shift to an outward-looking industrial development strategy. The Philippine peso was floated and a law providing incentives to exporters was enacted. Rules on foreign investments were relaxed substantially to encourage export-oriented FDI with the passage of the Omnibus Investments Code (OIC) in 1987 and the Foreign Investments Act (FIA) in 1991. With the OIC, the Board of Investments (BOI) was mandated to draw up a list of preferred investments and offer a menu of incentives to investors in listed areas. The FIA liberalized existing regulations by allowing foreign equity participation of up to 100 per cent in all areas not included in the Foreign Investment Negative List (FINL), as long as the enterprise was exporting at least 60 per cent (instead of 70 per cent under the OIC) of their output. According to the World Bank (1993), the FIA brought the Philippine foreign investment regime closer to that of its Asian neighbours in structure, comparing favourably in terms of equity share allowances (except for Hong Kong).

An important component of the FDI liberalization package was the establishment and expansion of industrial parks and export/economic processing zones (EPZs and 'ecozones'). As of 15 April 1997, as many as 56 ecozones had been identified. The Philippine Economic Zone Authority

(PEZA) was placed in charge of the ecozones. Investors in the ecozones received the same incentives as provided by the OIC but were free of obligations imposed on enlisted investors. As a result, some 85 per cent of approved investments in the highly export-oriented electronics industry was recorded by PEZA in 1995, while only 15 per cent registered with the BOI.

A recent World Bank comparison of incentives provided by EPZs in the region suggests that the Philippines' package is not only competitive but is 'the most generous and flexible set of incentives available anywhere'.[21] Duty-free import privileges are said to be without parallel in their provision of complete exemption in perpetuity for export and free trade enterprises for almost all project-related inputs; other countries restrict such privileges to production-related items or to those not available locally, or make it available only once. Moreover, the range of promoted activities in the ecozones is very broad, allowing services, utilities, infrastructure development and tourism in addition to manufacturing. The Philippine ecozone is also said to be unique in East Asia in that incentives are also provided to ecozone developers and other infrastructure providers (World Bank, 1997, p. 79). Being under the purview of PEZA, ecozones enjoy the benefits of a more efficient bureaucracy that simplifies procedures, coordinates national and local public agencies in activities affecting investors (such as payment of national and local taxes) and reduces the costs of importation.

How well have these policies helped the Philippines to acquire technological competence? The electronics industry is instructive in this context. FDI in the electronics industry, particularly in semiconductors, was drawn to the Philippines in the 1970s by the relative abundance of trainable labour for use in export production. However, despite the scale of demand in international markets, hardly any backward linkages were struck. No local manufacturers of parts and components to semiconductor assembly emerged, with the exception of simple packaging (cartons, plastic containers). The semiconductor assembly industry was until recently almost completely dependent on imported inputs. With limited backward linkages, there was little, if any, technology diffusion from FDI to the Philippine economy.

With the influx of Japanese semiconductor and HDD MNCs in the 1990s, a new phenomenon has emerged. Given the weaknesses of domestic suppliers of parts and components, the network of supplier firms – whether or not members of the same *keiretsu* – of the Japanese assemblers are moving into the country to be close to their principals. Among the new foreign investors are Dowa Hightech and Mitsui Hightech (integrated circuit lead frame), Cebu Chip Connection (gold bonding wire), and Dexter (moulding compound). Uniden, a Japanese assembler of telecommunications equipment, is said to have attracted seven of its suppliers to the country.

What accounts for the difference in the paths followed by the electrical appliance and the automotive industry on the one hand and the electronics industry on the other? Morisawa (2000) explains it by the difference in the degree of technological sophistication required in the manufacture of parts and components. Foreign investors generally prefer local sourcing of parts and components to imports to minimize costs and maximize flexibility. However, the level of a host country's technological competence determines the speed at which domestic firms become suppliers to foreign firms. Very high-technology components like silicon wafers are produced only in the USA, Japan or Europe and a few NIEs. Many parts and components are characterized by significant economies of scale, requiring huge cost outlays on capital equipment embodying state-of-the-art technology (for example, wafer fabrication). As a result, these industries tend to be dominated by MNCs; barriers to entry are too high for most developing country enterprises to overcome.

The experience of Singapore is instructive: appropriate policies *can* create backward linkages even in sophisticated activities. In the 1970s, a study of Singapore's electronic industry (Lim and Pang, 1982) painted a gloomy picture, similar to that of the Philippines today, with a high degree of MNC-dominance, rapid export growth based on electronics but few linkages to the host economy. A study by the same authors some years later (Pang and Lim, 1997) painted a very different picture. Over time, regardless of nationality and product type, MNC affiliates increasingly bought local inputs as they upgraded into more complex technologies. Singapore had been able to induce MNCs to develop local linkages by supporting capability development in local firms. The rapid growth of the assembly industries led to the birth and growth of numerous local supplier firms.

If one were to assess the effectiveness of industrial policy, then the appropriate measure would be the extent to which it transformed the economy from 'first-stage' FDI-based international sourcing to a more mature stage where FDI was firmly rooted in the local economy by extensive backward linkages. By this measure, Philippine industrial policy has obviously foundered.

Human Resource Development

The Philippines has a young and highly educated labour force. More than two-thirds of employed people are less than 45 years old; about 20 per cent belong to the 15–24 age bracket. To the extent that young workers are perceived to be more flexible and trainable than their older counterparts, this is an important advantage. About 61 per cent of the labour force has spent at least a year in secondary school.[22] The comparable figures in other developing economies such as Mexico and Indonesia are 46 per cent and 37 per cent, respectively.[23]

However, only two-thirds of the Philippine labour force is 'gainfully employed', with about 11 per cent unemployed and 22 per cent underemployed.[24] Even during the economic boom in 1996, when the economy was growing by 5.6 per cent, unemployment rate was stubbornly high at 7.4 per cent. Clearly the employment potential of the present production structure is insufficient to cope with an expanding labour force.[25] Many entrants to the job market are, as a consequence, compelled to accept low-paying or part-time jobs (Esguerra and Canlas, 2001). At the same time, the unit cost of labour is rising. Over a 10–year period from 1989, labour productivity declined by 0.9 per cent while the average wage increased by 85 per cent.[26] This is eroding the competitiveness of Philippine industry. Despite reforms in wage setting towards greater reliance on market mechanisms,[27] the links between wages and productivity remain loose.

An even more disturbing trend is high unemployment for highly educated young people. The unemployment rate for college undergraduates and college graduates was 15 per cent and 11 per cent, respectively, in 1999 (when the aggregate unemployment rate was 9 per cent).[28] The problem of educated unemployment has two facets. The first is that it signals poor quality education. Recent studies on Philippine education[29] concur that poor curriculum, inadequate training of teachers and low public and private investments in education are responsible for a declining quality of graduates (Tan, 2001). Many schools have become 'diploma mills' producing graduates that cannot be absorbed by the labour market. This is attested by a 1999 survey on the employment profile of new graduates, which found that those with degrees in computer science, computer engineering, electronic and communication engineering, and industrial and chemical engineering were among those experiencing above-average difficulty in finding employment (FAPE, 1999). Thus, despite an increasing and pervasive demand for information technology (IT) skills, larger numbers of IT graduates are unable to find jobs.

A second facet of educated unemployment is the mismatch between industry requirements and the training provided by the education system. There are more graduates in several academic programmes than the market can absorb, specifically education and teacher training and business administration. These degree programmes accounted for 12 per cent and 24 per cent, respectively, of the total graduates in 1997. In contrast, graduates of engineering and mathematics and computer science accounted for only 10 per cent and 8 per cent, respectively. The upshot is that graduates of academic programmes in less demand either land jobs that do not match their academic background or remain unemployed. Again, the 1999 survey confirms a high proportion of those employed have academic backgrounds that do not match their work. The mismatch is particularly high among graduates of social science programmes.

Paderanga (1998) traces the root of the mismatch to the dualistic industrial structure created by the long history of import-substitution. Protected sectors could pay higher than average salaries while the unprotected sectors had to pay lower salaries. This influenced course selection by students, many choosing courses demanded by the protected sectors. The result was a disproportionate enrolment in courses such as business administration and a paucity in science and technical courses.

There is broad consensus in the Philippines that educational reforms are needed, but the direction of reforms remains contentious. At the heart of the debate is the issue of equity versus quality of education: whether reforms should focus on broadening access to education or improving its quality. Politics favours the former and economic efficiency the latter. In the past, politics has prevailed over economics. State universities and colleges (SUC) mushroomed even as adjustments in public sector budgetary allocation for education lagged. There was only one SUC for half a century until 1960; at present, there are 107 SUCs. Free education was extended to secondary schooling in 1989 without adequate consideration of its resource requirements. Tan (1999) reports that in real terms, the 1996 education budget per student was only slightly above the 1978 level. Considering the higher infrastructure costs of modern education, the budget allocated was clearly insufficient to allow for an upgrading of education to international standards.

The dichotomy between equity and quality is deceptive. Tan (2001) notes that notwithstanding populist policies, access to higher education remains inequitable. This is shown by the wide differential between the proportion of those in lower income groups who are college graduates as compared to higher income groups. Thus, improving the quality of education ranks high on the agenda. This would require not only augmenting the current budgetary allocation to education, but more importantly, guarding against the division of the pie into too many parts.

Science and Technology Policy

The Philippines industrial strategy has not had a vision of technological development. In contrast, the industrialization strategies of successful NIEs like Taiwan and Korea were anchored on a technology agenda. All public policies contributed to goals for technological development. This is clearly not the case for the Philippines.

Technology policy has two important functions in industrializing economies. One, obviously, is to encourage investment in technological activity. This may involve subsidies for specific innovation activities, tax allowances for R&D, protection of intellectual property rights and regulation to promote use of innovative products. The other function is to foster institutions to support firms in technological activities. This involves strengthening the academic and research infrastructure and forging links between institutions and industrial firms. Technology policy is critical to industrialization to the extent that the capacity of firms to absorb, adapt and harness foreign technologies and to upgrade its industrial activities is a function of society's technology milieu.

A cogent set of technology policies only appeared in the Philippines in the late 1980s. In 1988, a Presidential Task Force on Science and Technology assessed the state of science and technology. It identified three factors inhibiting technology development: low investments in S&T, both by the public and private sectors; underutilization of available S&T infrastructure; and weak linkages between technology generation, adaptation and utilization. It found that Philippine R&D as a percentage of GNP had been declining, from 0.26 per cent in 1979 to 0.12 per cent in 1984. This expenditure was not only below UNESCO's prescribed spending of 1 per cent of GNP for developing economies, but also less than the spending by neighbours such as Thailand (0.36 per cent) and Indonesia (0.23 per cent). Four-fifths of the expenditures came from the public sector, with the private sector doing very little R&D. The task force also noted the falling supply of S&T manpower, partly due to the brain drain of S&T personnel, but also (and mainly) because of the low turnout by the education system. The report emphasized the need for a comprehensive strategy to invigorate domestic S&T. Subsequently, a 10-year Science and Technology Master Plan was formulated.[30] This plan, covering the decade 1990–2000, called for: (i) modernization of the production sectors through technology transfers from foreign and local sources and through industry-university linkages; (ii) upgrading of research and development capabilities; and (iii) development of S&T infrastructure and raising national S&T consciousness. The vision was for the Philippines to attain NIE status at the turn of the century.

The plan spelled out measures to attain its objectives. A timetable was set for the commercialization of some 50 technologies, mostly agro-based; promotion of business incubators and science parks; upgrading of S&T services by public agencies such as testing, standardization and quality control; and the strengthening of engineering and science education. The core strategy was to focus public S&T support on 15 'leading edge sectors' supposedly selected for their growth potential. The list was, however, an odd mix of industries, processes and technologies.[31] The targets were too broad and priorities were unclear. The action plans were incoherent. The S&T plan lacked a clear framework, organization and workable strategy.

In 1993, at the instigation of the Export Development Council (a private sector–government consultation body for export promotion), the targets were expanded to 24, to include 'export winners' and even broader areas such as housing, environment, defence and disaster relief. However, no new programmes were added to the Plan. Nonetheless it was renamed 'Science and Technology Agenda for National Development' (STAND). The changes showed that S&T policymaking, like industrial policymaking, was subject to lobbying from interest groups. As there were too many targets without matching programmes, the plan had to be redrawn once again. In late 1994, a narrower list of nine 'vanguard projects' emerged. But the targets still remained too diverse, from coconuts to information technology, spreading government efforts thinly in addressing the myriad concerns of these sectors.

STAND lacked a patron to marshal the resources needed to consummate the plan. DOST (the Department of Science and Technology), the designated standard bearer of STAND, had neither the resources nor the clout to launch massive programmes and pursue wide-ranging institutional reforms. DOST was set up in 1986 to provide central direction for government S&T efforts. It has nearly 5000 employees, deployed over two scientific advisory bodies, five planning councils, seven R&D institutes and 15 regional offices. The areas of concern of the research councils and institutes are broad and diverse: advanced science and technology, agriculture and natural resources, health, energy, industrial technology, food and nutrition, metals and metalworking industries, textiles and forest products. But these agencies are underfunded. The array of activities stipulated in STAND require an increasing allocation of government budget to S&T activities. DOST's budget was expected to rise from 0.3 per cent of GNP in 1990 to 1.5 per cent of GNP by 1996 (DOST, 1990). Instead, DOST's budget until 1997 was a mere 0.118 per cent of GNP (Padolina, 1998).

A shortage of high level S&T personnel in the agency further diminished the chances of the plan taking off. Only 2 per cent of DOST's personnel have doctorates and another 10 per cent master's degrees. Attracting scientists to public service is severely constrained by the size of the agency's budget and the low pay offered in line with government scales. To address this problem, DOST launched in 1993 the 'Balik-Scientist Programme', patterned after Taiwan's, to attract foreign-based Filipino scientists to return and work in their country. DOST instituted a science career system for its employees that allows those conferred the rank of 'scientist' to receive extra compensation.[32] Yet the compensation package offered is still too paltry to entice sufficient qualified recruits.

A criticism often made of DOST is weak linkage with the industry. Most of the technologies that DOST supports through its technology transfer and commercialization programmes are said to be far removed from the needs of the market. While claiming to adhere to the principle of 'demand-led' intervention, DOST's resources for commercialization have been used mainly to support research by its institutes, which are often initiated without a specific target client.[33]

Reflecting funding and the availability of S&T personnel, R&D activities have focused on biotechnology rather than other new technologies. From 1992 to 1998, biotechnology R&D grew six-fold. However, research focused mainly in agriculture, specifically on disease and pest resistance of crops, rather than on applied industrial research (Padolina, 1998). Notwithstanding the locus of R&D resources in agriculture, the Philippines agricultural research intensity is still lower than its neighbours. The research intensity ratios reported by Inocencio and David (2000) reveal 0.41 per cent for the Philippines versus 1.06 per cent for Malaysia, 1.4 per cent for Thailand and 4.65 per cent for Taiwan.[34]

Some incentives have been put in place to stimulate R&D in the industrial sector, but with meagre results. For example, tax incentives for R&D provided by the Board of Investments were used by only 11 companies (for 13 projects) over a span of six years, that is, 1991–97 (Nolasco, 1998). In 1992, legislation was passed to provide generous incentives to inventors, including financial assistance for commercial application of inventions. Yet a survey by Halos (1998) reveals that most respondents balked at availing of the incentives as they found the procedures too cumbersome (Cororaton 1998).

A more serious problem than the deficiencies in the DOST system is the *structure of governance*. STAND is a comprehensive plan that requires the collaboration of various agencies. The crucial task of DOST is to rally the support of other agencies for the plan. But the other agencies have their own priorities and budgetary constraints. Take the build-up of S&T manpower. The task of raising the supply and quality of engineering and science graduates is vested in the Commission on Higher Education (CHED). CHED's responsibility, however, is to the Department of Education, Culture and Sports (DECS). Moreover, CHED has been preoccupied in levelling the quality of education offered by public and private institutes, and spreads its resources thinly over numerous mediocre institutions. The funds that remain to support premier institutions with the potential to turn out better-quality engineering and science graduates are very limited.

CHED also maintains a laissez-faire approach towards educational institutions. It has not imbibed the thinking behind STAND, that government may have to subsidize the production of scientific, engineering and technical skills when an unfettered educational system fails to deliver. Enrolment has traditionally been highest in liberal arts, commerce, law and education degrees (57 per cent of enrolment in 1996–97); engineering and technical courses are less favoured, making up only 14 per cent. As one may expect, private educational institutions are inclined to focus their offerings on courses that are heavily demanded. CHED has not exercized its clout to influence the choices of profit-seeking private educational institutions. Nor has it been aggressive in supporting public educational institutions to align their course offerings with the skills requirements of the industries.[35] Consequently, the education system has not been responsive to market demand.

DOST's coordination with the Department of Trade and Industry (DTI), the agency that has the sole mandate to grant fiscal incentives to investment projects, is as loose as its linkage with CHED. DTI's incentives are granted to industries under the Investment Priorities Plan (IPP), which is drawn up independently of the S&T plan. The first set of S&T targets had to be revised as no incentives can be given to industries that are not included in the IPP. DOST has to ensure that the subsequent list of S&T targets were aligned with DTI's priorities. Indeed, it is a case of S&T agenda tailgating the industrial strategy.[36]

The danger with this kind of S&T intervention is that it diverts attention from the more crucial task of technological catch-up. Consider that DOST is made to support DTI's 'export champions.' These are electronics, garments, computer software, fashion accessories, gifts, toys and houseware, fresh and processed fruits, marine products, furniture, metal products, marble products, ornamental flowers, professional services and construction industry. With the exception of electronics, metal industry and some aspects of services, opportunities for technological learning in this set of industries are limited. Moreover, from the viewpoint of technological development, S&T support must be directed to sectors with wide-ranging linkages with the rest of the economy. And the appropriate measure of the benefits from intervention is not the direct gains obtained by the targeted sectors but the spillovers to the non-targeted. Since most of those targeted have limited linkages, one can only anticipate that spillovers will be tiny.

The seemingly low status of DOST in the bureaucracy is a reflection of the belief among technocrats that technological capacity building is a natural outcome of market liberalization. This is only partially true. Liberalization does provide the incentives for improving capabilities, but by itself, it cannot resolve the structural and institutional problems that plague capability development, for example the shortage of S&T skills.[37]

Early in 1998, DOST conceded that STAND had failed in its mission. Its place was taken by a six-year programme labelled 'Comprehensive Programme to Enhance Technology Enterprises' (COMPETE). The goal of COMPETE is to boost R&D in government research institutes, universities and industry by setting up technology parks, innovation centres and R&D institutes. COMPETE avoids too many targets and unfocused programmes: its focus is information and communications technology. The targets are to build local capability in microelectronics design and manufacture of more intricate and complete electronic product design; and to train and certify some 10000 IT professionals by 2004. To accomplish these tasks, universities and local electronic companies have been drawn into the programme.

Many pundits are, however, sceptical about COMPETE. First, the current capability of local electronics engineers is limited to discrete element design; moving into higher value-added design services will need a bigger push than the currently allocated resources can achieve.[38] Second, the main strategy is to exploit the synergies of universities, research institutions and private sector. But where is the knowledge? Universities would need sizeable resources (for upgrading faculty, curriculum, training and research facilities) to engage in frontier research. Local companies have a long way to go beyond their current capabilities in labour-intensive, back-end assembly. The private sector's enthusiasm over the programme is dampened by the slow progress on the few projects that have started, while many are still on the drawing board. Past experience with government programmes suggests that their chances of success are good as long as the hype lasts – sustaining the momentum is the most difficult part.

5. CONCLUSION

Few countries have been as bold as the Philippines in instituting market reforms. Recent trade and industrial policies have significantly contributed to improving market efficiency. Many local firms seem to have imbibed an outward orientation, as opposed to the inward-looking perspective that they acquired during the past decades of protection.

With outward orientation comes greater openness to various sources of technology. Market liberalization revives investment, including foreign investment, which is regarded as the principal bearer of technological change. The opportunities for technological learning and upgrading are however squandered by weak capacity for absorption and assimilation of the economy. And the weaknesses in technological capacity can only be traced to policy neglect.

Why has not enough attention been given to improving national technological capability? The answer must lie in the thinking of policymakers that creating a competitive environment is sufficient to call forth technological upgrading. Certainly the pressure of competition incites interest for technological learning and innovation. Yet the capacity for learning and innovation must exist; it does not come automatically but is developed through time with sufficient investments.

The lessons from the Philippine experience are palpable. In the past, the government coddled local firms without pushing them to harness their technological capabilities. When it was time to shift paradigm, firms were left to grow on their own intrinsic efforts. To be sure, market liberalization sets the grounds for technological learning to the extent that technological flows are unhampered and competitive pressure awakens the lethargic spirit bred by long years of protection. Yet even under a liberal environment, local firms must be supported by institutional infrastructure for absorbing, adapting, diffusing and, later, improving on technologies culled from diversified sources.

Can the Philippines extricate itself from the constraints of narrow export specialization, import dependence and shallow knowledge base? As it completes the process of market liberalization, the urgent task now is to leverage its liberal posture to obtain maximum access to technologies. Setting a national technology agenda and marshalling resources to meet these goals will help define the technological path that the economy is treading. Based on this agenda, investments must now flow into building technological infrastructure. An example of such infrastructure is a core of institutions, possibly formed out of public–private sector partnerships, that have the capacity to acquire, absorb and diffuse technologies. Another is an efficient educational system that can turn out high quality graduates that would not only meet the skills required by industries, but also produce a critical mass of scientists and engineers who would engage in R&D. Equally critical is creating a regulatory environment that will ensure the provision of state-of-the-art communication and transportation infrastructure. Finally, a stable macroeconomic environment will enhance the workings of the market and attract different technology sources to use the country as a production base, and over time, a knowledge-creation centre.

NOTES

1. To put things in perspective, the Philippines, up until the 1960s, had been regarded among Asian economies, as second only to Japan in economic development. Several decades later, the Philippines has earned the title of the 'basket case' economy in Southeast Asia.

