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**Productivity growth and Technological
Change in the East Asian NIEs:
The Case of Korea**

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**A thesis submitted for the degree of
Doctor of Philosophy
at the Australian National University**

June 1998

Declaration

This thesis was written while I was a student at the Australia-Japan Research Centre of the Australian National University. The work is my own, unless otherwise indicated.

Chang-Soo Lee

June 1998

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Special mention must be made of my wife, daughter and parents for their encouragement and support over a long time. This thesis is the crystallisation of their sacrifices. I dedicate this thesis to them.

Chang-Soo Lee

June 1998

Abstract

Growth accounting exercises suggest that the reason for the remarkable growth in East Asian newly industrialising economies over the past four decades was capital accumulation. Capital accumulation, rather than productivity growth, was identified as the main source of economic growth.

This thesis explores the character of East Asian growth, and how it has been driven by structural change over the past four decades. Structural change increased capital intensity in industrial production in new industries and high-quality production with the accumulation of capital. The argument is that this process mechanically leads to low productivity gains, because the joint contribution of capital and technology to output growth is solely attributed to capital, so underestimating the role of technological change. It is therefore misleading to interpret low measured productivity growth in growth accounting studies as a sign of the unsustainability of growth on the assumption that measured productivity growth is identical to technological change.

Verification of the sequencing of the sources of output growth (productivity growth in light industries leads to capital accumulation in heavy and petrochemical industries and in turn to productivity growth through R&D investment) and interaction between capital and productivity growth provides a new interpretation of the growth accounting results. East Asian NIEs have not yet arrived at the final stage of development, where innovation by R&D investment is the primary means of technological change. Rapid growth in these economies has been driven by structural adjustment, which links capital accumulation and technological change.

The thesis has two implications for technological change in follower countries. First, there are shifts in the major channels of technology transfer over different

phases of development (from informal methods to capital import to technology imports to R&D investment). Second, rival and bounded components of technology have played a crucial role in East Asian growth.

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Abbreviations

BEA	Bureau of Economic Analysis (United States)
D–W	Durbin–Watson statistic
FDI	Foreign direct investment
GDP	Gross domestic product
GNP	Gross national product
KDI	Korea Development Institute
KIEP	Korean Institute for International Economic Policy
LDCs	Less developed countries
MNEs	Multinational enterprises
NICs	Newly industrialising countries
NIEs	Newly industrialising economies
OECD	Organisation for Economic and Cultural Development
OEM	Original equipment manufacture
PWT	Penn World Table
ROK	Republic of Korea
R&D	Research and development
TFP	Total factor productivity
TL	Technology licensing
VAR	Vector autoregressive regression
WSSP	Weighted sum of sectoral productivity growth
WWII	The Second World War

***I* Productivity and the Sustainability of Growth in the NIEs**

The small contribution of technical change in industry to overall growth may thus in part be a statistical illusion; since the new technology has been embodied in capital, a significant part of its contribution may be misattributed to capital accumulation in the Denison-type growth accounting (Adelman 1991: 501).

The remarkable economic growth in the East Asian newly industrialising economies (NIEs) over the past three decades has been a major issue in the literature on economic growth. The East Asian growth phenomenon was widely viewed as a success story based on an outward-oriented strategy involving increasingly free trade, and it was regarded as a model for developing countries in the 1970s and 1980s. The debate on East Asian growth was revitalised in the 1990s. The view of World Bank (1993) was that East Asian success resulted from functional interventions affecting market fundamentals. Sound macroeconomic policies, an emphasis on investments in human capital and export orientation are examples of functional interventions. The Bank argued that selective interventions in Korea were unsuccessful considering total factor productivity (TFP) performance in targeted industries was considered a criteria of success. Opposing this view, revisionists argued that selective interventions played a role in creating dynamic advantages (Amsden 1994; Kwon 1994; Lall 1994a; 1996). However, the focus of the debate was on the validity of government interventions, so that important features of Asian growth, such as sequential structural adjustments, were not investigated. Subsequently, the weakness of productivity growth in NIEs became the main concern of economists.

Growth accounting exercises call into question the view that high productivity growth is the reason for the remarkable growth in this region, identifying resource mobilisation, in particular capital accumulation, as the main source of economic

growth (Young 1992; 1994; 1995; Kim and Lau 1993; 1994a; 1994b; Collins and Bosworth 1996). Kim and Lau (1993: 19–20; 1994b) estimate that productivity growth in the NIEs has not been significantly different from zero over the past few decades. On the other hand, according to Young's (1995) estimates, the contribution of TFP to growth in each country is 31.5 per cent in Hong Kong, 2.3 per cent in Singapore, 27.7 per cent in Taiwan, and 16.5 per cent in Korea, while the contribution of capital is 40.8, 64.9, 33.6 and 37.2 per cent, respectively, and according to Collins and Bosworth (1996), the contribution of TFP to growth is 27.8 per cent in Singapore, 34.5 per cent in Taiwan and 26.3 per cent in Korea.

Krugman (1994) concludes that growth in the NIEs is unsustainable, comparing them with former Soviet Russia, which experienced a dramatic slowdown after remarkable growth fuelled by capital mobilisation. He argues that East Asian economies may also inevitably experience a slowdown because of a lack of productivity gains. Low productivity growth, when combined with the view that disembodied technological change driven by innovation is the main contributor to long-run growth (Griliches 1973; 1979; 1980; 1986), implies that NIEs will not be able to achieve sustainable growth in the long run. The judgement on the sustainability of growth is based on two theoretical assumptions: that disembodied technological change driven by R&D efforts is the sole source of long-run growth; and that growth accounting techniques correctly measure technological change as productivity growth.

Another stream of studies, the proponents of convergence (or of the advantage of backwardness), emphasises that East Asian growth should be viewed from the perspective of follower countries, characterised by learning and utilising standardised foreign technology, rather than innovation. Empirical studies in this school show a convergence of per capita income levels but no convergence of TFP levels, confirming the findings of the growth accountants (Dollar and Sokoloff 1990; Dollar 1991; Dowrick and Gemmel 1991; Pack 1992a; 1993; Pack and Page 1994; Drysdale and Huang 1996). They do not, however, agree on the unsustainability argument because they maintain that capital intensity or

export orientation in these economies has a positive effect on productivity growth. This argument may not be strong because the measured productivity gain is not large.

The empirical findings and the implication that growth in the NIEs is unsustainable may not be robust.

First, highly aggregated data are used to calculate productivity growth, so aggregation bias is present. An aggregate production function approach can be justified only if all sectoral production functions are identical (Jorgenson 1990: 24). Second, capital stock data are unreliable because they are constructed from historical investment data using simplistic and arbitrary assumptions. Third, some studies using the production function estimation technique are also unreliable because of their assumption that the weights of inputs are constant over time. The first part of the thesis seeks to overcome these problems by employing a disaggregated standard growth accounting approach and by using capital stock data constructed directly from surveys. Then the robustness of the previous findings and their pessimistic conclusion can be checked to confirm whether the use of disaggregated data leads to a different conclusion.

Recently, the neoclassical approach to questions of growth has extended the debate to encompass an historical view which provides a different interpretation, questioning the argument of convergence in developed countries (Bernard and Jones 1996a; 1996b; Lau 1996; Landau 1989; 1992). The debate over the neoclassical and convergence paradigm, which mainly concentrates on economic growth in developed countries, has meant that the study of growth in the NIEs has proceeded in the light of experience in developed countries. Despite the limitations of this procedure, the debate has produced some valuable insights into understanding the puzzle of low productivity gains in East Asian NIEs. These include ideas about the sequencing of the sources of output growth, the interactions between capital formation and technological change, and the effect of structural adjustment on productivity growth. Later, the thesis explores reasons

for the low contribution of productivity growth to growth in the NIEs, on the basis of these theoretical developments.

Why is high growth in the NIEs explained by capital accumulation rather than productivity growth? Does this necessarily mean that technological change has played a minor role in the high growth in this region? These are some of the questions to be considered in the thesis.

Lau (1996) hypothesises that the sources of output growth change according to the stage of development. Capital accumulation is the main source of economic growth in the early stages of development. Later, disembodied technological change becomes a more important source of growth. This hypothesis successfully explains why capital formation rather than productivity growth was the main source of growth in the NIEs. These economies have not yet emerged from the earlier stage in which innovative technological change is not important. This hypothesis also questions the definition of technology used in the growth accounting framework. It questions the logic of judging whether growth is sustainable on the basis that disembodied technological change driven by R&D efforts is the sole source of long-run growth. It is a view that implies that economic growth driven by capital accumulation does not necessarily lead to a significant future decline in growth even though it is the sole source of output growth in the early stage of development. In this respect, Krugman's pessimism about sustainability of growth may be misleading.

Landau (1989; 1992) hypothesises that there are interactions between capital formation and technological change, so that capital accumulation can be a major source of long-term growth in transitional (or catching-up) economies. This hypothesis also successfully explains the reason for low productivity gains in the NIEs. Moreover, it undermines the logic of the growth accountants' judgements on the sustainability of growth. According to growth accounting methodology, capital and technology are independent of each other, and measured productivity growth, by definition, represents technological change. If capital accumulation

has a technological component, measured productivity growth may not be equivalent to real technological change. For this reason, productivity growth may underestimate the role of technological change. This hypothesis, combined with Lau's historical hypothesis, leads to the corollary that technology plays an important role even in the early phase of growth, since this phase is driven by capital accumulation which has the technological components. Thus, if both hypotheses are right, technological change may be a major source of long-run growth at any stage of development, in just the way predicted by the neoclassical growth model.

The arguments about the sequencing of sources of output growth and of the interactions between capital accumulation and technological change successfully explain the puzzle of low productivity gains and invalidate the pessimistic scenario of the sustainability of growth. Technological change may have played a bigger role in economic growth than would be predicted by measured productivity growth, since the technological component of capital formation is solely assigned to capital in the growth accounting technique. However, a detailed description of how capital accumulation is related to technological change has yet to be constructed.

Recent developments in models of endogenous growth provide an answer. This new theory models technological change as an expansion in the variety of products or improvements in the quality of products. The model of expanding varieties of products sees an increase in the number of products as basic innovations, akin to opening up a new industry, whereas the latter describes technological change as a continuing series of improvements and refinements of goods and techniques (Barro and Sala-i-Martin 1995: Chapters 6 and 7). Both kinds of technological change (entering new industries or moving to high-quality products) have in fact been present in East Asian NIEs, even though they cannot be categorised as innovation. Park and Kim (1992) argue that the engine of sustained growth in the Korean economy has been a succession of structural adjustments (movement in the industrial structure towards more technology-

intensive industries), which has led to productivity growth and overcome the pressures of higher wages. East Asian NIEs have periodically undergone structural adjustments, moving from labour- to capital-intensive industries and from labour-intensive to capital- or skill-intensive industries, and then from these industries to capital- and technology- and skill- and technology-intensive industries. This process has been accompanied by the importation of new capital and intermediate inputs. Thus, capital accumulation in new industries and high-quality products carries the components of technological change. Singapore, Taiwan and Korea show strong adjustments in production and export structures, while Hong Kong relies more on comparative advantage in the labour-intensive sector.

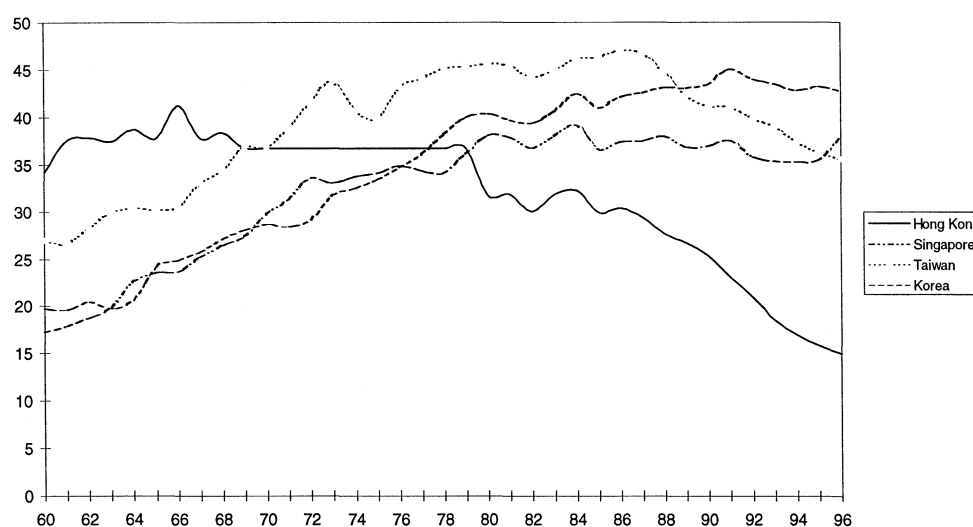
Growth accountants do not specifically concern themselves with sequential structural adjustments and their effects on productivity growth. However, Sarel (1995a: 246–47) verifies that estimates of productivity growth are very sensitive to capital (labour) shares and a specific estimation period in the case of NIEs. Sensitivity to capital (labour) implies that a more capital-intensive industrial structure results in lower productivity growth, and vice versa, because of the mechanical properties of growth accounting. Sensitivity to a specific estimation period may be another corollary: an estimation period characterised by capital- (labour-) intensive industry leads to lower (higher) productivity growth. Thus, structural adjustments in NIEs, accompanied by import and accumulation of capital goods, might lower productivity growth, and calculated productivity growth is not identical to technological change.

The thrust of this thesis is to examine the possible effect of structural adjustment on productivity growth and technological change. It argues that structural adjustment is very important to an understanding of the combination of rapid growth and low productivity gains in NIEs.

It is necessary here to distinguish the experience of the four East Asian NIEs from each other. The share of industry in Hong Kong's GDP declined rapidly from the

late 1970s, showing a different trend from other East Asian NIEs. In 1996, the share of industry in GDP had fallen to 14.9 per cent, more than 20 per cent lower than other countries (Figure 1.1). The share of textiles and clothing in merchandise exports, a proxy for labour intensity and structural adjustment, was larger in Hong Kong than other countries, whereas the export share of labour-intensive goods in Singapore was quite small (Figure 1.2). Growth accounting analysis suggests that there was high productivity growth in Hong Kong and insignificant productivity growth in Singapore. As can be inferred from the data in Figures 1.1 and 1.2, these results may be merely an artefact of the mechanical properties of growth accounting; high productivity growth in Hong Kong arising from its small industry share in GDP and low labour intensity and very low labour intensity in Singapore leading to insignificant productivity growth.

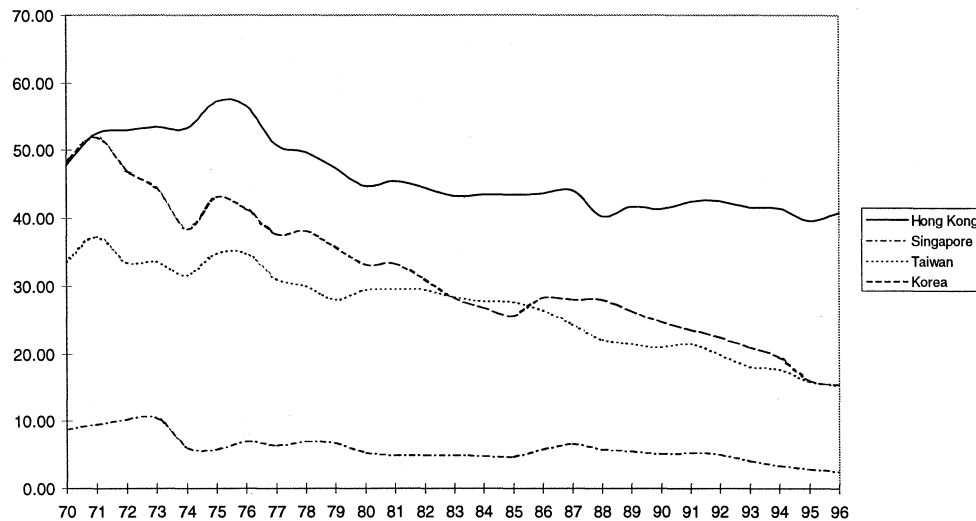
Figure 1.1 Changes in economic structure in NIEs: Industry share in GDP



Note: Data for industry's share in GDP in Hong Kong are not available for 1970–79.

Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

Figure 1.2 Share of textiles and clothing in merchandise exports



Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

The thesis takes up the case of Korea. Korea is an important and interesting case. It has had a rather different policy environment from other East Asian NIEs. Also, the share of industry in Korean GDP and labour intensity in merchandise exports are not outliers, unlike Hong Kong and Taiwan. The Korean data are acknowledged to be better than the data of Taiwan. Previous studies of the Korean case provide a useful point of departure.

This study questions the validity of the aggregated growth accounting approach and its conclusions on the sustainability of growth, and seeks to explain the reasons for the low productivity gains in the NIEs. The thesis proposes a new model for technological change in a follower country. Arguments about the sequencing of sources of growth and the interaction between capital formation and technological change provide a clear answer as to why productivity growth rates are so low and capital contribution so high in economic growth in the NIEs. Structural adjustments which require capital accumulation are proposed as an explanation for the relationship between capital accumulation and technological change in follower countries. A broad concept of technology needs to be employed in analysing economic growth in follower countries, and the notion of

the sequencing of the sources of technological change and technology transfer needs to be considered.

For this purpose industry-level disaggregated growth accounting data on the Korean manufacturing sector comprising 36 industries is used.

Structure of the thesis

Chapter 2 reviews past research on these issues. This includes the empirical findings of aggregate growth accounting studies and their implications for sustainability of growth, and theoretical issues such as the sequencing of the sources of output growth; interaction between capital formation and technological change; and structural adjustments and diminishing returns to scale.

Chapter 3 builds a disaggregated analytical framework and employs a standard growth accounting approach at the industry level. After reviewing past research on the concept of productivity growth and the measures of capital and labour, I construct a rationale for the sustainability of economic growth, through contribution of productivity growth to aggregate manufacturing. Then I calculate the sources of growth for the 36 industries in the Korean manufacturing sector. My aim in this chapter is: (1) to attain a standard measure for productivity and input growth; (2) to test the validity of aggregate versus disaggregate growth accounting studies; and (3) to address the problem of sustainability (by determining whether or not productivity growth contribution significantly to industrial output).

Chapter 4 analyses the reasons for low productivity gains in the East Asian NIEs. This chapter explores the various methods of enhancing output and productivity growth in a follower country at different stages of development. After testing the interaction between capital formation and productivity growth, the chapter examines the non-decreasing marginal productivity of capital in the Korean manufacturing sector, using additional data as well as those used in Chapter 3.

Chapter 5 describes structural adjustment towards more technology-intensive industries or products in the manufacturing sector, and puts forward the possibility that structural adjustment is the driving force behind the link between technological change and capital accumulation. Structural adjustment induces technological change, even though this results in lower productivity growth. The chapter reviews the past experience of structural adjustments and resulting changes in technological niches in NIEs, then makes some predictions about the future growth trajectory in these countries.

Chapter 6 explores developments in technology over the past three decades in terms of R&D investment and technology imports to clarify the characteristic technological change path of East Asian NIEs, and proposes the idea of the sequencing of sources of technological change. It defines technological change from the follower country's point of view, considering the empirical results of previous chapters.

Chapter 7 summarises of the results of previous chapters. It also recommends some policies for growth and sets out the limitations of the study.

The main interest in the thesis is how to incorporate into the standard analysis — low-level or capital-related technological change induced by structural adjustment in developing countries. A disaggregated growth accounting framework is employed, and growth accounting results are interpreted in different ways from the two hypotheses, namely the sequencing of the sources of growth and the interaction between capital accumulation and technological change. Then, structural adjustment is introduced as an underlying force linking capital accumulation and low-level technological change. Finally, an explanation of the sequencing of technological change and technology transfer is suggested.

2 Growth Accounting Studies and Reasons for Low Productivity Gains

Introduction

The literature review in this chapter focuses on the empirical findings of earlier studies; it also examines two hypotheses on the sequencing of the sources of output growth and interaction between capital accumulation and technological change. In the process of the literature review, theoretical arguments which are central to the whole idea of the thesis are raised. This survey leads to a re-evaluation of the results of growth accounting studies. However, issues relating to structural adjustment are not developed fully in this chapter. Later chapters of this thesis present a fuller and more systematic development of these arguments.

Many economists have employed growth accounting techniques to find the underlying reasons for the remarkable growth in the East Asian NIEs. They have attempted to identify how much of the growth has been due to productivity gains and how much to the accumulation of inputs. Some of these studies conclude that resource mobilisation rather than productivity growth was the main source of economic growth in NIEs, and that NIEs will therefore not be able to sustain growth in the longer term.

The first part of this chapter reviews the literature which questions the sustainability of growth in NIEs. Young (1992; 1995), Kim and Lau (1993; 1994a; 1994b), Dollar (1991), Dollar and Sokoloff (1990) and Krugman (1994) are among those who explore the sources of growth, technological catch-up, convergence of TFP levels, and sustainability of growth in the NIEs.

The chapter then focuses on the literature which explores the reasons for the low contribution of productivity growth and the high contribution of capital accumulation to growth in NIEs. Two hypotheses, relating to the sequencing of

the sources of output growth and the interaction between capital formation and technological change, are proposed. These hypotheses undermine the robustness of the growth accounting findings by questioning the theoretical basis of their conclusions about the sustainability of growth. The two proposals put forward are that disembodied technological change driven by R&D investment may not be the sole source of long-run growth; and that measured productivity growth may not be equivalent to real technological change.

Section 2 reviews the empirical findings of aggregate growth accounting studies: namely that resource mobilisation rather than productivity growth is the main source of growth; that there is little technological change and technological catch-up; and that, while there has been convergence of per capita income, there has been little convergence of TFP levels. This section also raises questions about the validity of the findings. Section 3 reviews the theoretical hypotheses which might explain the reasons for low productivity gains and the role of technological change in East Asian economic growth. Section 4 summarises and outlines the approach I take in developing the argument of the thesis.

Empirical findings of earlier studies

Earlier studies, involving both the growth accounting approach and the convergence approach, arrive at the consensus that economic growth in the NIEs was not significantly based upon productivity growth, and that capital accumulation (convergence in capital intensity) played the crucial role in the rapid growth of NIEs (Young 1995; 1994; 1992; Collins and Bosworth 1996; Nadiri and Kim 1996; Kim and Lau 1994b; Pack 1993; Dollar and Sokoloff 1990; Dollar 1991; De Long and Summers 1991; 1993; Levine and Renelt 1992; Jones 1994; Greenwood *et al.* 1997).² Kim and Lau (1994a; 1994b; 1996) and Pack

² These findings are not new. Westphal, Kim and Dahlman (1985) conclude that innovative technological change does not contribute to growth in NIEs, in contrast to the experience in developed countries. They find that resource reallocation accounts for most of the improvement in productivity growth in East Asian NIEs. According to Chenery, Robinson and Syrquin (1986), half of productivity growth in semi-industrialised, less developed countries is the result of resource reallocation rather than technological change.

(1993) suggest that the TFP gap between developed and developing countries in fact widened in the course of East Asia's rapid economic growth.

Resource mobilisation rather than productivity growth

Young (1995) undertakes a thorough growth accounting study of growth in the NIEs (see Table 2.1).³ The contribution of TFP to output growth is 31.5 per cent in Hong Kong, 27.7 per cent in Taiwan, 16.5 per cent in Korea, and 2.3 per cent in Singapore, while the contribution of capital is 40.8 per cent, 33.6 per cent, 37.2 per cent, and 64.9 per cent, respectively. In the case of manufacturing, the contribution of TFP in each country is 18.4 per cent in Korea, 15.7 per cent in Taiwan, and -11.8 per cent in Singapore, while the contribution of capital is 51.3 per cent, 50.7 per cent, and 78.5 per cent, respectively. Based on these results, Young concludes that 'with the exception of Singapore, productivity growth in the NICs is not particularly low, it is also, by postwar standards, not extraordinarily high' (Young 1995: 671). Young's result differs from Kim and Lau (1993: 19–20), who conclude, more strongly, that productivity growth (technological change) in the NIEs has not been significantly different from zero over the past few decades. Young concludes that rather than high productivity growth, rising participation rates, intersectoral transfers of labour,⁴ improving levels of education,⁵ and expanding investment rates,⁶ are the main factors in the extraordinary growth experienced.

Young's empirical finding that the productivity performances of NIEs, with the exception of Singapore, are not outliers, and that capital accumulation is the main contributor to rapid growth in the NIEs has had a strong influence on recent studies of long-run growth and the question of its sustainability.

³ Dowrick (1995) and Sarel (1995a) argue that calculations of productivity growth of the Four Tigers by Young and Lau and Kim are sensitive to estimations of capital stock and elasticity of capital, and that they underestimate the real productivity growth of the four countries.

⁴ Output per worker grew more slowly in the non-agricultural sector than in the aggregate economy.

⁵ In Hong Kong and Taiwan, average increases in educational attainment were offset by declining hours of work.

⁶ With the exception of Hong Kong, investment, particularly in machinery, has skyrocketed in the NIEs.

Table 2.1 TFP growth in the economy and manufacturing

	Time period	Output growth (%)	Capital growth and contribution (%)	Labour growth and contribution (%)	Labour share	TFP growth and contribution (%)
Hong Kong						
economy	66-91	7.3	8.0 (40.8)	3.2 (27.5)	0.628	2.3 (31.5)
manufacturing	—	—	—	—	—	—
Singapore						
economy	66-90	8.7	11.5 (64.9)	5.7 (33.3)	0.509	0.2 (2.3)
manufacturing	70-90	8.5	11.2 (78.5)	7.0 (33.3)	0.404	-1.0 (-11.8)
Taiwan						
economy	66-90	9.4	12.3 (33.6)	4.9 (38.7)	0.743	2.6 (27.7)
manufacturing	66-90	10.8	13.0 (50.7)	6.3 (33.8)	0.579	1.7 (15.7)
Korea						
economy	66-90	10.3	12.9 (37.2)	6.4 (43.7)	0.703	1.7 (16.5)
manufacturing	66-90	14.1	15.1 (51.3)	7.4 (27.3)	0.521	3.0 (18.4)

Notes: 1) In the case of Korea and Taiwan, the values of the economy represent those of the non-agricultural sector.

2) The values in parentheses represent the contribution of the factor to output growth.

Source: Tables V, VI, VII, VIII in Young (1995).

According to Collins and Bosworth (1996: 156–57), TFP growth in Singapore, Taiwan and Korea in 1960–94 period is 1.5, 2.0 and 1.5 per cent, respectively. Accordingly, TFP contributions to output growth are 27.8, 34.5 and 26.3 per cent, respectively. They (1996: 156) conclude:

as stressed by Young, it is quite surprising to note the extent to which the extraordinary growth of East Asia has been driven by factor accumulation, while gains in TFP have been rather modest.

Higher estimates of productivity growth are produced by Sarel (1995b), showing 3.8 per cent in Hong Kong, 1.9 per cent in Singapore, 2.8 per cent in Taiwan and 3.1 per cent in Korea in 1975–90. These differences in productivity growth arise from differences in capital shares and time period estimated. However, all the growth accounting studies are based on the same set of mechanical properties arising from the methodology itself. Productivity growth is calculated as a residual as follows:

$$(2-1) \quad \Delta \ln TFP(T) = \Delta \ln V(T) - \alpha \Delta \ln K(T) - (1-\alpha) \Delta \ln L(T),$$

where α is the capital share or elasticity of output with respect to capital, and V , K , and L represent value-added output, capital input and effective labour input.

Equation (2-1) can be simplified further in the assumption of the Cobb–Douglas production function with constant returns to scale:

$$(2-2) \quad \Delta \ln TFP(T) = \Delta \ln V/L(T) - \alpha \Delta \ln K/L(T).$$

Equation (2-1) shows that high capital share, more rapid capital growth, and low output growth mechanically result in lower total factor productivity growth. Equation (2-2) shows that high capital share, high capital intensity, and lower growth in labour productivity mechanically result in lower total factor productivity growth. Thus, there is a tendency for the extraordinary growth in capital in East Asia to lead to low productivity growth under the growth accounting scheme, even though this tendency may be affected by capital share and capital stock. In this respect, Young (1995) is more convincing than other studies because Singapore and Korea's capital growth far surpassed Hong Kong's and their productivity growth was lower, whereas Hong Kong's productivity growth was the highest among the NIEs. Thus, Young can be considered as the representative of all the growth accounting studies on East Asian NIEs. For this reason, the literature review mainly focuses on Young.