2. The Philippines spent most of the 1990s instituting market reforms. Among the critical reforms were the unilateral reduction in tariffs and elimination of non-tariff barriers during 1992–96; deregulation of strategic industries such as telecommunications and banking; liberalization of foreign equity rules in 1991; privatization of state-owned corporations; removal of foreign exchange controls in 1992; and opening of infrastructure projects to private investors. Recently, the groundwork for restructuring the power sector has been laid, but other reforms that can be expected to deliver large efficiency gains are still in the pipeline, such as those in the transport sector and government bureaucracy.
3. Balassa's (1965) revealed comparative advantage index (more popularly known by its initials RCA) measures the share of commodity group *i* in country *j*'s (manufactured) exports relative to the share of commodity group *i* in the world's total (manufactured) exports.
4. Ditto medium-high technology exports where 66 per cent is due to motor vehicles.
5. According to the global definition of the American Electronics Association, the eight sectors comprising the electronics industry are: components, electronic data processing (EDP), office equipment, medical and industrial, control and instrumentation, communication and radar, telecommunication and consumer electronics. The six allied industry groups are: tool and die, metal casting/stamping, machinery, services, chemicals and packaging.
6. A rough indication of the high import content of technology exports is the proportion of net exports to total exports. In 1998, net export of components was a mere 31 per cent of its export value.
7. It can be added that enrolment rates as measures of human capital formation are misleading when drop-out rates are ignored. While Philippine participation rates are high, cohort survival rates in 1998 are low: 68 per cent for primary and 70 per cent for secondary education (ADB and WB 1999).
8. To illustrate, Thailand's GNP in 1997 was 81 per cent higher than the Philippines. Since Thailand's participation rates are lower, but the proportion of its spending to GNP is almost twice that of the Philippines, then clearly, its budget per pupil is significantly more than the Philippines.
9. See HDN (2000) for an assessment of basic education.
10. The most recent official data on R&D, which are shown in Table 10.3, are for 1992. There were surveys conducted in 1998 to obtain data on R&D activity, but the results of such surveys remain unofficial.
11. In a regression analysis of the determinants of FDI in the Philippines, Mercado-Aldaba (1999) finds the fiscal incentive system an insignificant explanatory variable.
12. See Patalinghug (1996, 2000) for a comprehensive review of TFP studies in the Philippines.
13. The investments have been traced to the privatization of the state-owned enterprise, the Philippine National Oil Company, one of the three big players in the industry.
14. In the semiconductor industry, Raneses (2001) notes the use of advanced manufacturing methods in both MNCs and local firms. These include just-in-time, world-class manufacturing (WCM), total quality management (TQM), total productivity maintenance (TPM), agile manufacturing, automation, computer-aided/integrated manufacturing (CAM/CIM), statistical process control and design of experiments (for example, six sigma).
15. The non-ferrous metals industry is an exception to the general trend that subcontracting declines with size: the ratio to total industry output of work done for others was 16.07 per cent for firms of 200 or more workers as against 7.15 per cent for those employing 1–9 workers.
16. The apparel industry even shows a higher ratio to industry output of work done *by* others, that is, 18.96 per cent in 1988, and this is most intense in the larger firms: 24.02 per cent and 20.39 per cent in firms employing 100–199 and 200 and more workers. This may be due to international subcontracting done by large (export-oriented) firms.
17. There was no explanation given as to why the two variables have different effects on TFP when most of FDI firms are producing for exports.
18. In the late 1980s, some large local businesses tried to set up a venture capital group to support local inventors. But the undertaking failed for a number of reasons, among them

the apparent lack of trust between the fund providers and the inventors. The former were reluctant to invest without well-developed business plans, while the latter were suspicious of the commercial interests of their sponsors.

19. A third element that distinguishes Philippine industrialization experience is the 'de-industrialization' that started in the 1990s, perhaps accelerated by rapid import liberalization.
20. The Philippines is maintaining a 40 per cent local content ratio in the automotive industry until the year 2005 in contravention to the Agreement on Trade-Related Investment Measures (TRIMs).
21. This does not, however, preclude the fact that in some areas, the country's ecozone regime is less competitive than those in say Thailand or Malaysia. Such areas include: the lack of clarity of the ecozone concept, especially as it applies to non-manufacturing activities; the uncompetitive impact of the gross income taxation approach; unclear policies governing sales to the local market and excessively generous packages of fiscal incentives in certain instances (World Bank, 1997, p. 79).
22. Based on Philippine Labour Force Statistics for 1999.
23. Data were obtained from ILO (2000).
24. Based on the October 2000 *Labour Force Survey* by the National Statistical Office. Even during economic boom, for example when the economy was growing by 5.6 per cent in 1996, unemployment rate was stubbornly high at 7.4 per cent.
25. Both population growth and labour force participation rates are increasing.
26. Labour productivity is measured in terms of gross domestic product per employed person. The figures are based on data culled from the *Philippine Yearbook of Labour Statistics 1999* and *Yearbook of Philippine Statistics 2000* both published by the National Statistical Office.
27. The decentralization of wage-setting at the regional level began in 1989. Regional Tripartite Wages and Productivity Boards were formed to determine minimum wage levels and wage adjustments. The Congressional Commission on Labour (2001) reported that there are 300 minimum wage levels across the country reflecting differences in market conditions within and across regions.
28. Based on *Philippine Labour Force Statistics for 1998*, National Statistical Office.
29. The main authoritative studies on Philippine education are the *1995 Philippine Task Force on Higher Education Report*, published in Manilla by the University of Education, the *1998 ADB-WB Philippine Education Sector Study* and the *2000 Presidential Commission for Education Reforms Report*, published in Manila by the University of Education (Tan 2000).
30. Previous to this, the only policies relevant to S&T development were concerned with the establishment of a number of sector-focused research agencies. The utilization rate for research outputs of these agencies was next to nothing in the absence of well-defined and coordinated research direction.
31. These selected sectors were agriculture, aquaculture and marine fisheries, forestry and natural resources, metals and engineering, textile industry, mining and minerals, process industry, food and feed industry, energy, transportation, construction industry, information technology, electronics, instrumentation and control, emerging technologies, and pharmaceutical.
32. From 1984, when the Scientific Career System was established, until 1997, only 79 personnel have been conferred scientist rank.
33. The research priorities of the various councils and institutes within DOST are set in consultation with representatives from industry and academe. Notwithstanding this practice, the very low number of technologies that DOST commercializes is an indication of lack of market demand for the research outputs of these institutes.
34. Several studies justify this focus on agriculture. Libero (1997) and Cororaton (1998) found very high returns to R&D investment in agriculture. For some crops, such as sugarcane and mango, the returns range from 51 to 71 per cent, and 85 to 107 per cent, respectively. By contrast, the estimated returns to industrial R&D hover around 10 per cent (Pack, 1987; and Cororaton 1998).

35. From the perspective of educational institutions, offering new courses involves fixed costs on accumulating new skills, setting up laboratories, and so on. This represents market failure for which public intervention is required.
36. Curiously, agencies such as the Intellectual Property Office and the Bureau of Product Standards whose functions are more aligned with the mandate of DOST, are under the umbrella of DTI.
37. A case illustrating this point is the unsuccessful effort of the government in courting wafer fabricators to set up Philippine operations. Wafer fabrication is highly capital- and skill-intensive, both resources the Philippines sorely lack.
38. For year 2000, DOST has allotted US$5.8 million, equivalent to 10 per cent of its annual budget, to ICT initiatives. This amount is to be spread among numerous projects including infrastructure development, advocacy, and software and human resource development.

BIBLIOGRAPHY

Abrenica, M.J.V. (1994), *Building the Capital Goods Sector: An Agenda for Development*, Philippines Centre for Policy Studies.

Abrenica, M.J.V. (1997), 'The Philippine automotive industry: a case study in economic governance,' paper presented for AFTA Industry Studies, ASEAN.

Abrenica, M.J.V. (2000), 'Designing S&T policy for the new millennium', in D.B. Canlas and S. Fujisaki (eds), '*The Philippine Economy: Alternatives for the 21st Century*, Tokyo: Institute of Developing Economies-JETRO, and Manila: School of Economics, University of the Philippines.

ADB and World Bank (1999), 'The 1998 Philippine education sector study', Manilla and Washington, DC: Asian Development Bank and the World Bank.

Aldaba, Rafaelita (1994), 'Foreign direct investment in the Philippines: a reassessment', PIDS research paper series 94–10.

Amsden, A.H. (2000), 'Industrialization under new WTO law', paper presented at the High-level Round Table on Trade and Development: Directions for the Twenty-first Century, Bangkok, 12 February.

Austria, M. (2000), 'Philippine productivity performance in the 1990s: an assessment', PIDS-DAP Project on a Review of the Components of the Medium-Term National Action Agenda for Productivity.

Austria, M. and W. Martin (1992), 'Macroeconomic instability and growth in the Philippines: a dynamic approach', Economics Division working paper, Research School of Pacific Studies, Australian National University.

Balassa, B. (1965), 'Tariff protection in industrial countries: An evaluation', *Journal of Political Economy*, LXXIII, 579–94.

Congressional Commission on Labour (2001), 'Human capital in the emerging economy,' mimeo, report and recommendations to the Congress of the Philippines, February.

Cororaton, C.B. (1998), 'Rates of return to R&D developments', mimeo, Manila: Philippine Institute of Developmental Studies.

Cororaton, C.B. (1999), 'Study on public and private enterprises on research and development: an integrative report', discussion paper series no. 99–15, Philippine Institute for Development Studies.

Cororaton, C.B. and R. Abdula (1997), 'Productivity of Philippine manufacturing,' mimeo, Philippine Institute for Development Studies.

Cororaton, C.B. and M.T.D. Caparas (1999), 'Total factor productivity: estimates for the Philippine economy', discussion paper no. 99-06, Philippine Institute of Development Studies.
de Dios, E.S. (1996) 'Enhancing technological capabilities: the Philippines', paper presented before the Federation of ASEAN Economic Associations.
Department of Science and Technology (1990), 'Science and technology master plan', pamphlet.
Department of Science and Technology (1999), 'Competence, competitiveness, conscience: the medium term plan of the Department of Science and Technology, 1999–2004', pamphlet.
Department of Science and Technology (2000), 'DOST under the Estrada Administration: accomplishment report, July 1998–June 1999', pamphlet.
Esguerra, E.F. and D.B. Canlas (2001), 'Raising the quality of life through the workplace in the new millennium', in D.B. Canlas and Y. Nimura (eds), *Socio-Economic Reform Program in the Philippines: Impacts and New Directions*, Tokyo: Institute for Developing Economies.
Fabella, R. (1994), 'Investment and the allocation of resources under macro-economic Instability,' in R. Fabella and H. Sakai (eds), *Resource Mobilization and Resource Use in the Philippines*, Tokyo: Institute for Developing Economies.
Fund for Assistance to Private Education (1999), 'Graduate tracer study', mimeo, report submitted to the Commission on Higher Education.
HDN (2000), *Philippine Human Development Report*, New York: Human Development Network, UN Development Program.
Halos, S.C. (1998), 'Agricultural technology acquisition, development and dissemination in the private sector', mimeo, Manila: Philippine Institute of Development Studies.
Hill, H. (1982), 'Subcontracting and technological diffusion in Philippine manufacturing', University of the Philippines School of Economics discussion paper 81–12, Manila: University of the Philippines.
Hooley, R. (1985), *Productivity Growth in Philippine Manufacturing: Retrospect and Future Prospects*, Philippine Institute for Development Studies, monograph series no. 9
ILO (2000), *Yearbook of Labor Statistics 2000*, Geneva: International Labour Organization.
Inocencio, A.B. and C. David (2001), 'Assessment of medium-term national action agenda for productivity for the agricultural sector', discussion paper no. 2001–13, Manila: Philippine Institute of Development Studies.
Libero, A. (1997), 'Research investment in agriculture and natural resources', mimeo, Subic Bay: Zambales.
Lim, L. and E.F. Pang (1982), 'Vertical linkages and multinational enterprises in developing countries', *World Development*, 10, 585–95.
Mercado-Aldaba, R. (1999), 'Foreign direct investment in the Philippines: a reassessment', discussion paper no. 99–10, Manila: Philippine Institute of Development Studies.
Morisawa, K. (2000), 'The Philippine electronics industry and local suppliers', University of the Philippines School of Economics discussion paper no. 11, Manila: University of the Philippines.
NSO (various years), *Census of Establishments*, Manila: National Statistical Office.
NSO (1994), *Survey of Manufactures*, Manila: National Statistical Office.
Navaretti, G.B. and D.G. Tarr (2000), 'International knowledge flows and economic

performance: a review of the evidence', *The World Bank Economic Review*, **14**(1), 1–15.
Nolasco, L. (1998), 'Identifying areas in support of R&D for the manufacturing sector', mimeo, Manila: Philippine Institute of Development Studies.
Okamoto, Y. (1999), 'Multinationals, employment creation and spillover effects: the case of the Philippines', *The Philippine Review of Economics and Business*, **36**(2), 177–204.
Pack, H. (1990), 'Industrial efficiency and technology choice', in R. Evenson and G. Ranis (eds), *Science and Technology: Lessons for Development Policy*, Boulder, CO: Westview.
Padolina, W. (1998), 'Science and technology policy', in J.V. Abueva and E.R. Roman (eds), *The Ramos Presidency and Administration*, Quezon: University of the Philippines Press.
Paderanga, C. (1998), 'Tertiary education in the Philippines: individual rationality and social myopia', discussion paper no. 9814, University of the Philippines.
Pang, E.F and L. Lim (1997), *The Economics Industry in Singapore*, Singapore: University of Singapore Economics Research Centre.
Patalinghug, E. (1996), 'Competitiveness, Productivity and Technology', in C. Paderanga, Jr. (ed.), *The Philippine in Emerging World Environment*, Manila: University of the Philippine Press.
Patalinghug, E. (2000), 'A review of the components of the medium-term national action agenda for productivity: an integrative report,' report submitted to Philippine Institute for Development Studies.
PECC (Pacific Economic Cooperation Council) (1999), 'Pacific science and technology profile, 6th issue', pamphlet.
Posadas, R. (1996), 'The state of science and technology in the Philippines,' mimeo, paper presented at the First National Conference on the Management of Technology, 25–26 October 1996.
Power, J.H. and G.P. Sicat (1971), *The Philippines: Industrialization and Trade Policies*, Oxford: Oxford University Press.
Raneses, N. (2001), 'Measuring productivity in the semiconductor industry,' mimeo, paper submitted to the Development Academy of the Philippines and Society for the Advancement of Technology Management in the Philippines.
Tan, E. (1999), 'Measuring poverty in education', in A. Balisacan and S. Fujisaki (eds), *Causes of Poverty: Myths, Facts and Policies, A Philippine Study*, Quezon: University of the Philippines Press.
Tan, E. (2000), 'Is the Philippines prepared for globalization: an assessment of its science and technology capability?' in D.B. Canlas and S. Fujisaki (eds), *The Philippine Economy: Alternatives for the 21st Century*, Tokyo: Institute of Developing Economies-JETRO, and Manila: School of Economics, University of the Philippines.
Tecson, G.R. (1999a), *Present Status and Prospects of Supporting Industries in ASEAN (1)*, Tokyo: Institute of Developing Economies-JETRO, March.
Tecson, G.R. (1999b), 'The hard disk drive industry in the Philippines and Japanese direct investments', *The Philippine Review of Economics and Business*. **36**(2), 205–56.
Tecson, G.R. (2000), 'Industrial development in the Philippines: issues and prospects for the 21st Century', in D.B. Canlas and S. Fujisaki (eds), *The Philippine Economy: Alternatives for the 21st Century*, Tokyo: Institute of Developing Economies-JETRO, and Manila: School of Economics, University of the Philippines.

UNCTAD (2000), *World Investment Report 2000*, Geneva: United Nations Conference on trade and Development.
UNESCO (1997), *Statistical Yearbook 1997*, Paris: United Nations Educational, Scientific and Cultural Organization.
World Bank (1993), *The Philippines: An Opening for Sustained Growth*, Washington DC: The World Bank.
World Bank (1997), *Philippines: Managing Global Integration*, Washington, DC: The World Bank.
World Bank (1999), *World Development Indicators 1999*, CD-ROM, Washington DC: The World Bank.
World Economic Forum (1998), *World Competitiveness Report 1998*, Oxford: Oxford University Press.

11. Industrial technology transition in Malaysia

Rajah Rasiah[1]

1. INTRODUCTION

The economic development literature has conceptualized technical change in different ways. While the issues involved are too complex to treat here in any detail, it is important to note that there are two opposing views. One is the traditional neoclassical view that treats technology as largely exogenous. Its advocates see a passive role for governments, with economies achieving the 'natural' rate of growth and structural change under free markets or, at most, with market-friendly interventions. The other view is that of evolutionary institutionalists, who emphasize the building of national capabilities as central to rapid growth and structural change. The proponents see a proactive, and in some cases selective, role for government interventions.

List's (1885) industrial policy argument to create dynamic comparative advantage was perhaps the earliest institutionalist effort to conceptualize the development of national innovation capabilities. Dynamic national innovation systems have helped nations transform comparative and competitive advantages (Gerschenkron, 1962; Kaldor, 1979; Lall, 1996). Given the qualitative attributes of the term 'technology', pioneering works in this field have deliberately left the national innovation system (NIS) open, with several agents (including organizations) playing important interactive and mutually supportive roles to develop nations' productive capacities (Lundvall, 1985; Freeman, 1987; Nelson, 1985; Dosi, 1984). Technical change covers innovations, broadly defined, to include both the path-breaking inventions and the more mundane (but equally important) efforts by which firms introduce new manufacturing designs and processes, including minor improvements that are not entirely new to the universe. Firms typically move from acquiring existing technologies (often from abroad) through various stages of adaptation and development to the creation of new processes and designs. Large-scale research and development (R&D) thus comes at the end of sequential learning and technological development processes (Pavitt, 1984). The capacity of an NIS to stimulate innovations depends on the development of supporting organizations and effective coordination between them and firms. The unprecedented success of Northeast Asian firms in reaching technology frontiers, with active assistance by governments, has raised questions about the role of selective interventions in building competitiveness in industrial latecomers.

While firms in mature industrial countries also go through the processes of acquisition, adaptation, improvement and innovation, their competitive status depends primarily on their ability to innovate. In developing countries, by contrast, competitiveness rests mainly on capabilities to acquire, master and adapt (imported) technologies. The Northeast Asian economies were exceptional in their ability both to master technologies and then to raise domestic innovative capabilities (see Johnson, 1982; Kim, 1997; Wade, 1990). Malaysian industrialization is different. It has been driven strongly by foreign direct investment (FDI), with much greater reliance on MNC affiliates to deploy imported technologies generated by parent companies. Deeper technological capabilities have therefore been slower to develop. Given the structural significance of technical change, this paper attempts to examine the dynamics of industrial technology transition in Malaysia with specific focus on capability building.

This chapter takes the institutionalist perspective. It assumes that policies are critical for long-term growth and structural change, and that economies evolve with a cumulative sequence of structural change powered by technological transformation. Initial conditions and structures are important in selecting the particular framework of economic growth. Being small, Malaysia could not have relied extensively on import-substitution (IS) policies. It inherited the basic infrastructure for primary commodity exports, and then entered a long period of rapid growth and structural change by diversifying such exports while attracting FDI into export-oriented manufacturing. Commodity diversification helped Malaysia avoid the pitfalls of falling terms of trade typical of African economies, while export-oriented manufacturing helped raise incomes and exports, stimulate structural change and generate employment until the late 1990s.

However, rising factor costs and the emergence of cheaper sites in China, Indonesia and elsewhere now threaten Malaysia's economic prospects. It does not seem feasible to rely on primary commodities to drive further rapid growth. Further diversification is likely to be difficult, flexibility is declining, costs are rising and several markets are becoming overcrowded. In manufacturing, sustained growth will require moving into more complex activities that can sustain high wages: design, development and innovation. That this can happen with FDI is not in doubt. Ireland and Singapore have raised

R&D by stimulating MNCs to undertake R&D locally and by offering other incentives to local institutions. However, this has been based on strenuous efforts to raise human capital – and this is where Malaysia is lagging.

The chapter is divided into four sections. Section 2 deals with industrial transition. Section 3 deals with FDI, and Section 4 with domestic supporting institutions. Section 5 draws the main conclusions and implications.

2. INDUSTRIAL TRANSITION

The institutional base for economic growth in Malaysia was laid under colonialism. Revenues from the primary sectors funded the infrastructure for manufacturing: railways, roads, wage labour, health and education, effective demand, administrative structure, and law and order. Primary processing, consumer and support manufacturing industries emerged before independence (Rasiah, 1995b: chapter 3). However, the government's pursuance of a generally laissez-faire approach to industrialization, and its concern with the extraction of primary resources, limited the large-scale development of modern manufacturing.

The institutional capacities built during colonial rule were sustained in independent Malaysia. Oil, timber and palm oil overtook rubber and tin as the most significant primary commodities from the 1980s. Tin fell into insignificance following the Malaysian Mining Corporation debacle in the early 1980s (see Jomo, 1990). R&D grew in the oil palm and petroleum industries. In-firm and research institutes such as the Palm Oil Research Institute of Malaysia (PORIM) were at the technological frontier in their activities, and oil palm research generated spin-offs as downstream processing developed (Chantasmary, 1994; Jaya Gopal, 1996). However, the slack demand in developed economies and the expansion of production in other economies in the late 1990s seriously undermined oil palm value-added. R&D in petroleum activities is still confined to process technology activities, generated largely from spin-offs from the foreign ventures of Shell and Exxon.[2]

The significance of primary sectors in the Malaysian economy shrank steadily from the 1970s, and accelerated in the late 1980s. Only petroleum and palm oil remain major primary exports in the 1990s. The engine of growth was manufacturing, which overtook primary commodities as the major export earner from the late 1980s and reached 77.5 per cent of total exports by 1997 (see Table 11.1). Its share in GDP, which had stagnated in 1960 and 1965 at 9.0 per cent (World Bank, 1985), grew rapidly from 13.9 per cent in 1970 to 35.4 per cent in 1998. Manufacturing overtook agriculture in employment generation, contributing 27.1 per cent to the national total compared to 17.0 per cent by the latter in 1997.

Table 11.1 Sectoral employment, output and export, selected sectors, 1970–98 (%)

	Employment				GDP				Export			
	1970	1980	1990	1997	1970	1980	1990	1997	1970	1980	1990	1997
Agriculture	–	39.7	19.9	17.0	29.0	22.9	14.6	11.8	63	n/a	21	19.0
Mining & quarry	–	1.7	0.5	0.4	13.7	10.1	7.5	7.0	30	n/a	14	3.4
Manufacturing	–	15.6	24.6	27.1	13.9	19.6	31.6	35.4	7	n/a	65	77.5

Source: Malaysia (1991; 1995; 1999); World Bank (1995: 191).

Table 11.2 Manufacturing export structure, Malaysia, 1968–97

	As share of total exports					
	1968	1973	1979	1985	1990	1997
Food	0.175	0.196	0.123	0.127	0.081	0.023
Beverage and tobacco	0.009	0.029	0.025	0.002	0.002	0.005
Textile and garment	0.014	0.061	0.072	0.1	0.105	0.048
Wood	0.034	0.097	0.043	0.028	0.031	0.041
Chemical	0.03	0.052	0.034	0.033	0.031	0.051
Rubber	0.009	0.017	0.016	0.009	0.012	0.025
Non-metal mineral	0.008	0.011	0.01	0.011	0.018	0.011
Iron and steel	0.005	0.019	0.015	0.01	0.014	0.010
Metals	0.658	0.433	0.307	0.14	0.042	0.036
Machinery	0.025	0.038	0.037	0.051	0.086	0.042
Electrical machinery	0.007	0.021	0.284	0.446	0.534	0.710
Transport equipment	0.026	0.027	0.033	0.043	0.045	0.031

Source: Computed from Malaysia, *External Trade Statistics*, 1969; 1974; 1980; 1986; 1991; 1998.