The applicability of his findings to the question of sustainability is somewhat problematic from this perspective. First, his finding is based on a highly aggregated study rather than disaggregated data. As Jorgenson *et al.* (1987: 63–64) established, productivity calculations based on an aggregate production function can be misleading if aggregation bias exists. The aggregate approach requires very stringent assumptions about production patterns at the level of individual sectors of the economy. Intuitively, the technology of each sector must be a replica of the aggregate production function if this approach is to produce robust conclusions. In this context, Jorgenson (1990: 66) states:

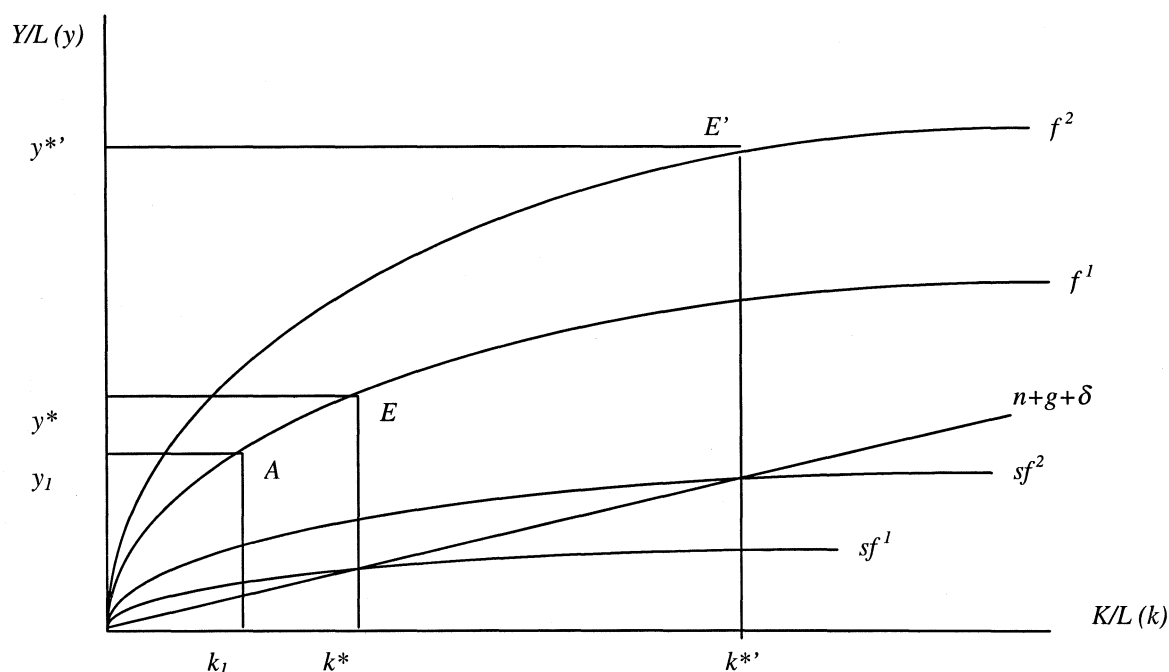
The existence of an aggregate production function requires that the technology of each sector is separable in value-added and that value-added is a function of capital and labor inputs and the level of technology. Moreover, the sectoral value-added functions must be identical for all sectors, while the functions relating labor and capital input to their components must be identical for all sectors. Finally, each component of these input aggregates must receive the same price in all sectors.

In Chapter 3, I ask whether Young's finding is robust in respect of this bias by analysing the sources of growth at an industry level following Jorgenson, and compare the findings with the results obtained using an aggregated approach. Moreover, resource reallocation (the difference between aggregate productivity growth and the weighted sum of sectoral productivity growth) in this disaggregated framework contains information about structural adjustment in NIEs. If structural adjustment occurs over time, the weighted sum of sectoral productivity growth becomes greater than the productivity growth of aggregate manufacturing because aggregate output and two aggregate inputs cannot capture the sectoral movements of disaggregated outputs and inputs towards more efficient sectors. This is tested in Chapters 3 and 5.

East Asian NIEs have increased their shares of investment and saving in GDP over the last three decades (see Table 2.1). Young (1995) interprets high investment growth rates as evidence of resource mobilisation growth in NIEs. However, expanding investment rates may be related to technological change for follower countries, even though this possibility has been ignored in the theory after being verified by data on developed countries. Pack (1993: 285–87) maintains that a portion of capital accumulation is related to technological change in transitional economies (see Figure 2.1). Suppose an economy is at point *A* now and point *E* is the steady-state equilibrium point. The neoclassical model predicts that an economy moves from point *A* to point *E* along the production function f^1 . But transitional dynamics, which feature a learning process, might suggest another interpretation: while the leader country operates along the production function f^2 , the follower country, operating at point *A* along the f^1 production

function, has the opportunity to move toward f^2 and to shift from technologies that have a lower TFP at any given capital–labour ratio to technologies that have a higher TFP. As a result transitional economies arrive at the point E' , and experience capital deepening.

Figure 2.1 Transitional dynamics: another interpretation



Source: Pack (1993: 286).

Capital accumulation involving structural adjustment, entering new industries or moving into high-quality products might be related to technological change in follower countries despite the fact that this is not the case where capital accumulation is unrelated to structural adjustment. For example, large Korean conglomerates have diversified their production activities over the last three decades. They entered new industries and moved into the production of high-quality products by setting up new plants or new processes, accompanied by imports of capital and intermediate inputs. This kind of capital accumulation is quite different from that of former Soviet Russia, where capital accumulation took place in the same industry or the same process. It may be that the marginal product of capital in aggregate declined more slowly in Korea than in Russia because new capital was accumulated in new (disaggregated) industries over time

without inducing decreases in marginal productivity in existing industries. If this is the case, Krugman's (1994) comparison of growth in Asian countries with that of former Soviet Russia is misleading.⁷

This question surrounding the relationship between capital accumulation and productivity growth is investigated further in several ways. First, when establishing the growth accounting framework, the embodiment effect or quality change of capital is classified as a component of productivity growth rather than a capital contribution, following Denison.⁸ Second, I investigate interactions between capital accumulation and productivity growth in Chapter 4. A positive relationship is expected. Third, I separate productivity growth into two components: the share effect, a proxy for the structural change effect; and the productivity growth effect. A positive share effect from structural change is expected. The structural change argument was at the heart of the analysis of Kuznets (1959), Denison (1985)⁹ and Chenery *et al.* (1986). But their definition of structural change is the movement of labour from the agricultural to the non-agricultural sectors. By contrast, the focus of this thesis is capital accumulation in new industries resulting from structural adjustment within the manufacturing sector.

Following the problem of aggregation bias and the relationship between capital and productivity growth, the third issue affecting the robustness of Young's finding is the possibility that stage of development and industrial structure strongly affect productivity performance in the case of follower countries. This point can be seen from the results of an early study by Young (1994). Estimating TFP in 118 sample countries using the Summers & Heston dataset, he shows that the rates of productivity growth in the NIEs are well matched with those of

⁷ Opportunities to delay the decline of the marginal product of capital are limited, as follower countries catch up to the economic level of leader countries. Follower countries' opportunities to enter new industries and processes will disappear or become unnecessary in the mature stage of development. In this way, they will ultimately experience a decline in marginal productivity, as Krugman argues.

⁸ I shall discuss this issue again in Chapter 3 when establishing a growth accounting framework.

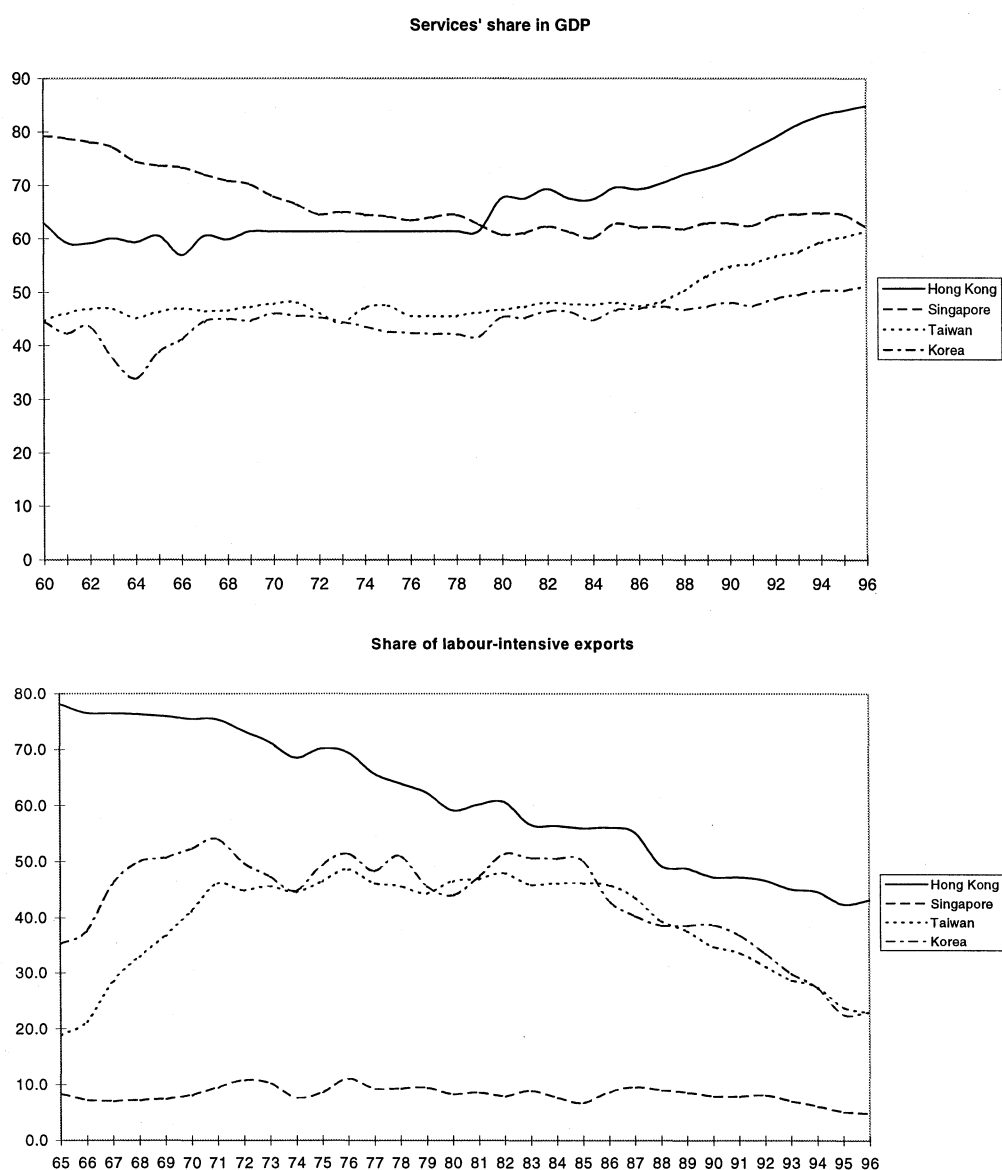
⁹ Denison finds that intersectoral shifts in production explain part of aggregate productivity growth.

developed or developing countries where the growth of output per capita was considerably slower than that of the NIEs. The four Asian NIEs are ranked highest in growth in GDP per capita but their rankings in TFP growth diverge. Hong Kong maintains a relative high ranking (6th) in TFP while the rankings of Singapore drop from 4th to 63rd. The rankings of Taiwan and Korea drop from 2nd and 5th to 21st and 24th, respectively. However, these results do not negate the possibility of technology catch-up in the NIEs. The TFP performance of NIEs is, nonetheless, stronger than that of Japan and many other OECD countries. Convergence literature suggests that a follower country experiences technology catch-up at a declining rate as follower countries approach the technology level of leader countries. In this respect, TFP growth in NIEs, which is neither high nor low, is well matched with the predictions of convergence literature. According to Dowrick (1995) and Drysdale and Huang (1996), labour productivity at the initial stage of development explains about one-third of the variation in subsequent rates of growth. This means that productivity performance in a developing country diverges according to the stage of development.

A country's measured productivity growth may also depend on the industrial structure. According to Table 2.1, the higher the labour share, the higher the TFP growth. Figure 1.1 shows industry's share in GDP. A striking feature of this figure is that Hong Kong's industrial structure is quite different from other NIEs. The low share of industry in GDP is offset by the share of services in Hong Kong, which is much higher than in other NIEs (Figure 2.2). The share of industry in Hong Kong declined from the early 1970s while the shares of Singapore and Korea merely stabilised in the late 1980s (Taiwan's share declined, but only from the late 1980s). The gap between the share of industry in Hong Kong and other NIEs is approximately 20 per cent. Figure 2.2 also shows the shares of labour-intensive exports in total merchandise exports in NIEs, when export products are classified into four categories; agriculture-, labour-, capital- and mineral-intensive (*Asia Pacific Profiles* 1997: 11–12). The labour-intensive export share in Hong Kong is much higher than that of the other NIEs, whereas the share in Singapore is quite low. This means that technological intensity in merchandise exports in

Hong Kong is not strong, even though the share of manufacturing in GDP is quite small. As can be inferred from the data in Figures 1.1 and 2.2, Hong Kong's high productivity growth and Singapore's negative productivity growth in Young (1995) may arise from the mechanical properties of growth accounting; high productivity growth in Hong Kong arising from its small industry share in GDP and low labour intensity, and very low labour intensity in Singapore leading to insignificant productivity growth.

Figure 2.2 Structural change and adjustment in NIEs, 1965–95



Note: Data for services' share in GDP in Hong Kong are not available for 1970–79.

Source: International Economic Data Bank, ANU

If higher labour intensity resulting from labour-intensive industrial structure leads to higher TFP growth and higher TFP contribution to growth, TFP may not be a good indicator of the technology level, contrary to the expectations of the growth accounting theorists. Growth accounting is mechanical in this respect. It might be that technological change is different from productivity growth in the case of follower countries. I argue that follower countries have opportunities to exploit standard technology via structural adjustment that entails capital accumulation in new industries and processes. If this is the case, the growth accounting approach may underestimate the role of technology and overestimate the role of capital because measured productivity growth does not include the technology components that are linked to structural adjustments. This issue is also related to the definition of technology adopted.

No technological change, no technology catch-up

Kim and Lau (1993; 1994b), in two influential papers on economic growth in NIEs, argue that technological change in the NIEs over the past few decades has not been significantly different from zero, and that consequently there is no evidence of technology catch-up. This finding is stronger than that of Young (1992; 1994; 1995), who simply suggests that productivity growth in the NIEs has not been extraordinary. This conclusion is quite different from the historical view, which argues that follower countries are capable of faster growth and technology catch-up, since they can exploit the technology backlog accumulated by leader countries through learning rather than innovation (Gerschenkron 1962; Abramowitz 1986; Baumol 1986; Dowrick and Nguyen 1989; Drysdale and Huang 1996).

Kim and Lau's quite strong conclusion derives from the peculiar meta-production function approach they adopt. Lau (1996: 68) explains the two basic assumptions of the meta-production function as follows:

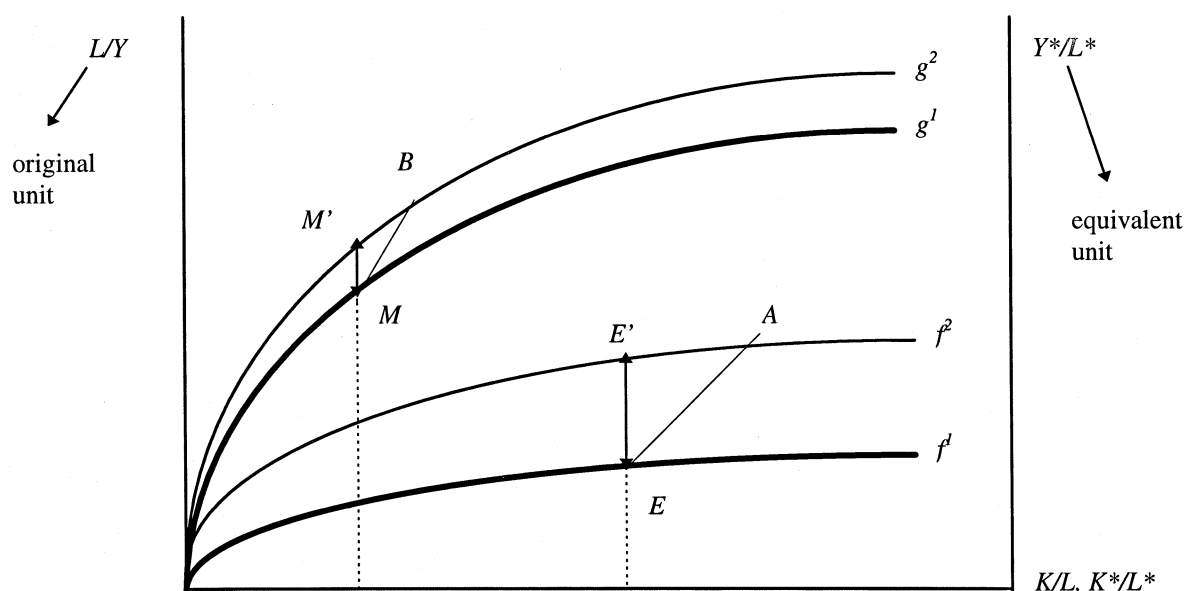
First, all the countries have the same underlying aggregate production function $F(\cdot)$ in terms of standardized, or 'efficiency-equivalent,' quantities of outputs and inputs. Second, the measured outputs and inputs of the different countries may be converted into the unobservable standardised, or 'efficiency-equivalent,' quantities of outputs and inputs by multiplicative country- and output- and input-specific time-varying augmentation factors.

The meta-production function means that 'if we can change the units of measurement to reflect differential efficiencies of the inputs across countries, then all countries will have the same production function' (Lau 1996: 73). After transforming country-specific input and output data into efficiency-equivalent units, or transforming country-specific production functions into a meta-production function on the basis of the United States' production function, Kim and Lau account for the sources of economic growth for all the countries. Of course, this methodology has the advantage that it does not require the assumptions of traditional growth accounting; namely constant returns to scale, neutrality of technological change, producers' equilibrium conditions and completely disembodied technological change. In particular, economies of scale, which are considered to be residual, are omitted from the technological change (residual) of the new methodology. Economies of scale are one of the most important factors determining traditional productivity growth in developing countries. In the case of Korean manufacturing, they were critical in the 1970s, when heavy and chemical industries were promoted and developed.

This approach also has weaknesses. First, it shares the aggregation bias problem with the standard aggregated growth accounting method. Second, it makes the growth accounting results difficult to interpret. For example, consider Figure 2.3. Suppose that the production function of the follower country moves from f^1 to f^2 , and that meta-production functions g^1 and g^2 correspond to f^1 and f^2 , respectively. Then, segment EE' represents the shift in production function (technological change) in country-specific units, and segment MM' , corresponding to segment EE' , represents technological change in efficiency units. There is the possibility of arbitrariness in this correspondence, and there is also room for dispute about

whether it is better to measure technological change by original units than by a meta-production function.

Figure 2.3 Technological change in the meta-production function



Source: Author's scheme.

Conceptually, a meta-production function is the same as the United States' aggregate production function, so technological change measured by a meta-production function will only be affected by those factors that can shift the United States' production function. Those factors are R&D investment and organisational change. Other factors, which might improve the technology of a follower country but cannot cause technological change in the leader country, are simply ignored in the process of transforming original units into efficiency-equivalent units. Based on their own growth accounting framework, Kim and Lau argue that technological change in the growth of the NIEs is not apparent, and they find an increasing technology gap between the OECD countries and the NIEs, instead of technology catch-up. This empirical finding is not at all surprising when their empirical setting is taken into account. However, Lau's argument on the absence of technological change and no technology catch-up loses force if we identify other factors which can cause technological change in NIEs, such as structural adjustment (entering new industries or high-quality

products), technology imports and informal means of foreign technology acquisition. It is true that R&D efforts are not major contributors to technological change in NIEs (for example Pack and Page 1994; Westphal, Kim and Dahlman 1985; Kim 1990; 1995; Enos and Park 1988; Amsden 1989). But that does not imply that technological change is not an important source of growth during the early phases of growth.

Kim and Lau (1994a; 1994b) also exhibit measurement problems such as aggregation bias, unreliable capital stock data and the assumption of the constant weights of inputs.

Convergence of per capita income but no convergence of TFP level

Much of the literature on convergence verifies empirically that developed countries exhibit TFP catch-up as well as a convergence in labour productivity (per capita income), particularly after the Second World War (Baumol 1986; Abramowitz 1986; Dowrick and Nguyen 1989; Dollar and Wolff 1988; 1994; Wolff 1991; De Long and Summers 1991; Mankiw *et al.* 1992; Jones 1994). Convergence proponents also attempt efforts to extend the convergence argument to NIEs. However, there is wide consensus that TFP catch-up did not occur, even though convergence in per capita income (Y/L) is evident among developing countries (Dollar and Sokoloff 1990; Dollar 1991; De Long and Summers 1993).

Dollar (1991) and Dollar and Sokoloff (1990) seek to account for the sources of labour productivity (Y/L) in the Korean manufacturing sector. Both studies provide valuable insights into the sources of growth at the industry level. In particular, their use of industry level data has merit over aggregate growth accounting studies. Dollar (1991) verifies that Korean labour productivity (Y/L) converges towards the German level, with capital deepening (K/L) and TFP accounting for two-thirds and one-third of labour productivity convergence, respectively. However, the source of convergence differs greatly across industries. For heavy industries, capital deepening is the sole source of the labour

productivity convergence. It follows that decomposing output (Y) growth into input growth, capital (K) and labour (L), would yield no evidence of productivity growth. For light industries, TFP is the sole source of labour productivity convergence. According to Dollar and Sokoloff (1990), TFP convergence explains 30 per cent of labour productivity convergence for heavy industry, and 60 per cent for light industries. From this evidence, they conclude that TFP convergence occurred. Dollar emphasises that the employment structure of Korean manufacturing changed from heavy industry to light industry over this period, promoting TFP convergence at an aggregated level. In Chapter 3 I shall examine whether or not productivity growth in heavy industries is at or near zero.

Yet contrary to Dollar's prediction, Korea's industrial structure changed in the opposite direction from the mid-1970s. The continuous change in the competitiveness of Korean manufacturing from light industries to heavy industries shifted manufacturing production continuously towards heavy industry in the 1980s and 1990s. This trend and the empirical finding of almost zero productivity growth in heavy industry lead to the conclusion that TFP catch-up did not occur, contrary to his expectation of catch-up, even though convergence in labour productivity was evident. On this point, Dollar finally arrives at the same conclusion as that of growth accounting studies.

The empirical finding of TFP convergence in these two studies appears fragile rather than robust. An important question arises: why did industry characterised by capital deepening and lower TFP growth (heavy industry) increase its production share, leading to a decreasing share in the production of the higher TFP growth industries (light industry)?

According to Dollar (1991) and Dollar and Sokoloff (1990), the Korean government's development program for heavy and petrochemical industries—subsidising investment in those industries in the 1970s¹⁰—distorted

¹⁰ Recent arguments by the World Bank (1993) on the ineffectiveness of selective interventions are an extension of Dollar (1991) and Dollar and Sokoloff (1990).

Korea's comparative advantage, increasing inefficiency. However, heavy industry displayed higher productivity growth than light industry over the whole period, even though there was lower productivity growth in this sector in the earlier period.¹¹ Lee (1995) verifies that Korea rapidly gained competitiveness in heavy industries, while it maintained competitiveness for a long time in light industries, as predicted by neoclassical theory. It appears that the explanation of Dollar, and Dollar and Sokoloff as to why heavy industry increased its share is not the whole story. Instead, the argument of sequential structural adjustment to create dynamic comparative advantage in more technology-intensive industries over the longer term has some merit.

Despite the fragility of the findings of Dollar, and Dollar and Sokoloff, they provide an insight into the sources of productivity growth in follower countries in the early stage of development. Dollar and Sokoloff (1990: 326) argue that 'developments in the labour-intensive industries were primarily responsible for the extraordinary record of total factor productivity growth in South Korean manufacturing', and that the main source of TFP convergence in Korean manufacturing may be 'scale economies associated with the transition from craft to modern labor-intensive production'. This argument implies that there are other sources of productivity growth than R&D investment, and that productivity growth is not identical to innovative technological change in follower countries. In this respect, the findings of Kim and Lau (1993; 1994a; 1994b) are misleading because their estimates of productivity growth (technical progress in their paper) in NIEs are confined to conceptually innovative technological change.

This finding describes well the characteristic of manufacturing growth in the 1960s and early 1970s, when light industry products, such as textiles, clothing, toys and plywoods were key export goods. However, it does not seem to be valid after the period in which capital-intensive industries replaced labour-intensive

¹¹ The relative increase in the production of capital-intensive products clearly decreases TFP growth rates in the Korean manufacturing sector over the period 1968–93. Of course, labour-intensive industries show a stronger declining trend in TFP growth than capital-intensive industries.

industries. There was a different mechanism for output and productivity growth, lowering productivity growth. If different stages of development and/or industrial structure (labour intensity) lead to different productivity growth, any international comparison of TFP performance at any particular time will be seriously biased.

Sustainability of growth in NIEs

The earlier empirical work in both growth accounting and convergence studies suggests that economic growth in the NIEs was not based on exceptionally strong productivity growth, and that capital deepening played a major role. Standard neoclassical growth theory predicts that long-run growth can only be achieved by technological change and that growth led by capital accumulation cannot be sustained.

If Y represents output, and K and L represent capital and labour, and E represents the efficiency of labour, then the aggregate production function can be written as:

$$Y = F(K, EL)$$

where EL is the labour force measured in efficiency units. If we assume a CRS (constant returns to scale) production function, the production function can be rewritten as:

$$y = f(k)$$

where $y = Y/EL$, $k = K/EL$, and $f(k) = F(k, 1)$.

We assume that L is growing at rate n , and introduce the simplest assumption about technical change, that it causes E to grow at some constant rate g . Then, the economy grows, as does labour measured in efficiency units, and k evolves according to

$$\Delta k = sf(k) - (n + g + \delta) k$$

where s is the rate of saving, and δ is the rate at which capital depreciates.

The economy arrives at the steady state when $\Delta k = 0$ or

$$sf(k^*) = (n + g + \delta)k^*.$$

In this steady state, output per efficiency unit, $y^* = f(k^*)$, is constant, output per physical unit grows at rate g , and total output grows at rate $(n + g)$. Thus, in the long run (steady state), only technological change can explain sustained growth in output per worker. It does not depend on the rates of saving and population growth (Mankiw 1995: 276–78). Technological change in the model is assumed to be neutral and disembodied. The growth accounting tradition, based on neoclassical theory, formulates that productivity growth is the output of R&D investment (Griliches 1973; 1979; 1980; 1986).

Thus, combining the earlier empirical findings with the influence of neoclassical theory leads to a pessimistic prediction about the sustainability of growth in the NIEs because it was the remarkable mobilisation of factors (in particular capital) rather than productivity growth which was the main contributor to rapid growth in East Asia (Krugman 1994).

Krugman (1994) compares the growth performance of NIEs (Singapore) with that of former Soviet Russia. Stalinist Soviet Russia experienced strong growth until the 1950s but growth declined dramatically thereafter because of a lack of technological change. He refers the possibility that the Tigers (NIEs) may turn out to be ‘paper tigers’. This argument is couched in careful terms but it represents an extreme position; it is supported empirically only by Kim and Lau (1993; 1994b), who use the meta-production function methodology to claim that these economies did not show technological change. This methodology has a bias toward the no technological change position, as discussed above. The question of aggregation

bias also weakens Krugman's pessimistic logic. This question of the sustainability of East Asia's growth is revisited in Chapter 3 by examining the role of productivity growth in output growth in a disaggregated framework, and in Chapter 4 by investigating the trend in the marginal product of capital. Any relationship between stage of development and productivity growth also weakens the pessimistic view of the sustainability of growth. This is dealt with in Chapter 4.

Theoretical issues: reasons for low productivity gains

Why is it held that high growth in the NIEs is explained by capital accumulation rather than productivity growth? Does this necessarily mean that technological change has played a minor role in the remarkable growth of this region?

Hypotheses about the sequencing of the sources of growth and the interaction between capital accumulation and technological change provide an answer.

There are two theoretical premises on which judgements about the sustainability of growth are based: the first is that disembodied technological change driven by R&D effort is the sole source of long-run growth; and the second is that the growth accounting technique is correct to measure technological change as productivity growth. Sequencing in the sources of output growth raises questions about the first premise. The interaction between capital accumulation and technological change raises questions about the second.

Sequencing of sources of output growth

A key idea is that the principal sources of output growth are likely to change according to the stage of development. Physical and human capital accumulation are the main sources of economic growth in the early stages of development. Later, disembodied technological change (innovation driven by R&D effort) becomes the main source of economic growth. This idea originated in the economic history of follower countries. Follower countries can grow faster than

leader countries by taking advantage of the backlog of technological opportunities accumulated by leader countries, while the technological catch-up of the former occurs through a learning process, without innovation (Gerschenkron 1962; Amsden 1989; Hikino and Amsden 1994). This historical view predicts that follower countries have access to sources of fast growth other than innovative technological change during the learning (catch-up) period. Follower countries first employ easier means of technological development, and finally resort to innovation when other means of technological change are exhausted.

Accepting this view, some proponents of neoclassical growth theory admit the possibility that capital deepening can be a long-run source of economic growth for transitional economies such as Japan and NIEs, but not in a steady-state economy. If a country is already at the technological frontier, with the stock of available technological opportunities independent of investment activity, the mere fact that some or all of the new technology must be embodied in capital does not increase the long-run rate of growth of output. However, Baily and Shultze (1990: 399) argue that capital deepening is a principal contributor to long-term growth before disembodied technological change becomes important:

In an economy well below the technological frontier the situation is quite different. So long as the education and general skills of the labor force are compatible with what is required by frontier technology, a higher investment share can for a long time generate an increase in the growth rate. The essential characteristic of catch-up growth is that the backlog of unexploited technological opportunities available to the economy is very large, so that one year's additional 'embodying' investment does not significantly eat into that backlog.

Recently the sequencing issue has again attracted interest. Lau (1996: 88) accepts the late industrialisation argument based on the experience of economic history:

Much of the economic growth in the United States in the late nineteenth and early twentieth centuries can be similarly [to NIEs now] explained by the growth in tangible capital and labor inputs. Technical progress was not found to be a significant

source of U.S. economic growth until the studies of Abramobitz (1956) and Solow (1957) for the period starting in the late 1920s. The same was also true of the Japanese experience. We may therefore reasonably draw the conclusion that physical (or tangible) capital accumulation is most important for countries at an initial phase of economic development.