Manufacturing has, over time, undergone significant structural change, albeit in low value-added activities. The share of capital goods in manufactured exports (machinery, electrical machinery, transport equipment) rose from 5.8 per cent in 1968 to 8.6 per cent in 1973, 35.4 per cent in 1979, 54.0 per cent in 1985, 66.5 per cent in 1990 and 78.3 per cent in 1997 (see Table 11.2). Electrical and electronic products saw the fastest expansion, their share in manufactured exports rising from 0.7 per cent in 1968 to 71.0 per cent in 1997. Their share in employment and output rose from 2.0 and 8.0 per cent respectively in 1968 to 30.2 and 25.4 per cent respectively in 1990, and 29.7 and 30.0 per cent respectively in 1997. Electronics has been Malaysia's largest export since 1987, and Malaysia holds significant world market shares in several products. Consumer electronics, industrial electrical apparatus and semiconductors from Malaysia accounted for 17.9, 10.6 and 9.7 per cent respectively of world exports in 1995 (see Table 11.3).

However, increased export orientation has been accompanied by rising import dependency. The import dependency ratio[3] of the manufacturing sector has remained high. Imports as a share of domestic demand of the export-oriented (EO) industries of electrical machinery and textile and garment fell from 87.3 per cent and 78.9 per cent respectively in 1968 to 64.7 per cent and 41.6 per cent respectively in 1973. They then rose to 98.7 per cent and 63.5 per cent respectively in 1985 (see Table 11.4). The dependency ratio for textiles and garments rose further to 81.3 per cent in 1990. Higher

Table 11.3 Malaysia's share of world electrical and electronic exports, 1995

Category	Malaysia's exports (RM m.)	World market share (%)
Electrical appliances	2820	6.4
Electrical industrial apparatus	3477	10.6
Semiconductors	32844	9.7
Consumer electronics	21407	17.9
Telecommunications equipment	9445	2.5
Computers & peripherals	6099	1.9

Source: Malaysia (1999).

domestic sourcing marginally reversed these ratios for electrical machinery in 1990, while falling imports caused by the financial crisis helped improve the dependency ratio of both industries in 1997. However, the share of imports in domestic demand of both industries remained high in 1997. Both industries are now threatened, electronics by rising factor costs and textiles and garments by the impending removal of multi-fibre quotas that protected Malaysian exporters against cheaper competitors.

Rising incomes from commodity production and EO manufacturing stimulated the growth of domestic-oriented (DO) industries. Transport equipment, iron and steel, non-metal mineral products, chemicals, plastics, pottery and glass grew strongly as a result. Among these, highly protected industries (such as automobiles, iron and steel, cement and chemicals) enjoyed the highest expansion. The share of manufacturing value-added contributed by DO industries fell initially from 35.8 per cent in 1971 to 32.6 per cent in 1979, but rose sharply to 49.7 per cent in 1990 following strong state support. Their share fell slightly to 46.7 per cent in 1997 following rising factor costs and the financial crisis (see Rasiah, 2001: table 6). Growth in final demand durables such as automobiles did not much affect the efficiency levels of other industries directly as sales went more to final consumers. However, intermediate industries such as iron and steel and cement had substantial knock-on effects on user industries. Despite expansion, the limited evidence available does not suggest that these industries achieved significant efficiency improvements.[4] However, while DO industries grew strongly, the heavily protected heavy industries of iron and steel and transport equipment remained strongly import-dependent. The import dependency ratio of iron and steel, and transport equipment exceeded 50 per cent in 1997.

Domestic-oriented industries with declining protection (like glass,

Table 11.4 Manufacturing trade ratios, Malaysia, 1968–97

	(xi−mi)/(xi+mi)					
	1968	1973	1979	1985	1990	1997
Food	−0.562	−0.358	−0.274	−0.308	−0.163	−0.454
Beverage and tobacco	−0.752	−0.106	0.15	−0.8	−0.509	0.061
Textile and garment	−0.897	−0.482	−0.058	0.106	0.159	0.233
Wood	0.778	0.935	0.913	0.874	0.932	0.848
Chemical	−0.736	−0.628	−0.71	−0.721	−0.672	−0.040
Rubber	−0.149	0.23	0.47	0.113	0.342	0.754
Non-metal mineral	−0.665	−0.507	−0.335	−0.518	−0.038	−0.213
Iron and steel	−0.91	−0.78	−0.759	−0.826	−0.738	−0.709
Metals	0.707	0.627	0.57	0.252	−0.307	−0.147
Machinery	−0.824	−0.778	−0.706	−0.746	−0.573	0.023
Electrical machinery	−0.877	−0.723	−0.031	−0.037	0.1	−0.026
Transport equipment	−0.808	−0.813	−0.652	−0.624	−0.595	−0.561
	mi/(yi+mi−xi)					
	1968	1973	1979	1985	1990	1997
Food	0.623	0.51	0.227	0.234	0.277	0.220
Beverage and tobacco	0.221	0.188	0.17	0.12	0.141	0.177
Textile and garment	0.789	0.416	0.41	0.635	0.813	0.608
Wood	0.025	0.011	0.01	0.014	0.012	0.081
Chemical	0.03	0.023	0.017	0.006	0.009	0.052
Rubber	0.429	0.225	0.491	0.586	0.457	0.087
Non-metal mineral	0.129	0.094	0.068	0.052	0.093	0.280
Iron and steel	0.616	0.259	0.306	0.251	0.198	0.532
Metals	0.569	0.357	0.802	0.669	0.89	0.728
Machinery	0.82	0.64	0.685	0.948	0.806	0.729
Electrical machinery	0.873	0.647	0.669	0.987	0.902	0.827
Transport equipment	0.869	0.822	0.81	0.839	0.834	0.594
	xi/yi					
	1968	1973	1979	1985	1990	1997
Food	0.316	0.329	0.143	0.139	0.216	0.096
Beverage and tobacco	0.039	0.157	0.217	0.015	0.051	0.196
Textile and garment	0.17	0.199	0.382	0.683	0.857	0.714
Wood	0.17	0.257	0.176	0.17	0.254	0.516
Chemical	0.179	0.275	0.235	0.098	0.196	0.048
Rubber	0.017	0.032	0.055	0.041	0.094	0.406
Non-metal mineral	0.088	0.096	0.114	0.084	0.246	0.201
Iron and steel	0.167	0.167	0.24	0.084	0.15	0.162
Metals	0.889	0.612	0.919	0.73	0.604	0.419
Machinery	0.506	0.408	0.488	0.917	0.819	0.373
Electrical machinery	0.16	0.11	0.728	0.99	0.94	0.819
Transport equipment	0.393	0.287	0.398	0.394	0.419	0.292

Source: Computed from Malaysia, *External Trade Statistics*, 1969; 1974; 1980; 1986; 1991; 1998; Malaysia, *Industrial Surveys*, 1969; 1974; 1980; 1986; 1991; 1998.

pottery, non-metal mineral products) improved their performance, but their share in manufacturing production is very small. The capacity of the main automobile manufacturers (Proton and Perodua) to face international competition is still in doubt, following the government's decision to defer related AFTA (Asian Free Trade Agreement) deregulation for 2003–2005. The government still maintains domestic content provisions for the industry. Thus, the automobile industry is likely to face serious pressures once the liberalizing currents of the WTO force the removal of tariffs and non-tariff barriers and local content rules.

The trade balance coefficient ($[xi-mi]/[xi+mi]$) of the highly import-dependent DO industries has improved since 1990. However, transport equipment, chemicals, machinery and iron and steel, with protected markets, remain strongly dependent on domestic demand. Chemical exports had the smallest share of output, while the transport equipment and iron and steel sectors, despite extensive subsidies, exported only 29.2 and 16.2 per cent of output in 1997 (see Table 11.4). The export ratio for transport equipment fell sharply between 1990 and 1997 following a decline in car exports to the United Kingdom. The trade balance for electrical machinery improved till 1990, but deteriorated by 1997.

Despite rapid growth (or perhaps because of it) EO industries have not expanded domestic linkages greatly. The legacy of the enclave nature of early export-oriented production persists, despite government efforts to raise local content. The reasons lie in rapid technological change, weak institutional support within Malaysia and inappropriate technology development strategies. Imports of inputs for the manufacturing sector rose at an average annual rate of 41.2 per cent in the period 1987–91, accounting for 50 per cent of total investment goods in 1991, compared to 43 per cent in 1986 and 36.4 per cent in 1980. Subsequently, imported inputs grew at around 15 per cent during 1991–95, accelerating towards the end of the period (32.7 per cent in 1994 and 31.0 per cent in 1995). Almost 66 per cent of exported manufactured goods had import content ratios exceeding 50 per cent.

While Malaysia has achieved rapid growth, structural change in products has not been matched by a similar upgrading in *functions*. It remains specialized in low value-added functions within high-tech activities, but this appears to be reaching its limits as wages and other costs rise. Growing deficits in skill and innovation are weakening the foundations of long-term growth. The inability to move into higher value-added activities has forced the government to allow the use of cheap foreign labour, which now forms about 15–25 per cent of the labour force.

3. FOREIGN DIRECT INVESTMENT

Developing countries have long feared that FDI saps domestic savings, crowds out local enterprises and stunts domestic technological capabilities (Rasiah, 1995b: chapter 2). Japan, Korea and Taiwan are often cited as successful examples of countries that restricted FDI (Hamilton, 1983; Amsden, 1989; Wade, 1990) to build strong domestic capabilities, Brazil and Mexico as examples of underdevelopment caused *inter alia* by heavy reliance on FDI (Frank, 1972). This section draws the lessons of the Malaysian experience.

FDI has been the engine of manufacturing growth in Malaysia. Table 11.5 shows the shares of fixed assets held by foreign investors by industry. These shares have risen continuously in key industries like electrical machinery (the slight rise in local shares in 1998 is a result of a decline in FDI participation rather than a rise in local investment).[5] Technology spillovers from FDI – through work experience, employee turnover and rising domestic capabilities – have helped the growth of locally dominated

Table 11.5 Foreign fixed assets ownership, Malaysian manufacturing, 1970–98 (%)

	1970	1975	1980	1985	1990	1993	1998
Food	71	55	32	25	30	33	27
Beverages and tobacco	89	79	76	67	62	58	69
Textiles	39	63	54	48	61	64	76
Leather	56	48	48	54	59	57	61
Wood	11	8	13	9	19	36	27
Furniture and fixtures	71	61	31	19	45	45	25
Paper, printing, publishing	n/a	16	10	20	14	13	10
Chemicals	61	63	53	16	24	25	46
Petroleum and coal	77	79	78	37	44	50	34
Rubber	14	42	46	42	55	51	50
Plastic	n/a	n/a	12	13	27	46	38
Non-metal mineral	60	52	19	32	33	39	34
Basic metal	45	42	35	32	17	33	30
Fabricated metal	69	59	26	23	30	56	36
Machinery	58	51	42	35	53	65	66
Electric/electronics	67	84	80	73	89	91	83
Transport equipment	58	51	32	15	25	35	29
Miscellaneous	67	69	57	53	69	81	56
Manufacturing	59	52	39	33	42	50	47

Source: Rasiah (1995b); data for 1993 and 1998 based on unpublished MIDA data.

industries like food processing, furniture and fixtures, petroleum and coal products, non-metal minerals, fabricated metals and transport equipment. In some domestic-oriented industries, like pottery, glass and non-metallic mineral products, there has also been a rise in local technological capabilities, although these are largely limited to production rather than innovation. Wood-based products had a rise in foreign ownership primarily following entry by Taiwanese and Japanese firms selling to their home countries.

Foreign firms continue to dominate the electrical machinery, scientific instruments, beverages and tobacco and textile and garment industries. They have also increased their share of the rubber products industry (from 14 per cent in 1970 to 50 per cent in 1998), primarily through investments in glove manufacturing. All foreign dominated industries except for beverages and tobacco are export-oriented, with the prime market destinations being the developed economies. Foreign ownership in these sectors is likely to rise further after policy liberalization following the financial crisis of 1997 (with the government trying to revive FDI) and compliance with WTO requirements.

FDI has played a critical role in Malaysia in terms of generating employment, investment and exports and in raising the skills of the labour force. It has also led to many spin-offs in sophisticated activities, especially in Penang. Rasiah (1994; 1995b), and Lai and Narayanan (1998) document the synergies generated by MNCs that transformed local clusters. For instance, the integration of Toyota's multi-product single flow line with 'lean production' and just-in-time delivery had significant spillover effects, especially in the western corridor of Peninsular Malaysia. Where strong integrated business networks emerged, as in Penang, MNC activity led to considerable local sourcing (see Rasiah, 1996; 2000). The number of firms supplying metal and plastic tooling and components to the electronics industry rose from around 150 firms in 1989 to around 455 in 1993.[6] However, in other states, weak business networks restricted the creation of new firms and backward linkages by MNCs.

MNCs were also training grounds for entrepreneurship and other skills. A whole range of enterprises was started by individuals who had worked in MNCs. Examples include Polytool, Prodelcon, Rapid Engineering and Metfab whose founders came from Micro Machining, and Shinca, Shintel, Globetronics and Sanmatech whose managing directors came from Intel (Rasiah, 1994; 1996). In addition, the Penang Development Corporation (PDC) played an important role in bringing MNCs and local firms together. It also supported the Penang Skills Development Centre (PSDC), which brought firms together to provide specialized industrial training geared to specific needs, particularly those of the electronics industry.

4. DOMESTIC SUPPORT INSTITUTIONS

Malaysia was successful in establishing the institutional base of political stability, basic infrastructure and an investment climate to stimulate labour-intensive FDI. The Malaysian Industrial Development Authority (MIDA) and to a lesser extent the Penang Development Corporation (PDC) played exemplary roles in attracting large FDI inflows into EO manufacturing. As noted, however, institutional and capability development could not keep up with the need to move the industrial structure from low value-added to high value-added functions. MNC-led structural change has slowed down as cheaper sites like China, the Philippines and Indonesia have emerged as serious competitors.

Institutional support is essential to allow firms to shift to higher value-added processes – it is not economic for firms to invest in improving factor markets beyond their immediate production needs. Moving into design and innovation requires an ample supply of technical and engineering manpower. It also calls for effective state–business relations to facilitate investment in activities with longer pay-off periods.

Human Capital

Human capital development in Malaysia has evolved unevenly. While general schooling facilities have grown, they lag behind other rapidly industrializing countries in tertiary and technical fields. This weakness has restricted firms' efforts to shift to more skill-intensive stages of production. For example, drawing on a survey of 2200 firms, Rasiah and Osman (1995: table 1) report labour supply and workers' quality as the prime deficiencies confronting manufacturing firms in Malaysia. The high wage premium enjoyed by skilled occupational categories reflects serious skill shortages (World Bank, 1995). The sector also faces serious shortages in science and engineering employees, critical to drive innovations. All 231 firms interviewed in 1996 considered the shortage of skilled workers as their biggest problem.[7]

The critical nature of this problem becomes clearer when comparisons are made across economies. Malaysia's participation rates in education fall short of Korea and the developed economies, especially at the tertiary level (see Table 11.6). It had only 2 per cent secondary students enrolled in technical fields compared to 19 per cent in Korea (see Table 11.7). Even Indonesia – which is far less developed than Malaysia – had a 12 per cent share of secondary students in technical education. Systematic governmental promotion of technical education in Taiwan led to the transformation of the ratio of vocational high school (VHS) graduates to academic high

Table 11.6 Educational enrolment, selected economies, 1970–92

	% of age group enrolled in educational institutions					
	Primary		Secondary		Tertiary	
	1970	1992	1970	1992	1970	1992
Japan	99	102	86	n/a	31	32
United States	n/a	104	n/a	n/a	56	76
Sweden	94	101	86	91	31	34
Germany	n/a	107	n/a	n/a	27	36
France	117	106	74	101	26	46
Canada	101	107	65	104	42	99
United Kingdom	104	104	73	86	20	28
Korea	103	105	42	90	16	42
Turkey	110	112	27	60	6	15
Brazil	82	106	26	39	12	12
Malaysia	87	93	34	58	4	7
Thailand	83	97	17	33	13	19
Indonesia	80	115	16	38	4	10
Jamaica	119	106	46	62	7	9
Kenya	58	95	9	29	1	2
Bangladesh	54	77	n/a	19	3	4

Source: World Bank (1995: 216–17).

school (AHS) graduates from 1:1.7 in 1950 to 1:1 in 1975 and 2:1 in 1988 (Lee, 1994: 5–6).

The government has launched several efforts to raise the supply of skills. It introduced the Double Deductions on Training Incentive (DDTI) in 1988 to encourage in-house training in firms. The Human Resource Development Fund (HRDF) replaced the DDTI in 1993. The DDTI, which applied to manufacturing firms with over 50 employees, was generally utilized by MNCs that would have trained their workers even in its absence (Rasiah and Osman, 1995). The HRDF imposed a levy of 1 per cent of enterprise payrolls, which firms could reclaim for approved training expenses, and penalized firms that did not train in line with specified conditions. The main problem now is the absence in several locations of training institutions; firms in Sabah and Sarawak are particularly disadvantaged.

The government introduced special directives and incentives in the mid-1990s to expand the supply of science and technology graduates. Training suppliers at all levels were expanded and modernized. The Private Universities Bill of 1995 helped open the way for new universities, especially in engineering. It is too early to judge these new initiatives.

Table 11.7 Public education and technical orientation, selected economies

	Public education (% of GNP)		Secondary technical enrolment (% of all levels)	Tertiary natural and applied sciences enrolment (% of total tertiary)	Science graduates (% of total graduates)
	1960	1990	1988–91	1990–91	1988–90
Japan	(4.9)	3.7(5.0)	28	26	26
United States	(5.3)	5.5(7.0)	n/a	14	15
Sweden	5.9	6.5(6.5)	73	43	26
Germany	(2.4)	4.0(5.4)	80	42	32
France	(3.6)	5.4(6.0)	54	31	27
Canada	(4.6)	(7.4)	n/a	14	16
United Kingdom	3.4	5.3	20	39	26
Korea	2.0	3.6	19	42	29
Turkey	2.6	n/a	25	33	36
Brazil	1.9	4.6	n/a	31	19
Malaysia	2.9	6.9	2	30	28
Thailand	2.3	3.8	19	22	18
Indonesia	2.5	n/a	12	n/a	11
Jamaica	2.3	6.1	4	35	19
Kenya	4.6	6.8	2	32	24
Bangladesh	0.6	2.0	1	27	16

Note: Figures in parentheses to total educational investment as a percentage of GNP.

Source: UNDP (1995: 158–9, 192–3).

Private initiatives to boost training followed the incentives offered by the government. The PSDC, founded in 1989 and coordinated by MNCs, local firms and the Penang Development Corporation, created skills tailored to cutting-edge production operations and subsequently became a model for training institutions in the western corridor states. The political structure of Penang, with strong relations between businesses and the government, has ensured effective state–business coordination to minimize both government and market failures (Rasiah, 1997). However, not many other states have this political structure.

Table 11.8 High-technology exports and patent application filed

	1996 High-tech export in manufactured export (%)	1995 (A) Residents	Non-residents	1995 Total of (A) as % of Japan
Malaysia	67	141	3911	1.0
South Korea	39	59249	37308	24.8
Singapore	71	10	11871	3.1
Thailand	36	n/a	n/a	n/a
Indonesia	18	n/a	n/a	n/a
China	21	10066	31707	10.7
India	10	1545	5021	1.7
USA	44	127476	107964	60.5
Japan	39	335061	53896	100.0
United Kingdom	40	25355	90399	29.8
Germany	25	51948	84667	35.1
France	31	16140	73626	23.1
Spain	17	2329	68922	18.3
Sweden	31	6396	64165	18.1
Jamaica	67	7	54	0.0

Note: n/a – not available.

Source: Calculated from World Bank (1999: Table 19).

Patents and Participation in R&D Activities

Malaysia has an extremely low level of domestic patent filing: only 4052 compared to 11881 in Singapore, 96557 in South Korea, 388957 in Japan and 235440 in the USA in 1995 (Table 11.8). The number of patents filed in Malaysia came to 1 per cent of the number in Japan in 1995, Korea's figure was 24.8 per cent. A significant number of technologies patented in Malaysia by non-residents are not developed in Malaysia.[8] The patent statistics reflect the low investment by private enterprises in R&D. Private sector expenditure on R&D only came to 0.17 per cent of GNP in 1992 (MASTIC, 1994).

While MNCs do not invest heavily in R&D in overseas affiliates, particularly in developing countries, the Malaysian data do not suggest that local firms spend much on R&D either. Table 11.9 shows that the foreign-dominated electrical machinery industry had the highest investment in R&D. However, MNC R&D consisted mainly of redesigning mature prod-

Table 11.9 R&D in selected industries, Malaysia, 1992 (RM million)

Industry	Local[a]	Foreign[b]	Total
Electrical/electronics	9.7	102.7	112.4
Transport equipment	82.0	0.0	82.0
Food	14.8	1.3	16.1
Rubber	1.2	1.4	2.7
Textiles	0.4	0.4	0.9
Chemicals	1.9	11.7	13.5
Total	123.7	122.6	246.3

Notes:
[a] local ownership exceeding 50 per cent.
[b] foreign ownership exceeding 50 per cent.

Source: MASTIC (1994).

ucts and minor process improvement. Only a handful of electronics firms undertook *product* (largely incremental) R&D, all of which were locally owned (for example, OYL Electronics and Sapura). Despite extensive investment in R&D, Proton's capabilities are still largely limited to body design and parts. Its latest car, the Proton Waja still uses a Mitsubishi engine for the 1.6cc model, and will use a Renault engine for the 1.8cc model.

A survey by Rasiah (1996) of 82 electronics firms in 1993 (29.3 per cent of firms in the industry) showed that only 9 undertook formal R&D. The one local firm that reported new product development in 1993 noted that its electronics business had declined in 1999. Most firms were engaged in product enhancement, extension, customization or redesign. Twenty-one firms undertook process R&D, of which 18 firms were foreign controlled. A higher share of firms, 73 out of 82, reported incremental engineering improvements without significant formal R&D. Foreign controlled firms accounted for 64 of the firms reporting minor innovation.

There are two major reasons for these findings. First, the reason for incremental rather than innovative R&D lies in the nature of electronics markets. Rapid product innovation in developed countries means that affiliates in developing countries cannot undertake significant product innovation. Nor do they need to adapt products to local market needs, since products are highly standardized. At the same time, there is a need for technological effort to adapt production processes as new technologies appear. Second, Malaysian affiliates are now able to undertake process development. The labour force has undergone considerable learning over the past

20–25 years, and has a cadre of engineers and technicians able to do applied R&D.