Lau is the first to provide a formal hypothesis about the sequencing of physical capital, human capital, and technological change in the process of a country's economic growth. Using the earlier empirical findings,¹² Lau (1996: 88) explains the idea of the sequencing of sources of output growth as follows:

After a certain level of capital intensity has been reached, diminishing marginal productivity of physical capital will inevitably set in, given that land and natural resources are fixed and the labor input can grow only slowly. When that happens, the desirability of intangible capital will increase relative to that of tangible capital; this preference is further reinforced by the complementarity between tangible and intangible capital, which requires a minimum level of the former for the latter to be productive. Technical progress can therefore be expected to assume increasing importance as an economy is transformed from developing to developed status. There is thus a time sequence—with physical capital accumulation being the most important source of economic growth in the initial phase and technical progress assuming an increasingly significant role in the mature phase, after sufficient capital accumulation has taken place. To this extent, technical progress may be considered to be endogenous in the aggregate.

Lau's sequencing argument is consistent with the late industrialisation experiences in the United States, Germany and Japan. This view provides a clue

¹² Lau summarises the earlier findings of Kim and Lau (1994b) as follows. First, technological change is the most important source of economic growth for the developed countries, while capital accumulation is the most important source of economic growth for the NIEs. Moreover, the hypothesis of no technological change in the NIEs cannot be rejected. Second, human capital is a significant contributor to economic growth; it explains 20 per cent of economic growth for the NIEs and 10 per cent for the OECD countries. Third, approximately 80 per cent of technological change is embodied rather than disembodied for OECD countries (Japan: 96 per cent). NIEs did not exploit embodied technological change because no technological change occurred. Fourth, there is evidence of catch-up in OECD countries, while there is a large and widening gap between the technologies of the OECD and the NIEs (NIEs are falling behind instead of catching up).

to understanding the growth process of NIEs using a perspective different from the neoclassical tradition, which is not always helpful in analysing catch-up or the learning process of follower countries. The sequencing idea predicts that NIEs have sources of long-term growth which differ from those of leader countries. Follower countries can grow fast by accumulating (physical and human) capital over a long period of time.

The sequencing hypothesis successfully explains why capital accumulation rather than productivity growth was the main source of growth in the NIEs. These economies have not yet emerged from the early stage in which innovative technological change has yet to assume great importance. This hypothesis also questions the premise, on which the judgement about the sustainability of growth is based, that disembodied technological change driven by R&D efforts is the sole source of long-run growth. This view implies that economic growth driven by capital accumulation does not necessarily lead to a significant future decline in growth even though it is the sole source of output growth in the early stage of development. In this regard, Krugman's pessimism about sustainability of growth may be misleading. This hypothesis is explored in Chapter 4 using Korea's manufacturing data.

Lau explains the sequencing of sources of growth using the complementary relationship between capital formation and technological change. Shortage of physical (human) capital decreases the efficiency or effectiveness of human (physical) capital and technological change. Lau (1996: 89) explains why it takes so long for innovation activity to become the main contributor to productivity growth and growth:

This complementarity may in fact be one reason why technical progress is not as yet an important source of economic growth in the developing countries. At the prevailing levels of physical capital and human capital, it has not yet become profitable for the developing countries to invest in R&D and other technical progress-creating activities. In time, with diminishing marginal productivity of physical capital and the increase in inputs complementary to technical progress

(physical and human capital), the attractiveness of technical progress creation will increase relative to traditional investment in physical capital.

According to this explanation, after the marginal productivity of capital diminishes and (human and physical) capital accumulation is sufficient to induce technological change, it becomes the main source of growth. This hypothesis, combined with the earlier argument that structural adjustment (entering new industries and production shift to high-quality products) slows down the diminishing trend in marginal product of capital in aggregate economy, implies that innovative technological change becomes the major source of growth after a period of time.

Lau suggests a sequencing in the sources of growth from capital to technological change. However, productivity growth by the introduction of modern labour-intensive production may be the first step in the sequencing of the major sources of growth, as suggested by Dollar and Sokoloff (1990).

This hypothesis, combined with the hypothesis of the interaction between capital accumulation and technological change, leads to the conclusion that even in the early phase of growth, technology plays an important role, one characterised by the technological components of capital accumulation. If such interactions exist, the earlier findings of the growth accounting studies that productivity growth played a minimal role in the rapid growth of NIEs lose their basis. A further implication is that technology should be defined in much broader terms. Collins, for example, comments on Page (1994a) that 'technological change and factor accumulation appear to interact in complex but difficult to measure ways, and we may learn a considerable amount by studying this interaction'.

Interactions between capital formation and technological change

Neoclassical theory and the growth accounting method assume that capital and technology are independent of one another, hence they are separate and independent contributors to economic growth. Some economists, however, have

raised doubts about this assumption (Landau 1989; 1992; Boskin 1988; Hulten 1975; 1979; 1992a; Greenwood *et al.* 1997). For example, Landau (1992: 304) argues that:

R&D and creative design are seldom performed by themselves—but rather only when they are expected to be employed in new or improved facilities and/or in superior operating modes. So technological change is not only embodied in physical capital investment, it is itself capital—intangible capital—and also a powerful inducement to it, since the availability of superior technology is a major incentive to investment. Investment in turn stimulates more R&D and creative learning.

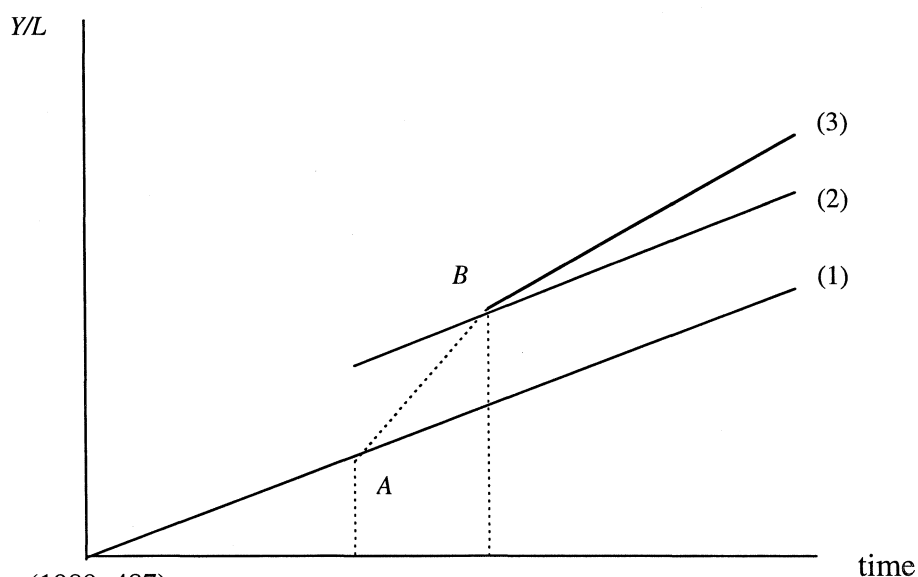
If the neoclassical assumption is not valid, productivity growth, as measured by growth accounting, does not represent separately and fully the role of technology in economic growth. Landau and Boskin, for example, argue that capital and technology must be viewed as interchangeable components; net capital formation and the depreciation or maintenance of capital always carry new technology components, and technological change also leads to both the retirement of old capacity and the installation of new. Technological change then becomes the driving force for productivity growth but is very strongly related to capital formation (Landau 1989: 504).

The interaction argument is strengthened by the example of Japan's rapid economic growth after the Second World War. Landau (1992: 303) explained Japan's rapid growth in the following way:

The comparative performance of the U.S. and Japanese labor productivity growth rates has been heavily influenced by the much higher (often doubled) rate of Japanese capital investment in a number of their industrial sectors, made possible by the very high Japanese savings rates...This helped fuel the rapid adoption by most Japanese industries of the latest available technologies from abroad...Other data also suggest a very high correlation between national investment and economic growth rates.

There are two ways in which the interactions between technological change and capital formation occur. One possibility is the embodiment effect (from capital formation to technological change); technology is embodied in new capital, so capital formation induces technological change. Recently the so-called Stanford technology school (Boskin, Lau and Kim) have emphasised the embodiment effect, based on the finding of meta-production function studies that approximately 80 per cent of technological change in OECD countries is embodied rather than disembodied. Boskin cited in Lau (1996), illustrates this possibility as in Figure 2.4. Suppose that an economy is at point A at t_0 , and that pro-investment policy leads to a higher capital formation and a transition to a higher level of income. Neoclassical theory suggests that the economy arrives at point B at time t_1 , where the economy returns to a long-run growth path (2). However, if there is an interaction between technology and capital formation, there is a possibility that the economy follows path (3) instead of path (2), and a higher growth rate than the former long-run growth rate. This hypothesis is tested in Chapter 4. Capital stock data in Chapter 3 are estimated without considering the embodiment effect. It follows that a positive correlation should be observed between the productivity growth rate and the growth rate of capital input, if the embodiment effect exists (Wolff 1991: 566).

Figure 2.4 Alternative growth paths: technological change and capital formation



Source: Landau (1989: 487).

Landau (1992: 305) explained the meaning of Boskin's path (3) as follows:

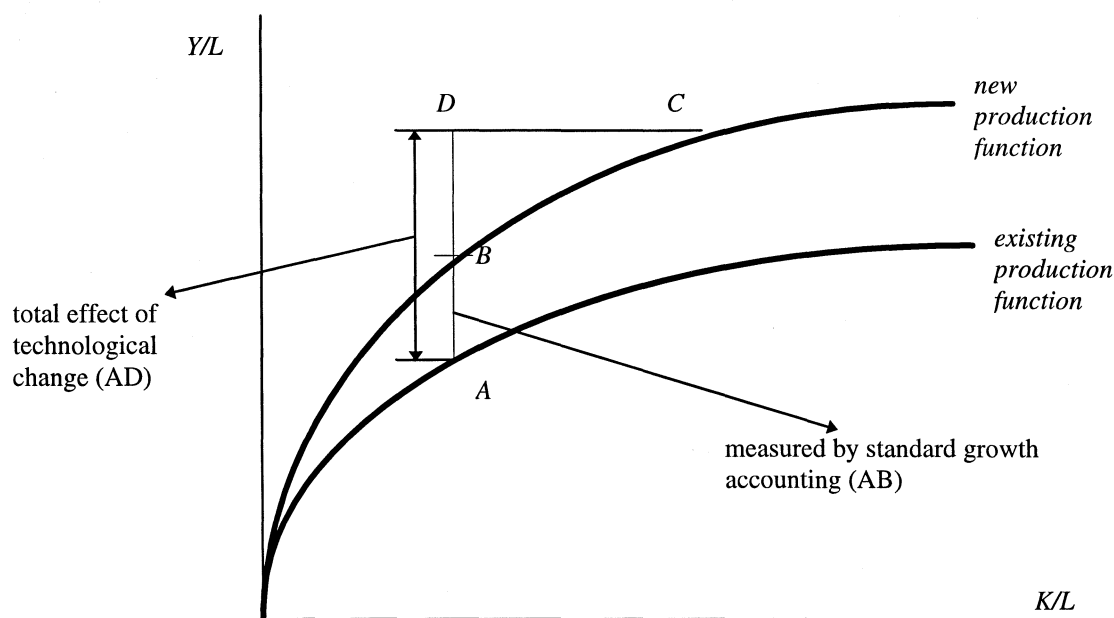
This increased growth path may be viewed as a series of transitions in a dynamic economy never really at equilibrium because of continuing unpredictable, endogenous technological changes. If technological change is not exogenous, embodiment and learning by doing interact with capital investment to improve growth rates, and capital investment is critical in reaching a higher equilibrium and approaching the technological frontier throughout the economy at a faster rate.

The other possibility is the hypothesis of induced technological change (from technological change to capital formation), which means that technological change increases capital formation. Under this scenario, capital accumulation appears to have almost no independent role in determining economic growth. Using Figure 2.5, Hulten argues that the real effect of technical progress is the sum of the shift in the production function plus induced capital accumulation.

Assume that there is a production function that relates capital per unit labor to output per unit labor. And let us assume that the economy is at some point *A* where labor force 'growth' is static and investment is just enough to keep the capital stock intact...Suppose that a new technology is introduced that causes the production function to shift. The multifactor productivity residual will now show a positive growth rate...Under the standard growth accounting story, we would measure the importance of multifactor productivity as a source of economic growth by the shift in the production function *A* to *B*. But we should also notice that this shift results in additional output per person and that the additional output will result in extra saving...The extra saving will result in more capital per worker, so the economy moves along the production function. This extra capital generates still more saving and capital, which generates still more output, etc. The economy will come to rest at some point *C* at which depreciation of large capital stock just equals the additional saving. The contribution of the initial shift in the production function is therefore not the distance *A* to *B*; it is really the vertical distance between *A* and *C* (the segment *AD*). That is, all of the economic growth that occurs as the economy moves from *A* to *C* is due to technical change, qua shift in the production function. The conventional

growth accounting story, on the other hand, would erroneously say that BD/AD per cent of total change in output per worker is due to capital, and AB/AD is due to technical change. (cited by Landau 1989: 488–89)

Figure 2.5 Induced technological change



Source: Landau (1989: 489).

This hypothesis also successfully explains the reason for low productivity gains in the NIEs. Moreover, it undermines the logic of judging whether growth is sustainable or unsustainable. According to growth accounting methodology, capital and technology are independent of each other, and measured productivity growth, by definition, represents technological change. If capital accumulation has a technological component, measured productivity growth may not be equivalent to real technological change. For this reason, productivity growth may underestimate the role of technological change.

Summary

The first section of this chapter reviewed previous empirical findings that support the hypothesis of unsustainability of growth in the NIEs. This literature suggests that: first, capital accumulation rather than productivity growth is the major

source of growth in NIEs; second, technology catch-up does not occur; third, convergence of labour productivity occurs without convergence of TFP level.

There are questions about the robustness of these empirical findings, and Chapter 3 proposes to test these findings under the disaggregated growth accounting framework. Among the issues to be explored further are: the problems of the aggregated growth accounting approach and the validity of the disaggregated approach; the embodiment hypothesis or changes in quality of capital; major sources of output growth at a disaggregated level; and sustainability of growth in Asian NIEs at a disaggregated level.

The second section of the chapter reviewed theoretical issues that might provide an explanation for the low productivity gains in the NIEs. It emerged from the review that productivity growth in labour-intensive industries, capital accumulation in heavy and petrochemical industries and productivity growth in relation to R&D investment were major sources of growth at different stages of development. Thus, the low productivity gains in NIEs identified by the growth accountants may simply result from the fact that these economies are in the second stage of growth, in which capital plays the major role.

Interaction between capital formation and technological change was also reviewed. If this hypothesis is verified, growth driven by capital accumulation does not necessarily mean a minor role for technological change even in the face of low productivity gains. This is because the intersection contribution of capital and technology to output growth is mechanically attributed to capital in the mechanical growth accounting scheme, underestimating the role of technological change. In this way, productivity growth and technological change in developing countries diverge in the case of follower countries and a new paradigm of low productivity growth but high technological change is formed. Chapter 4 investigates both these issues using the data for Korea's manufacturing sector.

Chapter 5 provides a more specific explanation for low productivity gains. Structural adjustment is the crux of the link between capital accumulation and technological change. In broad terms, technological change in developing countries is induced by structural adjustment towards more technology-intensive industries. Productivity growth in new industries or high-quality products, where structural adjustments occur, is relatively low compared with existing industries because of the mechanical properties of growth accounting in treating the interaction between capital accumulation and technological change.

Chapter 6 defines technology in broad terms from the perspective of follower countries, and sets out an explanation of the sequencing of the sources of technological change suggested by the two hypotheses and the argument about structural adjustment. It also verifies that the major means of technology transfer changed over different stages of development: from informal means in the 1960s, to import of capital in the 1970s to the early 1980s and technology imports in the 1980s.

3 Growth Accounting: Framework and the Results

Introduction

Chapter 2 reviewed earlier empirical findings at the aggregated level that resource mobilisation rather than productivity growth is the major source of East Asian growth, and that there is no evidence of productivity catch-up in this region. However, highly aggregated data were used in calculating productivity growth, and capital stock data are unreliable because they are constructed from the historical investment data under arbitrary assumptions on depreciation rate and the reference period used for extrapolation. This chapter seeks to account for the sources of output growth of Korean manufacturing at the disaggregated level, and examines whether or not the earlier findings are valid using a disaggregated industry study. It also tests two issues outlined in Chapter 2: the validity of the aggregate production function approach to growth accounting and the sustainability of growth. Another aim of this exercise is to produce data for use in the analysis in subsequent chapters, which focus on sequencing of sources of growth, interactions between capital input growth and technological change, structural adjustment across industries, and the relationship between technology imports and productivity growth and between R&D investment and productivity growth.

Section 2 reviews the controversy between Denison and Jorgenson concerning the growth accounting scheme. This section highlights the relationship between the estimation of capital stock and productivity growth on the one hand, and the importance of disaggregation by industry on the other hand. Section 3 develops a hybrid framework for the standard growth accounting analysis and expresses it mathematically. The aggregation procedure across industries is examined to test the validity of the aggregate production function approach used in the next

section. Section 4 explains the data and sets out the basic growth accounting results, aggregated and disaggregated, over various time periods. Section 5 explores issues arising from the basic results, such as the validity of the aggregated approach, the sustainability of growth and technology catch-up. It also compares the growth accounting results in this chapter with earlier studies. Section 6 provides a summary.

Literature review: the controversy between Denison and Jorgenson

The most important contribution of Jorgenson and his colleagues to the literature on growth accounting is their emphasis on disaggregation and the way in which they illustrate the problems of the highly aggregated approach. However, their growth accounting approach is not appropriate for our purpose, which focuses on follower countries' opportunities for technology catch-up and the effects of structural adjustment on technological change and productivity growth. Their basic conclusion is that capital accumulation is the most important contributor to growth, and that productivity growth is the least important contributor to growth in output. This conclusion differs sharply from the conclusions of other mainstream growth accountants, represented by Denison. There is general agreement from Solow to Denison that multifactor productivity growth is the most important source of growth, and the role of capital accumulation is less important. The difference in their results, of course, lies in the different growth accounting schemes used by Jorgenson and Denison and others.

The aim of this section is to review the debates on the growth accounting framework, and to seek a hybrid of the Denison and Jorgenson models combining the merits of both: capital estimation without quality change and disaggregation, and use of net output on the one hand, and a sectoral (industry) production function approach to overcome the aggregation bias problem on the other. Such a model would view productivity growth as a fundamental source of growth in a sectoral model on the one hand, and resource reallocation as a component of productivity growth in an aggregated model on the other.

Growth accounting tradition

Early growth accounting studies assigned the overwhelming part of productivity growth to the unexplained residual, while the contribution of capital to labour productivity was seen as very small (Abramovitz 1956; Solow 1957). For example, Solow (1957) argues that one-eighth of the long-term variation in output per worker is due to capital accumulation (K/L) and seven-eighths is a productivity residual interpreted as technological change. This result is a very powerful argument emphasising the lesser role played by capital accumulation in the long run. Yet these studies are unsatisfactory because they do not explain the residual term successfully. In this regard, Denison and Jorgenson attempt to reduce the size of the unexplained residual and provide a more satisfactory explanation of growth. Both stress the importance of careful measurement and adjustment of the factor inputs, especially labour and the role of human capital.

However, their views on the main contributors to long-run growth differ, and they arrive at different conclusions. Denison emphasises the role of technological change and assigns a small role to capital, as suggested by the neoclassical model. The contribution of productivity growth to output growth in the United States, for example, is 47.3 per cent (advances in knowledge: 31.1 per cent; resource reallocation: 10.8 per cent; economies of scale: 12.3 per cent) during the period 1929–82, while capital's contribution to growth is 13.7 per cent in the same period (Denison 1985: Table 7.1).¹³ In contrast, Jorgenson assigns a much bigger role to capital, reducing the size of the unexplained residual: in his analysis the contribution of productivity growth to growth in the United States was 21.7 per cent during the period 1947–85, while the contribution of capital was 44.2 per cent in the same period (Jorgenson 1990: 23).

¹³ Denison (1967) also studies the extent to which differences in growth rates of output can be accounted for by differences in growth rates of capital per capita in eight European industrialised countries. The answer is that only a small portion of the differences can be explained by differences in the growth rates of capital per capita.

The basic difference between the two approaches is well illustrated in the debate about the idea of 'identity'. Jorgenson and Griliches (1967), who contradict the earlier growth accountants' belief in the importance of TFP growth, argue that the value of total product is equal to the value of factor inputs as an accounting identity. Thus, the contribution of TFP to growth is negligible if real product and real factor inputs are accurately accounted for. On this issue, Denison (1972b: 100) states that:

The identity does and can hold in a current price output measure only if output is valued at factor cost; in that series it must hold because the value placed upon each unit of output is, by definition, the amounts earned by the factors in providing it. But current price measures have little to do with 'productivity measurement,' and the identity does not hold in constant prices even at factor costs—unless one abolishes the concept of productivity change. Productivity change is precisely a measure of the degree to which the identity does not hold.

Denison's point is that TFP terms (advances in technological, managerial and organisational knowledge, economies of scale by expansion of markets, and the allocation of resources) are not trivial sources of long-run growth, and that the other view is alien to common sense and contradicts previous research.

These two different views on the theory of growth lead to different growth accounting frameworks and to different empirical results. Denison believes that growth accounting can be a useful tool to classify sustainable and unsustainable sources of growth and to measure the welfare consequences of growth in the long run. He accounts for the sources of growth with an eye to identifying the contribution of growth to consumption in the long run. The production structure of an economy is not at the centre of his analysis. In contrast, the neoclassical production function is the basis of Jorgenson's analysis, emphasising the structure of economic production. In particular, he emphasises the need for rigorous aggregation procedures, which he accomplishes by assuming a translog production function and Divisia input indexes.

Their vastly different conclusions on the sources of long-run growth lead them to different theories on growth and investment policy. However, Denison's approach is consistent with the predictions of neoclassical growth theory. On this point, Denison's growth accounting approach can be employed in a practical way to construct the criterion for evaluating sustainability based on technological change. The debates and their origins are traced in the next section.

Debates on capital estimation

There are striking differences between the two approaches as far as the empirical base of estimation of capital is concerned. From the perspective of 'identity', Jorgenson and his colleagues concentrate on weighting, as far as possible, the different types and vintages of capital by their respective marginal products, so as to increase the contribution of capital input to growth. In practice, this process is the origin of the debate with Denison on the three issues related to capital estimation. The first issue is that of so-called embodied technological change (technological change embodied in the design of new capital goods), and the others are the extent of disaggregation and the degree of weighting, and the measurement of the decline in capital efficiency with age.

Take the first issue. Denison argues that embodied technology, if it exists, should appear in the residual, instead of in capital input, as was the case in Solow's original analysis (Denison 1964; Baily and Schultze 1990: 388). In contrast, Jorgenson and Griliches argue that embodied technology or unmeasured quality change of capital should be considered as a contribution of capital input rather than a contribution of the residual.

The embodiment effect is very important because some of the contribution of technological change will be transferred from productivity to input if unmeasured quality improvement in capital goods is counted as an increase in capital input. Denison (1972b: 97) explains Jorgenson's methodology and raises some problems.

[Jorgenson and Griliches] would like to weight capital goods of different vintages which are in simultaneous use by their relative marginal products if services prices were available from which relative marginal products could be inferred...Because of design improvement, each successive vintage would be counted as more input, relative to a vintage remaining in use, than the preceding vintage when it had been in the same physical condition. Hence, replacement of each vintage by a later vintage would raise capital input. The procedure would therefore raise the growth rate of the capital stock in constant prices (and hence capital input) relative to the conventional capital stock measure, and change the classification of growth sources by transferring from advances in knowledge to capital.

In response to Denison's argument about the problem of transfer, Jorgenson and Griliches (1972b: 168) distinguish two measures of quality change; 'quality change which make it equal to one or another version of the residual tautologically [embodied technological change], and quality change estimated from current differences in marginal products [measured quality change of capital]'. Jorgenson and Griliches agree with Denison about the first type of quality change but they stick to their argument on increasing the contribution of capital input to growth by emphasising the second type of quality change. Jorgenson (1966) had already pointed out the equivalence of embodied and disembodied technological change on the grounds that the two types of technological change are based on the same set of factual implications.

The two approaches generally agree that the gain that vintage models imagine to be derived from additional new investment is not great. This gain is realised by shortening the average life of capital while a reduction in the average amount of quality improvement incorporated in new capital has an offsetting effect, lowering the average age (Denison 1964;1980: 224). Hulten (1992a: 976) also concludes that 'changes in the quality of capital had a nontrivial impact on the growth of U.S. manufacturing industries...but they also suggest that Denison (1964) was right about the unimportance of this increase on output growth'. Accepting the general agreement on this issue, there is no need here to consider

embodied technological change as a component of capital input in my growth accounting framework. Like Denison, I will simply incorporate it in the residual. This is quite appropriate when considering follower countries' technological development, which is characterised by entry into new industries and movement into high-quality products through the import of capital goods.

The second issue is the extent of disaggregation and the weighting scheme. After arriving at a similar conclusion to Denison on the embodiment issue, Jorgenson and Griliches (1972a) emphasise the quality change of capital estimated from current differences in marginal products, which they distinguish from embodiment-related quality change, seeing this as a factor that can increase the contribution of capital input to growth. Using the translog indexes of capital input, Jorgenson and his colleagues attempt to increase the measured growth of capital services relative to Denison's approach. To use their words (1972b: 169),

we would wish to count it [quality change of capital different from embodied technological change] as part of input in the capital-using sector. This procedure will not eliminate productivity change by definition since it will result in higher productivity growth in the capital-producing sector. It will only attribute it where it belongs.

For Jorgenson and his colleagues, quality change is an important process, which can eliminate 'aggregation error' by disaggregating capital input as separate components wherever possible. Jorgenson *et al.* (1987) disaggregate sectoral capital stock by six types of asset class (producers' durable equipment, consumers' durable equipment, tenant-occupied residential or non-residential structure, owner-occupied residential structure, inventory and land) and four forms of legal organisation (corporate business, non-corporate business, household and business) for each of the disaggregated sectors. They then weight the sectoral growth rates of the capital stock with sectoral rental price measures (translog input indexes) to capture the effect of the shift in the composition of the aggregated capital stock among types of capital with different returns (that is, with different marginal products). In contrast, Denison distinguishes capital stock

and land, and disaggregates capital stock into two components (non-residential structures and equipment and inventories). He does not attempt the much more detailed disaggregation and weighting scheme that has been developed over the years by Jorgenson with various co-authors. Any quality changes of capital need to be incorporated in the residual of Denison's framework.

I shall also follow Denison's approach on this point. In particular, I do not propose to disaggregate capital stock by legal form, nor include consumer durables and residential structures in the category of capital, because these processes do not affect the long-run prospects for an economy.

Another difference between the two approaches related to the importance of capital is due to the different shares of capital and labour. Denison's capital-land share (property share) is lower than that of Jorgenson and his colleagues while Denison's labour share is higher. Thus, capital's contribution to growth is higher in Jorgenson's studies than in Denison's, and this leads to a lower estimate of the contribution of productivity to growth in Jorgenson and Griliches than in Denison. This gap mainly arises from the inclusion or exclusion of indirect business tax less subsidies (capital gains) in measuring income from capital.

Jorgenson and Griliches argue that factor shares for the components of capital must be imputed from the accounting data on total property income (gross private domestic product in current prices less private domestic labour income), and capital gains should be incorporated into the allocation of property income among classes of assets. They (1972a: 154) maintain that 'Denison is in error, not only in failing to take capital gains into account in measuring income from land, but omitting capital gains in measuring income from other assets'. In contrast, Denison (1972a: 40) argues as follows:

They count indirect business tax liability minus subsidies less current surplus of government enterprise and plus business transfer payments and the statistical discrepancy in the national accounts as earnings of capital and land...Inclusion of

these items in the earnings of capital and land raises their capital–land share from 29.2 percent to 36.2 per cent, or by almost one-fourth, and lowers their labor share from 70.8 to 63.8.

The last difference in the two streams is the measure of the decline in the efficiency of capital. Jorgenson assumes a geometrically declining pattern of efficiency when estimating capital stock while Denison assumes a straight-line (one hoss shay) depreciation. Jorgenson's assumption appears to reduce the measured growth of capital services related to the efficiency assumptions made by Denison, but the difference does not make for different results.

Debates on gross versus net output

It is generally believed that the differences in estimating capital input explain the differences in the empirical findings of Denison and Jorgenson. However, Baily and Schultze (1990: 388) find that it is not the case. They conclude that:

[Denison and Jorgenson] do not in practice seem to explain much of the wide discrepancy between the two sets of empirical results in their estimates of the importance of capital. Most of the divergence comes simply from the fact that the two studies cover different segments of the economy. When they are adjusted to cover the same 'domain' of output, the Jorgenson estimates of the contribution of capital turn out to be only moderately higher than those of Denison.

Denison analysed the growth of output net of depreciation, on the grounds that an increase in gross output that is due solely to the consumption of capital at an accelerated rate is simply trading future consumption for current consumption, without necessarily increasing national welfare. Jorgenson analyses gross output on the grounds that improvements in multifactor productivity tend to increase output gross of depreciation, and that the gross output measure is therefore appropriate for the analysis of productivity change.

Jorgenson's concept of output includes depreciation (capital consumption) and the services of consumer durables, residential structures, and non-profit institutions, in which capital contributes almost 100 per cent of the growth, and which are excluded in the analysis of Denison. This broader concept of output increases the contribution of capital to growth in the following way.

First, inclusion of capital consumption (depreciation) in the output concept in Jorgenson's framework leads to higher capital contribution in output growth.

Baily and Schultze (1990: 389–90) illustrate this result as follows:

Everything else being equal, an analysis of the sources of the growth in gross output will, simply from the arithmetic of growth accounting, assign a larger contribution to the growth of capital than will an analysis of net output...Think of gross national product as being composed of two components: net national product and capital consumption. That part of the growth in GNP represented by the growth in capital consumption is, by definition, 100 percent contributed by capital input. The contribution of capital to the other component is, of course, much smaller. When the growth of GNP is being analysed, the capital contribution will be a weighted average of its contribution to the first component (100 per cent) and its much smaller contribution to the second component. When net output is being analysed, only the capital contribution to the second component is included. Operationally this is reflected in the fact that the weight given to the capital input in studies of the growth of gross output is equal to the gross property income share, while Denison argues that the appropriate weight in analyses of net output is the net property share.

Neither approach is necessarily right or wrong. From the perspective of tracking an aggregate production function the Jorgenson approach—gross output and the gross share—makes sense. Denison, on the other hand, wants to adjust for the fact that the ultimate value of capital comes from its ability to produce net output. The fact that increases in capital add to gross output because they increase depreciation is a somewhat fictitious concept. Denison does not want to count this as part of capital's contribution to growth. He (1972a: 38; 1967: 14–15) comments that:

The reason I chose to analyse the growth of net rather than gross product is both fundamental and conventional. Insofar as a large output is a proper goal of society and objective of policy, it is net product that measures the degree of success in achieving this goal. Gross product is larger by the value of capital consumption. There is no more reason to wish to maximize capital consumption—the quantity of capital goods used up in production—than there is to maximize the quantity of any other intermediate product used up in production.

Second, services of consumer durables, residential structures, and non-profit institutions need to be considered. Baily and Schultze (1990: 390) explain how the inclusion of these services in the concept of output increases the role of capital:

The next important source of the difference in results stems from the inclusion of the services of residential structures, consumer durables, and nonprofit institutions in the Jorgenson team's analysis, outputs that are excluded from the Denison measure of output in the nonresidential business sector. These exceedingly capital-intensive sectors account for 21 percent of the Jorgenson output measure in 1979, and the capital share of income originating is 94 percent. The capital contribution to the growth of the Jorgenson–Gollop–Fraumeni aggregate output measure is thus a weighted average of a modest capital contribution in the business nonresidential sectors of the economy and a 94 percent contribution in the remaining sectors that, as noted, account for over 20 percent of output.

Partially offsetting this feature of the Jorgenson–Gollop–Fraumeni analysis is their inclusion, and Denison's exclusion, of the output of the general government sector where the capital contribution, by definition, is zero.

There has been a longstanding controversy over the use of net versus gross measures of national product in accounting for economic growth. However, I argue that neither approach is necessarily right or wrong. In this regard, Hulten (1992b: 9) concludes that:

the two measures are not substitutes, but complements which reveal different aspects of the growth process: gross product is the correct output concept for estimating the structure of production, while net product is the correct concept for measuring the welfare consequences of economic growth.

I accept this appraisal of the issue. However, given the focus of this study on long-run growth, I employ Denison's concept. One focus in this chapter is the long-run sustainability of growth in the Korean manufacturing sector. Another focus in this thesis is changing patterns of technological niches resulting from structural adjustment. These questions bear little relation to capital consumption, housing and consumer durables, where the role of capital is much larger.

Debates on disaggregation and intermediate input

In the preceding two parts of this section, I reviewed the discrepancies between Denison and Jorgenson and his colleagues from the perspective of the appropriateness of their model for evaluating the long-run sustainability issue. In this process, I inevitably focused on the sources of growth in one-sector aggregate economy models because of the aggregated nature of Denison's framework of analysis. Thus, I omitted the most important contributions of Jorgenson and his colleagues to the growth accounting literature—the importance of disaggregation of output into many sectors, and intermediate inputs. These aspects are very important to my framework. This section focuses on individual sectors and their relationship to the aggregate sector to provide a basis for later study of the validity of the aggregated approach and the sustainability of growth.

Most growth accounting studies have employed a highly aggregated model which provides broad simplifications and powerful predictions. However, as Jorgenson (1990) and Jorgenson *et al.* (1987) observe, the study of the sources of economic growth based on the notion of an aggregate production function is highly problematic; the aggregate approach requires very stringent assumptions about production patterns at the level of individual sectors of the economy. Intuitively

speaking, the technology of each sector must be a replica of the aggregate production function. In this context, Jorgenson (1990: 24) states:

The existence of an aggregate production function requires that the technology of each sector is separable in value-added and that value-added is a function of capital and labor inputs and the level of technology. Moreover, the sectoral value-added functions must be identical for all sectors, while the functions relating labor and capital input to their components must be identical for all sectors. Finally, each component of these input aggregates must receive the same price in all sectors.

As suggested in the previous chapter, I argue that each individual sector in developing countries, particularly in individual manufacturing industries, has reached a different level of technology, and that technological change in a small range of industries causes structural adjustment in aggregate manufacturing, resulting in resource reallocation. My intention is to incorporate this kind of equilibrium shift separately into the aggregate productivity growth term.

There are many studies of the relationship between aggregate productivity growth, sectoral productivity growth, and resource reallocation. Domar (1961), Hulten (1979), Jorgenson (1980; 1990) and Jorgenson *et al.* (1987) decompose aggregate productivity growth to a weighted sum of sectoral productivity growth plus resource reallocation, emphasising the disaggregated model. The meaning of resource reallocation is clearly set out by Hulten (1978: 511). He explains that:

it [is] important to distinguish between productivity change originating in a sector and the impact of productivity change on the sector. Productivity change in the first sense refers to the shift in the sectoral technology and is measured by the conventional productivity residual. Productivity change in the second sense measures the equilibrium response to the shifting sectoral technologies, and includes (a) the induced reallocation of factor input between sectors, and (b) the induced expansion in intermediate input, which serves to magnify the effect of technical change.

The disaggregation approach tends to induce intermediate input as a factor of production. It is believed that omitting intermediate input from growth accounting leads to an upward bias in the contribution of productivity, because technological change in an industry generally affects other industries via an interdependence relationship. As Jorgenson says, the assumption that value-added should be separable from intermediate input is required if we are to define the value-added production function. But this assumption is very stringent. Sectoral growth accounting studies with intermediate input show a different picture of sources of growth. According to Jorgenson (1990: 26):

Comparing the contribution of intermediate input with other sources of output growth [at the sectoral level], we find that this input is by far the most significant source of growth. The contribution of intermediate input exceeds productivity growth and the contributions of capital and labor inputs. If we focus attention on the contributions of capital and labor inputs alone, excluding intermediate input from consideration, we find that these two inputs are a more important source of growth than changes in productivity.

Jorgenson does not adjust intermediate input for quality change. He argues that the predominant role of intermediate input is unaffected by the omission of changes in quality, based on the empirical result that growth in quality is not an important component of growth in intermediate input.

This study takes a disaggregated approach and accounts for sources of growth with and without intermediate input. The former has merit when evaluating the sustainability of growth, and when comparing the results with other growth accounting studies, which largely calculate sources of growth without intermediate input.

Analytical framework

This section clarifies the growth accounting scheme of this chapter. I define the sectoral growth rates of productivity for each individual industry, and express the

aggregate productivity growth of the aggregate manufacturing sector. In addition I explore the aggregation procedure across all industries, while clarifying the relationship between aggregate productivity growth and growth rates of sectoral productivity. All the mathematical expressions in this section are based on Jorgenson *et al.* (1987) and Jorgenson (1990). Jorgenson and his colleagues emphasise the sectoral production function, and are critical of the aggregate production function approach. To clarify this point, they calculate productivity growth rates at the sectoral level and then calculate the aggregate productivity growth under stringent assumptions. This procedure offers an insight into separating the structural adjustment effect as a component of aggregate productivity growth.

Based on the literature survey in the earlier section, I now develop a hybrid framework for analysing productivity growth using growth accounting techniques. The basic strategies are as follows.

First, following Jorgenson, the manufacturing sector is disaggregated into 36 industries, and the sources of growth in each industry are calculated.

Second, following Denison, I shall not consider the embodiment effect and change in the quality of capital as components of capital input.

Third, following Denison, I do not include capital consumption (depreciation) and housing and consumer durables in the scope of output, where the role of capital is much larger, and would distort the question of long-run sustainability.

The first strategy avoids aggregation bias, and gives detailed information on productivity growth at the industry level. It also makes it possible to study structural adjustment across industries, interaction between capital formation and productivity growth, and sources of productivity growth.

Other strategies adopted make this study comparable to others, so providing answers to the sustainability question. They also guarantee relatively higher productivity growth than in Jorgenson's framework, retaining components which are not categorised as technological change for leader countries in the productivity growth term. These components include economies of scale and quality change of capital.

Sectoral productivity growth

In defining output, capital, and labour inputs, and productivity in terms of data on quantities and prices, we consider a specific form of the production function for each industry:

$$V_i = \exp[\alpha_0^i + \alpha_K^i \ln K_i + \alpha_L^i \ln L_i + \alpha_T^i T + 0.5 \cdot \beta_{KK}^i (\ln K_i)^2 + \beta_{KL}^i \ln K_i \ln L_i + \beta_{KT}^i \ln K_i T + 0.5 \cdot \beta_{LL}^i (\ln L_i)^2 + \beta_{LT}^i \ln L_i T + 0.5 \cdot \beta_{TT}^i T^2], \quad (i = 1, 2, \dots, 36)$$

where T is time, $\{V_i\}$ is the set of outputs, and $\{K_i\}$ and $\{L_i\}$ are the capital and labour inputs. Following Jorgenson and his associates, we refer to this production function as the transcendental logarithmic production function or, more simply, the translog production function.

We can define the shares of capital input and labour input, say $\{v_K^i\}$ and $\{v_L^i\}$, in the value of output by

$$v_K^i = P_K^i K_i / P_V^i V_i,$$

$$v_L^i = P_L^i L_i / P_V^i V_i, \quad (i = 1, 2, \dots, 36)$$

where $\{P_V^i\}$, $\{P_K^i\}$, $\{P_L^i\}$ denote the prices of outputs, and capital and labour inputs, respectively.

The necessary conditions for producer equilibrium are given by equalities between the shares of each input in the value of output and the elasticity of output with respect to that input:

$$v_K^i = \partial \ln V_i / \partial \ln K_i = \alpha_K^i + \beta_{KK}^i \ln K_i + \beta_{KL}^i \ln L_i + \beta_{KT}^i T,$$

$$v_L^i = \partial \ln V_i / \partial \ln L_i = \alpha_L^i + \beta_{KL}^i \ln K_i + \beta_{LL}^i \ln L_i + \beta_{LT}^i T, \quad (i = 1, 2, \dots, 36).$$

Similarly, we can define the rate of productivity growth, say $\{v_T^i\}$, for each sector as the rate of growth of output with respect to time, holding capital input and labour input constant:

$$v_T^i = \partial \ln V_i / \partial T = \alpha_T^i + \beta_{KT}^i \ln K_i + \beta_{LT}^i \ln L_i + \beta_{TT}^i T, \quad (i = 1, 2, \dots, 36).$$

The translog production function is characterised by constant returns to scale if and only if the parameters satisfy the conditions

$$\alpha_K^i + \alpha_L^i = 1,$$

$$\beta_{KK}^i + \beta_{KL}^i = 0,$$

$$\beta_{KL}^i + \beta_{LL}^i = 0,$$

$$\beta_{KT}^i + \beta_{LT}^i = 0, \quad (i = 1, 2, \dots, 36).$$

If we consider data at any two discrete points of time, say T and $T-1$, the growth rate of output can be expressed as a weighted average of the growth rates of capital and labour inputs plus the average rate of productivity growth:

$$(3-1) \quad \ln V_i(T) - \ln V_i(T-1) = v_K^i [\ln K_i(T) - \ln K_i(T-1)] \\ + v_L^i [\ln L_i(T) - \ln L_i(T-1)] + v_T^i, \quad (i = 1, 2, \dots, 36).$$

where the weights are given by the average value shares:

$$\bar{v}_K^i = 0.5[v_K^i(T) + v_K^i(T-1)],$$

$$\bar{v}_L^i = 0.5[v_L^i(T) + v_L^i(T-1)],$$

$$\bar{v}_T^i = 0.5[v_T^i(T) + v_T^i(T-1)], \quad (i = 1, 2, \dots, 36).$$

We refer to the average rates of productivity growth $\{\bar{v}_T^i\}$ as translog rates of productivity growth. Rearranging equation (3-1), we can write the rates of sectoral productivity growth as follows:

$$(3-2) \quad \bar{v}_T^i = [\ln V_i(T) - \ln V_i(T-1)] - \bar{v}_K^i [\ln K_i(T) - \ln K_i(T-1)] \\ - \bar{v}_L^i [\ln L_i(T) - \ln L_i(T-1)] \quad (i = 1, 2, \dots, 36).$$

Aggregate productivity growth

We can arrive at aggregate output, and aggregate capital and labour input by summation of sectoral output, and sectoral capital and labour input.

$$V = \sum V_i,$$

$$K = \sum K_i,$$

$$L = \sum L_i, \quad (i = 1, 2, \dots, 36).$$

We can also define the shares of value-added for all industries—say $\{w_i\}$ —in aggregate value-added by

$$w_i = P_V^i V_i / \sum P_V^i V_i \quad (i = 1, 2, \dots, 36),$$

denoting the prices of value-added by $\{P_V^i\}$.

As before, we consider a translog form for the aggregate production function in defining value-added in terms of data on quantities and prices:

$$V = \exp[\alpha_0 + \alpha_K \ln K + \alpha_L \ln L + \alpha_T T + 0.5 \beta_{KK} (\ln K)^2 + \beta_{KL} \ln K \ln L + \beta_{KT} \ln K T + 0.5 \beta_{LL} (\ln L)^2 + \beta_{LT} \ln L T + 0.5 \beta_{TT} T^2].$$

We can define the shares of aggregate capital and labour input, say v_K , and v_L , in the value-added by

$$v_K = P_K K / P_V V,$$

$$v_L = P_L L / P_V V$$

where P_V, P_K, P_L denote the prices of value-added and capital, and labour inputs, respectively.

Necessary conditions for producer equilibrium are given by equalities between the shares of each input in the value of output and the elasticity of output with respect to that input:

$$v_K = \partial \ln V / \partial \ln K = \alpha_K + \beta_{KK} \ln K + \beta_{KL} \ln L + \beta_{KT} T,$$

$$v_L = \partial \ln V / \partial \ln L = \alpha_L + \beta_{KL} \ln K + \beta_{LL} \ln L + \beta_{LT} T.$$

Similarly, we can define the rate of productivity growth, say v_T , as the rate of growth of aggregate output with respect to time, holding capital input, and labour input constant:

$$v_T = \partial \ln V / \partial T = \alpha_T + \beta_{KT} \ln K + \beta_{LT} \ln L + \beta_{TT} T.$$

The sectoral value shares and rate of productivity growth are identical to the corresponding aggregate value shares and rate of productivity growth.

The translog production function is characterised by constant returns to scale if and only if the parameters satisfy the conditions

$$\alpha_K + \alpha_L = 1,$$

$$\beta_{KK} + \beta_{KL} = 0,$$

$$\beta_{KL} + \beta_{LL} = 0,$$

$$\beta_{KT} + \beta_{LT} = 0.$$

If we consider the data at any two discrete points of time, say T and $T-1$, the growth rate of output can be expressed as a weighted average of the growth rates of capital, and labour inputs plus the average rate of productivity growth:

$$(3-3) \quad \begin{aligned} \vartheta_T = & [\ln V(T) - \ln V(T-1)] - \vartheta_K [\ln K(T) - \ln K(T-1)] \\ & - \vartheta_L [\ln L(T) - \ln L(T-1)] \end{aligned}$$

where the weights are given by the average value shares:

$$\vartheta_K = 0.5 \cdot [\nu_K(T) + \nu_K(T-1)],$$

$$\vartheta_L = 0.5 \cdot [\nu_L(T) + \nu_L(T-1)],$$

$$\vartheta_T = 0.5 \cdot [\nu_T(T) + \nu_T(T-1)].$$

I refer to the average rate of productivity growth ϑ_T as the translog rate of productivity growth.

Aggregation over sectors

Jorgenson *et al.* (1987) show the relationship between (the weighted sum of) sectoral productivity growth and aggregate productivity growth. They compute the resource reallocation effect (a measure of aggregation error) in order to advocate a disaggregation procedure and to illuminate the problems of the aggregate production function approach. This framework gives valuable insight into the puzzle of low productivity growth in East Asian NIEs, and makes it possible to calculate the effect of structural adjustment across industries (Chapter 5).

Conditions for producer equilibrium at the sectoral and aggregate levels are equivalent only under the restrictive conditions that there exist for all sectors value-added functions that are identical to the aggregate production function, that capital and labour inputs within each sector are identical functions of their components, and that the prices paid for primary factor inputs are the same for all sectors (Jorgenson *et al.* 1987: 66).

First, we can express the rate of productivity growth for the aggregate manufacturing as the equation (3-3).

$$(3-3) \quad \psi_T = [\ln V(T) - \ln V(T-1)] - \psi_K [\ln K(T) - \ln K(T-1)] \\ - \psi_L [\ln L(T) - \ln L(T-1)].$$

Second, we can express the rate of productivity growth for each of the 36 industries as equation (3-2).

$$(3-2) \quad \psi_T^i = [\ln V_i(T) - \ln V_i(T-1)] - \psi_K^i [\ln K_i(T) - \ln K_i(T-1)] \\ - \psi_L^i [\ln L_i(T) - \ln L_i(T-1)] \quad (i = 1, 2, \dots, 36).$$

Multiplying equation (3-2) by the ratio of value-added in the corresponding sector to value-added in all sectors, and summing over all sectors, we obtain

$$(3-4) \quad \sum w_i^i \cdot v_i^i = \sum w_i^i [\ln V_i(T) - \ln V_i(T-1)] - \sum w_i^i \cdot v_K^i [\ln K_i(T) - \ln K_i(T-1)] \\ - \sum w_i^i \cdot v_L^i [\ln L_i(T) - \ln L_i(T-1)], \quad (i = 1, 2, \dots, 36)$$

where

$$w_i = 0.5 [w_i(T) + w_i(T-1)],$$

$$w_i = P_V^i V_i / \sum P_V^i V_i, \quad (i = 1, 2, \dots, 36).$$

Subtracting equation (3-4) from equation (3-3) and rearranging, we arrive at the rate of productivity growth for the aggregate manufacturing sector.

$$(3-5) \quad v_T = \sum w_i^i \cdot v_i^i \\ - \sum w_i^i [\ln V_i(T) - \ln V_i(T-1)] + [\ln V(T) - \ln V(T-1)] \\ + \sum w_i^i \cdot v_K^i [\ln K_i(T) - \ln K_i(T-1)] - v_K [\ln K(T) - \ln K(T-1)] \\ + \sum w_i^i \cdot v_L^i [\ln L_i(T) - \ln L_i(T-1)] - v_L [\ln L(T) - \ln L(T-1)], \quad (i = 1, 2, \dots, 36).$$

Equation (3-5) shows that aggregate productivity growth can be defined as the sum of a weighted sum of sectoral productivity growths and three resource reallocations. The first term on the right hand side expresses a weighted sum of sectoral productivity growth in 36 manufacturing industries, with weights given by ratios of the value of output in each industry to value-added in aggregate manufacturing. The other terms on the right hand side express the growth rates of the reallocations, which capture the differences between the growth rates of aggregate indexes of value-added, capital input, and labour input, and the corresponding indexes obtained by weighting sectoral output and inputs by its output share in aggregate output.¹⁴

¹⁴ Jorgenson and his colleagues decompose capital and labour input into more detailed components to capture the differences in marginal productivity over components. See the debate on adjusting the scheme for quality change in capital in the earlier section. However, following Denison, I do not decompose sectoral input into detailed components, so resource reallocation effects in equation (3-5) are smaller than those of Jorgenson. In sum, my growth accounting framework follows Jorgenson in form but Denison in content.

Jorgenson (1990: 66–67) explains the meaning of resource reallocations as follows.

Reallocations of value-added, capital input, and labor input among sectors...provide measures of departures from these assumptions. Reallocations of value-added incorporate differences in value-added functions among sectors and departures from the separability assumptions required for the existence of a value-added function in each sector. Reallocations of capital and labor inputs include differences in capital and labor aggregates among sectors, departures from separability assumptions required for the existence of these aggregates, and differences in prices of individual capital and labor input among sectors.

According to Jorgenson, aggregate productivity growth has meaning only when the sums of the reallocations of value-added, capital, and labour are near zero. If they are markedly different from zero, we cannot define an aggregate production function, by definition. However, this may be not the case for NIEs because strong structural adjustments might change the industrial structures of these countries. In this case, aggregate productivity growth can no longer be defined (the one-sector aggregate model becomes inappropriate), and the weighted sum of sectoral productivity growth replaces the role of aggregate productivity growth. A corollary is that the use of aggregate productivity growth is also inappropriate in questioning long-run sustainability. Conversely, if the reallocation effect is near zero, it confirms the appropriateness of the one-sector aggregate model. In this event the prospects for long-run growth may be judged by the calculated aggregate productivity growth.

Growth accounting results

Aggregated growth results and their implication of unsustainable growth in the NIEs are problematic, because the data used were highly aggregated, and unreliable in the case of capital stock. Instead, I take a highly disaggregated approach and use capital stock data constructed by the national wealth survey.

The purpose of this section is to explain the data I employ and to account for the sources of growth the Korean manufacturing at both the aggregate and industry levels. I then test the validity of the aggregate production function approach and the long-run sustainability of growth.

Data

I employ the growth accounting data of Hong and Kim (1996) (KDI data hereafter), which are an extension study of Kim and Hong (1992), Kim and Park (1985) and Kim and Park (1988), because the dataset is consistent with my strategies for a growth accounting framework. They account for the sources of growth of 36 industries in the Korean manufacturing sector over the 1967–93 period. They include intermediate input as a factor of production, following Jorgenson, but calculate sources of growth with the extension of Denison's methodology. On this reason, the KDI data are consistent with Denison's framework; for example, capital and labour input data are calculated using Denison's approach.

Capital stock data are calculated as the sum of total fixed assets (non-residential structures and equipment plus land), weighted by 0.75, and inventories, weighted by 0.25. Inclusion of land and inventories decreases the growth rate in capital stock because land and inventories have grown more slowly than equipment and non-residential structures. Data on each component of capital stock are constructed using the *National Wealth Survey* and *Mining and Manufacturing Survey*; benchmark data for 1968, 1978 and 1987 are from the *National Wealth Survey* and *Mining and Manufacturing Survey* data are used to construct time series. Capital stock data from this study are more reliable than those constructed from historical investment data of the National Account, because they do not require arbitrary assumptions on depreciation rate and reference period used for extrapolation.

The labour input index is calculated by multiplying the total employment index, which includes self-employment as well as unpaid family workers, by the index of monthly labour hours and the index of quality change in labour. According to Kim and Park (1985), the increase in total employment explains 66 per cent of the increase in labour input, while the increase in labour hours and quality change due to enhancement of education each explains about 15 per cent. It is impossible to collect labour quality change data at the industry level. So Hong and Kim (1996), Kim and Hong (1992) and Kim and Park (1985) use the labour quality change data for the whole economy in all industries at the same time. The KDI labour input data are not weighted by age–sex profile. A one-to-one rule is applied in treating self-employed and unpaid family workers, where numbers have grown more slowly than in normal employment. Thus, the growth rate in the labour input index is lower than other cases.

This study accounts for the sources of growth with and without intermediate input,¹⁵ and employs aggregation over sectors, following Jorgenson. It also takes 15 sectors, integrating the 36 original industries as a basis of the study. However, a 36-industry model is also estimated to supplement the arguments of the study. The growth accounting data of the KDI dataset is similar to the data of Dollar and Sokoloff (1990), Dollar (1991) and the World Bank (1993) in the growth of output and capital. Classification of industries is explained in Table A3.1.

Aggregate productivity growth

The aggregate growth accounting results are summarised in Table 3.1. During the period 1967–93, growth rates in output (value-added) and productivity are 16.1 per cent and 6.0 per cent, respectively, and the contribution growth rates¹⁶ in capital and labour are 7.9 per cent and 2.3 per cent, respectively. The

¹⁵ A basic model of this study is constructed without intermediate input to make the results comparable with other studies. However, productivity growth measured with intermediate input is used in the analysis of Chapters 4 and 6, when a strict concept of productivity is required.

¹⁶ The contribution growth rate is calculated by multiplying the growth rate in an input by its share in output.

contributions of productivity growth, capital, and labour to output growth are 36.9 per cent, 49.1 per cent, and 14.1 per cent, respectively.

These results confirm the earlier findings that capital deepening plays a major role in rapid output growth; capital deepening explains 49.1 per cent of the output growth of Korean manufacturing. However, this study also suggests that productivity growth is a significant contributor to output growth, a somewhat different perspective from earlier findings. A 6 per cent productivity growth and 36.9 per cent contribution ratio are not low when compared with the values of developed countries in the same period, even though productivity is not a leading contributor to growth, as predicted in Denison's framework. This conclusion is very similar to Drysdale and Huang (1996: 20–21), who argue against Krugman that 'although increases in factor inputs were significant contributors to growth of output in East Asian economies, productivity growth was also an important factor contributing to rapid growth'.

Korean manufacturing continued to change its production structure from labour-intensive industries to chemical and heavy industries from the early 1970s. The Korean manufacturing sector continued to accomplish high growth (20.6 per cent) by proceeding with chemical and heavy industrialisation in 1973–78, but in 1980 and 1981 the Korean economy faced recession, following the prolonged boom of the previous two decades. The economy recovered from the recession of the early 1980s with some restructuring. To identify the changes in trends, I divide the whole period into five sub-periods: 1968–73, 1973–78, 1978–83, 1983–88 and 1988–93. The 1983–88 and 1988–93 periods were characterised by a production shift to chemicals, machinery, electronic products and automobiles, while the 1968–73 and 1973–78 periods were characterised by labour-intensive products such as textiles and clothing. In the 1973–78 period, the production share of chemical and heavy industries increased within the manufacturing sector, but labour-intensive industries still maintained their international competitiveness.

Table 3.1 Sources of growth of aggregate output, 1968–93
(per cent)

	68–73	73–78	78–83	83–88	88–93	68–93
Growth rate						
Value-added	20.85	20.59	12.07	15.43	12.15	16.14
Productivity	10.36	6.53	2.49	5.57	4.80	5.95
Capital	7.02	10.56	8.62	7.62	6.13	7.92
Labour	3.48	3.50	0.96	2.24	1.22	2.27
Contribution						
Value-added	100.0	100.0	100.0	100.0	100.0	100.0
Productivity	49.67	31.72	20.64	36.08	39.52	36.87
Capital	33.65	51.28	71.41	49.38	50.42	49.07
Labour	16.68	17.00	7.95	14.54	10.06	14.06
Capital share	61.62	62.15	60.61	59.83	57.08	60.23

Source: Author's calculation.

Productivity growth in 1968–73 is extraordinarily high. This phenomenon is not surprising at all when recalling Dollar and Sokoloff (1990), who identified ‘scale economies associated with the transition from craft to modern labor-intensive production’ as a main source of rapid productivity growth.¹⁷ In contrast, productivity growth in 1978–83 is extraordinarily low because of the over-investment in chemical and heavy industries in the previous two periods as well as the second oil shock. If we do not consider the performances of these two periods to capture the long-run trend, productivity growth, capital growth, labour growth, and output growth declined steadily.

There is some evidence that structural adjustment and liberalisation policies in the early 1980s were successful; the contribution of productivity growth to output growth increased to 36 per cent in 1983–88 while the contribution of capital growth fell to 49 per cent compared with the earlier period.¹⁸ Korean

¹⁷ Developing countries show high productivity growth in the initial phase of development. The contribution of productivity to output growth was about 50 per cent in Korea in 1968–73, similar to that of developed countries. However, growth rates and the contribution of productivity growth to output growth decline thereafter (Chen 1997). The surprising thing is that high productivity growth in the initial phase of development is used as evidence of productivity catch-up. This is not the case. High productivity growth merely arises from the introduction of the modern factory system in labour-intensive industries.

¹⁸ The development program for heavy and chemical industries caused over-investment and over-capacity in these industries, resulting in inefficiencies in the economy. At the same time a decrease in competitiveness in light industries caused inefficiencies in economy. Structural adjustment efforts occurred for these reasons. Less competitive plants in heavy industry, and

manufacturing stabilised in the 1988–93 period compared with the 1983–88 period; the contribution of productivity to output growth increased a little.

Table 3.2 decomposes aggregate productivity growth in the Korean manufacturing sector into the weighted sum of sectoral productivity growth and resource reallocations of value-added, capital input, and labour input, using equation (3-5) on the assumption that Korean manufacturing comprises 36 industries.