However, no electronics firm – local or foreign – has undertaken frontier 'blue-sky' research in Malaysia. Even the most sophisticated design activities in foreign firms have generally been limited to second or third generation technologies, to improve performance and expand uses for maturing products. Intel, AMD and Alterra are examples of MNCs engaged in the redesigning of mature products.

Technology Transfer Agreements

Technology transfer agreements (TTAs) have been a major source of technology acquisition in all developing countries. In Malaysia, the official promotion of technology transfer can be traced to the Industrial Coordination Act (ICA) of 1975. The ICA acted, *inter alia*, as the legal framework for registering formal technology imports. The electrical and electronics industry was the biggest importer of technology through TTAs (see Table 11.10); Japan was the largest supplier.

While industrial activity in Malaysia became more technology-intensive from the end of the 1980s (Rasiah and Anuwar Ali, 1995), the government did not undertake policies to build local innovative capabilities. In this, it differed greatly from Korea and Taiwan, where there was a deliberate and widespread effort to transfer and build such capabilities. The only regulatory activity in Malaysia was vetting of TTAs *ex ante*, and even this was poorly performed because of the absence of suitable skills (Anuwar Ali, 1992). There was no preference for technology transfers to local firms; around 90 per cent of TTAs in manufacturing involved intra-MNC transfers.[9] Only a few industries such as passenger cars had strong local–foreign TTAs.

There was virtually no monitoring and appraisal of technology transfers *ex post*. Institutions governing technology transfer agreements, especially MITI, showed little appreciation of technology development issues, and did not bargain over the terms of transfer. Unlike Japan, Korea and Taiwan, therefore, FDI continues to dominate TTAs in Malaysia without significant levels of local absorption or deepening. Hence, the relative fall in FDI inflows from the late 1990s led to a visible fall in TTAs (Table 11.10).

R&D Support

The sustainability of rapid growth in Malaysia will depend considerably on firms' capacity to deepen their technological capabilities and conduct more R&D. As noted above, Malaysia lacks the critical mass of human capital

Table 11.10 Technology transfer agreements by industry, Malaysia, 1975–2000

Industry	1975–77	1978–80	1981–83	1984–86	1987–89	1990–92	1993–95	1996–98	1999–2000
Electrical machinery	31	55	50	53	106	124	143	132	91
Chemical	7	38	41	48	74	64	54	35	43
Transport equipment	9	22	34	52	20	62	56	48	30
Fabricated metal	16	29	43	34	45	33	20	12	10
Food	13	24	40	24	45	12	15	6	6
Rubber	7	15	23	22	48	26	16	13	8
Non-metallic mineral	8	13	29	31	26	26	17	7	7
Basic metal	8	15	28	7	8	13	9	5	8
Textile and garment	15	12	12	14	12	20	7	2	4
Plastic	3	8	9	11	8	17	22	7	18
Wood	11	9	5	10	1	11	4	0	0
Paper	0	0	0	7	4	10	8	2	1
Others	16	43	42	25	61	42	45	40	31
Total	144	283	356	338	458	460	416	309	257

Source: MIDA (unpublished data).

required to support extensive R&D activity. The share of graduates and students enrolled in science and technical fields is well below figures in the industrialized economies and the Asian NIEs (Table 11.11). Malaysia only had 4 R&D scientists and technologists per 10000 people compared to 22 in Korea in 1988–90 (Table 11.12). R&D spending in 1992 was only 0.4 per cent of GNP compared to 2.1 per cent in Korea.

Table 11.11 Scientists and engineers/population

Country	Year	Per 10000 pop.	24-year-olds with National Science and Engineering degree (%)
Japan	1993	43	6.4
United States	1991	38	5.4
Norway	1992	32	4.4
West Germany	1989	28	5.8
Taiwan	1993	26	6.4
Singapore	1992	23	7.6
Denmark	1991	23	6.5
France	1991	23	5.0
United Kingdom	1992	22	n/a
South Korea	1993	22	7.6
Italy	1991	13	2.5
Mexico	1990	7	n/a
China	1993	3	1.3
Malaysia	1994	2.3	0.8

Sources: National Science Board (1996: pp. 3–25; 1998: Appendix table 2.1); MASTIC (1994: table 3–19).

The depth and width of R&D is generally a function of the structure and level of development of an economy (Rasiah, 1997). Malaysia's industrial structure – especially in terms of the dominance of electronics assembly activities – appears more knowledge-intensive than that of Taiwan and Korea, but lags in terms of technological effort. Most firms are engaged in simple manufacturing and do not have serious plans to move up the technological ladder; most do not seek R&D support or employ R&D scientists and technologists (Selvaratnam et al., 1996).

High-technology MNCs in Malaysia rely on parent company innovation for their basic technologies. Most retain their key innovation in the USA, Western Europe and Japan. This reliance helped Malaysia greatly in early stages of industrial development, but the stage has now come for it to launch – and attract – more innovative activity.

Table 11.12 Research and development statistics

	Scientists and technologists per 1000 people 1986–90	R&D scientists and technologists per 10000 people 1986–89	R&D expenditure as % of GNP 1987–92
Japan	110	60	2.8
United States	55	n/a	2.9
Sweden	262	62	2.8
Germany	86	47	2.9
France	83	51	2.3
Canada	174	34	1.4
United Kingdom	90	n/a	2.3
Korea	46	22	2.1
Turkey	26	4	n/a
Brazil	30	n/a	0.6
Malaysia	n/a	4	0.4
Thailand	1	2	0.2
Indonesia	12	n/a	n/a
Jamaica	6	0	n/a
Kenya	1	n/a	n/a
Bangladesh	1	n/a	n/a

Sources: UNDP (1995); MASTIC (1994).

R&D Funding

The Malaysian government has set up a number of special programmes to fund R&D activities. The Intensification of Research in Priority Areas (IRPA) and Industrial Technical Assistance Fund (ITAF) offer funding for innovation. The Malaysian Technology Development Corporation (MTDC) has been introduced to fund promising firms to expand their technological capacities; by the end of 1993 it had invested RM16 million in 12 firms (Malaysia, 1994a: 300, 303). The Credit Guarantee Scheme – operated by the *Bank Negara* – allows small and medium enterprises to access loans at subsidized rates without commensurate collateral. Much of the internally generated savings from wage income, including employee provident fund contributions, have been directed to government funding. A proportion of household investments have been absorbed into *Bumiputera* trusts – *Amanah Saham Nasional* and *Amanah Saham Bumiputera* – through *Permodalan Nasional Berhad*. Some of these funds are targeted to innovative activities.

However, the allocation of funds has not been coordinated and directed effectively to innovative activities. A major drawback is the lack of funding for innovators lacking collateral. Venture capital is poorly developed in Malaysia because of the continued reliance on pecuniary collateral. As Timmons and Bygrave (1986) note for Silicon Valley, identifying and establishing contacts with entrepreneurs rather than access to capital is the most important factor in the successful allocation of venture capital. Business networks linking capital to prospective innovators remain underdeveloped in Malaysia. The most advanced form of network cohesion has emerged in Penang, but it is confined to inter-firm and firm–institution links.

Complementary Business and Technical Support

The Malaysian government has set up sectoral institutions to promote innovation. These include the Malaysian Institute of Microelectronics Systems (MIMOS),[10] 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 provide quality assurance and testing and later took on the task of improving productivity. From the late 1980s SIRIM has attempted to propagate quality establishment and improvement in firms. Hundreds of Malaysian firms have been accredited with ISO 9000 standards to enhance their export potential. SIRIM has played a particular role in upgrading quality in locally controlled firms that do not face external competition.

'Malaysia Incorporated' was launched in 1983 to improve government–business coordination. Government officials were sent to Japan and Korea to understand better their collaborative mechanisms. Consultative committees were formed between the public and private sectors. A broad collaborative umbrella, the Malaysia Industry–Government Group for High Technology (MIGHT), was launched in 1993 to promote technology prospecting and help identify new markets, businesses and investment opportunities for R&D and technology development. These efforts suffer from some flaws. First, insufficient effort has been made to involve the private sector. Officials representing the private sector in consultative committees have been appointed following their retirement from public service. Second, there is little effective participation of governmental officials in the private sector, as their role is not clearly defined. Third, most public sector officials seconded to the private sector have generally been appointed to parastatals. Even here, not many have been involved in the business and technical aspects of production.

Small and Medium Enterprise Support Programmes

Three programmes have been introduced to stimulate the growth of SMEs. The Umbrella Concept of Marketing (UCM) was launched in 1984; Besta Distribution, Guthrie Furniture and Guthrie Malaysia Exchange Programme were the pioneers, acting as marketing support organizations for *Bumiputera* SMEs. The remaining two programmes, the subcontract exchange (SEP) and anchor company (ACP) programmes were introduced in 1986 and 1992. *Bumiputera* equity has been strongly emphasized in ACPs involving state-sponsored firms such as Proton, which were supposed to provide special help to linked SMEs. The SEP acted as a platform for matching MNCs with local SMEs. SMEs were also encouraged to access the ITAF, launched in 1990 to facilitate feasibility studies, product development and design, productivity and market development (Malaysia, 1994b). SMIDEC was formed in 1995 to coordinate and facilitate the development of SMEs in the country.

Despite such support, SMEs have yet to develop effective capabilities outside Penang (Anuwar Ali, 1992; Rasiah and Anuwar Ali, 1995). Production linkages have been strongest in state-sponsored anchor firms, but even here linkages have been rather superficial. For example, Proton was reported to have sourced 80 per cent of its components locally in 1995–2001; this figure could dip below 30 per cent if imports by local supplier firms are taken into account.[11]

There are a number of reasons for the weakness of SME support mechanisms. First, a significant number of SMEs were jump-started to boost *Bumiputera* participation in industry. Their lack of entrepreneurial experience has often led to poor management. Second, captive rents offered to state-sponsored anchor firms were not tied to performance standards. Hence, there was little pressure or competition to improve efficiency and poor performers continued to be supported by anchor firms at the expense of their own competitiveness. Third, the 30 per cent domestic content condition for firms applying for pioneer status and investment tax allowance was not applied to strategic industries. Fourth, the 30 per cent sourcing condition also applied to foreign firms, and several MNCs met the requirement by purchasing from their subsidiaries in Malaysia. Fifth, government participation in spin-offs to match the SMEs with transnationals was not strong, with the exception of Penang. Many such linkages have generally emerged in the electronics, machine tools and plastics industries where, as noted, the need for flexibility strengthened production linkages between foreign and local firms (Rasiah, 1994; 1996). From 45 firms in 1989, the number of such suppliers rose to 250 in 1993 and 455 in 1996.[12] As with PSDC, the Penang

Development Corporation was an important intermediary in stimulating such developments.

Industrial Master Plan

The government launched the second Industrial Master Plan (IMP2) in 1996, basing it on cluster-based development (Malaysia, 1996b). The earlier Industrial Master Plan, launched in 1986, was sector-based. While IMP2 was a refreshing effort to use production and network interrelationships, the strategy lacks the effective technology management seen in Silicon Valley (see Rasiah and Best, 2000). The plan relies essentially on network synergies, strengthening component firms and assisting in restructuring of existing firms and the creation of new firms. Its logic can be traced to Young's (1928) work re-emphasizing Adam Smith's (1776) dictum that the division of labour is determined by the size of the market. Young argued that the division of labour in turn determined the size of the market: increased differentiation, division of labour and specialization generated synergies that expanded markets. It is here that the IMP2 lacks a realistic strategy to stimulate the production capabilities necessary to intensify differentiation, division of labour, specialization and horizontal integration. If clustering requires cross-industry links, the IMP2 retains much of the sectoral strategies associated with IMP1.

Technology Parks and the Multimedia Super Corridor

Technology parks have sprung up in Malaysia since the late 1980s, but they show little evidence of dynamism. Aggressive promotion by the government, including direct approaches to selected MNCs, has helped attract firms into the Technology Park at Bukit Jalil and the High-Tech Park at Kulim. However, the majority of these firms have yet to invest in technology development. Unlike the Hsinchu Science Park in Taiwan, where effective coordination has led to intense technological activity, the rush to fill space in Malaysia seems to have attracted firms only interested in minor process improvements. On present trends, most innovation in the country will be undertaken outside technology parks. Local firms – especially those backed by the government – are likely to operate there but without significant movement towards the technology frontier.

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

A major effort to enhance technological deepening in the information technology (IT) sector has been the Multimedia Super Corridor (MSC). This was envisioned as a cluster of information technology development institutions and firms located in the corridor between Kuala Lumpur and a new administrative centre in Putra Jaya. This community was to be served by a world-class telecommunications and information technology infrastructure, with liberal investment incentives for approved projects and streamlined procedures for foreign technical experts and the training of local personnel. The government revised the legal and administrative barriers viewed as impediments to new applications of technology and to foreign investment in technology development.

Substantial efforts have been made in selling the MSC concept to leading IT firms in North America, Europe and Japan. There has been some initial interest. The technologies 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 to focus the energies of private individuals, the corporate sector and the public sector on the tasks ahead.

However, interviews suggest that little R&D is being undertaken in the MSC because of the lack of human capital and innovation synergies. Malaysia would have to conduct another major restructuring if the MSC is to catalyse the nation's technology base. The entire resources of the nation, with particular emphasis on education, would have to be deployed efficiently to make the MSC the engine of Malaysia's development.

In sum, Malaysia has set up a wide array of institutions to stimulate industrial upgrading and technology development. MIDA and PDC have stimulated rapid manufacturing growth, but mainly in low value-added activities. The rise in factor costs has not engendered a corresponding growth in innovation capabilities. The government, acutely conscious of the problem, has launched several initiatives to facilitate upgrading and deepen technological activity. However, the new initiatives and institutions have still to bear fruit.

5. CONCLUSIONS AND IMPLICATIONS

Export-oriented manufacturing in Malaysia, while highly successful for several decades, is running out of momentum. Cheaper sites are emerging and rising costs are not being sufficiently offset by a move into higher value-added functions. Access to external technology by FDI continues to drive export-oriented activities, especially in the high technology but low value-added activities. The expansion of resource-based palm oil, where Malaysian companies operate at the technology frontier, was successful until a glut in the world market caused by competing producers. In any case, stagnating demand in developed economies limits further growth of such exports.

The experience of import-substitution in Malaysia has been different from that in other economies. High protection in some industries like automobiles has not had serious effects on other industries because they serve final consumers. EO manufacturing has been allowed to operate in a separate trade regime that has not undermined its efficiency. However, other heavy IS industries have not been very successful, and many firms have been unable to reach world levels of technical efficiency. Even in automobiles, key technologies are controlled by foreign companies and the licensing costs involved have kept tariffs very high. The industry will come under severe competitive pressure under WTO rules, and may not be able to survive in the long term.

What lessons do Malaysian industrial growth and competitive success offer? First, political stability and a pro-private business environment are necessary to ensure that production and trade can grow (and attract FDI). Second, resource-based exports should be diversified. Unlike many resource-rich countries (in Africa or Latin America), Malaysia resolved problems of declining terms of trade and current account deficits by diversifying commodity exports. These then provided the foreign exchange and savings needed for infrastructure development and industrialization. Third, financial incentives can be useful to attract FDI. In Malaysia, they were used to offset some of the risks associated with instability – Malaysia had just come out of bloody ethnic riots in 1969 when the first wave of EO manufacturing FDI arrived in the early 1970s. Finally, countries that are successful in attracting labour-intensive FDI must ensure that over time, as wages rise, they provide the skills and capabilities needed to take on more value-added functions and activities. Malaysia has so far not been able to move into high value-added innovation-driven operations rapidly enough to overcome emerging competitive threats.

Thus, good physical infrastructure, a sound framework for orderly business transactions (including protection for foreign investors) and political stability helped attract EO FDI, which then led manufacturing expansion in Malaysia. Growing incomes from resource exports and EO manufacturing raised domestic demand for IS industries like steel, cement and cars. Since domestic savings levels were high, FDI contributed more in terms of employment generation, skill formation and export expansion. These lessons are still relevant to most developing countries. However, the situation regarding the spread of electronics MNCs looking for cheap assembly sites has changed. Such sites are relatively well established now, and it is unlikely that many other countries (China excepted) will be able to capitalize on them in the way Malaysia did. In addition, rapid technological progress has made several formerly labour-intensive industries knowledge-intensive, making it more difficult for less-developed economies to find an export niche. Hence, Vietnam and Indonesia are unlikely to attract much activity in electronics industries, despite rising wages in Malaysia.

A number of the instruments used by Malaysia and other East Asian countries will no longer be permissible in the new global environment. Domestic linkages can no longer be stimulated by local content requirements. Infant industries can no longer be offered protection. Export subsidies and requirements will not be permissible. In Malaysia, the share of foreign equity ownership was made contingent on exports; such discriminatory treatment of foreign firms will no longer be permissible. Technological arrangements under the Trade Related Intellectual Property Rights (TRIPs) have similar provisions, restricting the ability of developing countries to imitate or reverse-engineer foreign technologies. This will close an avenue for technology development that proved invaluable to NIEs like Korea and Taiwan (and several rich countries at critical stages of their industrialization processes).

The liberalization of world markets and the ending of the Multi-Fibre Agreement (MFA) quotas will open up new markets to developing country producers. However, the benefits are likely to be very unequally distributed. Only countries with strong capabilities and cluster potential are likely to benefit. In the high-technology area, such a structure is emerging in Penang but it lacks innovation and systems integration tendencies. Developing economies have to launch strategies to create cluster dynamics if they are to attract FDI and benefit from the resulting agglomeration and learning economies.

The Malaysian experience suggests that it is critical for policymakers to focus on the creation and sustenance of human capital coordinated with firms' capability building. There are two issues here. The first concerns skill formation and the second the development of new entrepreneurs. The first involves institutional development on a national scale, so that the education and training system can create the requisite human capital. The second involves creating an enabling framework for entrepreneurs to start new firms. The open system framework of Penang resembles Silicon Valley except that it has not absorbed the product innovation capabilities pioneered by Canon and Intel's systems integration business model. The open systems framework of Penang has led to professionals entering firms and leaving them to open new businesses. An integrated business network linking MNCs, local firms, chambers of commerce, political institutions and the community has stimulated the continuous creation of new firms. This is generally missing in other locations in Malaysia.

The Malaysian experience also shows that MNCs are unlikely to invest in building local capabilities and institutions when they cannot appropriate the returns fully and when they do not have effective control over their coordination. There is thus a need for significant government intervention to overcome market failures and to resolve collective action problems. The Penang government played an exemplary role in subsidizing and promoting the PSDC to resolve collective action problems on the supply of training. MNCs participated but only after the Penang Development Corporation took the lead by subsidizing PSDC operations.

Finally, developing economies, even though they do not seek to push back frontiers of knowledge, must invest in R&D activity. Expanding the base of high-level technical skills is critical. It is also important for R&D institutions (including universities) to establish closer coordination with firms. At the enterprise level, firms must be encouraged to engage in product and process development and research. A comprehensive strategy to address all these needs is essential if growth is to be launched and sustained.

NOTES

1. Professor and Senior Research Fellow, UNU-INTECH, Maastricht. Comments from Sanjaya Lall in particular were very useful in the revision of this paper. I am also grateful to Farukh Iqbal, Migara De Silva, Sujiro Urata, Linsu Kim, Peter Brimble and Frederich Sjoberg for their comments. The usual disclaimer applies.
2. Interviews conducted in 1995.
3. The import dependency ratio is measured as $((mi/(yi+mi-xi)$, where mi, xi and yi refer to import, export and gross output of the ith industry.
4. Most studies on effective rates of protection, and profits adjusted to account for protection involving state supported industries are still classified as confidential.
5. Drawn from figures supplied by MIDA officials.
6. Fieldwork by Rasiah (1994).
7. This unweighted sample had firms from all industries at the 3 digit standard industrial classification (SIC) level, located in all states except for Kelantan, Terengganu, Perlis and the federal territory of Labuan.
8. Interviews with 15 managing directors from the electronics industry.
9. Interview conducted by the author in 1994.
10. Placed initially under the Prime Minister's department, MIMOS was subsequently moved to the Science, Technology and Environment Ministry until its recent corporatization.
11. Interviews by the author in 1994.
12. Traced by the author in the respective years. The actual number can only be more.

REFERENCES

Amsden, A. (1989), *Asia's Next Giant*, New York: Oxford University Press.

Anuwar, Ali (1992), *Malaysian Industrialization: The Quest for Technology*, Kuala Lumpur: Oxford University Press.

Chantasmary, M. (1994), 'Impact of trade AFTA on the palm oil industry in Malaysia', report submitted to the Thailand Development Research Institute, Bangkok.

Dosi, G. (1984), *Technical Change and Industrial Transformation*, London: Macmillan.

Frank, A.G. (1972), 'Development or underdevelopment', in C.K. Wilber (ed.), *Political Economy of Development and Underdevelopment*, Harmondsworth: Penguin.

Freeman, C. (1987), *Technology Policy and Economic Policy: Lessons from Japan*, London: Frances Pinter.

Gerschenkron, A. (1962), *Historical Backwardness in Historical Perspective*, Cambridge, MA: Harvard University Press.

Hamilton, C. (1983), 'Capitalist industrialization in East Asia's four Little Tigers', *Journal of Contemporary Asia*, **13**(1), 35–73.

Jaya, Gopal (1996), 'Malaysia's palm oil refining industry: policy, growth, technical change and competitiveness', in K.S. Jomo, G. Felker and R. Rasiah (eds), *Industry Technology Development in Malaysia*, London: Routledge.

Johnson, C. (1982), *MITI and the Japanese Miracle*, Stanford, CA: Stanford University Press.

Jomo, K.S. (1990), *Growth and Structural Change in the Malaysian Economy*, Basingstoke: Macmillan.

Kaldor, N. (1979), 'Equilibrium theory and growth theory', in M.J. Boskin (ed), *Economics of Human Welfare: Essays in Honor of Tibor Scitovsky*, New York: Academic Press.

Kim, Linsu (1997), *Imitation to Innovation: The Dynamics of Korea's Technological Learning*, Boston: Harvard Business School Press.

Lai, Y.W. and S. Narayanan (1999), 'Technology utilization levels and choice', in K.S. Joma, G. Felker and R. Rasiah (eds), *Industry Technology Development in Malaysia*, London: Routledge.

Lall, S. (1996), *Learning from the Asian Tigers*, London: Macmillan.

Lee, J.S. (1994), 'The Role of the state in economic restructuring and development: the case of Taiwan', occasional paper series no. 9403, Chung-Hua Institution for Economic Research, Taipei.

List, F. (1885), *The National System of Political Economy*, London: Longman.

Lundvall, B.A. (1985), 'Product innovation and user-producer interaction', *Industrial Development Research Series*, vol. 31, Aalborg: Aalborg University Press.

Malaysia (1991), *Second Outline Perspective*, Kuala Lumpur: Government Printers.