Table 3.2 Aggregate productivity growth and its components, 1968–93
(per cent)

	68–73	73–78	78–83	83–88	88–93	68–93
Aggregate prod. growth (A+B+C+D)	10.35	6.55	2.50	5.58	4.83	5.96
WSSP (A)	11.66	7.16	3.83	5.35	4.69	6.45
Output reallocation (B)	-1.93	-0.46	-1.77	0.05	0.04	-0.74
Capital reallocation (C)	0.48	-0.65	-0.18	-0.16	0.10	-0.07
Labour reallocation (D)	0.15	0.50	0.61	0.35	0.00	0.33
Sum of reallocations (B+C+D)	-1.30	-0.61	-1.34	0.23	0.14	-0.49

Source: Author's calculation.

Table 3.3 decomposes the weighted sum of sectoral productivity growth in Table 3.2 into contributions by industry. The contribution of each industry is a function of productivity growth in that industry and its output share.¹⁹ For the first two periods (1968–73 and 1973–78), chemicals and textiles are the main contributors to the weighted sum of sectoral productivity growth of Korean manufacturing. But fabricated metals and machinery, office machinery and medical and precision instruments, electrical and electronic products, and motor vehicles as well as chemicals are the main contributors to the weighted sum of sectoral productivity growth in the last two periods (1983–88 and 1988–93).

marginal firms in light industries, which previously enjoyed competitiveness, were the objects of restructuring in the early 1980s.

The industry policy of the Korean government changed in the 1980s towards a reduced role for government and increased liberalisation (Smith 1995; 1994a).

¹⁹ Output shares have a great effect on the values in the table. For example, food, beverages and tobacco contribute more than 10 per cent to the weighted sum of sectoral productivity growth over the whole period, not because productivity growth in this industry is high but because its share is big.

Table 3.3 Industry contribution to WSSP, 1968–93
(15 sectors, per cent)

	68–73	73–78	78–83	83–88	88–93	68–93
Food, beverage, tobacco	19.55	11.67	19.08	2.56	10.3	13.98
Textiles	16.75	16.9	1.27	9.92	6.18	13.51
Clothes, leather	4.45	3.78	6.88	4.84	4.39	4.68
Wood, paper, printing	7.09	3.42	10.55	6.26	4.96	6.4
Chemicals	17.29	30.77	15.66	12.13	10.49	18.23
Refined petroleum	7.39	1.99	-12.17	4.95	5.38	3.06
Rubber, plastic	2.71	2.28	2.72	8.14	0.61	3.22
Non-metallic mineral	4.17	4.66	-4.9	2.78	8.45	3.63
Steel, non-ferrous metals	4.95	3.42	4.01	4.99	5.07	4.4
Machinery, fabricated metals	3.52	6.34	10.59	11.34	10.8	7.07
Office, medical machinery	1.39	2.6	5.87	7.93	12.35	4.68
Electric and electronic products	3.32	5.48	14.01	9.76	7.56	6.1
Motor vehicles	3.11	4.65	8.11	6.15	11.58	5.58
Other vehicles	2.48	-0.41	13.69	4.13	3.94	3.22
Others	1.85	2.45	4.63	4.12	-2.08	2.22
Manufacturing as a whole	100	100	100	100	100	100

Source: Author's calculation.

Sectoral productivity growth

Table 3.4 summarises the growth accounting results of 15 integrated industries which are based on the two-input model. Productivity growth is the largest contributor to output growth in eight of the 15 industries. They are textiles, clothes and leather, wood and paper and printing, chemical products, machinery and fabricated metals, office and medical machinery, motor vehicles and other vehicles. Past and present leading industries are included in this category, except electrical and electronic products. Disaggregate growth accounting leads to a somewhat different conclusion from aggregated growth accounting studies, namely that productivity growth played the major role in these industries. The other four industries also show significant productivity growth with a contribution ratio over 33 per cent. They are food and beverage and tobacco, rubber and plastic, non-metallic minerals and other manufacturing.

The five industries with the highest productivity growth over the whole period are office machinery and medical/precision instruments, chemicals and chemical products, other transportation vehicles, motor vehicles, and fabricated metals and machinery. The industries with the highest productivity are all in the chemical and heavy industry sectors. Textiles is sixth in productivity growth. The industries with the lowest productivity growth are refined petroleum, food and beverages and tobacco, non-metallic minerals, and other manufacturing. Their capital contribution ratios are 77.3, 61.7, 51.5 and 40.6 per cent, respectively. The industries with the lowest productivity growth are also the highest capital contribution industries.

Table 3.4 Sources of growth of sectoral output, 1968-93
(per cent)

	Output	TFP	Capital	Labour	TFP	Capital	Labour
Food, beverages, tobacco	12.12	4.04	7.48	0.61	33.31	61.66	5.03
Textiles	14.60	7.03	5.71	1.85	48.19	39.12	12.69
Clothes, leather	12.73	5.69	4.69	2.35	44.72	36.84	18.45
Wood, paper, printing	12.87	6.12	4.48	2.27	47.54	34.82	17.64
Chemicals	21.12	10.07	8.45	2.60	47.68	40.00	12.32
Refined petroleum	13.05	2.67	10.09	0.29	20.42	77.32	2.25
Rubber, plastic	17.63	6.70	7.44	3.49	38.03	42.19	19.78
Non-metallic minerals	14.29	4.84	7.36	2.10	33.83	51.51	14.66
Steel, non-ferrous metals	20.43	5.95	11.63	2.85	29.12	56.91	13.97
Machinery, fabricated metals	19.41	8.06	6.66	4.69	41.53	34.33	24.14
Office, medical machinery	25.11	10.49	8.20	6.42	41.77	32.67	25.56
Electrical/electronic products	23.95	6.05	12.44	5.46	25.26	51.93	22.81
Motor vehicles	22.28	9.13	9.12	4.04	40.95	40.92	18.14
Other vehicles	19.71	9.88	6.16	3.67	50.13	31.23	18.64
Others	14.10	5.07	5.72	3.30	35.98	40.59	23.43

Source: Author's calculation.

Table 3.5 shows the trends in productivity growth of 15 integrated sectors over various periods. During the 1968–73 period, chemicals and chemical products, other transportation vehicles, and steel and non-ferrous metals showed the highest productivity growth while other manufacturing and food and beverages and tobacco showed the lowest productivity growth.

Table 3.5 Productivity growth by time period, 1968–93
(per cent)

	1968– 73	1973– 78	1978– 83	1983– 88	1988 –93	1968– 93
Food, beverages, tobacco	8.38	4.31	2.93	1.16	3.23	4.04
Textiles	13.00	10.76	0.33	6.04	3.35	7.03
Clothes, leather	8.47	5.24	3.95	6.24	4.18	5.69
Wood, paper, printing	9.03	4.53	5.72	6.52	4.07	6.12
Chemicals	20.06	21.18	3.34	4.76	2.97	10.07
Refined petroleum	9.78	1.91	-3.88	3.60	3.45	2.67
Rubber, plastic	13.23	6.62	2.71	10.31	0.44	6.70
Non-metallic mineral	9.38	8.74	-2.91	3.32	6.79	4.84
Steel, non-ferrous metals	14.33	5.89	2.16	4.33	3.33	5.95
Machinery, fabricated metals	10.47	13.22	5.50	7.90	4.58	8.06
Office, medical machinery	13.69	13.34	6.92	10.94	8.18	10.49
Electric and electronic products	8.46	7.41	6.75	6.48	3.32	6.05
Motor vehicles	10.57	14.34	7.21	7.70	6.60	9.13
Other vehicles	17.45	0.22	16.36	6.04	9.68	9.88
Others	7.26	8.07	5.91	7.71	-4.01	5.07
Total	10.36	6.53	2.49	5.57	4.80	5.95

Source: Author's calculation.

During the 1973–78 period, chemicals and chemical products, motor vehicles, office machinery and medical/precision instruments, and fabricated metals and machinery showed the highest productivity growth while other transportation vehicles and refined petroleum showed the lowest productivity growth. During the 1978–83 period, other transportation vehicles, motor vehicles, office machinery and medical/precision instruments, and electric and electronic products showed the highest productivity growth while refined petroleum and non-metallic mineral showed the lowest productivity growth. During the 1983–88 period, office machinery and medical/precision instruments, rubber and plastic, fabricated metals and machinery, and motor vehicles showed the highest productivity growth while industry and food and beverages and tobacco and non-metallic mineral showed the lowest productivity growth. During the 1988–93 period, other transportation vehicles, office machinery and medical/precision instruments, and non-metallic mineral and motor vehicles showed the highest productivity growth while other manufacturing and rubber and plastic showed the lowest productivity growth.

Comparison with earlier studies

Earlier growth accounting studies on Korean manufacturing show a wide range of productivity growth estimates, from 1.1 per cent to 7.0 per cent. These differences arise from various factors. First, growth rates in output, capital stock and labour input differ according to the data source. For example, growth rates in output and labour in the *Mining and Manufacturing Survey* are higher than in other sources because it covers only those firms with more than five workers. This directly increases the estimate of productivity growth. Output growth is about 2.5–5.1 per cent higher according to Kim and Hong (1992) and Young (1995). The growth rate in capital stock estimated from the *Mining and Manufacturing Survey* and the *National Wealth Survey* is also higher than the estimate from the National Account.

Second, capital stock estimates differ according to the exclusion or inclusion of land and inventories. Inclusion of land and inventories in estimating capital stock, as in the case of KDI dataset, decreases the growth rate because growth rates in other types of capital stock, machinery and non-residential structures have grown faster. In this case productivity growth will be higher. Third, labour input growth rates differ according to the degree of weighting procedure, and the treatment of self-employed and unpaid family workers. For example, the KDI labour input index does not weight the input by age–sex profile, and applies a one-to-one rule in treating self-employed and unpaid family workers. This decreases labour input growth, and so increases productivity growth. However, the one-to-one rule has an offsetting force by decreasing productivity growth through lowering the labour share.

**Table 3.6 Productivity growth estimates of earlier studies
(two-input model, manufacturing)**

	Period	TFP growth (per cent)
This study	1968–93	5.95
Young (1995)	1966–90	3.0
Pyo <i>et al.</i> (1993)	1970–90	1.1
Moon <i>et al.</i> (1991)	1971–89	3.7
Dollar and Sokoloff (1990)	1953–79	6.1
Kim and Park (1988)	1966–83	7.0

Source: Young (1995), Kim and Park (1988).

According to Table 3.6, this study falls within the higher productivity group as noted by Kim and Park (1988) and Dollar and Sokoloff (1990). In contrast, other studies show lower productivity growth (1.1–3.7 per cent). Table 3.7 examines the causes for the difference in productivity growth between this study and Young (1995). According to Table 3.7, capital stock data in the two studies do not make any difference in calculating productivity growth, even though the growth rate in Young is two percentage points higher, because a higher labour share completely compensates for the effect of higher capital growth in Young’s study. The labour

contribution growth rate of Young's study is 1.59 per cent higher than in this study. This difference can also be decomposed by a difference in weighting of labour (0.58 per cent) and differences in data source (1.01 per cent). Young's weighting scheme for labour is more stringent than the KDI data set. He weights the working population by sex, age, education, industry, income, hours of work, and class of worker. In contrast, the KDI dataset weights total employment by education and working hours only. However, these different weighting schemes only result in a 0.58 per cent of difference in labour input growth.

About 70 per cent of the difference in productivity growth (2.04 in 2.95 per cent) is simply a result of the difference in output growth. The KDI output data are estimated from the *Input Output Table* and the *Mining and Manufacturing Survey*, whereas Young uses National Account data. Productivity growth calculations based on National Account data require some assumptions such as capital share, depreciation rate, the reference period used for extrapolation, and the beginning of capital accumulation. According to Sarel (1995a: 246–47), capital share and the specific estimation period result in different levels of productivity growth in East Asia. In contrast the *Input Output Table* data does not require strong assumptions in calculating productivity growth, and allows a disaggregated approach.

Table 3.7 Productivity growth comparison with Young (1995)

	This study (1968–93)	Young (1966–90)	Difference in TFP growth
Productivity growth (%)	5.95	3.00	2.95
Output growth (%)	16.14	14.10	2.04 (+)
Capital contribution growth (%)	7.92	7.23	0.69 (-)
Labour contribution growth (%)	2.27	3.86	1.59 (+)
Capital growth (%)	13.10	15.10	2.00 (+)
Labour growth (weighted, %)	5.81	7.40	1.59 (+)
Capital share	0.602	0.479	0.123 (-)

Source: Calculated by the author.

Tests for hypotheses under the growth accounting framework

Validity of the aggregate production function approach

Jorgenson and his colleagues earlier argued that aggregate productivity cannot be identified if the sum of resource reallocation is markedly different from zero in dealing with aggregation over sectors (see equation 3-5: 21). I predict this will happen in the application of growth accounting technique to Korean manufacturing, because production diversification over industries (entry into new industries) in a transitional economy will lead to significant resource reallocation effects of capital and labour input.

Table 3.2 show that the sum of resource reallocations is not far from zero over the whole period. This can be interpreted as a sign of the appropriateness of the aggregate model over the whole period. Hence, it is possible to assess long-run growth on the basis of calculation of aggregate productivity growth. However, an examination of the sum of resource reallocations by time period (the last row in Table 3.2) leads to a different conclusion. It is quite different from zero in 1968–73, 1973–78 and 1978–83, though not in 1983–88 and 1988–93.

These results suggest that the aggregate production function approach is not valid for the first three periods, and that the validity of the approach over the whole period is spurious. Thus, the sum of sectoral productivity growth weighted by industry share is a better measure of aggregate productivity growth. It also indicates that diversification across industries (entering new industries sequentially) is a prominent source of productivity growth in the first three periods. Aggregation bias disappears after the early 1980s, reflecting the exhaustion of opportunity for productivity growth by diversification across industries. Thus, the earlier aggregate growth accounting studies such as Young (1995) and Kim and Lau (1994a; 1994b; 1996) are somewhat misleading because the aggregate production function approach up until the early 1980s cannot be defined. This calls their findings into question. According to Equation (3-5),

aggregate productivity growth is equal to the weighted sum of sectoral productivity growth plus three kinds of resource reallocation. Note that the sum of resource reallocations is negative rather than positive. The weighted sum of sectoral productivity growth is greater than aggregate productivity growth. Hence, the earlier aggregated approach underestimated the real aggregate productivity growth of Korean manufacturing.

Do these results mean that the opportunities for productivity growth through diversification are over? This may be not the case. Follower countries have other opportunities to enhance productivity growth, namely by production shift from low-quality to high-quality products within an industry. This study does not capture within-industry effects because more disaggregation is needed to detect such effects. This study merely captures the effects of expanding production activities over industries (across-industry effects). For example, the framework has the power to identify structural adjustment from labour-intensive to capital-intensive industries, but has no power to identify a production shift from 4M DRAMs to 16M DRAMs. This kind of structural adjustment has been more common than entrance into new industries since the 1980s.

Sustainability of growth

Krugman (1994) and Kim and Lau (1994a; 1994b) argue that growth in East Asian NIEs cannot be maintained because their productivity performance is very poor, likening their situation to the case of former Soviet Russia. I evaluate this issue under the standard disaggregated growth accounting framework.

According to Table 3.4, productivity growth is the largest contributor to output growth in eight industries: textiles, clothes and leather, wood and paper and printing, chemicals, fabricated metals and machinery, office machinery and medical/precision instruments, motor vehicles, and other transportation vehicles. Krugman's hypothesis in the case of these industries is debatable. Four other industries show that productivity growth is an important source of growth, with

productivity contribution ratios of over 33 per cent. In contrast, capital is the dominant contributor only in four industries: food and beverages and tobacco, refined petroleum, steel and non-ferrous metals, and electric and electronic products. Krugman's criticism is valid only for these industries. In the case of Korean manufacturing, productivity growth can explain output growth to such an extent that we can reject the unsustainable growth hypothesis. Moreover, the smooth declining trend in productivity growth over time implies that Korean manufacturing has not yet reached its growth limit.

Although disaggregated growth accounting results reveal some evidence against Krugman's argument on the sustainability of growth, it cannot be disputed that capital growth is the largest contributor to output growth in the whole manufacturing sector.²⁰ Does this mean that growth in the East Asian NIEs is necessarily unsustainable? Why was capital accumulation so important in East Asian growth? Does productivity growth measured by growth accounting techniques represent technological change? The growth accounting approach has limitations in answering the sustainability question because the growth accounting model lacks an explanation for the characteristics of the growth process of follower countries. In the following chapters I shall concentrate on theoretical issues that are helpful to understand the mechanism of growth in the East Asian NIEs, and that undermine the unsustainability criticism.

Summary

The question posed in this chapter concerns the validity of earlier empirical findings and their implication of unsustainable growth. Earlier findings may not be robust because highly aggregated data lead to aggregation bias, and because capital stock data constructed from investment data are unreliable.

²⁰ Although the weighted sum of sectoral productivity growth, rather than aggregate productivity growth, is adopted in considering the aggregation bias problem, the role of productivity growth is not much magnified; it is 6.5 per cent in the 36-industry model over the whole period.

After the literature survey on Denison's and Jorgenson's framework, a hybrid model was constructed to overcome these problems and to confirm whether the use of disaggregated data leads to a different conclusion. First, the manufacturing sector was disaggregated into 36 industries, following Jorgenson, to check the validity of aggregate analysis. Second, the embodiment effect and quality change of capital in each industry were considered as components of productivity growth, following Denison, to see productivity growth as a fundamental source of growth.

According to growth accounting results based on this framework, the earlier finding that the contribution of capital to growth is relatively high in the case of NIEs could not be denied in the aggregated Korean manufacturing sector, even though productivity's contribution to growth is significantly high, at about 37 per cent. However, disaggregated growth accounting leads to a different conclusion. Productivity growth was the largest contributor to output growth in eight of the 15 industries. The aggregate production function approach was not valid in considering the sum of resource reallocations. It was quite different from zero in 1968–73, 1973–78 and 1978–83, when the Korean manufacturing sector experienced structural adjustments through diversification. The results of no aggregation bias in 1983–88 and 1988–93 are also doubtful. They may arise from the failure of growth accounting to capture structural adjustment within industries (production shift to high-quality products).

Earlier growth accounting studies directly link low productivity growth in NIEs to low technological change, and some of them go to the extreme of interpreting low productivity gains as evidence of unsustainable growth. However, the results in this chapter, in particular the aggregation bias story, show that we are just at the starting point of further investigation. Aggregation bias may be systematically linked to sequential structural adjustments in the Korean manufacturing sector, requiring careful interpretation of the growth accounting results. In that case, the mechanical properties of growth accounting become more severe than in other cases. As argued in Chapters 1 and 2, the characteristics of industrial structure affect productivity growth in mechanical ways. Establishing a direct link between

low productivity growth and sustainability of growth is also problematic. Explicit and implicit bases of this link are that measured productivity growth is identical to real technological change, and that R&D investment is the force behind productivity growth. However, productivity growth may not be identical to real technological change in follower countries and there are methods other than R&D investment to enhance production technologies. Chapters 4 and 5 seek a new interpretation of the growth accounting results and explain the relationship between the mechanical properties of growth accounting, capital accumulation and structural adjustment.

Other findings of this chapter are as follows. First, the differences in productivity growth in several studies arise from the data source. The *National Wealth Survey* and the *Mining and Manufacturing Survey* allow a disaggregated approach, and result in relatively high productivity growth. In contrast, National Income Account data only allow an aggregated approach, and require some arbitrary assumptions to estimate capital stock and productivity growth. Second, Sarel's (1995a: 246–47) argument that estimates of productivity growth are very sensitive to a specific estimation period is quite right. Productivity growth and its contribution to output growth are very high in 1968–73 but very low in 1978–83. Thus, extending the estimation period in the 1960s and/or in the 1990s leads to relatively high productivity growth, whereas focusing on the late 1970s and 1980s leads to low productivity growth. Third, the trends in productivity growth in the 1970s and 1980 are quite different from the picture put forward by Dollar (1991) and Dollar and Sokoloff (1990), who emphasise changes in manufacturing structure from heavy industry to light industry and resulting TFP convergence. What really happened in Korea is a change in manufacturing structure from light industry to heavy industry and TFP convergence (Appendix 1).

4 Reasons for Low Productivity Growth

Introduction

The disaggregated growth accounting study in Chapter 3 found that productivity growth was an important contributor to output growth in Korea's manufacturing sector; it is the largest contributor to growth in eight out of 15 industries. Chapter 3 also found that an aggregated approach is not acceptable because of detected aggregation bias (entry into new industries) in the periods 1968–73, 1973–78 and 1978–83, or undetected aggregation bias (movement into high-quality products within industries) in the periods 1983–88 and 1988–93. Nevertheless, it is apparent that capital accumulation played the major role in Korea's rapid economic growth, confirming the earlier empirical findings of the aggregated studies.

Why is high growth in the NIEs explained by capital accumulation rather than productivity growth? Does this necessarily mean that technological change has played a minor role in the high growth in this region? The aim of this chapter is to understand the puzzle of low productivity gains in NIEs. The sources of output growth are not independent of the stage of industrialisation through which an economy is passing. Nor is the rate of technological change independent of the role of capital accumulation, as the discussion in Chapter 2 suggested.

This chapter tests two hypotheses about these relationships, using Korean data, and examines why productivity has been so high in Korea's manufacturing sector. Section 2 examines the sequencing of sources of economic growth. Section 3 tests the interaction between capital accumulation and technological change. Section 4 explores the relationship between productivity growth, the output–capital ratio, and capital–labour ratio. Section 5 provides a summary.

Sequencing of sources of output growth

Lau (1996) hypothesises that the sources of output growth change according to the stage of development: capital accumulation is the main source of economic growth in the earlier stages of development, then disembodied technological change (by R&D investment) becomes more important. Following Dollar and Sokoloff (1990) and Dollar (1991), I hypothesise that productivity growth is the main source of growth in the initial stage of development, reflecting the transition to modern labour-intensive production, before capital accumulation becomes the major contributor to growth. Hence, productivity growth (through the introduction of the modern factory system), capital growth, and then productivity growth (through R&D investment) would be the major sources of growth, in that sequence. I test this modified version of the hypothesis, and use it as an explanation for the puzzle of low productivity gains in NIEs.

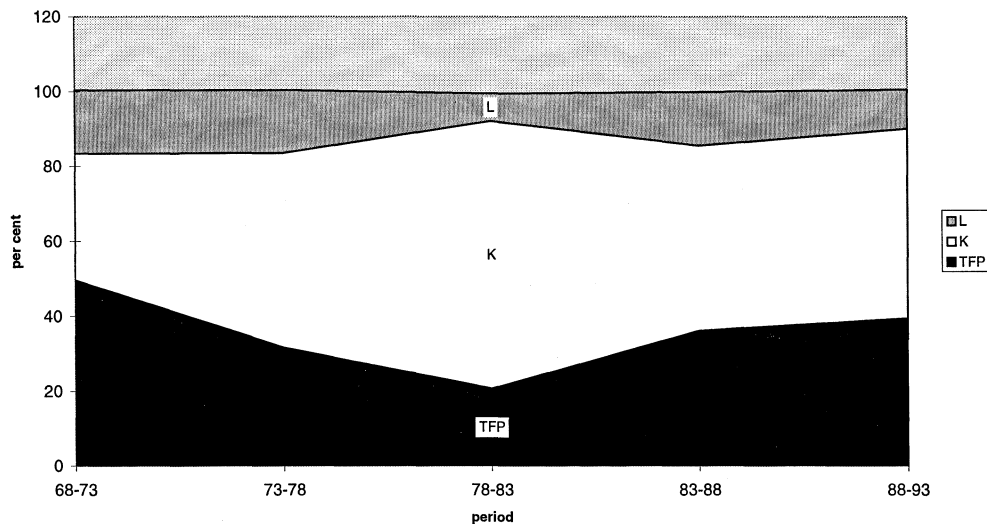
Figure 4.1 shows the contribution ratios of productivity and capital growth to output growth over the period 1968–93. The major source of output growth appears to change over time. Productivity growth is the major source of growth in the first stage of growth (1968–73). Capital deepening is the major source of growth in the second stage (1973–78 and 1978–83). Capital deepening plays the major role in growth but the role of productivity growth increases in 1983–88 and 1988–93.²¹ Figure 4.1 confirms that the experiences of Korea's manufacturing sector are consistent with the hypothesis of sequencing the sources of growth, and that the manufacturing sector is in a period of transition from the second stage to the third stage, where innovation is the sole source of technological change.

The hypothesis is also validated in the industry-level analysis (Table A4.1, A4.2 and Figure A4.1). Sequencing of the major sources of growth is identified in the disaggregated industries, such as food and beverages and tobacco, textiles, clothes and leather, refined petroleum, non-metallic mineral, steel and non-ferrous metals, machinery and fabricated metals, office and medical machinery and other

²¹ At the third stage, the capital contribution decreases while the productivity share increases.

vehicles. Quite different trends are seen in wood and paper and printing, rubber and plastic, electrical and electronic products and motor vehicles, which are characterised by major changes in product items within the same classification.

Figure 4.1 Sources of growth in the manufacturing sector
(per cent)



Source: Author's calculation.

Figure 4.1 and Table A4.1 and A4.2 reveal that productivity growth is the major contributor to output growth in 1968–73. This is consistent with the findings of Dollar and Sokoloff (1990) and Dollar (1991) that productivity catch-up occurred in labour-intensive industries in Korea, even though this was not the case in the second (1973–83) and third transition period (1983–93), when the share of light industry in total output decreased. The second stage is characterised by capital deepening and poor performance in productivity growth, as Young (1995) and Lau and Kim (1994) argue. But their finding is not valid for the first stage, when productivity growth was the major contributor to growth. In the last period, capital input growth and capital contribution gradually decreased while productivity contribution increased gradually, as observed by Lau (1996) and economic historians. Perhaps the next period (the third stage of development), when all the opportunities for faster growth for a follower country are exhausted and innovation activity is the sole source of technological change, will confirm

the neoclassical prediction that productivity growth through R&D efforts is the major source of output growth.

This hypothesis successfully explains why capital accumulation rather than productivity growth was the major source of growth in the NIEs. These economies have not yet graduated from the earlier stages of growth in which innovation by R&D investment is not the only method of technological change. This hypothesis challenges the criticism that poor productivity performance in NIEs means that they will be unable to sustain growth. For example, though capital accumulation is the sole source of output growth in the earlier stages of growth, in particular in the second stage, this does not necessarily imply that growth will show a significant decline in the future.

As argued in reviewing Dollar (1991) and Dollar and Sokoloff (1990), the high productivity gains in the initial stage of development should be interpreted carefully; high productivity growth does not necessarily arise from innovative technological change but may arise from the introduction of improved manufacturing production in labour-intensive industries. Thus, there is some value in validating the presence of technology catch-up by referring to high productivity gains in the initial stage of development.

It is not useful to compare the productivity growth of a country in the first stage of development with that of another country in the second or third stage, without consideration of sequencing of sources of growth or stage of development. Poor productivity performance in the NIEs is not necessarily evidence of an unsound pattern of economic growth.

Verification of the importance of sequencing also makes clear why different studies have arrived at different conclusions about the sources of East Asian growth, and how these conclusions depend heavily on the time period under study. The argument of Dollar and Sokoloff on technology catch-up seems to be verified by the experience in the 1960s and early 1970s, when labour-intensive

production was dominant and productivity growth is likely to have been very high. In contrast, capital deepening appears to have been the major source of economic growth in the 1970s and early 1980s.

Interaction between capital and productivity growth

In the literature survey in Chapter 2 we hypothesised that there may be interactions between capital growth and technological change: embodied²² and induced technological change. I test this hypothesis employing a Granger causality test to clarify the direction of the interaction between the two.²³

I estimate the cross-correlation function²⁴ of productivity growth and capital input growth with a maximum of six lags at the industry and aggregated level.²⁵ Then the Ljung Box Q statistic is calculated to test the joint hypotheses that the six cross-correlation coefficients between productivity growth and lagged capital input growth, and between capital input growth and lagged productivity growth, are zero. The first statistic gives information about the embodiment effect (from capital growth to productivity growth) whereas the second gives information about the induced technological change (from productivity growth to capital growth).

Table 4.1 suggests that most industries are characterised by interaction between the two. Both the embodiment hypothesis (hypothesis I) and the induced technological change effect (hypothesis II) are identified in food and beverages and tobacco, textiles, refined petroleum, non-metallic minerals, office machinery and medical and precision instruments, other manufacturing, and aggregate

²² Capital stock data are constructed without considering the embodiment effect. So, the existence of embodied technological change leads to a positive correlation between capital input growth and productivity growth, as suggested by Wolf (1991).

²³ I assume that measured productivity growth is identical to technological change in this stage. This assumption does not cause a problem in identifying the interactions between capital growth and technological change because productivity growth underestimates the role of technology.

²⁴ The cross-correlation function of X and Y is

$$\rho_{XY}(k) = \{\sum (X_t - \bar{X})(Y_{t-k} - \bar{Y})\} / \sqrt{(\sum (X_t - \bar{X})^2) \sum (Y_t - \bar{Y})^2}.$$

²⁵ The 36 Korean manufacturing industries have been categorised into 15 groups. Estimation has been made for aggregated manufacturing, for all 15 groups, and for all 36 industries.

manufacturing. Only hypothesis I is accepted in chemicals and chemical products and other transportation vehicles. Only hypothesis II is accepted in clothes and leather, steel and non-ferrous metals, machinery and fabricated metals, electric and electronic products and motor vehicles. Neither hypothesis is accepted in wood and paper and publishing, and rubber and plastic.