Malaysia (1994a), *Mid-Term Review of Sixth Malaysia Plan*, Kuala Lumpur: Government Printers.

Malaysia (1994b), *Ministry of International Trade and Industry Report*, Kuala Lumpur: Government Printers.

Malaysia (1995), *Economic Report 1995/96*, Kuala Lumpur: Government Printers.

Malaysia (1996), *Second Industrial Master Plan 1996–2005*, Kuala Lumpur: Government Printers.

Malaysia (1999), *Economic Report 1999–2000*, Kuala Lumpur: Government Printers.
MASTIC (1994), *1992 National Survey of Research and Development*, Kuala Lumpur: Malaysian Science and Technology Information Centre.
MIDA (1992), *Statistics on the Manufacturing Sector*, Kuala Lumpur: Malaysian Industrial Development Authority.
National Science Board (1996), *Science and Engineering Indicator – 1996*, Washington, DC: US Government Printing Office.
National Science Board (1998), *Science and Engineering Indicators – 1998*, Washington, DC: US Government Printing Office.
Nelson, R. (1985), 'Institutions supporting technical advance in industry', *American Economic Review*, 75, 186–9.
Pavitt, K. (1984), 'Patterns of technical change: towards a taxonomy and a theory', *Research Policy*, **13**(6), 343–73.
Rasiah, R. (1994), Flexible production systems and local machine tool subcontracting: electronics component transnationals in Malaysia', *Cambridge Journal of Economics*, **18**(3), 279–98.
Rasiah, R. (1995), *Foreign Capital and Industrialization in Malaysia*, London: Macmillan.
Rasiah, R. (1996), 'Institutions and innovations: moving towards the technology frontier in Malaysia's electronics industry', *Industry and Innovation*, **3**(2), 79–102.
Rasiah, R. (1997), 'Class, ethnicity and economic development in Malaysia' in R. Robison, G. Rodan and K. Hewison (eds), *Political Economy of Southeast Asia*, Melbourne: Oxford University Press.
Rasiah, R. (1998), 'The Malaysian financial crisis: capital expansion, cronyism and contraction', *Journal of Asia Pacific Economy*, **3**(3), 358–78.
Rasiah, R. (2000), 'Globalisation and private capital movements', *Third World Quarterly*, **26**(1), 943–61.
Rasiah, R. and Ali Anuwar (1995), 'Governing industrial technology transfer' paper presented at conference, ' Governance Mechanisms and Technical Change in Malaysian Manufacturing', Bangi, 14–15 July.
Rasiah, R. and M. Best (2000), 'Malaysian electronics in transition', UNIDO report submitted to the Economic Planning Unit, Kuala Lumpur.
Rasiah, R. and S. Ishak (2001), 'Market, government and Malaysia's new economic policy', *Cambridge Journal of Economics*, **21**(3), 57–78.
Rasiah, R. and R.H. Osman (1995), 'Enterprise training in Malaysia's manufacturing sector', paper presented at the World Bank conference 'Enterprise Training and Productivity', Washington DC, 12–14 June.
Selvaratnam V., S. Lall, N. Danaraj, R. Rasiah and W. Rees (1996) 'Review of the action plan for industrial technology development, Malaysia', World Bank report submitted to the Ministry of Science Technology and the Environment, Kuala Lumpur.
Timmons, J.A. and W.D. Bygrave (1986), 'Venture capital's role in financing innovation for economic growth', *Journal of Business Venturing*, **1**(2), 161–76.
UNCTAD (1995), *World Investment Report*, Geneva: United Nations Conference for Trade and Development.
UNDP (1995), *Human Development Report 1995*, New York: Oxford University Press.
Vijaya, Letchumy (1993), 'SMI development programmes', paper presented at MITI/MIDA/FMM seminar, 'Domestic Investment in the Manufacturing Sector', Penang.

Wade, R. (1990), *Governing the Market*, Princeton: Princeton University Press.
World Bank (1985), *World Development Report*, Oxford: Oxford University Press.
World Bank (1993), *The East Asian Miracle*, Oxford: Oxford University Press.
World Bank (1995), *World Development Report*, Oxford: Oxford University Press.
World Bank (1999), *World Development Report*, Oxford: Oxford University Press.
Young, A. (1928), 'Increasing returns and economic progress', *Economic Journal*, 38, 527–42.

12. Foreign direct investment, technology and competitiveness in Thailand

Peter Brimble[1]

1. INTRODUCTION AND CONTEXT

1.1 Background

Foreign direct investment has long played an important role in Thailand's economic development. Several researchers have examined the impact of FDI on investment, long-term capital inflows, exports, and employment generation, but few have looked at the broader impact on human resource development and technology transfer.[2] Given the growing importance of industrial competitiveness and the potential significance of the relationship between inward FDI and technological upgrading, this chapter explores the links between competitiveness and FDI and domestic technological effort.

Thai policymakers must address two important questions. First, what are the most effective ways in which technology transfer can take place through FDI, and how can such transfers be accelerated and enhanced? Second, what are the policies needed to stimulate alternative (non-FDI) modes of technology development within the country?

1.2 Framework for Analysis

In the Ninth Economic and Social Development Plan, which will run from 2002 to 2006, one of the main pillars of Thailand's development strategy is improving competitiveness. The framework proposed for this chapter (Figure 12.1) goes further, defining the level of technological development at the firm-level – including MNCs, large local firms, and small and medium-sized enterprises (SMEs – largely local in Thailand) – as the critical determinant of competitiveness. Technological progress is taken to require a continuous upgrading of technology, information and skills. The

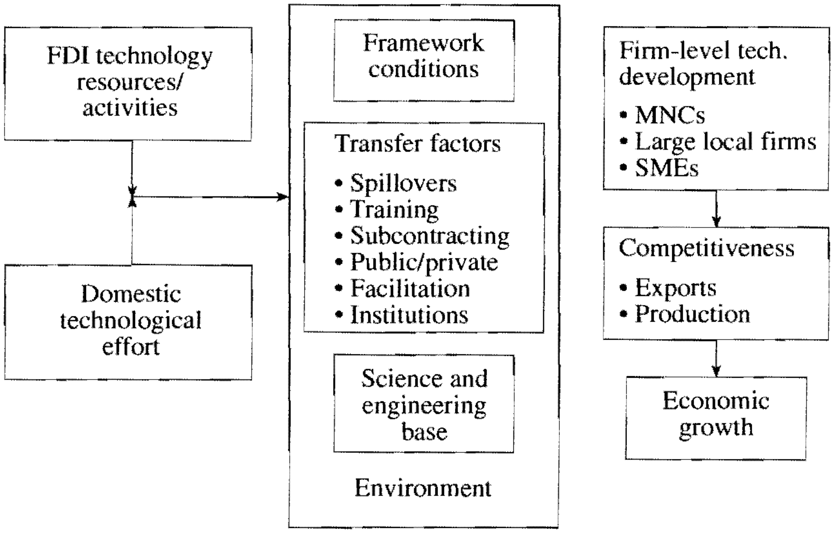


Figure 12.1 *FDI, technology and competitiveness, framework for analysis*

process becomes more complex in an environment where both export competition and technical changes take place simultaneously and at very high levels. The two critical sources that determine the level of technological development – FDI and domestic technological effort – are shown to feed through the environment to the firms in the economy. The environment includes three elements: (i) the framework conditions – the state of the macro-economy and overall policy environment, (ii) the science and engineering base, and (iii) the 'transfer factors' that affect how the technological assets of the economy are transformed into firm-level capabilities. These include spillovers, training, subcontracting, public–private interaction, institutions, facilitators and so on.

Section 2 presents the macroeconomic backdrop in Thailand and an overview of its industrial development process and present levels of competitiveness. Section 3 considers Thailand's approach to FDI and recent FDI trends in Thailand. The role of FDI in human resource development and technological development is also discussed and evaluated. Section 4 analyses the policy approach to, and present status of, science and technology and human resource development issues, and evaluates technological development at the firm level. Section 5 presents conclusions and recommendations.

2. INDUSTRIAL DEVELOPMENT: LEADING TO A CROSSROADS

2.1 The Macroeconomic Backdrop and Challenges

Thailand's economy grew at double-digit rates for several years following the world recession of the mid-1980s and by over 8 per cent per year from 1991–95. Over the period 1985–94, Thailand recorded the highest growth of GNP per capita in the world – 8.2 per cent.[3] This rapid growth, driven largely by growing FDI inflows and exports, was accompanied by a shift towards manufacturing, with the manufacturing share of total GDP reaching 29.6 per cent by 1995. Over this period (1988–96), per capita incomes rose steadily and the percentage of people in poverty fell from 32.6 to 11.4 per cent.[4] However, the rapid growth placed pressures on infrastructure, manpower and the environment and was accompanied by increasing costs of production across the board. This began to force Thai manufacturers to move into higher value-added, more sophisticated products.

The key challenge to Thai-based producers, domestic and foreign, by the mid-1990s was to enhance production capabilities and move up the value-added ladder as competition from lower wage countries such as China, India, Indonesia and Indochina intensified. Then came the financial crisis. On 2 July 1997, the Thai government floated the baht, triggering a collapse of the financial sector and a devastating economic recession. GDP declined by 1.7 per cent in 1997 and by a further 10.4 per cent in 1998. This compares to expected 1998 growth rates of over 7 per cent as recently as 1996. Inflation was estimated to have reached around 8 per cent in 1998, after levels of around 5–6 per cent for many years. The value of the baht fell from 25 to the dollar to around 36–38 in early 2000 (though this was better than the rate of 55 seen in early 1998). Table 12.1 shows Thailand's key macroeconomic indicators.

While the financial collapse was primarily a short-to-medium term phenomenon caused by inadequate financial regulations and weak public and private sector governance, the situation was exacerbated by deteriorating industrial competitiveness. Export performance worsened dramatically in 1996, falling by 1.3 per cent after many years of 10 to 20 per cent growth rates.[5] The stock exchange went through a 'meltdown' in the same year. While GDP grew by 5.9 per cent in 1996, the storm clouds were already looming.[6]

While the effects of the crisis have yet to run their course, the economy returned to 4 per cent growth in 1999, albeit with continuing low capacity utilization and significant disruptions in the real sector. Thailand's economic recovery sustained most of its momentum in 2000 with real GDP

Table 12.1 Thailand's key macroeconomic indicators, 1995–2000

	1995	1996	1997	1998	1999	2000p
GDP at current prices (US$ billion)	168.1	181.8	150.7	112.2	123.7	135.0
Real GDP growth rate (%)						
• Overall	8.7	5.9	−1.7	−10.4	4.1	4.2
• Agriculture	2.5	3.6	−0.7	−0.3	1.9	0.8
• Manufacturing	11.2	6.9	0.2	−11.6	10.5	5.8
• Construction	7.4	7.2	−26.6	−36.8	8.9	1.0
• Services and Others	9.0	5.7	−0.1	−9.0	1.5	3.6
Sectoral shares of GDP (%)						
• Agriculture	9.6	9.6	9.8	11.7	10.0	n/a
• Manufacturing	29.6	29.6	29.6	30.7	33.0	n/a
• Construction	7.3	7.4	5.7	4.1	3.5	n/a
• Services and Others	53.5	53.4	54.9	53.5	54.4	n/a
Inflation (% change)						
• Consumer Prices	5.8	5.9	5.6	8.1	0.3	1.6
• Wholesale Prices	8.3	4.6	4.0	13.8	−11.6	1.8
Exports:						
• Value (US$ billion)	56.7	55.9	58.3	54.5	58.5	69.9
• Growth (%)	25.1	−1.3	4.3	−6.6	7.3	19.5
Total debt service ratio (%)	11.4	12.3	15.7	21.4	19.4	15.4
• Public (%)	2.8	2.5	2.7	3.3	4.0	4.2
• Private (%)	8.6	9.8	13.0	18.1	15.4	11.2
Fiscal expenditures (FY)						
• Level (US$ billion)	25.8	29.6	32.4	20.2	21.9	21.8
• Fiscal Balance (% of GDP)	2.8	2.7	−0.9	−2.6	−2.4	−2.0
Stock exchange index (end-period)	1281	832	373	356	482	269

Note: 2000p column is provisional data.

Source: Bank of Thailand, June 2001

growth of 4.2 per cent, despite slower industrial expansion. Exports were the main engine of growth, rising by almost 20 per cent, as domestic demand remained weak and the level of bank credit contracted.

In 2001 GDP growth is projected to slow (to 1.0–2.0 per cent or lower) due to weak export demand caused by the global slowdown, especially for electronics products. This increases the economic risks facing the government elected in early 2001, making a fiscal stimulus package necessary to reinvigorate the economy, spur domestic demand and offset the slowdown in exports. This will place pressures on the fiscal balance that was recovering from the negative levels caused by the economic crisis. As economic growth slows, the economy will become more vulnerable to weak performance in the USA and Japan. Reducing the level of non-performing loans and restructuring the corporate sector becomes even more critical to continued economic improvement and investor confidence. Even if the global picture improves and the government continues to reform the finance and real sectors, Thailand will still require significant increases in competitiveness in the major export sectors.

In this context of recession and slow recovery, the role of FDI, important in the past, becomes even more critical. FDI is needed to help recapitalize failing industries, bring in new technologies, generate or save jobs, assist with policy reforms and play a role in addressing the challenges in the areas of poverty and social unrest.[7] Two particularly important areas in the Thai economic reform process are massive industrial restructuring and improvements in corporate governance. FDI may play critical roles both in providing the resources to support industrial restructuring and bringing in 'best practice' in the area of corporate governance.

2.2 Structural Changes in Industry and the Policy Response

Industrialization began in Thailand in the late 1950s when the government, under the advice of the World Bank, adopted the policy of promoting private investment. Since the early 1960s, when the first development plan was implemented, the government has supported private enterprise and limited government involvement in the economy to the key utility and infrastructure sectors and to maintaining an incentive structure to encourage the private sector.

In the 1960s, the government followed a traditional import-substitution strategy, imposing tariffs on imports, particularly on finished products. The role of state enterprises was greatly reduced from the 1950s and investment in infrastructure raised. Attention was given to nurturing the institutional system necessary for industrial development, and several new organizations were established. These included the Board of Investment (BOI), to promote domestic and foreign investment through the provision of tax and non-tax incentives; the Industrial Finance Corporation of Thailand (IFCT), to provide finance to industrial investments; the Small Industry Finance Office, to provide finance to SMEs; the Thailand Institute of Scientific and Technological Research (TISTR), to enhance research and development and testing facilities; and several other agencies to promote SMEs.

By the late 1960s and early 1970s, the import-substitution policy had led to balance of payments problems since most components, raw materials, and machinery to support finished product production had to be imported. A major policy shift towards export promotion took place. The government implemented numerous policies to facilitate exports, including import duty rebates on inputs into export production, incentives for export industries and concessionary packing credit. However, high protective barriers on many products remained, and policymakers resorted to quantitative controls on imports and industrial activities in conjunction with tariff protection. Import bans on automobiles and local content requirements on refrigerators and cars are some examples.

The late 1970s and early 1980s saw continued interest in export industries, small-scale industries and the promotion of regional industries. In 1977 a new Investment Promotion Law was passed which provided the BOI with more power to provide incentives to priority areas and remove obstacles faced by private investors. The government started to place more emphasis on hard and soft infrastructure development, with private sector financing becoming increasingly important.[8] Regional inequalities also became a key concern and the BOI steadily shifted its emphasis from promoting export activities to promoting regional areas.

By the early 1980s, policymakers had become aware of the inefficiencies fostered by high protection. In the late 1980s and early 1990s, therefore, they started to promote openness and competitiveness. However, the strategy of opening up was not well thought through; the selection of sectors was carried out in a rather ad hoc manner, based on short-term assessments of industrial weaknesses rather than on long-term strategy. The financial crisis, in particular, forced the government to focus on the short-run financial restructuring and corporate restructuring of the large distressed companies. It is only in the last year or so that efforts have returned to the formulation of longer-run policies to develop the industrial base and stimulate exports.

In terms of long-term structural change, Thailand's export structure is lagging those of the East Asian NIEs (Table 12.2). In the other three countries, agriculture has fallen almost to negligible levels, industry has generally increased (with the exception of Taiwan) and services now account for around 50–60 per cent. In Thailand, services are a little less important while agriculture remains at 10 per cent.

On the export front, Thailand also appears to lag (Table 12.3). Since 1980 resource-based and labour-intensive products have fallen in share by some 20 percentage points and science-based products have increased by around 25 percentage points. However, it is likely that much of this increase is in the labour-intensive end of science-based production.

Although S&T and R&D indicators will be discussed later, it is instructive to compare Thailand with Korea at similar levels of industrial

Table 12.2 Changes in Thailand's distribution of GDP (%) by sector as compared to the NIEs

	1960	1970	1980	1990	1999	1960	1970	1980	1990	1999
Sector			Korea					Singapore		
Agriculture	36.9	28.9	14.9	8.5	5.0	5.8	2.3	1.3	0.4	0.2
Industry	14.7	24.4	41.3	43.1	43.5	10.4	29.8	38.1	34.4	35.8
Services	48.4	46.7	43.7	48.4	51.5	83.8	67.9	60.6	65.3	64.1
			Taiwan					Thailand		
Agriculture	n/a	17.7	7.7	4.2	2.6	37.1	30.2	23.2	12.5	10.4
Industry	n/a	40.9	45.7	41.2	33.1	14.1	25.8	28.7	37.2	40.1
Services	n/a	41.4	46.6	54.6	64.3	48.8	44.0	48.1	50.3	49.5

Source: ADB (2000).

development.[9] In terms of average GDP per capita and manufacturing value-added per head, Thailand in the mid-1990s was lagging Korea by around 10–15 years; however, Thailand's R&D indicators lagged *some additional 10–15 years* behind Korean levels.

The issue of competitiveness has resonated throughout Southeast Asia following the financial crisis. Countries like Thailand have re-examined their approach to growth and development. As noted, growing competition, particularly from lower wage nations such as China, India, Indonesia, the Philippines and Vietnam has eroded Thailand's edge in labour-intensive exports, and the country failed to undertake the necessary measures to continue moving up the value-added chain. A recent analysis of the Thai response to the economic crisis (Flatters, 1999) concludes:

> While overall productivity growth was moderate, most of it was in agriculture or arose from inter-industry shifts. There was little indication of growth of technological capabilities, or movements 'up the ladder of comparative advantage'. Among the widely recognized barriers to growth in competitiveness were very low levels and quality of education, serious deficiencies in infrastructure development, and a policy regime at the microeconomic level which was much too geared to creating and preserving rents than fostering market competition.

The critical challenge for Thailand now is to build the capacity to absorb very complex and fast-moving technologies and to develop and commercialize new products. The Thai government must therefore strengthen the technological and skill base of the economy.

Innovation derives from many factors, many of which fall outside the field narrowly defined by science and technology. The crisis has highlighted

Table 12.3 Distribution of manufactured exports by technological categories (%)

	Korea			Singapore			Taiwan			Thailand		
Sector	1980	1990	1999	1980	1990	1999	1980	1990	1999	1980	1990	1999
Resource-based	9.0	6.8	11.6	44.4	26.9	13.2	9.8	8.2	9.2	21.7	13.8	10.7
Labour-intensive	49.2	40.8	23.2	10.6	10.3	7.6	54.3	41.2	31.0	47.0	45.5	35.8
Scale-intensive	23.6	19.3	21.0	9.3	5.9	5.5	9.1	10.3	10.6	7.8	6.3	7.7
Differentiated	11.3	15.6	18.7	20.5	22.3	21.2	12.4	20.6	20.4	22.2	14.1	19.5
Science-based	6.9	17.4	25.5	15.1	34.6	52.5	14.5	19.8	28.9	1.2	20.2	26.4

Source: Calculated from UN Comtrade database.

Thailand's glaring deficiencies in R&D, science and technology and its education system. The investments in human resources and R&D that are required to build the foundations for innovation involve a significant public good element, are relatively bulky (or indivisible), and require a long time for the results to become evident. This provides clear economic rationale for a strong government policy to develop higher quality S&T manpower and raise R&D both in the public and private sectors.

3. FDI POLICIES AND TRENDS

3.1 The Evolving Policy Approach

Foreign investment policies The Thai government has generally adopted very favourable policies towards FDI. Although there have been laws and regulations which limit foreign ownership in certain activities, they have been progressively liberalized over the past decade, with an acceleration of this trend in the period since the crisis. In particular, the Alien Business Law was relaxed in 1999. However, the relaxation on retail business has caused public outcry about the impact of large foreign discount stores on local retail outlets, and the present government has been under pressure to review the law.[10] The Board of Investment (BOI) has also gradually relaxed foreign ownership conditions over the past decade, and abolished foreign ownership restrictions for new manufacturing projects in Zones 1 and 2 since August 2000 under a new incentive package. The BOI has recently been active in undertaking other policy and service measures to stimulate expansion projects from existing investors and new greenfield projects, and also to encourage new foreign investment.

In the service arena, the BOI has enhanced its role in matchmaking by introducing a Vendors Meet Customers programme (VMC) into the BOI Unit for Industrial Linkage Development (BUILD) programme, which involves regular supplier tours to selected automotive and electronics assemblers and aims to encourage subcontracting businesses in Thailand. BUILD has also launched the ASEAN Supporting Industry Database (ASID) in order to encourage sourcing of local parts and components.

Financial sector liberalization Thailand's weak financial sector played a major role in triggering the economic crisis in 1997. The banking and financial sector had been lending to unsound clients, with inadequate or no collateral and low bank capital requirements. The result was widespread misallocation of funds. The result was the near collapse of the financial sector in Thailand. Fifty-six finance firms closed by the end of 1997, and six banks were nationalized in 1998. The remaining banks were in frail condition, saddled by 2.73 trillion baht in non-performing loans (NPLs), equal to nearly half of all lending. Faced with tremendous recapitalization needs of the Thai financial sector, the authorities removed foreign ownership controls for financial institutions, announcing in October 1997 that it would allow foreign firms to hold a majority or 100 per cent stake in operating financial institutions for up to 10 years. The government also embarked on a privatization programme for state-owned banks, the sale of billions of baht worth of assets from the closed financial institutions, and more recently, drafted legislation to establish the Thailand Asset Management Corporation, which will consolidate the remaining NPLs in the banking sector.

Legal infrastructure The legal framework for foreign involvement in industrial restructuring and M&A (mergers and acquisitions) activities remains weak but has recently been considerably revamped. In particular, the Bankruptcy Law was significantly amended by parliament in March 1999 to provide improved security for new lenders among other measures designed to facilitate corporate rehabilitation and debt restructuring. Overall, these reforms are expected by most observers to create an environment of certainty over ownership that will encourage much greater foreign involvement in the disposition of the assets from the defunct finance companies as well as working out the non-performing loan problems of the financial sector.