Table 4.1 Correlation between capital and productivity growth

	Test 1 (embodied)		Test 2 (Induced)	
	Q statistic	signif.	Q statistic	signif.
Food, beverages, tobacco	13.1	4.1**	14.8	2.2**
Textiles	18.2	0.6**	31.4	0.0**
Clothes and leather	6.3	39.3	13.4	3.7**
Wood, paper and publishing	9.3	15.7	9.4	15.3
Chemical and chemical products	86.7	0.0**	9.8	13.4
refined petroleum	14.1	2.9**	20.0	0.3**
Rubber and plastic	2.5	87.3	9.0	17.1
Non-metallic mineral	18.3	0.6**	22.6	0.1**
Steel and non-ferrous metals	3.1	80.0	66.2	0.0**
Machinery and fabricated metals	6.2	39.8	14.8	2.2**
Office machinery, medical/precision instruments	28.3	0.0**	35.3	0.0**
Electrical and electronic products	2.4	88.4	22.5	0.1**
Motor vehicles	6.5	37.0	12.9	4.5**
Other transportation vehicles	25.6	0.0**	2.5	87.3
Other manufacturing	25.6	0.0**	2.5	87.3
Aggregate	34.0	0.0**	24.9	0.0**

Note: 1)* means that the hypothesis is rejected at the 10 per cent significance level.

2)** means that the hypothesis is rejected at the 5 per cent significance level.

Source: Author's calculation.

The cross-correlation function gives only weak evidence for interaction between productivity growth and capital accumulation. First, the Ljung Box Q statistic has limited power to test the joint hypotheses that all the correlation coefficients are zero. Second, there is a possibility that third variables affect both productivity growth and capital input growth. In that case, cross-correlation coefficients between the two may be misleading. Thus, the Granger causality test is employed.

I test whether there is causality between productivity growth and capital input growth in a bivariate environment.²⁶ Capital input growth (productivity growth) is said to Granger-cause productivity growth (capital input growth) if productivity growth (capital input growth) can be forecast better using past productivity growth (capital input growth) and past capital input growth (productivity growth), rather than just by productivity growth (capital input growth). Causality from capital to productivity growth supports the embodied technological change hypothesis, whereas causality in the opposite direction supports the induced technological change hypothesis.

To test whether X Granger-causes Y , we run two regressions: equation (4-1) and (4-2).

$$(4-1) \quad Y = \sum \alpha_i Y_{t-i} + \sum \beta_j X_{t-j} + \varepsilon_t$$

$$(4-2) \quad Y = \sum \alpha_i Y_{t-i} + \varepsilon_t$$

Then, the hypothesis that $\beta_1 = \beta_2 = \dots = \beta_j = 0$ is tested, using the F statistic. The number of lags of Y is determined by correlogram, and that of X is determined by Akaike–Schwartz criteria.²⁷

²⁶ I performed a bivariate cointegration test using the Johansen procedure for capital and productivity levels. According to $\lambda_{\max}$ and λ_{trace} tests, there is no cointegrating factor. So, I conclude that there exists no cointegration relation between capital and productivity level. This result implies that the Granger causality test under a traditional VAR framework is valid.

²⁷ Optimal lag length is chosen where the Akaike statistic (equation 1) and/or the Schwartz statistic (equation 2) is minimised.

(1) $N \log (RSS) + 2K$

(2) $N \log (RSS) + K (\log N)$

where N is the number of observations, RSS is the residual of squares, and K is the number of regressors.

Table 4.2 reports the results. Causality from capital growth to productivity growth is found in chemical and chemical products (three-factor model only), refined petroleum, non-metallic minerals, office machinery and medical/precision instruments, electrical and electronic products, and motor vehicles at the 10 per cent significance level. This implies that capital input growth causes the increase in productivity growth (embodied technological change).

**Table 4.2 Interaction between capital and productivity growth
(Granger causality test)**

	2-factor model		3-factor model	
	K→TFP	TFP→K	K→TFP	TFP→K
	F stat (sig. level, %)	F stat (sig. level, %)	F stat (sig. level, %)	F stat (sig. level, %)
Food, beverages, tobacco	2.0 (16.8)	1.2 (38.1)	2.2 (15.1)	2.7 (8.5)*
Textiles	1.7 (22.7)	3.4 (6.3)*	1.7 (25.9)	3.4 (6.2)*
Clothes and leather	1.0 (46.4)	1.6 (25.2)	1.5 (24.8)	0.1 (77.8)
Wood, paper and publishing	1.2 (34.3)	3.1 (5.3)*	1.2 (34.7)	2.8 (6.7)*
Chemical and chemical products	2.1 (12.0)	2.0 (14.3)	2.4 (9.0)*	2.2 (11.8)
Refined petroleum	2.7 (6.5)*	0.8 (53.1)	2.5 (8.8)*	1.5 (25.9)
Rubber and plastic	0.4 (86.8)	7.3 (0.5)**	0.4 (90.0)	5.2 (3.2)**
Non-metallic minerals	9.1 (0.3)**	0.2 (65.1)	5.9 (1.1)**	0.2 (63.3)
Steel and non-ferrous metals	0.5 (47.6)	2.8 (6.6)*	12.5 (0.1)**	3.2 (5.9)*
Machinery and fabricated metals	1.7 (21.3)	1.6 (25.7)	1.7 (20.6)	3.0 (4.9)**
Office machinery, medical, precision instruments	6.3 (0.9)**	8.0 (0.4)**	5.9 (1.1)**	7.4 (0.5)**
Electrical and electronic products	12.0 (0.1)**	9.7 (0.0)**	12.5 (0.1)**	2.0 (16.8)
Motor vehicles	2.4 (9.1)*	0.7 (65.6)	2.3 (9.7)*	1.4 (27.7)
Other transportation vehicles	0.8 (62.0)	6.2 (2.1)**	0.7 (68.2)	9.1 (0.3)**
Other manufacturing	0.8 (37.0)	2.6 (9.7)*	0.9 (34.3)	4.6 (4.2)**
Aggregate	3.4 (5.0)**	1.3 (35.0)	3.4 (5.0)**	1.3 (35.0)

Note: 1)* means that the hypothesis is rejected at the 10 per cent significance level.

2)** means that the hypothesis is rejected at the 5 per cent significance level.

Source: Author's calculation.

Causality in the opposite direction is found in food, beverages, and tobacco (three-factor model only), textiles, wood and paper and publishing, rubber and plastic, steel and non-ferrous metals, machinery and fabricated metals (three-factor model only), office machinery and medical/precision instruments, electrical and electronic products (two-factor model only), other transportation vehicles, and other manufacturing at the 10 per cent significance level. This implies that productivity growth causes the increase in capital input growth (induced technological change).

The causality test is not valid when a third variable causes increases in both capital input and productivity growth. According to Figure A4.2, which shows similar trends in productivity growth and output growth, this might be a strong possibility. Kim and Hong (1992) and Hong and Kim (1996) find the strongest relationship between productivity growth and output growth. To eliminate this bias, we also test the causalities running from output growth to productivity growth on the one hand and to capital input growth on the other. According to Table 4.3, industries such as rubber and plastic, machinery and fabricated metals, office machinery and medical/precision instruments, and other manufacturing support the third variable bias possibility. This means the idea that embodied or induced technological change is verified in these four industries (in Table 4.2) is spurious. Hence, these four industries should be omitted from the interaction list. Then, the industries which support the embodied technology hypothesis are reduced to chemical and chemical products (three-factor model only), refined petroleum, non-metallic minerals, electrical and electronic products, and motor vehicles. The industries which support the notion of induced technical progress are also reduced, to food and beverages and tobacco (three-factor model only), textiles, wood and paper and publishing, steel and non-ferrous metals, electrical and electronic products, and other transportation vehicles at the 10 per cent significance level. Combining the two lists, interaction between productivity growth and capital input growth is found in ten of the 15 industries: food and beverages and tobacco, textiles, wood and paper and publishing, chemical and

chemical products, refined petroleum, non-metallic minerals, steel and non-ferrous metals, electrical and electronic products (both interactions), motor vehicles, and other transportation vehicles.

Table 4.3 Causality from output growth to capital and productivity growth

	Y→TFP		Y→K
	2-factor model	3-factor model	
	F stat (sig. level, %)	F stat (sig. level, %)	F stat (sig. level, %)
Food, beverages, tobacco	0.4 (88.2)	0.3 (94.0)	1.2 (39.9))
Textiles	1.0 (45.1)	1.0 (46.0)	1.9 (17.6)
Clothes and leather	1.1 (44.1)	1.4 (27.9)	3.3 (8.1)*
Wood, paper and publishing	0.4 (52.8)	0.4 (52.1)	0.1 (74.7)
Chemical and chemical products	1.9 (18.7)	0.1 (78.2)	1.7 (19.2)
Refined petroleum	3.5 (5.1)*	0.1 (93.9)	0.4 (68.1)
Rubber and plastic	3.7 (3.0)**	4.2 (1.7)**	8.8 (3.0)**
Non-metallic minerals	2.1 (16.1)	2.1 (15.7)	0.3 (57.9)
Steel and non-ferrous metals	0.5 (67.8)	1.0 (43.0)	1.5 (25.6)
Machinery and fabricated metals	5.3 (8.6)*	5.9 (0.6)**	4.0 (1.9)**
Office machinery, medical, precision instruments	3.9 (2.6)**	18.1 (0.1)**	3.5 (3.6)**
Electrical and electronic products	1.2 (40.0)	1.3 (36.4)	10.6 (0.2)**
Motor vehicles	3.7 (3.1)**	3.8 (2.2)**	2.4 (11.1)
Other transportation vehicles	2.6 (12.2)	2.5 (10.9)	2.0 (15.1)
Other manufacturing	6.6 (1.7)**	9.0 (0.7)**	6.9 (0.5)**
Aggregate		2.7 (9.1)*	2.7 (8.8)*

Note: 1)* means that the hypothesis is rejected at the 10 per cent significance level.

2)** means that the hypothesis is rejected at the 5 per cent significance level.

Source: Author's calculation.

Verification of the interaction between capital and productivity growth successfully explains the reasons for low productivity gains in NIEs, especially in the second stage of growth driven by capital accumulation. These economies have not yet emerged from the second stage of development in which capital-related low-level technological change plays a significant role in growth.

Most growth accountants only emphasise the large role of capital deepening in growth and interpret this feature as evidence of the unsustainability of growth under the assumption that capital and technology are independent of each other. However, the assumption is not empirically verified because capital and technology have interchangeable components. Interaction between the two mean that technology plays a significant role even in the second stage of growth through the technological components of capital accumulation. Thus, the fact that capital deepening is the largest contributor to growth in NIEs does not necessarily mean a significant future decline in the growth rate. It simply suggests that these economies benefited from the low-level standardised technologies embodied in or induced to capital goods imported. Interactions between capital accumulation and technological change, combined with the sequencing of the sources of growth, lead to the insight that technological change is a major source of growth at any stage of development, in just the way predicted by the neoclassical growth model.

According to growth accounting methodology, measured productivity growth is equivalent to technological change. This may be not the case; if capital accumulation has a technological component, measured productivity growth may underestimate the role of technological change. This is because the intersection contribution of capital and technology to output growth is attributed solely to capital accumulation. In this sense, growth accounting's decomposition of output growth into inputs and productivity is mechanical. According to the growth accounting scheme, productivity growth (φ_T) is defined as follows:

$$(4-3) \quad \varphi_T = \Delta \ln V(T) - \varphi_K \Delta \ln K(T) - \varphi_L \Delta \ln L(T),$$

where ν_K , ν_L and ν_T represent the average value shares of inputs.

If an increase in capital stock is separated into two parts: capital accumulation without a technological component ($\Delta \ln Ka$) and with a technological component ($\Delta \ln Kb$), then technological change (ν_{TC}) is defined as follows:

$$(4-4) \quad \nu_{TC} = \nu_T + \nu_K \Delta \ln Kb(T) \\ = \Delta \ln V(T) - \nu_K \Delta \ln Ka(T) - \nu_L \Delta \ln L(T).$$

Equation (4-3) and (4-4) show the divergence of technological change and productivity growth in mechanical growth accounting techniques. In this way, the question of why productivity growth has contributed so little to growth in follower countries can be answered, and thus Krugman's paradigm of low productivity gains in NIEs should be replaced by new paradigm: low productivity growth but high technological change. This conclusion is quite consistent with Adelman's (1991) speculation that the small contribution of technological change to growth may be a statistical illusion:

In the industrial sectors of LDCs, the limited contribution of technical change may in fact be due to the fact that the modern factories that have been established in less developed countries have generally been turnkey operations involving the combined transfer of both capital and technology. The small contribution of technical change in industry to overall growth may thus in part be a statistical illusion; since the new technology has been embodied in capital, a significant part of its contribution may be misattributed to capital accumulation in the Denison-type growth accounting. (Adelman 1991: 501)

Output–capital ratio, marginal product of capital and productivity growth

A stylised fact made famous by Kaldor is that the output–capital ratio is constant over the long term. Solow's version of the neoclassical growth model also predicts that capital grows at the same rate as output in the steady state. The past

experiences of the United States and other developed countries provide evidence of long-run stability in this ratio. Stability of the output–capital ratio implies that the marginal product of capital is constant over the long term.

If we suppose a Cobb–Douglas production function, then the average and marginal product of capital can be expressed as follows:

$$Y = AK^{\beta}L^{\alpha}$$

$$AP_K = Y/K = A \cdot (K/L)^{\beta-1}$$

$$MP_K = dY/dK = \beta \cdot A(K/L)^{\beta-1}$$

Inserting the average product of capital into the marginal product, the marginal product of capital is expressed as equation (4-5).

$$(4-5) \quad MP_K(t) = \beta(t) \cdot Y/K(t)$$

Hence, a stable output–capital ratio directly means a stable marginal product of capital, on the condition that β is stable over the period, while the decreasing (increasing) output–capital ratio means decreasing (increasing) marginal product of capital.

The output–capital ratio plays a crucial role in determining not only the level of marginal product of capital (equation 4-5) but also productivity growth.

Rearranging equation (3-3), which calculates productivity growth in terms of growth rates in output, and effective labour and capital input, we arrive at:

$$g(Y) = \nu_T + \nu_K g(K) + \nu_L g(L)$$

where $g(Y) = [\ln V(T) - \ln V(T-1)]$, $g(K) = [\ln K(T) - \ln K(T-1)]$, and $g(L) = [\ln L(T) - \ln L(T-1)]$.

Subtracting labour input growth, $g(L)$, from both sides of the equation and rearranging, we obtain:

$$(4-6) \quad g(Y/L) = \nu_T + \nu_K g(K/L) + (\nu_K + \nu_L - 1) g(L)$$

$$\text{or} \quad g(Y/L) = \nu_T + \nu_K g(K/L), \quad \text{if } \nu_K + \nu_L = 1$$

where $g(Y/L)$ and $g(K/L)$ are growth rates of labour productivity and capital intensity.

The rate of growth in the output per effective labour unit can be expressed by the sum of the growth rates in the output–capital ratio and the capital–labour ratio, because $Y/L = (Y/K) \cdot (K/L)$. Inserting this relationship into equation (4-6) and rearranging, we obtain equation (4-7).

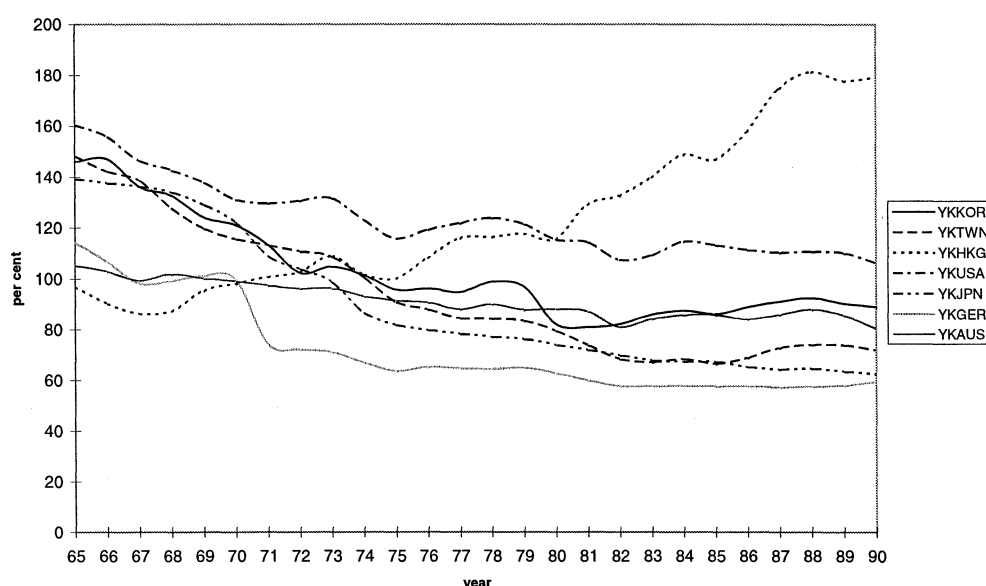
$$(4-7) \quad \nu_T = g(Y/K) + \nu_L g(K/L) - (\nu_K + \nu_L - 1) g(L)$$

$$\text{or} \quad \nu_T = g(Y/K) + \nu_L g(K/L), \quad \text{if } \nu_K + \nu_L = 1$$

Equation (4-7) means that productivity growth is the sum of growth of the output–capital ratio and the contribution growth rate in the capital–labour ratio. Note that the two components are not independent of each other. For example, capital deepening leads not only to an increase in $g(K/L)$ but also a decrease in $g(Y/K)$ in normal steady-state or decreasing marginal productivity conditions. However, $g(Y/K)$ plays a more crucial role in determining productivity growth than $g(K/L)$, because the increase in $g(K/L)$ is less than the decrease in $g(Y/K)$ in the normal condition when capital stock increases. This arises from the fact that the latter's contribution to productivity growth is reduced by labour share (output elasticity with respect to effective labour).

I calculate the output–capital ratios of the United States, Japan, West Germany, France, United Kingdom, Australia, Korea, Taiwan, and Hong Kong for the period 1966–90, using the Penn World Table Mark 5.6.²⁸ Figure 4.2 shows that the output–capital ratios of all countries, except Hong Kong, decline.

Figure 4.2 Output–capital ratios of selected countries



Source: Penn World Table, Mark 5.6

This declining trend in output–capital ratios suggests that the increase in capital stock results in lower productivity growth, because the increase in $g(K/L)$ is less than the decrease in $g(Y/K)$. Thus, the output–capital ratio is the crucial factor in determining the productivity growth of a country. In contrast, an increasing trend in the ratio, or a positive rate of growth in the ratio, as shown in the case of Hong Kong, is a sufficient condition for higher productivity growth. This means that capital deepening results in higher productivity growth through positive $g(Y/K)$, which is negative in normal conditions, as well as $g(K/L)$ in equation (4-7). How can this abnormal situation be possible? One possibility is that large technological change overwhelms the counter-force of the decreasing marginal product of

²⁸ Output–capital ratios are calculated by dividing real GDP per worker (RGDPW) by capital stock per worker (KAPW).

capital and so an upward Y/K ratio is revealed. Another possibility is that a country's industrial structure may be characterised by labour-intensive and/or service production. In this case, the Y/K ratio is higher, and expansion of productive activity necessarily leads to relatively small increases in capital stock, resulting in a rising Y/K ratio.

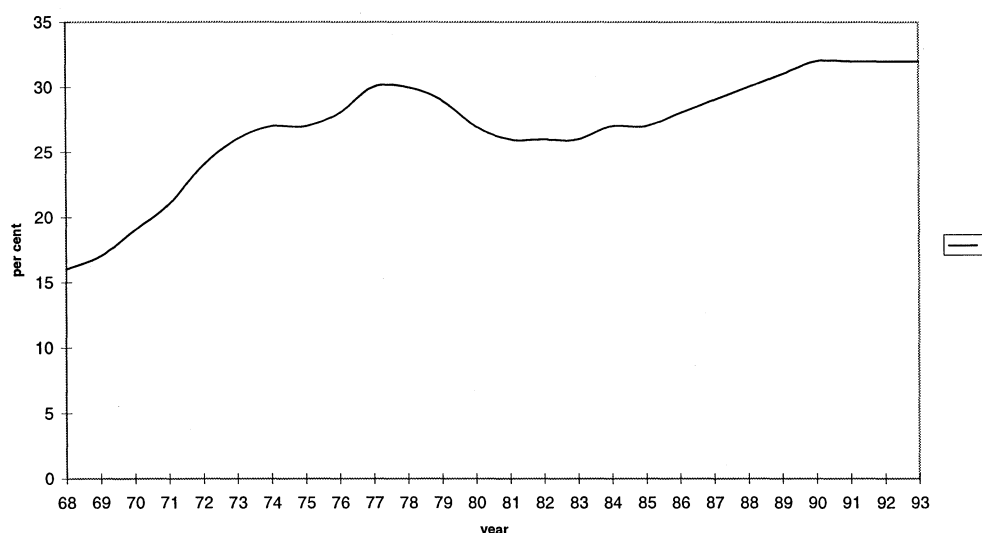
I calculate the average and marginal product of capital in each industry using the KDI data set. Figure 4.3 shows the output–capital ratio of the aggregate manufacturing sector. According to the figure, contrary to the expectation of stable trends, the output–capital ratio increases over time.²⁹ The output–capital ratios increased rapidly from 14 per cent to 30 per cent in the period 1967–78 before decreasing to 26 per cent in 1981. They then increased slowly, reaching 32 per cent in 1990, and remaining at that level thereafter. The marginal product of capital exhibits the same trend as the output–capital ratio. Figure 4.3, combining equation (4-5) and (4-7), demonstrates clearly that Korean manufacturing enhanced its production technology, in conjunction with the accumulation of capital stock.

Industry level data show a pattern similar to manufacturing overall. The output–capital ratio increased over time, except during the 1978–81 period. There is clear evidence of a continuous increase in marginal product in fabricated metals and machinery, office machinery and medical/precision instruments, motor vehicles, and other transport vehicles over time. These industries revealed the highest productivity growth in the growth accounting study set out in Chapter 3. In contrast, in textiles, refined petroleum, non-metallic minerals, iron and steel, and electrical and electronic products, there was declining marginal product of capital.

²⁹ The KDI data set shows increasing output–capital ratio whereas the PWT 5.6 data shows a decreasing trend. This difference results largely from the data source. Output and capital stock in the KDI data set are based on the *National Wealth Survey*, *Input Output Table*, and the *Mining and Manufacturing Survey*, which supply industry-level data. In contrast, the output and capital stock data in PWT 5.6 are estimated from the *National Income Account*, from which manufacturing cannot be disaggregated. The latter is also represented by international units instead of original units.

It is noteworthy that these industries showed the lowest productivity growth in the growth accounting study in Chapter 3.

Figure 4.3 Output–capital ratio in manufacturing, 1968–93



Source: Author's calculation.

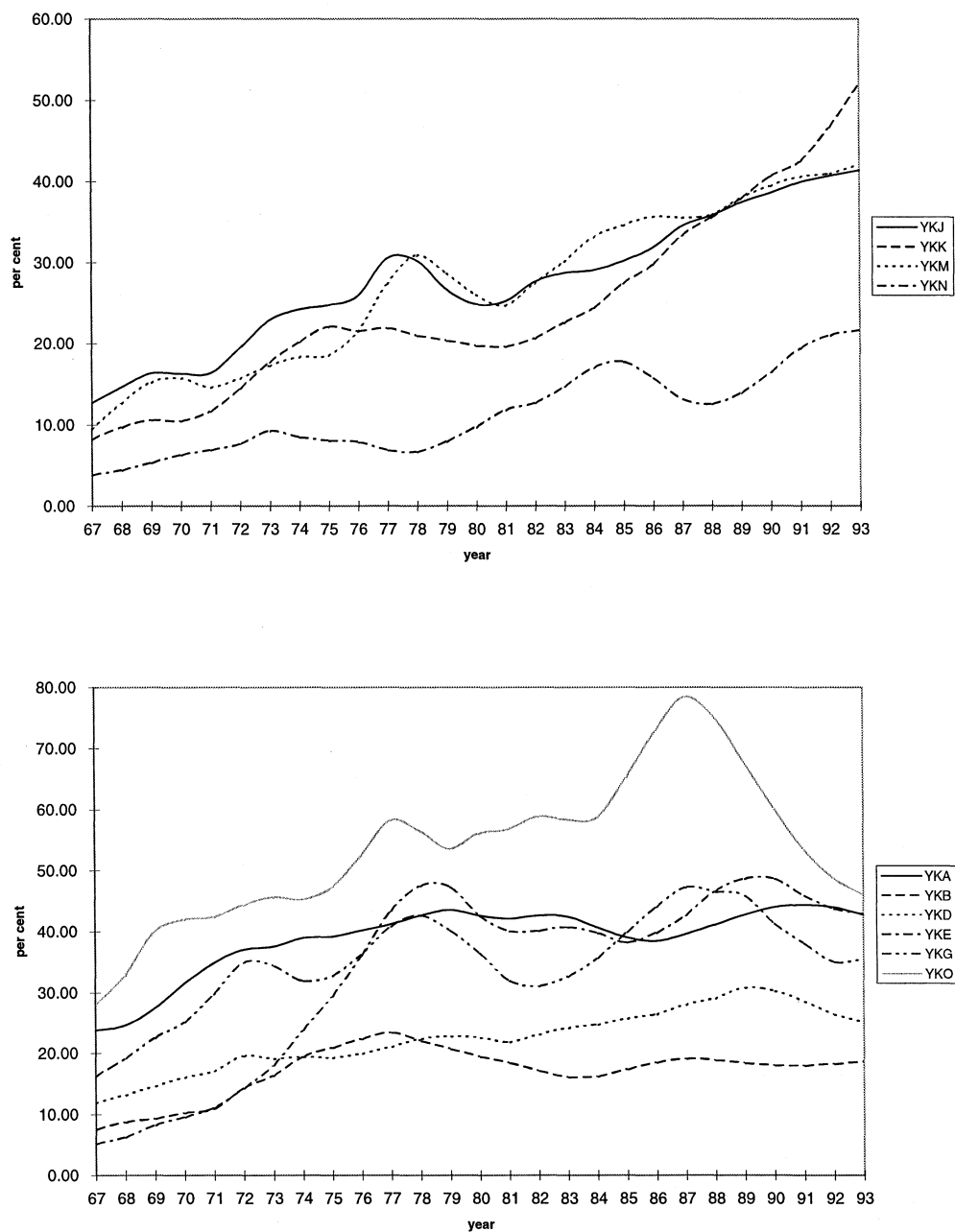
As observed earlier, an upward trend in the Y/K ratio may be the result of two possibilities: extraordinary technological change or a labour-intensive industrial structure. Both of these factors contributed to an upward trend in the Y/K ratio in the Korean manufacturing sector. Production in the early and mid-1970s was characterised by labour-intensive production techniques while heavy and chemical industries were boosted in the mid- and late 1970s.³⁰ The rapid increase in output–capital ratios until 1978 reflects these two facts.

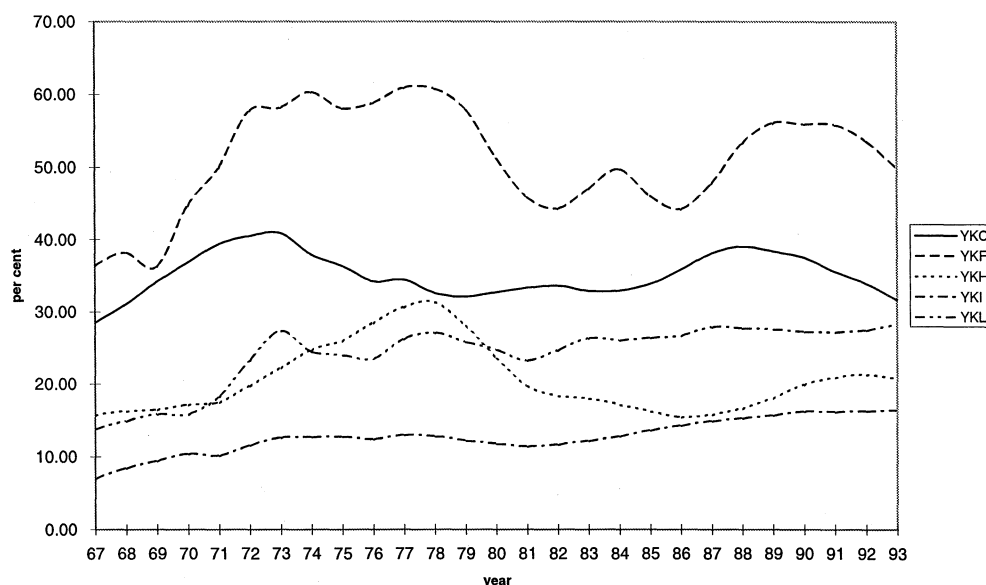
It is possible that the capital stock data are underestimated. However, according to Young (1995), the contribution growth rate of capital stock is 7.23 per cent

³⁰ The production share of heavy and petrochemical industries in total manufacturing has increased gradually: 43.8 per cent in the 1968–73 period, 53.3 per cent in the 1973–78 period, 55.7 per cent in the 1978–83 period, 57.6 per cent in the 1983–88 period, and 63.4 per cent in the 1988–93 period. But a more important factor is that production techniques changed gradually towards capital-intensive ones within each industry over time.

over the 1966–90 period, not significantly different from the 7.92 per cent in the present growth measure for the period 1968–93. According to PWT 5.6 data, the output–capital stock ratio in the Korean economy declines over time. However, if residential capital stock is excluded from the capital stock, the ratio increases.