Although the general policy framework for foreign investment in the past few years has become more liberal, it must be admitted that relatively little attention has been placed on the technological features of FDI; it has been sought mainly to generate employment or exports, or to play a role in the massive restructuring process.

3.2 Recent Trends in FDI

FDI inflows into Thailand increased substantially in the second half of the 1980s after the Plaza Accord, which resulted in currency appreciation in Japan and NIEs such as Taiwan, Hong Kong and Korea. In addition, rising labour costs and the loss of GSP status in these countries encouraged MNCs to relocate their production base to Thailand. From 1986 to 1989 Thailand attracted on average US$1.2 billion per annum of net FDI flows, accounting for around 7 per cent of private business investment.

From 1990 to 1996, FDI hovered around a plateau of over US$2 billion per year, with a slight drop to US$1.7 billion in 1993 and US$1.3 billion in 1994 as the effects of the political unrest in the early 1990s affected foreign

Table 12.5 Net flows of foreign direct investment in Thailand by sector[a]

	Million US$					
Sector	1991–1995	1996	1997	1998	1999	2000
1. Industry	2836	709	1818	2207	1269	1900
1.1 Food & sugar	233	45	226	73	94	161
1.2 Textiles	166	49	41	124	21	33
1.3 Metal & non metallic	387	113	216	342	262	111
1.4 Electrical appliances	1022	241	602	264	425	276
1.5 Machinery & transport equipment	352	109	396	661	393	543
1.6 Chemicals	544	183	164	226	8	503
1.7 Petroleum products	−226	−250	10	329	9	36
1.8 Construction materials	55	4	−10	23	38	58
1.9 Others	304	216	173	164	20	180
2. Financial institutions[b]	664	72	112	842	247	107
3. Trade	1591	545	1035	1052	1042	75
4. Construction	964	70	164	192	−152	−19
5. Mining & quarrying	439	19	20	22	−42	−309
6. Agriculture	34	2	1	1	2	1
7. Services	312	125	292	276	485	726
8. Investment	59	−22	26	364	571	273
9. Real estate	2547	753	112	28	149	75
10. Others	−202	−3	47	161	−9	−383
Total	9245	2271	3627	5142	3562	2447

Sector	Shares in total (%)					
	1991–1995	1996	1997	1998	1999	2000
1. Industry	30.7	31.2	50.1	42.9	35.6	77.6
1.1 Food & sugar	2.5	2.0	6.2	1.4	2.6	6.6
1.2 Textiles	1.8	2.2	1.1	2.4	0.6	1.4
1.3 Metal & non metallic	4.2	5.0	6.0	6.6	7.4	4.5
1.4 Electrical appliances	11.0	10.6	16.6	5.1	11.9	11.3
1.5 Machinery & transport equipment	3.8	4.8	10.9	12.9	11.0	22.2
1.6 Chemicals	5.9	8.1	4.5	4.4	0.2	20.5
1.7 Petroleum products	−2.4	−11.0	0.3	6.4	0.2	1.5
1.8 Construction materials	0.6	0.2	−0.3	0.5	1.1	2.4
1.9 Others	3.3	9.5	4.8	3.2	0.6	7.4
2. Financial institutions[b]	7.2	3.2	3.1	16.4	6.9	4.4
3. Trade	17.2	24.0	28.5	20.4	29.3	3.1
4. Construction	10.4	3.1	4.5	3.7	−4.3	−0.8
5. Mining & quarrying	4.8	0.9	0.6	0.4	−1.2	−12.6
6. Agriculture	0.4	0.1	0.0	0.0	0.1	0.0
7. Services	3.4	5.5	8.1	5.4	13.6	29.7
8. Investment	0.6	−0.9	0.7	7.1	16.0	11.2
9. Real estate	27.6	33.2	3.1	0.5	4.2	3.1
10. Others	−2.2	−0.1	1.3	3.1	−0.2	−15.6
Total	100.0	100.0	100.0	100.0	100.0	100.0

Notes:
[a] The figures cover investment in non-bank sector only.
[b] Direct investment = equity investment plus loans from related companies.

Source: Bank of Thailand, by Economic Research Department.

of FDI. Once the banking sector essentially reached its limits for foreign participation, FDI dropped to 6 and 4 per cent in 1999 and 2000, respectively. One of the favourite sectors for FDI in the early to mid-1990s was real estate, which peaked at 33 per cent of FDI in 1996, but since the property bubble burst in 1996 and 1997, the sector has struggled to attract investment.

Within the manufacturing sector, the electronics industry used to attract the largest share of FDI but was overtaken by machinery and transport equipment in 1998 and 2000. The surge in machinery and transport equipment derived mainly from the automotive industry, as many Japanese automotive parent companies injected capital to assist their subsidiaries and suppliers in Thailand. The chemical industry is also challenging electronics for FDI following its large increase in 2000, taking in over 20 per cent of FDI.

Sources of FDI in Thailand have traditionally been quite diversified, including Japan, the USA, Europe, Taiwan, Hong Kong, and Singapore as shown in Table 12.6. Japan had been the largest source of FDI since the late 1980s until being overtaken by the USA in 1999 and 2000. Japanese FDI dropped sharply in 1999 and 2000 as a result of the weak economic condition in the home economy. In 1998, Singapore ranked third behind the USA due to its major investments in Bangkok Bank and Thai Danu Bank. There was a significant increase in FDI from Europe in 1998 and 1999, especially from Dutch investors that have taken control of the Bank of Asia and invested in several power plants. It should be noted that FDI from the UK and Hong Kong rose significantly in 2000 as they respectively ranked third and fourth after the USA and Japan. Closer to home, Thailand's ASEAN neighbours remain an important source of FDI despite the regional economic difficulties.

Table 12.7 shows that there has been a decline in investment interest in Thailand as the total planned investment of foreign projects approved by the BOI dropped by 58 per cent from 326 billion baht in 1996 to 136 billion baht in 1999. However, the number of approved projects increased slightly from 490 to 517 projects, reflecting the fact that foreign projects have become smaller. This was because since the economic crisis, domestic demand has shrunk resulting in oversupply in many industries. However, foreign approved projects increased suddenly in 2000 by 48 per cent over the previous year, with investment rising by 56 per cent. This was partly due to expansion investments of export-oriented projects which performed very well after the baht devaluation and partly to a change in the BOI incentive package in August 2000 which prompted many investors to apply for promotion status before tax incentives were reduced.

The number and investment capital of Japanese approved projects dropped in 1998 and 1999 as their parent companies were busy injecting capital to help existing subsidiaries rather than investing in new projects. However, Japanese investment significantly increased in 2000 especially in automotive and electronic sectors.

Total planned investment from other sources, such as Singapore and Taiwan, also fell in 1998 and 1999, while 1998 was the peak year for Europe. Investment from the USA and Canada also increased remarkably in 1999. It should be noted that investment from Taiwan, Hong Kong, Singapore, Malaysia, India, the UK and Germany also expanded in 2000. As domestic demand continued to shrink, most new investment projects tended to be export-oriented, especially in electronics and light industries.

The role of FDI in exports has increased quite significantly over the years. Sibunruang (1986) estimated that foreign firms accounted for at least 25 per cent of Thailand's total manufactured exports by the end of the 1970s, and that the export propensity of foreign firms rose over time from 10 per cent to 33 per cent in 1984. In a later study, based on BOI survey data covering 777 companies, Sibunruang and Brimble (1992) found that foreign firms accounted for 24 per cent of Thailand's total manufactured exports. However, this figure understated the true contribution of FDI, because 777 firms accounted for only 40 per cent of BOI promoted manufacturing firms and the sample excluded non-promoted exporters. Therefore, it was estimated that the real contribution lay between 30–40 per cent. The 983 foreign promoted firms surveyed by the BOI in 1996 accounted for 35 per cent of Thailand's total manufactured exports. Total FDI exports could have amounted to *as much as 50 per cent* of the total. Export shares of foreign firms were relatively large in high-tech industries such as fabricated metal products, machine tools, electronic products, chemicals and petroleum products. Indeed, by 2000, the electronic and automotive sectors, which were dominated by foreign firms, already accounted for 43 per cent of Thailand's total manufactured exports. Therefore, the current export share of foreign firms could be as high as 60 per cent.

3.3 FDI Impact on Skill Formation and Technology Development

A recent study found that foreign firms on average utilized labour and capital 50 per cent more efficiently than Thai firms, although a group of highly productive Thai firms also performed as well as their foreign counterparts.[13] This indicates strongly the critical role that FDI can play in contributing to overall productivity (Dollar et. al., 1998). It has also been found that foreign enterprises in Thailand are becoming more involved in innovative programmes in training and in undertaking technological activities.[14] While not yet constituting a statistically significant quantitative trend, there are a number of interesting stories of such activities.

Table 12.6 Net flows of foreign direct investment in Thailand by region/country

Region/country	1991–1995	1996	1997	1998	1999	2000
				Million US$		
Japan	1942	524	1348	1485	488	582
USA	1401	429	781	1283	641	844
European Union (EU)	998	168	360	912	1368	404
UK	399	57	124	102	186	425
Germany	150	42	60	100	288	67
France	304	30	3	279	240	6
Netherlands	149	−41	155	332	643	−110
Newly industrialized countries	3250	653	877	1115	899	768
South Korea	62	25	30	73	6	−4
Taiwan	424	138	134	106	122	192
Hong Kong	1832	215	442	394	234	325
Singapore	932	275	271	542	538	254
ASEAN (less Singapore)	56	33	27	28	32	20
Other countries	1597	464	234	320	134	−170
Total	9245	2271	3627	5142	3562	2447

Region/country	1991–1995	1996	1997	1998	1999	2000
	Shares in total (%)					
Japan	21.0	23.1	37.2	28.9	13.7	23.8
USA	15.2	18.9	21.5	25.0	18.0	34.5
European Union	10.8	7.4	9.9	17.7	38.4	16.5
UK	4.3	2.5	3.4	2.0	5.2	17.4
Germany	1.6	1.8	1.6	2.0	8.1	2.7
France	3.3	1.3	0.1	5.4	6.7	0.2
Netherlands	1.6	-1.8	4.3	6.5	18.1	−4.5
Newly industrialized countries	35.2	28.8	24.2	21.7	25.2	31.4
South Korea	0.7	1.1	0.8	1.4	0.2	−0.2
Taiwan	4.6	6.1	3.7	2.1	3.4	7.8
Hong Kong	19.8	9.5	12.2	7.7	6.6	13.3
Singapore	10.1	12.1	7.5	10.5	15.1	10.4
ASEAN (less Singapore)	0.6	1.5	0.7	0.5	0.9	0.8
Other countries	17.3	20.4	6.5	6.2	3.7	−7.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

Note: The figures cover investment in non-bank sector only. Direct investment = equity investment plus loans from related companies.

Source: Bank of Thailand, by Economic Research Department.

Table 12.7 Foreign investor interest in Thailand: BOI approvals (million baht)

Country	1995 No.	1995 Total Invest.	1996 No.	1996 Total Invest.	1997 No.	1997 Total Invest.	1998 No.	1998 Total Invest.	1999 No.	1999 Total Invest.	2000 No.	2000 Total Invest.
Total foreign invest.	561	397168	490	326335	516	301596	485	255070	517	136060	763	212866
100% foreign invest.	136	36856	142	75109	188	36846	204	79977	264	77226	380	123231
Asia												
Japan	267	190569	233	143693	220	147619	158	54113	188	27042	282	107382
Asian NIEs												
Taiwan	91	39945	61	69135	56	11931	69	10029	86	7910	120	17632
Hong Kong	12	2032	8	1675	9	1389	16	5064	25	1899	31	6241
Korea	14	42247	19	22189	20	3965	13	1836	19	981	17	1394
Singapore	36	32033	41	41798	43	59028	49	10647	52	7003	84	19910
PRC	5	196	4	889	1	45	2	69	7	560	8	367
Malaysia	23	5121	23	1730	33	4713	21	4129	27	3418	43	6096
Indonesia	3	712	3	634	3	559	2	480	5	1149	4	1300
Philippines	2	220	0	0	0	0	0	0	1	72	0	0
India	9	8658	11	8307	5	180	10	10157	6	1374	11	10166
North America												
USA	45	62613	46	64780	4	88366	62	18646	53	46351	73	37916
Canada	4	542	2	56	6	310	9	2631	3	26002	6	1089

Australia												
Australia	7	14775	6	1026	16	4733	13	2756	10	1177	21	2705
All Europe	72	53592	87	58021	95	88813	123	134326	83	34007	144	31175
UK	18	6067	22	9952	24	28460	33	31380	17	3919	38	5815
Germany	12	4352	19	7775	19	9425	22	8606	12	1868	39	6394
Switzerland	7	1980	9	2630	10	898	11	1548	10	3170	10	2283
France	5	558	8	4389	9	1698	12	181	11	2829	13	1097
Belgium	5	927	7	3498	3	1720	8	948	7	858	2	316
Italy	10	1235	2	38	7	935	4	783	3	106	9	425
Netherlands	9	1749	15	17476	12	4258	22	88066	18	22481	22	6381

Note: Firms with investment from more than one country are double counted. Foreign projects are those with a foreign component of 10% or more.

Source: Board of Investment.

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 the production needs. ACS has also assisted with training local subcontractors by sponsoring off-site programmes and through the provision of Australian engineers and skilled technicians.

Phoenix Pulp and Paper in northeast Thailand has been very proactive in subcontracting. In order to supply the two production lines, the company has utilized local villagers to produce individual plantations of eucalyptus, bamboo and kenaf plants. These villages raise enough wood and are paid nearly one billion baht a year. The company estimated that over 1000 villagers gain employment either directly or through subcontracting.

Many MNCs have recently participated in the BOI's VMC programme (as a part of the BUILD initiative) 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 the matchmaking activities of the BUILD programme since its inception in the early 1990s. This resurgence of interest and initiative in BUILD is a very positive indication of greater technology transfer from foreign firms in the future.

The benefits of foreign firms go beyond training and technology development. One additional impact they have had in Thailand is to promote higher standards of employment practices such as safety and sexual discrimination. Foreign firms have also played an instrumental role in addressing issues such as AIDS in the workplace.[17]

3.4 A Summing Up

FDI has played a significant role in Thailand's economic development, especially since the late 1980s as the country liberalized and sought expanded markets overseas. The onset of the economic crisis actually generated record levels of FDI in Thailand, with M&A being the preferred mechanism for investment. The current patterns of FDI show a continuing strong interest in the manufacturing sector, and it does not appear that this will change in the near future as long as Thailand's economy remains based heavily on exporting manufactured, labour-intensive goods. The surge of FDI in the financial sector in 1998 probably represents an anomaly in response to the change in regulations for foreign participation, and other sectors such as trade and services have failed to show consistent gains over the past few years.

FDI has made important contributions to the Thai economy beyond generating employment. It has also saved countless jobs during the crisis by helping to capitalize failing local industries. Other less evident benefits include bringing in new technology and industries to spur competitiveness, improving corporate governance and standards for working conditions, strengthening local capabilities through linkages, and assisting with policy reforms and industrial restructuring.

4. SCIENCE AND TECHNOLOGY DEVELOPMENT: POLICIES AND TRENDS

4.1 The Policy Approach

Attention to science was paid in Thailand more than 100 years ago when the Department of Science Service was established. But it was not until 1956 that the government established the National Research Council of Thailand (NRCT) to encourage R&D to systematically upgrade the country's scientific and technological capabilities. NRCT sets research policy and provides research funding, albeit limited, to a wide range of disciplines including science, engineering, social science and humanities. To conduct and support research, the Applied Scientific Research Corporation of Thailand, now known as the Thailand Institute of Scientific and Technological Research (TISTR), was created in 1963. Its broad objectives are to implement research in applied sciences and to promote the utilization of natural resources for industrial and national development.

An important milestone in the development of science and technology policies was the establishment of the Ministry of Science, Technology, and Energy (MOSTE) in 1979 to play the central role of coordinating science and technology policy and planning at the national level by bringing six key departments belonging to the Office of the Prime Minister and the Ministry of Industry under its wing. They are NRCT, TISTR, the National Energy Board, the National Environment Board, the Office of Atomic Energy for Peace and the Department of Science Service. In 1992, MOSTE was renamed the Ministry of Science, Technology, and Environment with the restructuring of the National Energy Board and the National Environment Board, and the addition of two new departments on environment issues.

The Fifth National Economic and Social Development Plan (1982–86) was the first plan with a chapter exclusively devoted to science and technology. The key policies were to screen and adapt imported technology to local conditions and to develop Thailand's own technology. The country's scientific and technological base was to be strengthened by emphasizing

Table 12.8 Rankings of selected technology indicators, 2000

Indicator	Unit	Thailand	Singapore	Malaysia	Philippines
1. Technological sophistication	Bus. Per.	3.4	5.9	4.2	2.9
2. Average years of schooling	No. of years	6.10	8.09	7.88	7.62
3. Secondary school net enrolment	Percentage	56	90	59	77
4. Maths and science education	Bus. Per.	3.9	6.5	4.6	3.9
5. Approach to human resources	Bus. Per.	3.5	5.5	4.5	4.0
6. Management education	Bus. Per.	4.6	5.8	4.9	5.9
7. Research institutions	Bus. Per.	2.7	5.1	3.5	3.0
8. R&D spending	% of GDP	0.13	1.13	0.24	0.22
9. Private sector spending on R&D	Bus. Per.	2.5	4.1	2.8	2.6
10. Research collaboration	Bus. Per.	3.6	4.2	2.5	2.8
11. Technology development	Bus. Per.	2.8	4.2	3.2	2.9
12. Licensing of technology	Bus. Per.	5.2	5.5	5.2	5.2

Notes:
Bus. Per.: Business perceptions on a scale of 1 (strongly disagree) to 7 (strongly agree with the following statements).

1. Your country's position in technology ranks among the world leaders.
2. Average years of schooling by population age 25 and up.
3. Secondary education enrolment indicator, 1997.
4. The school system excels in maths and basic science education.
5. Companies invest heavily to attract, develop, motivate, and retain staff.
6. Management education is locally available in first-class business schools.
7. Scientific research institutions are truly world-class
8. Research and development spending in percent of GNP, latest available year.
9. Companies invest heavily in research and development relative to their international peers.
10. Companies collaborate closely with local universities in their research and development activities.
11. Companies obtain technology by pioneering their own new products or processes.
12. Licensing of foreign technology is a common means to acquire new technology.

Source: WEF, *The Global Competitiveness Report 2000.*

Unsurprisingly, Singapore is well ahead of Thailand in every category. However, Thailand is also ranked behind Malaysia in nearly every category, and in several items fails to keep pace with the Philippines. Both have much smaller economies than Thailand. Some interesting features of Table 12.8 are:

- Thailand comes well behind Singapore, Malaysia and the Philippines in most areas of basic education. Particularly worrying is the net secondary school enrolment rate – indicating that nearly half of Thailand's children are not enrolled in secondary school.
- The perceived emphasis on staff training in Thailand falls one full point below that of Malaysia and two points behind Singapore.
- The stronger overall scores of the Philippines in these key HRD areas likely explain why it has been able to maintain its competitiveness position, despite other problems.
- Private sector spending on R&D is the lowest of the four countries.

Thailand also lags far behind its neighbours in key information technology indicators, as shown in Table 12.9.

Some of the shortcomings of Thailand here are clearly a result of the language barrier. Singapore, the Philippines and Malaysia have a distinct advantage over Thailand because of the extensive use of English, with the former two countries using it as the national language of business and administration.

Thailand spends, according to Table 12.8, a mere 0.13 per cent of its GDP on R&D. A recent study on Thailand's innovation and R&D suggests a higher figure, 0.29 per cent.[20] According to the latter survey, of the total of US$358 million spent on R&D in 1999, the manufacturing sector accounted for US$147 million, non-manufacturing firms and SMEs for US$26 million and the public sector for US$185 million. Even this more optimistic estimate, however, falls far short of the target of 0.75 per cent of GDP of the Eighth National Economic and Social Development Plan.

A detailed comparison of R&D in Asia (Table 12.10) shows that Thailand's R&D spending per capita of US$5.8 is only ahead of India, Indonesia and the Philippines, but is less than half that of Malaysia. While Thailand's total R&D exceeds Malaysia's, the amount spent by the private sector on R&D is well below. The gap is even more pronounced between Thailand and Malaysia in terms of private sector R&D per capita: Thailand's US$2.8 is approximately one-third of Malaysia's US$8.57. Thailand also fares poorly in its ratio of business R&D in total R&D. Its ratio of 48.3 per cent is higher than only the Philippines and India.

In terms of R&D personnel, despite Thailand's population of 62 million and Malaysia's 22.7 million, the former has only 5300 R&D workers in manufacturing business enterprises for a per capita ratio of 0.086 (full time equivalent per 1000 people).[21] Malaysia by comparison employs 3500 R&D workers in the private sector for a ratio of 0.16 (full time equivalent per 1000 people).

4.3 Human Resource Development

Thailand lags behind many of its regional competitors in human resource development, raising serious concerns about its ability to sustain competitive growth in the future. The English language issue is a structural handicap, but this could have been compensated by investments in education (after all, Korea and Taiwan also suffered this handicap). In early stages of economic development, Thailand concentrated on developing lower levels of education and relied on foreign expertise for higher education and research. Before the economic crisis, the education and skill levels of the population lagged behind many neighbouring countries. In the mid-1990s, only 40 per cent of workers had completed secondary or post-secondary education.

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 to more than 2500 each in 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 dissuade academics from conducting R&D. This makes it very difficult for students to acquire the skills and attitudes needed for R&D.

Thai universities also suffer from staffing problems. In 1997, around 55 per cent of academic staff in public universities had a masters degree, while 27 per cent held doctorates. Breakdowns of staff qualifications for science and engineering were not available, but there are strong indications that staff–student ratios in S&T university faculties have been deteriorating as academic staff leave for the private sector while student enrolments continue to rise. This trend may well be exacerbated by the recent moves to support early retirement of public university lecturers. A major problem is the wide disparity between academic salaries and salaries in the private sector. In areas like telecommunications the gap can be as wide as five times or more. The disparity in basic wages is too wide to be covered by the additional income academics might earn from private consulting. The university wage structure is very inflexible. High-level S&T skills can be acquired abroad, but very heavy reliance on foreign training is undesirable. It is more expensive, may have less direct application to Thai industry and raises the risk of a brain drain.

One of the major initiatives to improve the quality and quantity of S&T in Thai universities is the Higher Education Development Project financed by the Asian Development Bank (ADB). This project intends to raise S&T human resources by funding Thai university training at the postgraduate level. Various consortia have been formed among Thai universities and in partnership with industry to develop postgraduate S&T projects in seven fields: chemistry; environmental science, technology, and management; environmental and hazardous waste management; energy and environmental technology; petroleum and petrochemical technology; agricultural biotechnology; and post harvest technology. The project is expected to produce S&T postgraduates to meet the public and private sectors' labour demands, stimulate research and technological development, and facilitate Thailand's structural shift up the technology ladder in manufacturing and services.