Figure 4.4 Output–capital ratios at industry level, 1968–90





Note: YKA: food, beverage and tobacco, YKB: textiles, YKC: clothes and leather, YKD: wood, paper and printing, YKE: chemicals, YKF: refined petroleum, YKG: rubber and plastic, YKH: non-metallic minerals, YKI: steel and non-ferrous metals, YKJ: machinery and fabricated metals, YKK: office and medical machinery, YKL: electrical/electronic products, YKM: motor vehicles, YKN: other vehicles, and YKO: others.

Source: Author's calculation.

The increasing output–capital ratios at the aggregate and at the industry level in the Korean manufacturing sector are a sufficient condition for sustainability of growth. This contradicts Krugman's argument that economic growth in the NIEs can be compared to the experience of former Soviet Russia, which enjoyed high growth driven by capital accumulation but experienced a significant setback due to decreasing marginal productivity.

Summary

This chapter investigated the reasons for the high contribution of capital accumulation to growth in NIEs and examined the validity of the unsustainability of growth. Section 2 found evidence of a predictable sequence in the principal sources of output growth over the period. Productivity growth was a dominant source of output growth due to the labour-intensive nature of the industrial structure in the period 1968–73, after which capital accumulation became the major source of output growth in the Korean manufacturing sector. Subsequently,

productivity growth played a more important role in output growth from the late 1980s, lowering the contribution of capital to output growth.

Section 3 examined the interaction between productivity growth and capital accumulation. According to a Granger causality test, five of the 15 industries studied supported the embodiment hypothesis, and six of the 15 industries showed induced technological change at the 10 per cent significance level.

Verification of sequencing of the sources of output growth and interactions between capital and productivity growth explain the reason for the low productivity gains in NIEs. These countries have not yet arrived at the third stage of development, where innovation by R&D investment is the sole means of technological change. Rapid growth in these economies has been driven by utilising low-level technology, such as technology in a declining product-cycle in labour-intensive light industries and standardised technology embodied in capital goods in capital-intensive industries. Verification of the two hypotheses is also inconsistent with Krugman's unsustainability hypothesis which was derived from apparently low productivity gains. His logic is too simplistic. Growth accounting techniques measure productivity growth as residual under the assumption that technology and capital are independent of each other, and that productivity growth is identical to innovative technological change. However, these assumptions are not valid for follower countries. Thus, the intersection contribution of capital and technology to output growth is mechanically attributed to capital accumulation, underestimating the role of technological change. In this way, productivity growth and technological change diverge in the case of follower countries and a new paradigm, low productivity growth but high technological change, arises.

Section 4 showed that output–capital ratios at the aggregate and sectoral level have increased with decreasing growth rates in the past three decades. These trends lifted the marginal product of capital. These findings support my argument that low-level technology plays a significant role in rapid growth even though it is

not apparent in mechanical growth accounting exercises. These findings also throw doubt on the idea that growth in the East Asian NIEs is unsustainable. The growth rate of the output–capital ratio was an important component of productivity growth: it could explain why productivity growth declined over time, and why during the 1968–73 period there was extraordinary productivity growth.

5 Structural Adjustment in NIEs

Introduction

Chapter 4 successfully explained the reasons for low productivity gains in NIEs. The answer was provided by an argument based on the sequencing of sources of output growth and on the interactions between capital accumulation and technological change. Rapid growth in these economies has not been driven by technological innovation but by utilising low-level or standardised technologies. Low-level technology in labour-intensive light industries is easily transferable because it is in a declining product cycle. Standardised technology in capital-intensive industries is also easily transferable through the market because it is usually embodied in capital goods. Empirical verification of the two hypotheses in Chapter 4 also invalidated the pessimistic scenario on the sustainability of growth in NIEs. Technological change has played a bigger role in economic growth than would be predicted by measured productivity growth, since the technological component of capital formation is solely assigned to capital in the mechanical growth accounting technique. Thus, a new paradigm of growth in NIEs was proposed: low productivity gains but rapid technological change. However, a detailed description of how capital accumulation is related to technological change has yet to be constructed.

The aim of this chapter is to clarify the role of structural adjustment in the rapid growth of NIEs. I suggest that structural adjustments are the driving force behind the link between capital accumulation and technological change in follower countries, and this claim can be verified if the effects of structural adjustments on productivity growth are positive. Thus, structural adjustments accompanying capital accumulation in new industries or in the manufacture of high-quality products are the reasons for the divergence between technological change and

productivity growth (high technological change but low productivity growth) in NIEs.

Section 2 defines structural adjustment after reviewing traditional structural change arguments. Section 3 illustrates the experiences of structural adjustment in NIEs. Section 4 empirically identifies the role of structural adjustment in productivity growth. Section 5 gives a summary.

Structural change and structural adjustment

Kuznets (1959),³¹ Denison (1985) and Chenery *et al.* (1986) emphasise structural change as an important characteristic of modern economic growth. They argue that marginal productivity in agriculture is lower than marginal productivity in the non-agricultural sector, so resource movement (in particular labour) from the former to the latter leads to enhancement of aggregate productivity.

Developed countries show regularities of structural change in the process of economic growth in the long term. The share of the agricultural sector in production decreases, whereas the share of the services sector increases. The production share of the manufacturing sector increases during periods of industrialisation but decreases steadily when approaching the mature stage. These regularities are explained by differences in productivity growth and in the elasticity of demand with respect to income across sectors. Production and employment in the agricultural sector decreases over time because productivity growth in the sector is relatively low and demand for this sector decreases as per capita income increases. Production and employment in the non-agricultural sector increases over time because productivity growth in this sector is higher

³¹ Kuznets observes that when a country embarks on a path of sustainable growth, qualitative changes have to occur. Investment grows sharply, and industrial structures change, resulting in growth and social change. Kuznets coined the phrase 'modern economic growth,' listing some common features: (1) the application of modern scientific thought and technology to industry; (2) sustained and rapid increase in real product per capita, usually (but not always) accompanied by a high rate of population growth; (3) rapid transformation of the industrial structure (changing sectoral output, labour force, and capital stock distribution); and (4) expansion of international contracts.

than in the agricultural sector and demand for this sector increases as per capita income increases. In separating the non-agricultural sector into the manufacturing and services sectors, the production and employment shares of the services sector increase over time. This is because higher income elasticity of demand and greater increases in prices and wages in the services sector overwhelm higher productivity growth in the manufacturing sector.³² Production and employment shares in the manufacturing sector decrease in the approach to the mature stage of development because high productivity growth in this sector is totally compensated by relatively low income elasticity (Park and Kim 1992).

Economic growth in East Asian NIEs shows similar regularities of structural change, even though their production technologies have yet to reach the level of the developed countries. According to Table 5.1, the industrial structures in NIEs are already very similar to developed countries. The share of agriculture in GDP is very low in NIEs (0.2 to 6.3 per cent) whereas the share of the services sector in GDP is very high (50.9 to 84.9 per cent). With the exception of Hong Kong, industry's shares in NIEs are in the range of 35.6–42.8 per cent. These regularities are also explained by differences in productivity growth and in the income elasticity of demand across sectors. East Asian NIEs show faster structural change than developed countries

East Asian NIEs also show different characteristics in structural change. This may arise from different growth strategies in NIEs where, over the past three decades, follower countries have realised opportunities by maximising economies of scale in trade or by entering new and high-technology industries. The industry share in GDP in Hong Kong arrived at a peak of 41.2 per cent in 1966, and decreased thereafter. Corresponding to the movements of industry share, a strong declining trend in the share is observed from the mid-1980s. In contrast, the services' share in GDP in Hong Kong increased rapidly in the 1980s, signalling the arrival of a services-oriented economy. The share of services in Hong Kong reached 84.9 per

³² Productivity growth in the services sector is usually lower than in the manufacturing sector. However, this is not the case when knowledge intensity increases in the services sector.

cent in 1996, considerably larger than the shares of 62.0 per cent in Singapore, 61.1 per cent in Taiwan and 50.9 per cent in Korea (Table 5.1, Figure 5.1 and Figure 2.2). This implies that Hong Kong's rapid growth over the last three decades was not fuelled by technological change.

Table 5.1 Industrial share in GDP, East Asian NIEs, 1960–96
(per cent)

	1960	1970 ¹	1975	1980	1985	1990	1995	1996
Hong Kong								
Agriculture	3.0	1.9	–	0.8	0.5	0.3	0.2	0.2
Industry	34.1	36.7	–	31.7	29.9	25.3	15.8	14.9
Manufacturing	22.3	29.7	–	23.7	22.1	17.6	–	–
Services	62.9	61.3	–	67.5	69.6	74.5	84.0	84.9
Singapore								
Agriculture	3.5	2.3	1.9	1.3	0.8	0.3	0.2	0.2
Industry	17.3	29.7	34.1	38.1	36.6	37.0	35.5	37.8
Manufacturing	11.4	20.0	23.9	29.1	23.6	29.6	26.7	28.6
Services	79.2	67.9	64.0	60.6	62.6	62.7	64.3	62.0
Taiwan								
Agriculture	28.5	15.5	12.7	7.7	5.8	4.2	3.6	3.3
Industry	26.9	36.8	39.9	45.7	46.3	41.2	36.2	35.6
Manufacturing	19.1	29.2	30.9	36.0	37.6	33.3	28.1	28.0
Services	44.6	47.7	47.4	46.6	47.9	54.6	60.2	61.1
Korea								
Agriculture	35.8	25.4	24.1	14.5	12.5	8.7	6.5	6.3
Industry	19.8	28.7	33.4	40.4	41.0	43.4	43.3	42.8
Manufacturing	13.6	20.8	26.1	28.7	29.3	29.2	26.9	25.8
Services	44.5	45.9	42.5	45.1	46.5	47.9	50.2	50.9

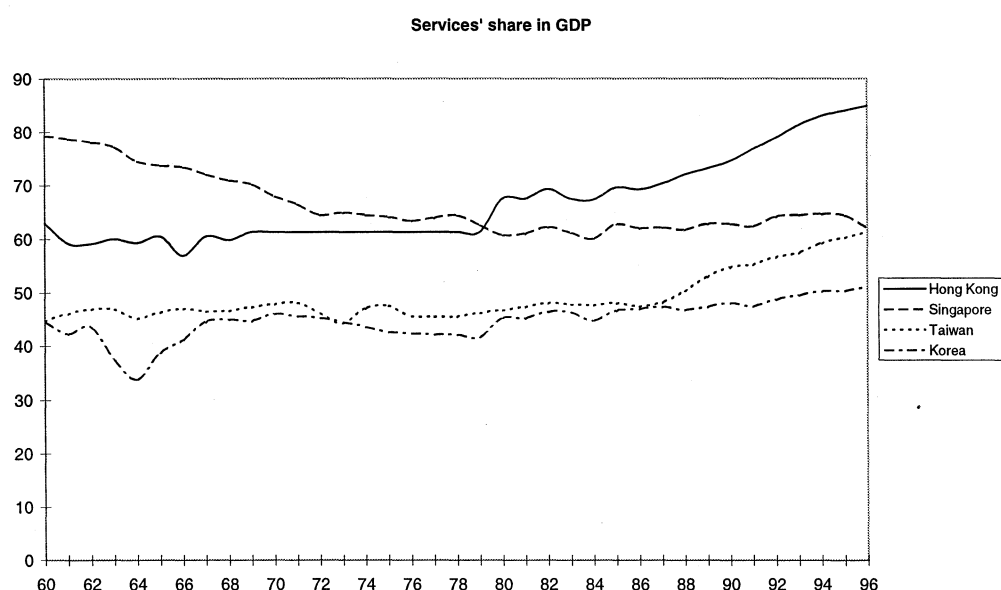
Note: 1) Hong Kong's data in 1970 are 1969 values.

Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

In the case of Singapore, the picture is quite different from Hong Kong. Singapore started as a services-oriented economy in 1960, with a share of almost 60 per cent of services in GDP. However, the share of services decreased in the 1960s and 1970s, after which it stabilised at around 60–65 per cent. Industry's share in GDP shows an increasing trend until the mid-1980s. It reached a peak of 39.2 per cent in 1984, then stabilised at around 35–40 per cent. Singapore seemed to arrive at the mature stage of growth in the mid-1980s, but there the characteristics of maturity differ from those in Hong Kong, which only displays a services orientation. Taiwan and Korea show similar pattern in terms of the

shares of industry and services in GNP until the mid-1980s; industry's shares in both countries increased, while the shares of services remained around 45–50 per cent. However, the picture changes from the mid-1980s. Taiwan's industry share reached a peak of 47.1 per cent in 1986 then declined, while the share of services increased rapidly from 1986. In contrast, Korea's industry has yet to peak, while the share of services has increased slightly. It is apparent from this difference that Taiwan arrived at the mature stage of development in the late 1980s, whereas in the case of Korea, there remains potential for industrial growth.

Figure 5.1 The share of services in GDP in NIEs, 1960–96



Note: Data for services' share in GDP in Hong Kong are not available for 1970–79.

Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

Denison calculates the effects of structural change by identifying the movement of labour from the agricultural to the non-agricultural sector, and employs it as a component of aggregate productivity growth. This traditional approach is based on the implicit assumption that industries comprising the non-agricultural sector have the same production functions and technologies. This assumption may be largely valid in developed countries, which have arrived at the steady state, and marginal productivities across industries are equalised. However, if various industries within the sector have different production functions and technologies,

then marginal productivity in some industries is lower than in other industries. Thus, resource movement from the former to the latter leads to enhancement in aggregate productivity in the manufacturing sector. If this is the case, the traditional calculation for structural change may underestimate its real effect, since it ignores opportunities for structural change in the non-agricultural sector.

Identification of structural change at an industry level (structural adjustment hereafter) may be valid for East Asian countries after the Second World War. These countries could achieve rapid growth by diversifying their production into new industries and moving to high-quality products within the same industries. This means that industries have different production functions and technologies from each other and over time. Pilat (1994) demonstrates that structural change plays a role in postwar Japanese economic growth when the economy is disaggregated into nine sectors (manufacturing is not disaggregated at the industry level). Bernard and Jones (1996a) also introduce a concept similar to Pilat's in investigating the convergence of OECD countries at an industry level.

Recent developments in the endogenous growth model provide a useful basis on which to construct an argument about structural adjustment. This new theory models technological change as an expansion in the variety of products or improvements in the quality of products. The former model sees an increase in the number of products as basic innovations, akin to opening up a new industry, whereas the latter describes technological change as a continuing series of improvements and refinements of goods and techniques (Barro and Sala-i-Martin 1995: chapters 6 and 7). I claim that both kinds of technological change (entering new industries or moving to high-quality products) have been present in East Asian NIEs, even though they have not been categorised as innovation.

Park and Kim (1992) define structural adjustment as a movement in the industrial structure towards more technology-intensive industries which can sustain higher wage rates. They argue that the engine of sustained growth in the Korean economy has been a succession of structural adjustments, which have

subsequently led to higher productivity growth. Singapore, Taiwan and Korea have periodically undergone structural adjustments, moving from labour- to capital-intensive industries and from low- to high-quality products. Figure 5.2, and Table 5.2 show the movement from labour- to capital-intensive industries in merchandise exports in NIEs. The share of capital-intensive exports, a proxy for structural adjustment towards high technology intensity, increases over time whereas the share of labour-intensive products in total exports decreases, when all industries are classified into four categories: agriculture-, labour-, capital- and mineral-intensive industry. This movement is quite strong in Singapore but relatively weak in Hong Kong.

Table 5.2 Composition of merchandise exports in NIEs, 1965–96
(per cent)

	1965	1970	1975	1980	1985	1990	1995	1996
Hong Kong								
Agriculture intensive	5.4	2.8	2.4	2.1	2.5	3.3	3.3	3.4
Capital intensive	14.2	19.4	25.9	36.0	38.7	46.7	50.4	49.6
Labour intensive	78.1	75.5	70.2	59.2	55.9	47.2	42.4	43.2
Mineral intensive	1.9	2.0	1.3	1.9	1.6	1.6	2.1	1.9
Singapore								
Agriculture intensive	44.7	46.0	23.6	19.7	13.5	8.4	5.3	4.7
Capital intensive	20.4	17.8	31.0	36.7	43.3	62.9	78.3	78.3
Labour intensive	8.2	8.0	8.4	8.2	6.6	7.8	5.1	4.7
Mineral intensive	22.2	25.2	35.2	28.2	29.5	19.8	9.1	9.9
Taiwan								
Agriculture intensive	62.7	29.2	21.8	14.5	10.1	8.8	6.9	6.4
Capital intensive	13.0	26.4	29.3	36.8	40.6	53.7	66.6	68.0
Labour intensive	18.8	41.0	46.3	46.3	46.0	34.8	23.8	22.8
Mineral intensive	4.5	3.1	2.4	2.3	3.3	2.6	2.5	2.6
Korea								
Agriculture intensive	35.6	28.0	19.7	11.3	5.3	5.4	5.2	5.2
Capital intensive	13.1	12.3	25.6	41.3	40.0	53.4	68.9	67.6
Labour intensive	35.1	52.1	49.2	43.8	50.1	38.6	22.5	22.8
Mineral intensive	16.0	7.6	5.3	3.4	4.5	2.5	3.4	4.4

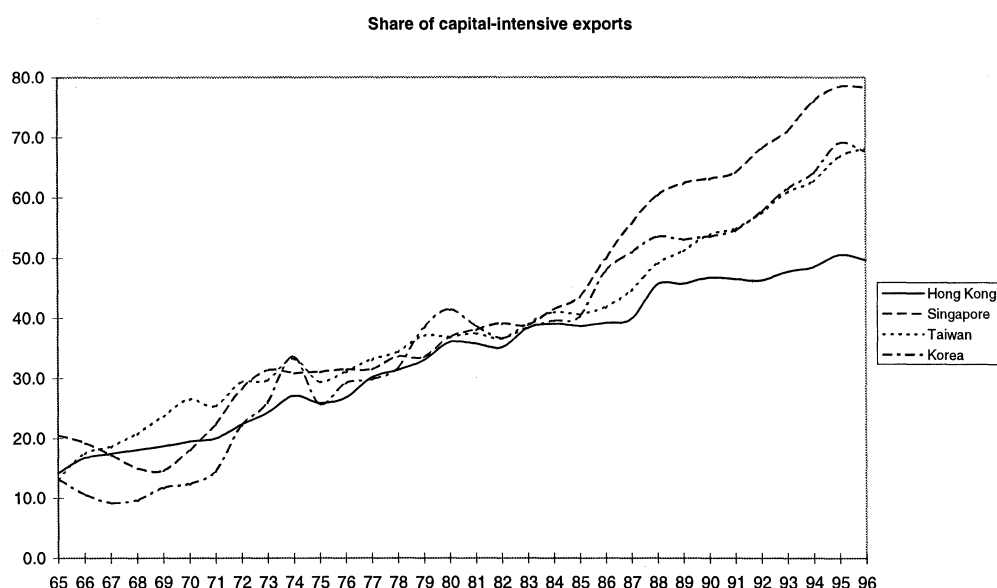
Note: Data for Hong Kong exports do not include re-exports.

Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

The structural adjustment process has been accompanied by the import of new capital and intermediate inputs. When firms in NIEs entered new industries or new production lines for high-quality products, related capital and intermediate goods, which embody new technology components, were imported. So it is not

surprising at all that capital accumulation is the largest contributor to growth in NIEs. An important element is that capital accumulation is accompanied by structural adjustment towards higher-technology industries, and that capital accumulation in new industries and high-quality products carries the components of technological change.³³ Thus, structural adjustments are the driving force behind the link between capital accumulation and technological change, and represent another expression of the two hypotheses verified in Chapter 4: the interaction between technological change and capital accumulation and the non-decreasing marginal product of capital.

Figure 5.2 The share of capital-intensive exports in NIEs, 1965–96



Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

The structural adjustment argument predicts that East Asian NIEs do not necessarily experience a significant decline in the marginal product of capital at the aggregate level, as predicted by the endogenous growth model. This is because the force of the declining marginal product of capital at the aggregate

³³ In this respect, Hong Kong's ranking as the economy with the highest productivity growth among the NIEs may arise from the mechanical properties of growth accounting; a relatively small increase in capital in Hong Kong results in a substantial productivity growth. When structural adjustment involving capital accumulation is taken into account, Singapore's rate of technological change may be the highest among the NIEs, even though it records the lowest productivity growth.

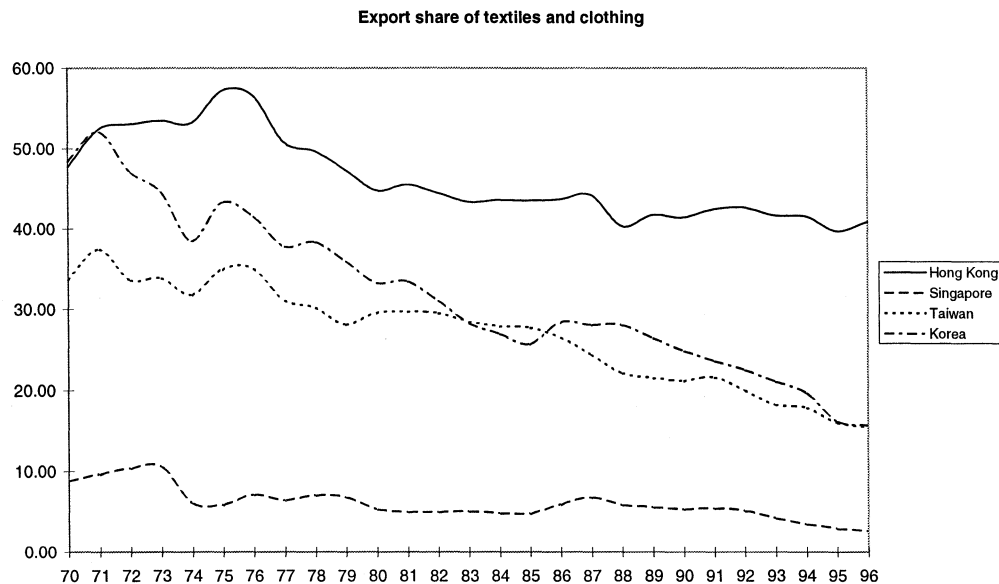
level can be delayed by industry-level structural adjustment which can offset declines in the marginal product of capital at the industry level; if follower countries have many potential 'new' industries or products (potential for structural adjustment), the marginal product of capital need not decline as neoclassical theory would suggest. This claim is partially verified by the result in Chapter 4 that showed the marginal product of capital in the Korean manufacturing sector exhibits a non-decreasing trend over time. This characteristic of growth in NIEs sits in striking contrast to neoclassical transitional dynamics, which maintains that the marginal product of capital should decline.³⁴

Structural adjustments in NIEs

It is interesting to identify changes in industrial structure (structural adjustment) and resulting changes in the technological niches in East Asian NIEs over the past three decades. In all the Asian NIEs, labour-intensive light manufacturing was a technological niche in the early stage of industrial growth; the textile and clothing industry played a predominant role in all cases except Singapore. The export share of textiles and clothing in Hong Kong reached a peak of 57.2 per cent in 1975 and declined steadily thereafter. However, the share in Hong Kong has been much higher than in other countries. The export shares in Taiwan and Korea, 33.6 per cent in 1970 and 48.3 per cent in 1973, respectively, declined significantly, and reached 15–16 per cent in 1996. The production share of textiles and clothing in Hong Kong was over 40 per cent until the late 1970s, whereas the shares in Taiwan and Korea were about 20 per cent in the same period. In the case of Singapore, the export share of textiles and clothing was about 10 per cent in the early 1970s but declined steadily to about 3 per cent in 1995 and 1996.

³⁴ 'Overall, for realistic parameterizations of the production function, our results suggest that neoclassical transitional dynamics can only play a minor role in explaining observed growth rates. That is, the physical capital accumulation process—which is the key mechanism behind the neoclassical model's transitional dynamics—cannot account for much growth without generating very large marginal products in the early stage of development...a version of the neoclassical model with a capital share close to unity yields protracted transitional dynamics and avoids the high initial marginal product; but this model is patently unrealistic unless we broaden our notion of capital accumulation.' (King and Rebelo 1993)

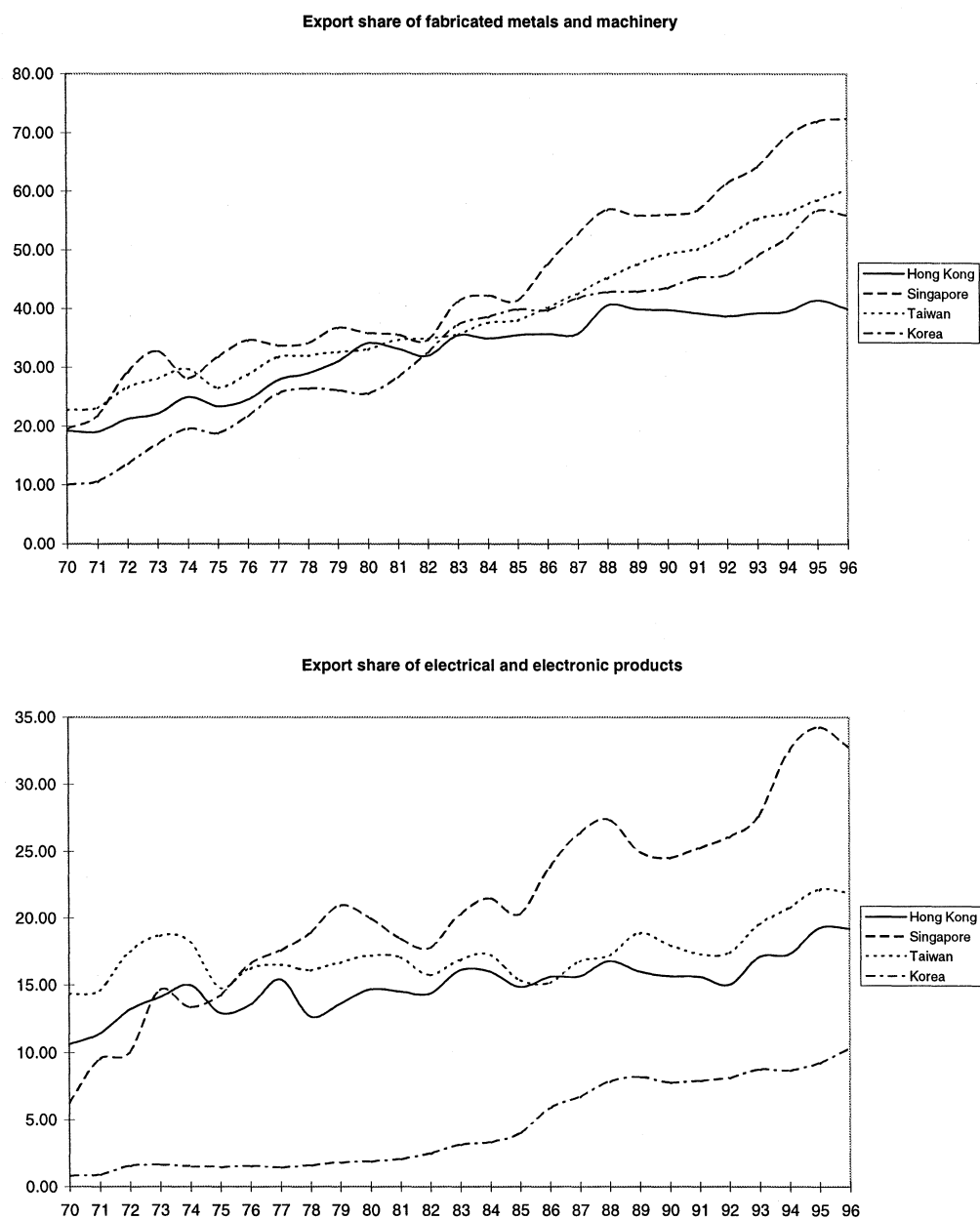
Figure 5.3 Production and export shares of textiles and clothing in NIEs, 1970–96



Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

Subsequently, a strong wave of growth occurred in fabricated metals and machinery, in particular electrical and electronic industries, and these industries became the technological niches from the 1970s, the next phase of growth in East Asia. East Asian NIEs successfully adjusted their industrial structures to take advantage of the world-wide wave of technological change in electrical and electronic equipment, and reaped the benefits during this period. The shares of fabricated metals and machinery in merchandise export in NIEs, 10–20 per cent in the 1970s, increased rapidly and reached 40–70 per cent in 1996: 72.3 per cent in Singapore, 60.1 per cent in Taiwan, 55.8 per cent in Korea and 40.0 per cent in Hong Kong (Figure 5.4). Most of these shares can be explained by the shares of electrical and electronic equipment in merchandise exports, except in the case of Korea. Shares of electrical and electronic equipment increased from about 1–15 per cent in 1970 to 10–32 per cent in 1996: 32.1 per cent in Singapore, 21.9 per cent in Taiwan, 19.2 per cent in Hong Kong and 10.3 per cent in Korea.

Figure 5.4 Export shares of fabricated metals and machinery, and electrical and electronic equipment in NIEs, 1970–96



Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

From the mid-1990s, East Asian NIEs had reached a mature stage of development. The importance of the services industry increased significantly while that of manufacturing declined. They also began to face difficulties finding new growth industries or new processes except in the frontier industries, so opportunities for high growth through structural adjustment became more limited.