4.4 Technological Development at the Firm Level

Thai companies have focused on acquiring strong manufacturing capabilities through imports of foreign technology, with little attention being paid to engineering, design, development and research. Yet, as noted, these capabilities will be essential for Thailand's future growth as lower-cost competitors emerge and the world market becomes more competitive. Most studies of the technological capabilities in Thai firms indicate that growth has been based on low-technology activities with little attention paid to strengthening long-run technological capacities and technological learning (Intarakumnerd et al., 2002). A recent study of technology development supported by the World Bank (Arnold et al., 2000) uses the framework presented in Figure 12.2 to analyse technological activity among different types of Thai firms.

Most large MNC subsidiaries, some large domestic firms and a few SMEs are generally able to acquire and assimilate technologies reasonably well, and are therefore on the threshold of technology upgrading and reverse engineering. Relatively few such firms have actually gone further into research and technology development.[22] The situation for the remaining large firms and SMEs is more worrying. In many of these firms, even

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Main Conclusions

(a) Thai policymakers have generally not been aware of the importance of technology and the need to devise policies supportive of R&D and S&T. Government expenditures in these areas have been insufficient, as have policies to encourage private R&D. The coordination of technology support policies has been weak, especially in linking such policies to broader economic policies and institutions.
(b) Thai industrial firms have not recognized the importance of investing in R&D and human resources. Many have diversified into peripheral businesses rather than consolidate their position in regional or global markets. They generally lack a strategic vision of moving up the value chain, and do not engage in collective action (through business associations and groupings) to undertake technological activity.
(c) The education and training system is not geared to providing the human resources needed for technology upgrading and innovation. Despite rising enrolment rates, Thailand's educational system, particularly the higher education system, remains weak. The resources provided are inadequate, curricula are outdated and teachers poorly paid and under-trained. Technical subjects receive little emphasis. At the firm level, employee training is low, partly because of employers' attitudes but also because of the lack of suitable institutions to provide the necessary training.
(d) The full potential of FDI has not been realized. Despite the billions of dollars of inflows, little attention has been given to raising linkages between foreign and domestic firms, inducing affiliates to deepen technological activity and parents to transfer innovative activities and skills.

5.2 How to Kill some Demons among Policymakers

There are some features of Thai science and technology policymaking that have to be addressed:

- There is insufficient realization that industrial firms are not only users of S&T services but also the major generators of technology – firms are in fact at the centre of the national innovation system. Evidence from developed countries shows that up to 80 per cent of technological effort is expended by firms. The perception in Thailand remains that the government's role is to support technological activities through public sector research institutions. This leads the government to neglect the role of measures to stimulate firm-level technological effort.

- Policymakers must understand that the main challenge today is to build knowledge, not just buildings and machines. Most incentives in place are aimed at capital investments of one kind or another. While there has been much talk of the 'knowledge economy' and the value of information, policies to support the acquisition, utilization and development of such assets have yet to be developed and implemented.
- The prevailing perception is that MNC strategies are completely determined by the head office, and that there is little is to be gained by closer collaboration with local affiliates. In fact, MNCs often give autonomy to their affiliates to devote resources to a range of technological activities and increasingly regard this as crucial to their global competitiveness. This trend is also evident in Thailand and needs to be exploited.
- A common perception in Thailand is that large or foreign firms do not require assistance from the government. International evidence suggests that the government can use incentives to encourage large and progressive firms to raise their technological activity and link up more closely to domestic suppliers and institutions.
- There is insufficient appreciation of the significance of clusters, networks, partnerships and the like in enhancing competitiveness.

5.3 An Agenda for FDI Policies

Promoting linkages and spillovers Efforts to enhance spillover benefits from FDI should be an intrinsic part of government strategies to enhance competitiveness and restructure industry. There is a strong case for government interventions because of the widespread externalities and information problems involved in building local linkages (UNCTAD *World Investment Report, 2001*). Such programmes are weak or absent in Thailand. It is recommended that:

- The government set up mechanisms to interact with MNCs in formulating policies and getting feedback on the impact and implementation of policies. The recent activities of the foreign business community to meet regularly with key government agencies have been fruitful and should be intensified.[26]
- The government should support local firms through vendor development programmes and other activities such as cluster and supply chain development. UNCTAD's *World Investment Report, 2001*

NOTES

1. This paper was prepared by Peter Brimble of The Brooker Group plc, as an input into a World Bank project on Competitiveness, FDI and Technological Activity in East Asia. Substantive inputs were received from Atchaka Sibunruang on Section 3 and from David Oldfield on parts of Section 2 and 4. The research in this paper is based mainly on secondary sources, with a few selected interviews and industry meetings.
2. Brimble et al. (1999) present a comprehensive overview of these issues.
3. As documented in the World Bank Atlas of 1996.
4. See Development Evaluation Division (1998).
5. A constellation of factors led to the rapid decline in exports in addition to declining competitiveness, including a slowdown in world trade, the emergence of China in global markets, EU restraints on certain Thai exports, and fluctuations in global electronic markets.
6. See Siamwalla (1997).
7. In this context, the increasing anti-foreign feelings that have characterized the policy approach in the first half of 2001 are a cause for concern, especially if they eventually extend beyond simple rhetoric to actual measures to roll back the critical reforms and to introduce anti-foreign regulations into the business environment.
8. See Brimble et al. (1993) for an analysis of the role of the private sector in the infrastructure sector. Annex 1-E summarizes the private sector initiatives of the Seventh Plan.
9. This comparison is developed in more depth in Arnold et al. (2000).
10. Indeed, a committee has been established to review the law, and preliminary indications are that a more restrictive definition of foreign ownership will be recommended as an amendment to the law. The time frame for the consideration and possible implementation of this are uncertain.
11. It should be noted that the Bank of Thailand did not include foreign capital inflows for banking capitalization in FDI statistics. The figure was about US$2 billion in 1998, which is when most of the capital injections into the banking sector occurred.
12. See the *World Investment Report 1992*, published by UNCTAD, for a more detailed analysis of the productivity of foreign firms versus that of domestic firms in developing countries.
13. These results were calculated from firm-level data of more than 1000 firms from which a simple production function was estimated. More details are provided in Dollar et al. (1998).
14. See Brimble et al. (1999) for additional examples. More such case studies are presently being compiled by The Brooker Group for a number of research projects related to competitiveness.
15. Storage Technology essentially includes all elements of the technology that is embodied in the products of the HDD industry.
16. See UNCTAD World Investment Report (2001) for a detailed profile of the TMT supplier initiative.
17. An innovative position paper presented in Joint Foreign Chambers of Commerce in Thailand (JFCCT) (2001) contains additional examples of the beneficial impacts of MNCs and identifies, from the perspective of the MNCs themselves, ways and means of enhancing these impacts.
18. Arnold et al. (2000) consider these issues in some depth.
19. It deserves to be emphasized that the figures in Table 12.8 that are derived from business perceptions must be treated with caution. However, they are included here as they represent the perceptions of business and are often used by foreign investors when making investment decisions.
20. See the draft final report of the NSTDA R&D/Innovation Survey in Brooker Group (2001).
21. See the draft final report of the NSTDA R&D/Innovation Survey in Brooker Group (2001). Since the survey only covered the manufacturing sector, no results are available for the entire business sector.

22. A recent survey of R&D in Thailand confirms this, finding that only around 15 per cent of medium to large manufacturing firms carried out some form of R&D (Brooker Group, 2001).
23. '. . . given Thailand's present level of economic development and its desire to continue rapid growth based on greater internationalization and competitiveness . . . The country needs to strengthen considerably its technological capability in industry. While most firms in the modern sector have reasonably adequate capability to operate their existing technology, they are weak in searching for, acquiring and adapting foreign technology. They are even weaker in developing their own technology. Local R&D efforts are minimal in the private sector . . .' (Dahlman and Brimble, 1990, p. 41).
24. Brooker Group interviews with private firms.
25. Arnold et al. (2000).
26. See Joint Foreign Chambers of Commerce in Thailand (JFCCT) (2001) for more details on the content and nature of these meetings and related activities of the foreign business community.
27. See Brooker Group (2001). The proposal has been widely accepted, yet not acted on to date.

BIBLIOGRAPHY

ADB (2000), *Key Indicators of Developing Asian and Pacific Countries 2000*, Volume XXXI, Manilla: Asian Development Bank.

Arnold, Erik, Martin Bell, John Bessant and Peter Brimble (2000), 'Enhancing Policy and Institutional Support for Industrial Technology Development in Thailand – The Overall Policy Framework and The Development of the Industrial Innovation System', paper prepared for the National Science and Technology Development Board with support from the World Bank, Bangkok, December 2000.

Brimble, Peter (1999), *Building Partnerships for Better Development: Outlook for Partnerships in Thailand*, Conference Proceedings of The 1st International Outlook Conference on Community Development in Asia-Pacific, Bangkok, Thailand.

Brimble, P., S. Greer and A. Brimble (1993), 'The private sector in Thailand: Towards enhancing ADB's private sector strategy', paper prepared for the Asian Development Bank, Bangkok.

Brimble, P., J. Sherman, A. Sibunruang and W. Rachatatanun (1999), 'The Broader Impacts of Foreign Direct Investment on Economic Development in Thailand: Corporate Responses', paper prepared for the High-Level Roundtable on Foreign Direct Investment and its Impact on Poverty Alleviation, Singapore, 14–15 December 1998; Revised April 1999.

Brimble, Peter and Chatri Sripaipan (1994), 'Science and Technology Issues in Thailand's Industrial Structure: The Key to the Future', prepared for the Asian Development Bank, June.

Brimble, P., C. Sripaipan, S. Vanichseni, and Y. Mukdapitak (1997), 'Towards a Technological Innovation Strategy for Thailand', paper prepared for the First International Conference on Technology Policy and Innovation, Macau, 2–4 July.

Brooker Group (2001), *NSTDA R&D/Innovation Survey*, Draft Final Report, July.

Dahlman, Carl and Peter Brimble (1990), 'Technology Strategy and Policy for International Competitiveness: A Case Study of Thailand', Industry and Energy

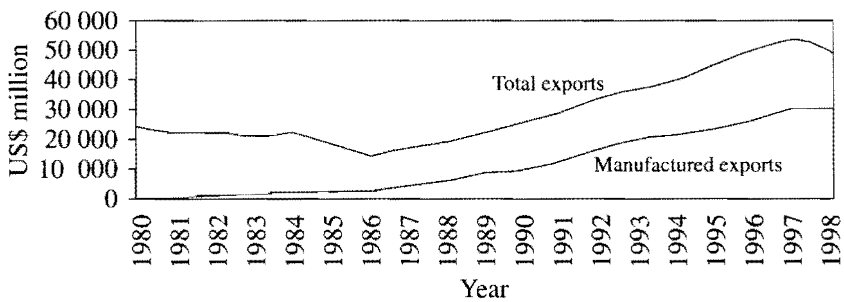
development and the policies that supported this. Section 4 discusses the lessons from Indonesia's technological development.

2. INDICATORS OF INDONESIAN TECHNOLOGICAL DEVELOPMENT

Technological development cannot be captured in a single measure; it is necessary to use several complementary indicators to get a clear picture (Hill and Wie, 1998: 13). It can be evaluated from 'inputs' – R&D, education – or 'outputs' – export competitiveness or productivity.[2] Let us start with one output indicator: exports. Figure 13.1 shows total and manufactured exports in Indonesia for 1980–98. Total exports grew very rapidly, at around 12 per cent per year; the performance of manufactured exports, at 23 per cent per year, was even more impressive. As a result, the share of manufactured products in total exports increased from 4 per cent in 1980 to 56 per cent by 1997.

At the sectoral level, most industries enjoyed high export growth (Table 13.1); with the exception of wood and steel, other industries had annual growth rates of over 20 per cent in dollar terms. Moreover, although resource-based and labour-intensive industries (such as food, garments, footwear, and toys) still account for over half of total manufactured exports, Indonesia did diversify its export base significantly. For instance, exports of textiles and electronics increased rapidly, their shares in manufactured exports rising from 10.8 and 3.2 per cent, respectively, in 1990 to 14.5 and 11.2 per cent by 1996.

However, despite this strong performance, Indonesian exports remain dominated by resource-based and labour-intensive products. In comparison to other countries in the region, its export structure is relatively unso-



Source: Asian Development Bank (1999).

Figure 13.1 Total and manufactured exports in Indonesia, 1980–98 phisticated (Table 13.2), even relative to other industrial latecomers like Malaysia and Thailand. For instance, about 50 per cent of Thailand's export is categorized as being technologically complex, whereas the corresponding figure for Indonesia is around 23 per cent.

It should be stressed that export figures are an imperfect measure of technology. For instance, classifying industries at different levels of technological intensity may be misleading: some low-technology products may use relatively sophisticated technological processes; and conversely, apparently high-technology activity may consist of simple assembly of imported components. In Indonesia, the latter is illustrated by electronics. The share of high-technology electronics products in manufactured exports was above 11 per cent in 1996, while its share of manufacturing value-added is below 4 per cent. This suggests that the industry consists largely of assembling imported inputs rather than making complex components. Of course, it should be expected that a country like Indonesia, with abundant labour and plentiful natural resources, would specialize in products that intensively use these factors rather than in high-technology products. At the same time, maintaining dynamic export growth does require a steady move up the technology ladder, and other resource-rich countries, such as Malaysia, have supplemented healthy growth of resource based products with far more dynamic high-technology ones.

Other measures of technological performance seem to confirm Indonesia's technological lags. Take some 'input' measures. Table 13.3 shows R&D expenditure as a percentage of GNP in some Asian countries. Indonesia allocated only 0.07 per cent of GNP to R&D in 1994, substantially less than any other country in the region, even those with a similar or lower GNP per capita (Philippines and India). Similarly, Indonesia has very low patent applications between 1981 and 1990: 12 compared to Korea's 6629, Malaysia's 406, the Philippines' 141, Singapore's 812, and Thailand's 144.[3]

The stock of skilled professionals shows, indirectly, the ability of a country to undertake technological effort. Indonesia possesses one of the smallest pools of skilled workers in the region, attributable to the low proportion of Indonesians enrolled in, or graduating from, science and technology courses at tertiary level (Hill, 1995: 94).

International comparisons of measures such as R&D and education may, however, underestimate technological efforts in Indonesia. They do not capture the kinds of informal technological activity that predominate in early stages of development, when most new technology is likely to be imported rather than created locally (Evenson and Westphal, 1995: 2249). The following discussion offers a more complete picture of technology development in Indonesia.

Table 13.1 Average annual growth rates of manufactured exports 1990–96 and sectors' shares of total manufacturing export (%)

Group	Sector	International Standard Industrial Classification	Export growth	Sector's share of total export	
				1990	1996
Resource-intensive	Food, beverage, tobacco	31	26.6	11.5	11.7
	Wood and furniture	33	18.4	31.3	19.3
	Coal and oil refineries	353, 354	n/a	0.0	0.0
	Rubber	355	20.9	11.9	8.5
	Non-metallic minerals	36	21.6	2.0	1.5
Labour-intensive	Garment	322	25.0	7.7	7.1
	Leather and footwear	323, 324	40.8	3.2	7.6
	Toys, etc.	39	43.0	0.4	1.2
Scale-intensive	Textile	321	31.3	10.8	14.5
	Paper and printing	34	27.0	2.3	2.4
	Chemicals[a]	351, 352	21.8	4.7	3.6
	Steel and non-ferrous met.	37	9.2	7.1	2.5
	Transport	384	57.9	0.5	3.6

Differentiated	Metal products	381	29.3	1.7	2.1
	Machinery	382	56.3	0.1	0.6
Science-based	Pharmaceuticals[b]		33.1	0.2	0.3
	Plastics	356	32.6	1.2	1.7
	Electronics	383	47.4	3.2	11.2
	Precision	385	68.6	0.0	0.5
Total			26.4	100	100

Notes:
Exports calculated in US dollar terms.
[a] except 35221, 35222, 35223, 35224.
[b] =35221, 35222, 35223 and 35224.

Source: Calculation based on data from the Indonesian Central Bureau of Statistics.

Table 13.2 Distribution of manufactured exports by technological categories, 1995

Country	Technologically complex	High-technology
Korea	65.2	44.1
Taiwan	59.9	49.3
Singapore	79.2	73.7
Indonesia	23.1	14.8
Malaysia	78.7	72.8
Thailand	53.6	45.9

Notes:
'Technologically complex' includes three categories: scale-intensive, differentiated, and science-based products.
'High-technology' includes two categories: differentiated and science-based products.

Source: Lall (1998: 142–3).

Table 13.3 R&D expenditures as percentage of GNP in Indonesia and other selected Asian countries

Country	Year	R&D expenditure as % of GNP
Indonesia[a]	1994	0.1
India	1994	0.7
Korea	1994	2.6
Malaysia	1994	0.4
Philippines	1992	0.2
Singapore[b]	1995	1.1
Thailand	1995	0.1

Notes:
[a] Figures refer to the productive sector only.
[b] Not including R&D in social sciences and humanities.

Source: UNESCO (1999).

3. SOURCES OF TECHNOLOGICAL CAPABILITY AND POLICY ISSUES

3.1 Sources of Technological Capability

There are two (complementary) ways for a country to improve its technological capability. The first is to undertake domestic innovation, by building a strong R&D capability. The second is to import technology from other countries by inward FDI, licensing, subcontracting and original equipment manufacturing (OEM) arrangements. Both have been used in Indonesia.

Domestic R&D

R&D is, as noted, relatively low in Indonesia throughout the manufacturing sector (Table 13.4). Even highly R&D-intensive industries internationally spend little on R&D in Indonesia (R&D is only 0.24 per cent of sales in pharmaceuticals). However, some Indonesian firms have started to conduct R&D, with the share of establishments engaged in R&D higher in scale-intensive, differentiated and high-technology industries. Over time, this should increase as industry moves into more complex technologies where local R&D is essential even to absorb and adapt new technologies.

The public infrastructure supporting industrial R&D is weak (Hill and Wie, 1998; Lall, 1998; Thee, 1998). There are 12 national public R&D institutes and several regional R&D centres. According to Hill and Wie (1998: 50), most institutes face two problems. The first is a weak funding base, as a result of which they have difficulties in hiring qualified staff. The second is the lack of ties with the private sector: R&D programmes tend to be supply rather than demand driven, carrying out programmes devised by their managers and politicians rather than in response to industrial needs. For example, linkages between public R&D institutes and the successful export-oriented textile, garment and electronics firms have been very weak (Thee, 1998: 125). Many public R&D institutions have been involved in projects like aircraft manufacturing in Bandung, a strategic initiative of the government rather than a commercial venture.

Foreign direct investment

Indonesia has traditionally relied on capital inflows through external borrowing rather than FDI. One reason has been the widespread suspicion in Indonesia of foreign involvement in general and of FDI in particular. However, falling oil prices in the early 1980s led to a liberalization of the FDI regime, and this continued throughout the 1980s and 90s. These policy changes led to a large influx of FDI and the number of foreign establishments

Table 13.4 *R&D intensity by industry, 1995*

Group	Sector	International Standard Industrial Classification	R&D as a share of output (%)	Share of establishments engaged in R&D (%)
Resource-intensive	Food, beverage, tobacco	31	0.02	6.8
	Wood and furniture	33	0.03	5.4
	Coal and oil refineries	353, 354	0.15	13.5
	Rubber	355	0.05	14.4
	Non-metallic minerals	36	0.02	6.1
Labour-intensive	Garment	322	0.01	3.0
	Leather and footwear	323, 324	0.03	9.6
	Toys, etc.	39	0.04	7.4
Scale-intensive	Textile	321	0.02	5.5
	Paper and printing	34	0.05	7.0
	Chemicals[a]	351, 352	0.08	17.4
	Steel and non-ferrous met.	37	0.02	13.3
	Transport	384	0.05	12.4
Differentiated	Metal products	381	0.04	7.7
	Machinery	382	0.05	12.5
Science-based	Pharmaceuticals[b]		0.24	31.1
	Plastics	356	0.01	4.6
	Electronics	383	0.09	13.8
	Precision	385	0.02	8.1

Notes:
[a] except 35221, 35222, 35223, 35224.
[b] =35221, 35222, 35223 and 35224.

Source: See Table 13.1.

increased by 80 per cent between 1980 and 1990 (Table 13.5). However, the foreign share of value-added and employment decreased for some time because of the rapid expansion of domestic enterprises, perhaps because they were more aware than foreign investors of policy changes and better able to take advantage of them. After 1990, however, FDI rose even faster, with the number of foreign-owned establishments increasing by more than 120 per cent between 1990 and 1996. The share of foreign enterprises in manufacturing employment rose from 10 to 16 per cent and in manufacturing value-added from 22 to 30 per cent over 1990–96.

Table 13.5 shows that the foreign share of value-added exceeds the foreign share of employment: value-added per employee is higher in foreign than in domestic establishments. Part of this higher labour productivity can be explained by the larger size and greater capital-intensity of foreign affiliates. Part is likely to be explained by the use of more advanced technologies by foreign-owned firms. Okamoto and Sjöholm (2000a) find that the pace of technological change, as measured by TFP growth, is relatively high in foreign establishments. In fact, foreign establishments, despite accounting for relatively small shares of sector output (Table 13.5), generate the bulk of TFP growth in many sectors. One plausible explanation for this is that foreign affiliates have access to superior technology from parent firms.

Foreign firms have played a vital role in Indonesia's recent manufactured export growth. Exporting is a difficult process, requiring detailed knowledge of foreign markets, distribution systems, regulations and other characteristics; multinationals have a clear advantage in collecting such information. It also needs specialized skills, technologies and capabilities that MNCs generally possess to a greater extent than local firms. It is not surprising, therefore, that foreign firms in Indonesia export more in relation to output than domestic firms (Ramstetter, 1999). Moreover, even the foreign firms that start by producing only for the Indonesian market tend to be relatively flexible and seek out foreign markets when this is profitable (Sjöholm, 1999a). Figure 13.2 shows the correlation between inward FDI flows and manufactured exports.

While MNCs have certainly introduced new technologies and manufacturing capabilities to Indonesia, their impact on domestic firms is more ambiguous. There are likely to be both positive and negative effects on domestic firms from the entry of FDI. Some domestic firms face decreases in their market shares and may even be forced out of business; in contrast, firms supplying foreign affiliates may enjoy larger markets. Some firms may gain access to the new technologies brought in by MNCs and so raise their productivity and competitiveness. Others may respond to increased competition by investing in new technologies. There may be other spillover benefits from MNCs from labour turnover or demonstration effects.

the wider dissemination of technology. Hence, FDI attraction should be complemented by policies to increase the degree of competition and raise the level of local skills and capabilities.

Other external private sources: the case of local textile companies

Formal technology transfers through FDI and licensing agreements are clearly important in acquiring and mastering new technology. However, a case study of some local Indonesian firms reveals that these mechanisms are only part of technology inflows from abroad. Table 13.6 shows various sources of technology in seven major Indonesian textile firms.[4] All these firms are successful exporters. Two have licensing agreements with Japanese textile companies, buying proprietary technologies from Japanese companies in return for royalty fees. However, this formal channel is only one source of technological acquisition.

Another source is imported capital equipment. All companies surveyed purchased capital equipment from abroad, mainly from Japan. As Evenson and Westphal (1995: 2264) note, imports of capital goods played an important role in the industrial development of many successful export-led economies. Indonesian trade statistics show that equipment imports are rising in importance. As Figure 13.3 shows, the total value of Indonesian imported capital equipment has increased sharply since the mid-1980s. Japanese trading companies often played an important role in facilitating such imports, for instance by providing loans. In many cases, trading companies also provided valuable marketing know-how and information on foreign markets.

Foreign technical experts have also been an important source of technological upgrading. All the surveyed companies used foreign, mainly Japanese, experts. Many of these experts were financed by Japanese aid. It is important to note, however, that tied aid was not the main reason for hiring Japanese experts; these experts already have long-standing and extensive contacts with Indonesian firms, and employment contracts have been generally made through private contacts. Korean and Taiwanese experts may be more important in the future, as the number of Japanese experts is falling with the decline of Japan's textile industry.

Japanese and Korean affiliates in Indonesia provide technical assistance in the textile industry through inter-company linkages. Almost all the surveyed textile exporters purchase synthetic fibres mainly from foreign affiliates, which provide technical assistance as part of the business arrangement.

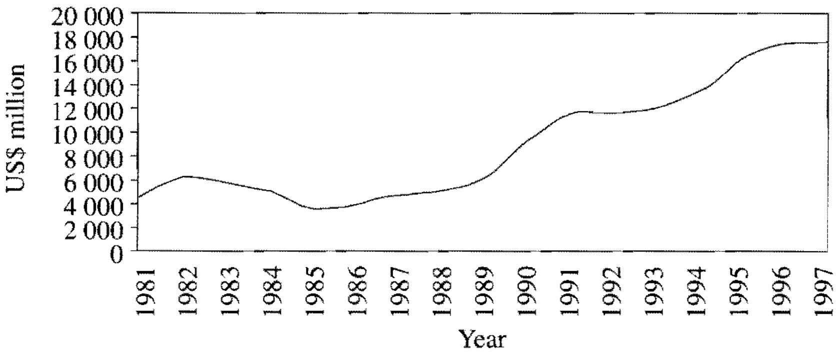
This case study shows the importance of various sources of technological capability in addition to explicit channels such as FDI and licensing. The importance of such sources cannot often be inferred from conventional data on technology purchases or innovation. Our findings are

Table 13.6 Sources of technological capability in seven Indonesian textile firms

Company	Founded	No. of employees	Export markets	Licensing agreements	Imported capital equipment	Foreign trading companies and buyers	Foreign technical experts	Technical assistance through inter-company linkages
A	n/a	1200	Japan Others	None	Made in Japan	JTC Indian merchants	Japanese Korean	Japanese and Korean affiliates in Indonesia Non-*pribumi* firms (Indian)
B	1968	1552	Malaysia, Brunei, Canada, Australia, Others	Yes From 1985–present (Japan)	n/a	n/a	Japanese	Mainly a Japanese affiliate in Indonesia
C	1976	2400	Middle East (55%) Europe (20%) Others	None	Made in Japan, purchased in 1989 through JTC	Indian merchants	Japanese	Japanese and Korean affiliates in Indonesia Non-*pribumi* firms (Indian)
D	1962	1600	Europe Middle East	None	Made in Japan, purchased between 1986–96 through JTC	Chinese buyers	Japanese	Japanese and Korean affiliates in Indonesia
E	1976	1500	Europe (60%) Middle East (10%) USA (5–10%) Others	None	Made in Japan	JTC	Taiwanese Japanese	Mainly a Japanese affiliate in Indonesia
F	1969	1230	Middle East Europe	None	Made in Japan Made in Korea	n/a	Japanese	Japanese affiliates in Indonesia
G	1970	2500	Asia (30%) Europe (30%) Middle East (20%) Others	Yes (1994–present) (Japan)	Yes	JTC KTC TTC	Japanese Taiwanese Korean	Mainly a Japanese affiliate in Indonesia

Note: JTC = Japanese trading company; KTC = Korean trading company; TTC = Taiwanese trading company.

Source: Based on research material provided by Mr Abe, Institute of Developing Economies, Japan.



Source: Asian Development Bank (1999).

Figure 13.3 Machinery imports in Indonesia, 1981–97

consistent with another study on Indonesian textiles (Pangestu, 1997), according to which the main sources of technological capability are imports. Imports of equipment and provision of support services by foreign firms are some of the observed channels of technology transfer.

Other external private sources: the case of local SMEs in three industries

What about technology development in small enterprises? We draw upon a survey of small and medium-sized enterprises (SMEs) by Berry and Levy (1994), who studied successful Indonesian exporters in the garment, rattan furniture and carved wooden furniture industries. The findings are similar to those for large textile companies, with private external channels being pivotal in acquiring technology. Foreign buyers played a dominant role in establishing and sustaining export market linkages for SMEs. Local firms and foreign buyers had a strong mutual interest in improving the quality of the product; the buyers consequently provided designs and technical assistance to producers. In addition, expatriate employees were critical to acquiring new technical know-how. In particular, experts from Hong Kong and Korea facilitated the introduction of advanced technical know-how. SMEs have also been supported in technology development by industry association and public agencies. This is particularly the case for *pribumi* (indigenous Indonesian) firms, which lack access to international networks. In general, however, private channels tend to be the most important sources of technology in all industries surveyed.

3.2 Public policy issues

Studies on technology development stress the importance of incentives, education and training, well-developed technical infrastructure and science and technology (S&T) policies.[5] This subsection evaluates policy and institutional arrangements in Indonesia in these four areas.

Incentives

Most channels of technology transfer, formal or informal, are related to trade and FDI. Thus, the adoption of more outward-oriented economic policies in the mid-1980s led to a rise in technology inflows into Indonesia. Export-oriented investments were stimulated by the duty exemptions and drawback scheme introduced in 1986, which allowed exporters to buy inputs and capital equipment at international prices (Pangestu, 1997:45). Several other measures to reduce the earlier anti-export bias were also introduced. Effective rates of protection for manufacturing fell significantly, from 59 per cent in 1987 to 16 per cent in 1995 (Fane and Condon, 1996: 40). Economic reforms were extended in 1994, with further liberalization of FDI and international trade (Pangestu, 1998: 5).

It may be argued that Indonesia's economic reforms in the 1980s and early 1990s did more to promote technology development than any explicit technology policy (Hill, 1995: 110, Hill and Wie, 1998:40). Indonesia's stable and growing economy, together with policies to promote international trade and FDI, facilitated technology inflows and induced indigenous firms to upgrade existing technologies and adopt new ones.

Education and training

Education and training provide most of the skills needed for technology development (Thee, 1998: 119; Lall, 1996). Educational requirements change over time: basic literacy and numeracy may be sufficient for the first phase of industrialization, but more advanced and specialized skills become necessary as the industrial structure becomes more complex and diverse.

Indonesia expanded basic education rapidly in the 1970s. Over 60000 new schools were built; real expenditures spent on education more than doubled; primary education was made compulsory; and school fees were abolished (Duflo, 2000). As a result, a near 100 per cent enrolment ratio was achieved in primary education by the 1980s. Secondary school enrolments increased from 35 to 48 per cent for male students and from 23 to 39 per cent for female students between 1980 and 1993 (Thee, 1998: 121). The expansion of primary education received widespread international recognition and it is likely to have facilitated Indonesia's first stage of industrial development.

However, despite the expansion, the Indonesian education system remains weak. Government education expenditures comprise only 2 per cent of GDP, substantially lower than most neighbouring countries (Booth, 1999). Though junior secondary school was made compulsory in 1994, enrolment rates are still only about 70 per cent (Booth, 2000: 154). The quality of education at all levels remains poor.[6] Indonesian 9–10 year olds perform below the international average in comparative tests (World Bank, 1997: 120) and most university graduates are said to require months of extensive on-the-job training (Booth, 1999: 301). The poor quality of education is attributable to large classes, poorly trained teachers and a lack of proper school materials.

There are additional problems at the tertiary level. The system seems to emphasize cheap education rather than the provision of the science and engineering skills needed by the economy. This has resulted not only in a weak skill base but also in high rates of unemployment among university graduates. The 44 state universities, 24 state polytechnics and 5 state fine arts academies have not been able to meet the demand for higher education (Mukhopadhaya, 2000). As a result, more than a thousand private institutes have been established to meet this demand, but inadequate monitoring has led to widespread quality problems. The government has recently abolished university subsidies, which may exacerbate skill shortages.

Although poor education could be partly offset by extensive on-the-job training, Indonesian firms spend relatively little on human resource development (HRD). Table 13.7 shows HRD expenditures as a percentage of sales and the proportion of establishments with HRD programmes in 1995. Expenditures on employee training are low, similar in size to R&D.[7] The proportion of establishments with HRD is small apart from a few industries like rubber, steel, pharmaceuticals and electronics.

A weak skill base may not be a significant problem in the early stage of industrial development when low wages and natural resources provide the basis for exports and investment. However, more sophisticated production technologies require a higher quality of education and training. The weak industrial skill base is perhaps the single most important deterrent to technology development in Indonesia.

Technological infrastructure

The technological infrastructure is another important determinant of technology development. Many forms of technical information and support, with public good characteristics, cannot be provided by the market and have to be provided by the government (Lall, 1996: 44). The government's role includes the setting of industrial standards, the promotion of quality awareness, the provision of metrology services, testing or information

Table 13.7 Human resource development (HRD) in the Indonesian manufacturing sector, 1995

Group	Sector	International Standard Industrial Classification	HRD expenditures as a share of output (%)	Share of establishments engaged in HRD (%)
Resource-intensive	Food, beverage, tobacco	31	0.02	9.5
	Wood and furniture	33	0.02	11.9
	Coal and oil refineries	353, 354	0.02	10.8
	Rubber	355	0.10	23.2
	Non-metallic minerals	36	0.02	7.7
Labour-intensive	Garment	322	0.01	5.6
	Leather and footwear	323, 324	0.04	12.9
	Toys, etc.	39	0.02	11.6
Scale-intensive	Textile	321	0.02	9.2
	Paper and printing	34	0.06	14.7
	Chemicals[a]	351, 352	0.03	19.6
	Steel and non-ferrous metals	37	0.03	22.1
	Transport	384	0.04	18.9
Differentiated	Metal products	381	0.03	14.3
	Machinery	382	0.04	15.1
Science-based	Pharmaceuticals[b]		0.26	35.1
	Plastics	356	0.01	8.4
	Electronics	383	0.06	27.4
	Precision	385	0.03	14.9

Notes:
[a] except 35221, 35222, 35223, 35224.
[b] = 35221, 35222, 35223 and 35224.

Source: See Table 13.1.

search for firms that lack the facilities or skills, undertaking contract research, and extension services for SMEs.

The public provision of information and support is particular important for SMEs. In a study of SMEs in Japan, Korea, Indonesia and Colombia, Levy (1994) concluded that although the leading sources of marketing and technical support were private, public initiatives in this area were also important. More precisely, public provision of technical information, technological training and assistance, and joint and contract technology development were of significant help to SMEs. Moreover, the need for public support tends to be high when technological requirements are complex or when private technology networks are weak (Levy, 1994: 30). This suggests that as Indonesia moves up the quality ladder, the role of government will tend to increase.

Indonesia has not yet developed an effective technological infrastructure. There are numerous examples of institutions failing to address the tasks for which they were set up (Thee, 1998: 127). Metrology, standards, testing, and quality assurance services are inadequate. This is partly because the importance of such services is not fully understood, and partly because comprehensive industrial standards are lacking (Lall, 1998: 154). Indonesia lacks an effective productivity centre to provide industry-wide technical training and assistance, especially for SMEs. Organizations such as the Institute for Machine Tools, Automation and Production Technology, established to provide such services, tend to meet the demands of only a few 'strategic' industries (Lall, 1998: 155).

To sum up, a technical infrastructure is needed to adopt, disseminate, and upgrade technology, but presently such an infrastructure is poorly developed in Indonesia.

Specific S&T policies

One of the most notable, and controversial, of all government interventions in Indonesia since the late 1970s, has been the aggressive high-technology programme. The government targeted and tried to promote indigenous technological capability in ten high-technology industries, including aircraft, shipbuilding, railroads, telecommunications, electronics, steel and machine goods. The best known part of the program is the development of an aircraft industry (IPTN), which has been the government's largest and most ambitious programme of technology development (Lall 1998: 158).

Despite the accumulation of some engineering and production knowledge, IPTN has never been financially viable. According to McKendrick (1992: 64), managerial weakness, the absence of an independent aviation agency and Indonesia's weak scientific and engineering infrastructure account for its poor performance. The industry has few linkages with other sectors of the economy, and there are few noticeable spillovers (Lall, 1998: 158).

Indonesian S&T policy since the late 1970s illustrates that high-technology projects do not always lead to a broad-based and efficient technology development, particularly when the underlying research, education and technical infrastructure is weak (Hill, 1995: 118).

3.3 Technology Policy after the Crisis

No country in Southeast Asia was more severely hurt by the financial crisis than Indonesia. GDP fell by about 15 per cent, unemployment and poverty increased, many businesses closed down and there were dramatic social and political changes. As a result, the scope and potential for technology policy is different from the pre-crisis period. Technology seems to be of less immediate concern than raising employment and revitalizing firms forced out of business; thus, efforts are likely to focus on labour-intensive rather than technology-intensive industries.[8] The government's ability to fund technology policy is seriously constrained, as there are many other pressing economic needs. The crisis in the financial sector is estimated to cost the government somewhere between 60 and 100 per cent of GDP (spread over several years).

Considering the limited benefits of previous public technology projects, perhaps it does not matter very much that the government cannot continue with these projects. It seems more important that the government concentrate its efforts on maintaining high enrolment rates in primary and secondary education. Rising rates of school dropout in poor urban areas following the crisis alarmed the government, which responded by abolishing school fees (Booth, 2000: 151–4). The situation seems to have improved, but new problems lie ahead. Most importantly, the new decentralized structure of Indonesia may affect the education system. Two new laws on political and fiscal decentralization were introduced in 2001. As a consequence, the districts and regions were allowed to keep a larger share of taxes and revenues from oil and gas, which had previously been transferred to Jakarta. On the other hand, they will also receive fewer transfers from Jakarta and will be responsible for certain expenditures, including education. The new system will benefit a few resource rich provinces as well as West Java and Jakarta, but other parts of Indonesia will suffer substantial reductions in resources. There is an obvious risk that these regions will find it increasingly difficult to obtain the resources adequately to educate their citizens.

Liberalization of the FDI regime will probably continue since Indonesia is likely to be more dependent on FDI in the future. The financial crisis has wiped out large parts of domestic capital and foreign banks are reluctant to offer further loans. Financing current account deficits by external borrowing has been found to be much riskier than by relying on FDI. Unfortunately, FDI inflows have declined in the last few years, falling from a peak of US$6 billion in 1996 to minus US$3 billion in 1999 (Ramstetter, 2000). To attract new FDI and cope with intensified competition in the region, a robust investment regime is needed. If Indonesia can attract more FDI, there is the potential for increasing technology diffusion by improving the skill base and increasing competition in the economy.

4. SUMMARY AND LESSONS FOR OTHER DEVELOPING COUNTRIES

In Indonesia's present economic predicament, it is easy to forget its remarkable economic performance during previous decades. Indonesia achieved not only high growth rates and improved living standards for the population, it also underwent substantial structural transformation.

At least four lessons can be learned from Indonesia's technology development. First, several external sources of technology are important in the early stages of industrial development when technological requirements are relatively low. Foreign buyers, trading companies, and foreign experts are channels through which new technology and know-how are acquired. This implies that openness to trade, investment and skilled labour will enhance industrial technology development.

Second, the public sector has to make greater efforts to acquire, upgrade, and disseminate technology and know-how as a country moves up the technology ladder. This is particularly the case when private industrial linkages and networks are weak. Hence, government intervention in technology development may increase over time.

Third, FDI can play an important role in introducing new technology, generating employment and expanding production and exports. FDI is crucial to technology development when there are constraints on domestic efforts, notably insufficient government funding. However, FDI does not automatically generate substantial spillovers and linkage effects, nor does it necessarily lead to technological upgrading. Complementary efforts to maximize benefits from FDI are important in enhancing technological development.

Finally, policies targeting high-technology industries tend to fail when the technological, managerial and institutional infrastructure is underdeveloped. Hence, a micro-level intervention to promote technological development might be useful, but only when sufficient skills are available and the technical infrastructure is in place.

NOTES

1. Asian Development Bank (1999).
2. For instance, Lall (1998: 138) uses the technological structure of manufactured exports (divided between low, medium and high-technology products) as an indicator of technological sophistication.
3. See table 1 of Hill (1995: 92).
4. More specifically, they are producers and exporters of woven fabric of polyester filament yarn or polyester filament fabric. We are grateful to Mr Makoto Abe, Institute of Developing Economies in Tokyo, for providing the information in Table 13.6.
5. Lall (1996, 1998), Thee (1998), Nelson (1993), and Evenson and Westphal (1995).
6. See, for instance, Hill (1995), Hill and Wie (1998), Lall (1998), Thee (1998), and Booth (1999).
7. See Table 13.4 for figures on R&D.
8. However, technology, in the sense of market knowledge, will continue to be important. In fact, exports will be crucial in any expansion of production since domestic demand is constrained by the recession. Trade contacts, foreign trading houses, FDI and other channels will have to be utilized to achieve the necessary knowledge for this export expansion.

REFERENCES

Asian Development Bank (1999), *Key Indicators of Developing Asian and Pacific Countries, 1996*, Hong Kong: Oxford University Press.

Aswicahyono, H., C. Basri and H. Hill (2000), 'How not to industrialise? Indonesia's automotive industry', *Bulletin of Indonesian Economic Studies*, **36**, 209–241.

Berry, A. and B. Levy (1994), 'Indonesia's small and medium-size exporters and their support systems', World Bank policy research working paper No.1402.

Blomström, M. and F. Sjöholm (1999), 'Technology transfer and spillovers: does local participation with multinationals matter?', *European Economic Review*, **43**, 915–23.

Booth, A. (1999), 'Education and economic development in Southeast Asia: myths and realities', *ASEAN Economic Bulletin*, **16**(3), 290–306.

Booth, A. (2000), 'The impact of the Indonesian crisis on welfare: what do we know two years on?', in C. Manning and P. Van Diermen (eds), *Indonesia in Transition: Social Aspects of Reformasi and Crisis*, Singapore: Institute of Southeast Asian Studies.

Duflo, E. (2000), 'Schooling and labor market consequences of school construction in Indonesia: evidence from an unusual policy experiment', NBER working paper No. 7860.

Evenson, R.E. and L.E. Westphal (1995), 'Technological change and technology strategy', in J. Behrman and T.N. Srinivasan (eds), *Handbook of Development Economics Vol. III*, Amsterdam: Elsevier.

Fane, G. and T. Condon (1996), 'Trade reform in Indonesia, 1987–95', *Bulletin of Indonesian Economic Studies*, **32**(3), 33–54.

Hill, H. (1995), 'Indonesia's great leap forward? Technology development and policy issues', *Bulletin of Indonesian Economic Studies*, **31**(2), 83–123.
Hill, H. and Thee Kian Wie (eds) (1998), *Indonesia's Technological Challenge*, Singapore: Institute of Southeast Asian Studies.
Lall, S. (1996), *Learning from the Asian Tigers: Studies in Technology and Industrial Policy*, London: Macmillan Press.
Lall, S. (1998), 'Technology policies in Indonesia', in H. Hill and Thee Kian Wie (eds), *Indonesia's Technological Challenge*, Singapore: Institute of Southeast Asian Studies.
Levy, B. (1994), 'Technical and marketing support systems for successful small and medium-size enterprises in four countries', The World Bank policy research working paper No. 1400.
McKendrick, D. (1992), 'Obstacles to 'catch-up': the case of the Indonesian aircraft industry,' *Bulletin of Indonesian Economic Studies*, **28**(1), 39–66.
Mukhopadhaya, P. (2000), 'Income gap and educational opportunity in some Southeast Asian countries: government efforts in bridging inequality', mimeo, Department of Economics, National University of Singapore.
Nelson, R.R. (1993) (ed.), *National Innovation Systems: A Comparative Analysis*, New York: Oxford University Press.
Okamoto, Y. and F. Sjöholm (2000a), 'FDI and the dynamics of productivity: microeconomic evidence', APEC discussion paper No. 34, Nagoya University.
Okamoto, Y. and F. Sjöholm (2000b), 'Productivity in the Indonesian Automotive Industry', *ASEAN Economic Bulletin*, **17**, 1–14.
Pangestu, M. P. (1997), 'The Indonesian textile and garment industry: structural change and competitive challenges', in M. E. Pangestu and Y. Sato (eds) *Waves of Change in Indonesia's Manufacturing Industry*, Tokyo: Institute of Developing Economies.
Pangestu, M. P. (1998), 'The Indonesian textile and garment industry: structural change and corporate responses', in Y. Sato (ed.), *Changing Industrial Structures and Business Strategies in Indonesia*, Tokyo: Institute of Developing Economies.
Ramstetter, E.D. (1999), 'Trade propensities and foreign ownership shares in Indonesian manufacturing', *Bulletin of Indonesian Economic Studies*, 35, 43–66.
Ramstetter, E.D. (2000), 'Survey of recent developments', mimeo, Kitakyoshu, International Centre for the Study of East Asian Development.
Rock, M. T. (1999), 'Reassessing the effectiveness of industrial policy in Indonesia: can the neoliberals be wrong?', *World Development*, **27**(4), 691–704.
Sjöholm, F. (1999a), 'Learning to export: the role of foreign contacts', working paper No. 326, Stockholm School of Economics.
Sjöholm, F. (1999b), 'Technology gap, competition and spillovers from direct foreign investment: evidence from establishment data', *Journal of Development Studies*, **36**, pp. 53–73.
Sjöholm, F. (1999c), 'Productivity growth in Indonesia: the role of regional characteristics and direct foreign investment', *Economic Development and Cultural Change*, **47**, 559–84.
Thee Kian Wie (1998), 'Determinants of Indonesia's industrial technology development', in H. Hill and Thee Kian Wie (eds), *Indonesia's Technological Challenge*. Singapore: Institute of Southeast Asian Studies.
UNESCO (1999), *Statistical Yearbook*, Lanham, MD: Bernan Press.
World Bank (1997), 'Training and the Labor market in Indonesia: productivity gains and employment growth', report No. 16990–IND, Washington DC.

Index