Hong Kong

Textile and clothing industries were the first technological niches for Hong Kong during the early phase of growth. The share of textiles and clothing in total merchandise exports was about 43 per cent throughout the 1960s (O'Connor 1995). Their relative importance declined a little after arriving at a peak of 57.2 per cent in 1975. The share of exports reached 41.8 per cent in 1981, decreased steadily in the 1980s and 1990s, reaching 40.8 per cent in 1996 (Table 5.3). The production share of these industries to value-added manufacturing also declined in the 1970s; it was 48.1 per cent in 1973 but decreased to 41.5 per cent in 1980. Production in the textiles industry declined in the 1980s: it was 38.2 per cent in 1981 but only 36.0 per cent in 1990. Despite a temporary increase in 1984–86, 40.2, 41.3 and 40.6 per cent, consecutively, the share decreased to 31.5 per cent in 1993 (Table 5.4).

**Table 5.3 Industry share in merchandise exports in Hong Kong
1970–96 (per cent)**

	1970	1975	1980	1985	1990	1995	1996
Food, beverages and tobacco	1.43	1.13	0.99	1.64	2.35	2.46	2.73
Textiles and clothing	47.74	57.16	44.74	43.50	41.37	39.67	40.84
Wood	1.41	0.64	0.56	0.52	0.34	0.22	0.19
Paper and printing	1.10	2.55	3.43	1.97	2.75	3.60	3.78
Chemical products	8.93	7.79	8.26	7.21	6.60	6.20	6.05
Non-metallic minerals	0.30	0.24	0.42	0.41	0.28	0.34	0.29
Basic metals	0.68	0.26	0.49	0.36	0.52	0.91	0.94
Fabricated metals and machinery	19.20	23.38	34.09	35.49	39.82	41.48	39.99
Fabricated metals	4.40	3.77	4.15	3.22	2.73	2.28	2.22
Non-electrical machinery	0.75	2.22	3.69	8.00	9.56	9.26	7.85
Electrical/electronic products	10.62	12.96	14.68	14.86	15.66	19.28	19.24
Transport equipment	0.57	0.25	0.32	0.24	0.17	0.20	0.17
Scientific/measuring equipment	1.67	3.70	10.64	8.78	11.01	9.73	9.79
Other manufacturing	19.21	6.85	7.03	8.90	5.99	5.14	5.18

Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

Table 5.4 Industry share of industries in total manufacturing in Hong Kong, 1970–96 (per cent)

	1970	1975	1980	1985	1990	1993
Food, beverages and tobacco	3.98	5.67	4.64	6.43	8.24	10.29
Textiles and clothing	41.46	47.44	41.53	40.18	35.97	31.51
Wood	2.38	2.04	1.45	1.31	0.87	0.51
Paper and printing	5.12	4.99	5.45	6.70	9.58	12.57
Chemical products	16.00	10.74	9.64	11.18	8.36	6.35
Non-metallic minerals	0.82	0.66	0.96	1.02	1.00	1.11
Basic metals	1.98	1.13	0.90	0.56	0.69	0.92
Fabricated metals and machinery	23.40	24.62	32.02	28.78	31.70	32.33
Fabricated metals	6.18	7.38	8.69	6.99	5.95	5.82
Non-electrical machinery	1.24	2.25	2.56	3.59	8.95	7.76
Electrical/electronic products	11.75	9.87	13.45	11.43	9.58	11.04
Transport equipment	3.38	2.95	2.39	2.38	2.77	3.89
Scientific/measuring equipment	0.85	2.16	4.93	4.39	4.45	3.83
Other manufacturing	4.85	2.69	3.41	3.84	3.59	3.85

Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

In line with the declining trend in the textiles and clothing industry, fabricated metals and machinery, in particular electrical and electronic equipment and fabricated metals, became growth industries in the 1970s and the early and mid-1980s. The export share of fabricated metals and machinery in merchandise export increased from 19.2 per cent in 1970 to 34.1 per cent in 1980. It increased until 1988, when it reached a peak of 40.5 per cent. The share of the electrical and electronic industry rose from 10.6 per cent of merchandise exports in 1970 to 14.7 per cent in 1980, and it reached a peak of 16.8 per cent in 1988. However, textiles and clothing have been by far the largest export sector over the period as a whole. In 1996, exports of these goods were twice those of electrical and electronic equipment, the second largest export industry, but exports of fabricated metals and machinery (electrical and electronic industry plus non-electrical machinery and equipment plus scientific and measuring equipment plus fabricated metals plus transport equipment) have rivalled textile and clothing exports since 1988. The share of fabricated metals and machinery in total manufacturing production increased in the 1970s. From 23.4 per cent in 1970, it increased to 32.0 per cent in 1980 and 34.0 per cent in 1981. The production share of electrical and electronic products also increased from 11.8 per cent in 1970 to 15.6 per cent in 1981. It was 10–11 per cent in the early 1990s.

However, the services sector, notably banking and finance, and trade and tourism, has dominated economic growth in Hong Kong. When Hong Kong arrived at the mature stage of growth in the 1980s, the share of the services sector in GDP was nearly 70 per cent, while that of manufacturing was about 22 per cent. The share of the services sector in GDP exceeded 80 per cent in 1993 and recorded 84.9 per cent in 1996, while shares of manufacturing in these two years were 11.2 per cent and 7.3 per cent, respectively (see Table 5.1 and Figure 5.1).

Hong Kong experienced adjustment in its industrial structure. In the early phase of growth, labour-intensive light industries like textiles and clothing were technological niches, along with service sector activities such as trade and tourism. Fabricated metals and machinery, in particular electrical and electronic industries, became important thereafter, and the role of labour-intensive manufacturing industries and the services sector was quite strong. In this respect, Hong Kong's experience of structural adjustment differs markedly from experience in other East Asian NIEs; Hong Kong's economy has been heavily dependent on the services sector, in which income elasticity of demand rather than productivity growth plays a major role in growth, and maintained its comparative advantage in labour-intensive industries rather than improving technological niches (entering the capital- and skill-intensive sectors) during the second stage.³⁵

Considering these characteristics, Young (1992; 1995) is quite misleading in arguing that only Hong Kong shows strong evidence of sustainability of growth because it enjoys the highest productivity growth among NIEs. The high productivity growth in Hong Kong may simply be a product of the labour-intensive nature of the manufacturing and services sectors.

³⁵ The share of labour-intensive goods in total merchandise exports of Hong Kong is quite large in comparison with other East Asian NIEs. The share in Hong Kong is over 40 per cent, whereas the share in Singapore is under 10 per cent and those of Korea and Taiwan are about 20 per cent.

Singapore

Textiles and clothing were not technological niches in Singapore in the early phase of growth, in contrast to the experiences of the other three Asian NIEs. The export share of these industries in merchandise exports and their production share in manufacturing value-added in 1973 were just 8.4 and 10.5 per cent, respectively, when the highest share of the whole period was recorded (Tables 5.5 and 5-6). Instead, Singapore experienced an early phase of growth, functioning as a processing centre for raw materials from Malaysia and Indonesia and as a regional base for international trade and finance for multinational corporations (O'Connor 1995: 61). For these reasons, the technological niches in Singapore's early growth phase were chemicals (rubber processing, petroleum refining), fabricated metals and machinery (fabricated metals, shipbuilding and repair, and electrical and electronics), food and beverage processing, printing and publishing, and timber processing. In particular, the leading industry in exports until 1983 was chemical products. The share of the chemical industry in merchandise exports exceeded 40 per cent until 1983 (except in 1973 and 1979). The production share of this industry in manufacturing was 23–32 per cent over the same period. Fabricated metals and machinery was the second largest export industry and the largest production industry in 1970–83. The export share of this industry was 19.4 per cent in 1970, rose to 31.6 per cent in 1975, reaching 35.7 per cent in 1980.

Singapore experienced dramatic structural adjustment in the 1970s and 1980s. Industries which were dependent on primary commodity processing declined, while labour-intensive electronics (radio, televisions, semiconductors and others) became the next technological niches. Their share in merchandise exports rose dramatically: it was 6.2 per cent in 1970, 14.2 per cent in 1975, and 20.0 per cent in 1980. By 1980 exports of electronics (electrical and electronic products) were half those of exports of chemical products (petroleum refining and rubber processing). Moreover, there was structural adjustment within the electronics industry, in the form of a production shift to high quality products in the 1980s.

Semi-skilled labour-intensive assembly activities became Singapore's technical niche in the 1960s and 1970s but skill- and capital-intensities increased rapidly in the early 1980s, strengthening Singapore's competitive position in these activities. The electronics industry has continued to experience breath-taking development. Its export share in merchandise exports was 20.3 per cent in 1985, 24.5 per cent in 1990 and 34.2 per cent in 1995. Electronics became the largest export industry from 1992, replacing chemical products. More interesting is the decrease in production share after 1987–88; after increasing rapidly in 1970s and 1980s, the production share reached a peak of 39.6 and 39.7 per cent in 1987 and 1988, then dramatically decreased thereafter. This contrasts with continuous increases in the export share of this industry. This seems to be strong evidence for successful structural adjustment, and a production shift to high-quality production in Singapore's electronics industry. In this respect, Singapore's technological change may have been the fastest among the NIEs, a trend which was not detectable in the growth accounting framework.

Table 5.5 Industry share in merchandise exports in Singapore, 1970–96 (per cent)

	1970	1975	1980	1985	1990	1995	1996
Food, beverages and tobacco	17.51	8.32	7.24	6.57	3.99	3.16	3.10
Textiles and clothing	8.83	5.83	5.28	4.74	5.25	2.87	2.53
Wood	5.59	3.44	3.65	2.28	1.58	0.84	0.72
Paper and printing	1.62	1.09	0.92	1.28	1.45	1.20	1.06
Chemical products	41.94	46.00	42.21	39.71	28.29	15.67	16.22
Non-metallic minerals	1.43	0.81	0.72	0.54	0.49	0.52	0.48
Basic metals	1.88	2.25	3.35	2.60	2.05	2.58	2.23
Fabricated metals and machinery	19.42	31.58	35.72	41.28	55.91	71.88	72.31
Fabricated metals	2.71	1.89	1.74	1.90	2.12	1.94	1.84
Non-electrical machinery	4.74	6.91	7.02	12.73	23.75	30.64	32.66
Electrical/electronic products	6.20	14.17	20.02	20.26	24.47	34.23	32.76
Transport equipment	4.33	5.51	4.89	4.26	3.18	2.21	2.19
Scientific/measuring equipment	0.86	2.93	1.82	1.85	2.10	2.64	2.66
Other manufacturing	1.78	0.69	0.91	1.00	0.98	1.29	1.37

Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

Table 5.6 Industry share of industries in total manufacturing in Singapore, 1970–96 (per cent)

	1970	1975	1980	1985	1990	1995
Food, beverages and tobacco	12.05	7.03	4.92	5.99	4.40	3.93
Textiles and clothing	5.05	5.46	5.31	4.04	3.23	1.38
Wood	6.29	2.96	3.09	2.14	1.21	0.74
Paper and printing	5.58	4.56	4.34	6.38	5.90	6.18
Chemical products	29.06	25.65	25.21	19.04	20.66	17.12
Non-metallic minerals	2.95	3.57	2.32	2.98	1.53	2.14
Basic metals	1.95	1.83	1.78	1.35	1.15	0.67
Fabricated metals and machinery	34.51	47.82	51.31	56.88	60.95	67.46
Fabricated metals	6.38	5.03	5.13	6.14	6.13	7.09
Non-electrical machinery	2.48	9.59	7.97	7.61	22.96	27.88
Electrical/electronic products	11.25	16.07	23.71	31.64	22.71	23.83
Transport equipment	14.09	14.58	12.49	9.67	7.47	6.90
Scientific/measuring equipment	0.31	2.56	2.01	1.83	1.68	1.77
Other manufacturing	2.57	1.10	1.71	1.19	0.96	0.38

Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

The services sector, particularly banking and finance, and trade, has been a strong contributor to economic growth in Singapore, even though Singapore's manufacturing base was stronger than Hong Kong's. The industry's share in GDP is 37.8 per cent in 1996, comparable to 35.6 per cent in Taiwan and 42.8 per cent in Korea, much higher than Hong Kong's 14.9 per cent (Table 5.1). The share of capital-intensive products in total merchandise exports in Singapore is 78.3 per cent in 1996, a little higher than in Taiwan and Korea, whereas Hong Kong records just 50.4 per cent (Table 5.2). The industrial structure of Singapore did not change much in the 1980–96 period. The share of the services sector in GDP was in the range of 60–65 per cent while the manufacturing share over this period fluctuated in the range of 24–30 per cent. The rapid de-industrialisation process which was observed in Hong Kong did not occur in Singapore (see Table 5.1). The share of services in GDP in Singapore, about 80 per cent in 1970, declined until the mid-1980s, in contrast with Hong Kong.

Overall, structural adjustment in Singapore was accompanied by rapid changes in technological niches. In the early phase of growth, the services sector and the low technology manufacturing sector, such as petroleum refining, rubber processing,

shipbuilding and repair, and food and beverage processing, were Singapore's technological niches. However, in the later stage of growth, structural change occurred in capital- and skill-intensive industries such as electronics, and high value-added service industries such as banking and finance. Viewed from an organisational perspective, Singapore has been continuously upgrading the tasks it performs for multinational corporations, from a labour-intensive role to a more skilled- and capital-intensive one. In this respect, the earlier growth accounting studies which are most pessimistic in relation to Singapore are misleading. Instead, Singapore is a good example of sustained growth in the midst of successful structural adjustment. The low productivity that growth accounting studies identify may simply arise from the rapid changes in technological niches towards capital- and skill-intensive industries.

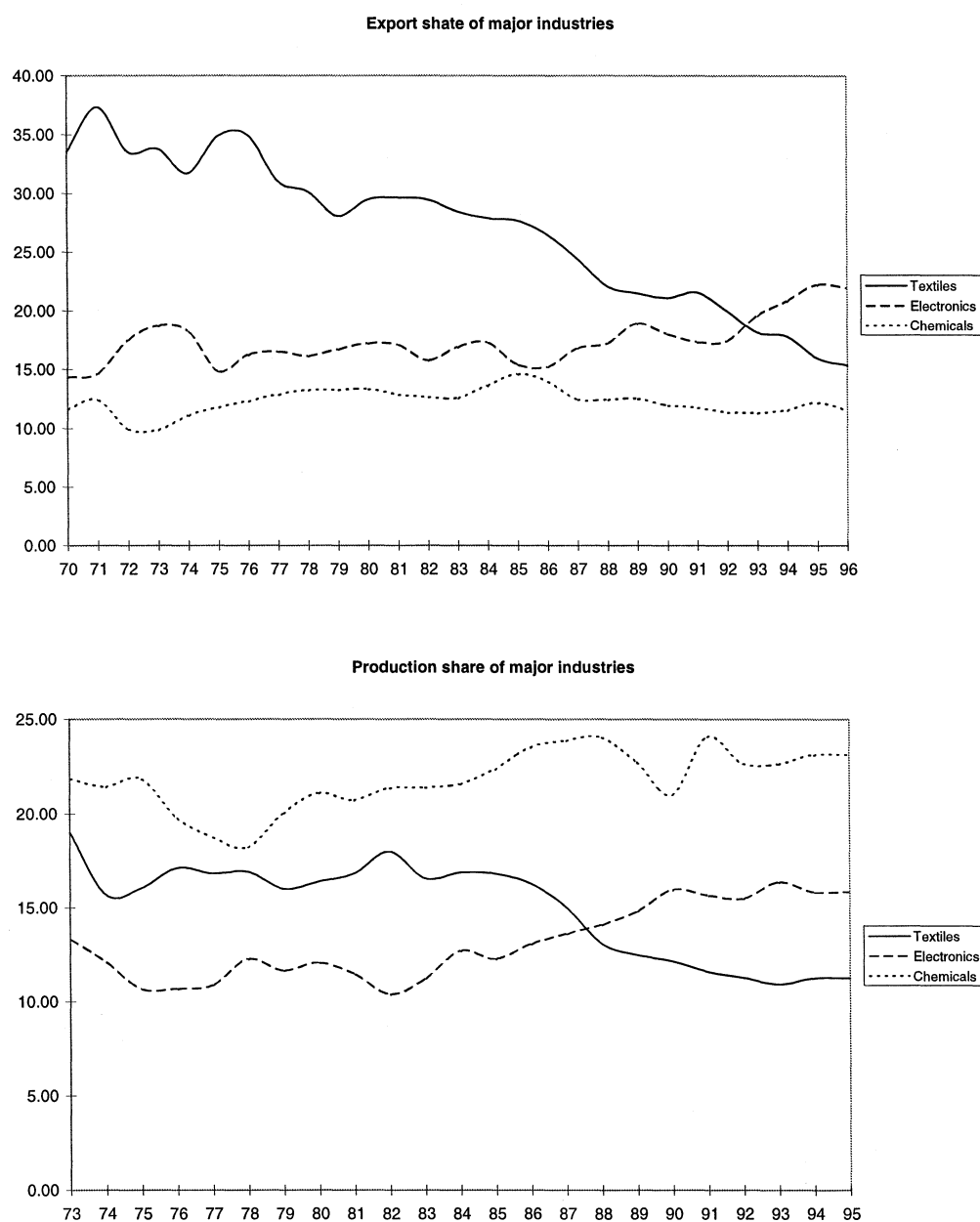
Taiwan

Like other East Asian NIEs, Taiwan's technological niches were in labour-intensive sectors in the early phase of growth. They were in clothing and textiles, semi-skilled electrical and electronic products, leather goods and wood products. The labour-intensive sector was quite strong in the 1960s. However, structural adjustment took place towards more skill- and capital-intensive production and away from unskilled labour-intensive manufacturing products in the 1970s.

The textile and clothing industry was the leading industry in merchandise exports until 1993, when it was overtaken by electrical and electronic products. The export share of this industry was considerably larger than any other industry in the 1970s: 33.6 per cent in 1970, 34.9 per cent in 1975, and 29.5 per cent in 1980. However, the industry's export share declined rapidly throughout the 1973–1996 period: from 33.6 per cent in 1970 to 15.3 per cent in 1996. In contrast, the export share of electronics increased over the 1973–1996 period and it became the leading industry in merchandise export in 1993. It was 14.3 per cent in 1970, 17.2 per cent in 1980, 18.0 per cent in 1990, and 20.1 per cent in 1994. An important development was structural adjustment in electronics from the 1980s; Taiwan

generally strengthened its competitive position in electronics by shifting production to high-quality products. The export share of chemical products was 10–15 per cent in 1970–96, without showing any trends (Figure 5.5 and Table 5.7).

Figure 5.5 Export and Production shares of major industries in Taiwan, 1970–96



Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

Table 5.7 Industry share of industries in merchandise exports in Taiwan, 1970–96, (per cent)

	1970	1975	1980	1985	1990	1995	1996
Food, beverages and tobacco	11.13	11.14	6.09	3.41	2.76	2.48	2.30
Textiles and clothing	33.59	34.86	29.45	27.67	21.08	15.92	15.32
Wood	10.06	6.01	5.76	4.47	3.17	2.01	1.87
Paper and printing	0.94	1.12	1.15	0.68	1.37	1.04	1.02
Chemical products	11.57	11.74	13.27	14.55	11.90	12.12	11.49
Non-metallic minerals	1.90	1.15	2.16	2.39	2.03	1.11	1.04
Basic metals	4.98	2.61	2.17	2.64	2.64	3.46	3.61
Fabricated metals and machinery	22.66	26.41	32.94	37.97	49.21	58.44	60.12
Fabricated metals	2.57	2.62	4.80	5.58	6.57	6.35	6.11
Non-electrical machinery	3.64	4.59	5.13	9.86	16.82	22.69	25.33
Electrical/electronic products	14.30	14.76	17.15	15.35	17.97	22.14	21.89
Transport equipment	1.04	2.39	3.49	4.42	5.36	5.06	4.75
Scientific/measuring equipment	0.71	1.88	2.25	2.46	2.31	2.05	1.96
Other manufacturing	3.16	4.96	7.01	6.24	5.84	3.42	3.23

Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

Production shares of major industries show a different picture from export shares. The share of textiles and clothing in manufacturing value-added was 16–18 per cent with no significant decline from 1974 to 1986, followed by a sharp decrease. In contrast, the production shares of chemicals and electronics increased sharply from the 1980s. Chemical products were the leading industry in terms of production share in 1970–96. O'Connor (1995: 65) explains the rise of the upstream chemical industry in 1970s as a result of Taiwan's import substitution efforts in this sector, which aimed at supplying synthetic fibre and yarn to the textile sector. Production in electronics (electrical and electronic equipment) also grew strongly in the 1970–88 period (Figure 5.2 and Table 5.8).

There are some noteworthy characteristics in Taiwan's case. The first is that the production share of textiles and clothing in manufacturing value-added did not decrease sharply in 1973–86, whereas the export share in merchandise exports did. This suggests that Taiwan's structural adjustment into more technology-intensive industries progressed only slowly. The second is that the electronics industry had a larger share of exports than the chemical industry from the mid-1980s, even though its share in production was relatively small. This

suggests that Taiwan's competitiveness in electronics was stronger than in chemicals. It also suggests that the chemical industry in Taiwan was supported by the domestic rather than the world market.

Table 5.8 Industry share of industries in total manufacturing in Taiwan, 1973–96 (per cent)

	1973	1975	1980	1985	1990	1995
Food, beverages and tobacco	12.89	16.83	12.33	12.65	10.24	9.36
Textiles and clothing	18.97	16.06	16.40	16.81	12.14	11.25
Wood	5.52	3.76	2.92	2.67	2.20	1.84
Paper and printing	4.32	4.22	4.61	3.91	4.00	3.61
Chemical products	21.84	21.83	21.07	22.33	20.95	23.10
Non-metallic minerals	2.90	4.64	4.58	3.76	4.42	4.73
Basic metals	5.87	3.95	6.49	5.89	6.86	6.73
Fabricated metals and machinery	24.04	23.76	25.99	26.40	35.41	36.51
Fabricated metals	2.66	2.32	3.90	4.41	6.41	7.02
Non-electrical machinery	2.73	3.43	2.89	3.04	4.46	4.92
Electrical/electronic products	13.31	10.63	12.02	12.23	15.93	15.81
Transport equipment	4.58	6.39	5.90	5.46	7.50	7.69
Scientific/measuring equipment	0.75	1.00	1.28	1.25	1.12	1.07
Other manufacturing	3.65	4.94	5.62	5.56	3.78	2.87

Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

The manufacturing sector has been a strong contributor to economic growth in Taiwan, as it has been in Singapore and Korea. This characteristic differs from the experience of Hong Kong, which features a strong services sector. The share of the manufacturing sector in GDP reached a peak of 39 per cent in 1987, then steadily declined. It dropped to 28 per cent in 1996 (see Table 5.1). Like other NIEs, Taiwan experienced rapid changes in its technological niches in the wake of changes in its industrial structure. In the early phase of growth, labour-intensive light industries were Taiwan's technological niches. However, in the next stage of growth, Taiwan upgraded and diversified its technological niches. Taiwan increased its technology intensity in labour-intensive industries like electronics, and moved into new industries such as electronics (electrical and electronic equipment). Taiwan secured different technological niches over time, adjusting to changes in the world economy. Viewed from an organisational perspective, Taiwan's economic growth was relatively stable because it

succeeded in specialising in the production of higher technology components and parts under the international subcontract and network system.

Korea

Like the other East Asian NIEs, labour-intensive sectors were Korea's technological niches in the early phase of growth. In the 1960s they were textiles and clothing, footwear, electrical and electronic products. In particular, textiles and clothing occupied the major role in production and export products until fabricated metals and machinery (transport equipment, electrical and electronic equipment and scientific and measuring equipment) became the leading industry in the early 1980s.

Structural adjustment towards more capital- and skill-intensive industries occurred in the 1970s. The Korean government announced a plan to promote heavy industry and petrochemicals in 1973. The targeted industries were steel, petrochemicals, non-ferrous metals, machinery, shipbuilding and electronics.³⁶ Under this program, Korea undertook substantial structural adjustment towards the targeted industries; heavy industry and petrochemicals (which includes consumer electronics) accounted for a rising share of both manufacturing output and merchandise exports during the 1970s.

Like Taiwan, textiles and clothing industry was the leading export industry. The share of this industry in merchandise exports was about 50 per cent in the early 1970s, but decreased markedly thereafter. The export share of this industry was 33.2 per cent in 1980, 24.8 per cent in 1990 and 15.5 per cent in 1996. Corresponding to declines in this industry, fabricated metals and machinery, in particular transport equipment and electronics, increased their shares rapidly. For example, the export share of transport equipment, the largest export industry in

³⁶ The promotion of these heavy industries was in part motivated by an export pessimism which questioned the sustainability of an export drive based on labour-intensive manufactures, given rapidly increasing wage rates in the early 1970s and the growing protectionism of OECD countries against labour-intensive developing country exports such as textiles and clothing (O'Connor 1995: 66).

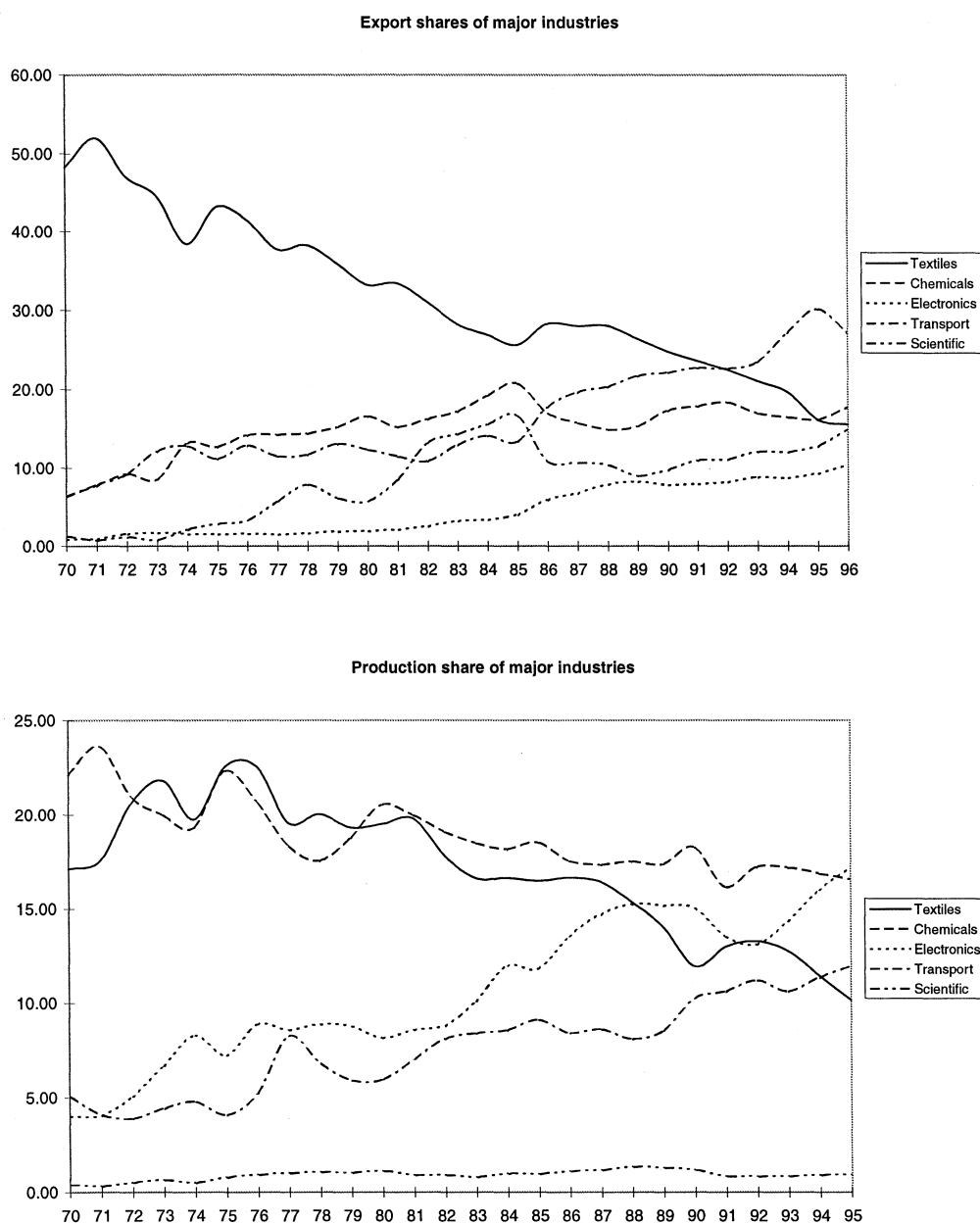
1992–96, was 6.4 per cent in 1970, 12.3 per cent in 1980, 22.3 per cent in 1990 and 30.1 per cent in 1995. Similarly, electrical and electronic products and scientific and measuring instruments showed a rapid increase in export shares; in the case of electrical and electronic products, the shares were 0.8 per cent in 1970, 1.84 per cent in 1980, 7.75 per cent in 1990 and 10.3 per cent in 1996; For scientific and measuring instruments, the shares were 1.2 per cent in 1970, 5.6 per cent in 1980, 9.7 per cent in 1990 and 14.8 per cent in 1996. If electronics is defined to include both industries, the export share of electronics was 2.0 per cent in 1970, 17.4 per cent in 1990 and 25.0 per cent in 1996. Later, it increases to become the second largest exporting industry, after transport equipment (motor vehicles and ship building). The chemical industry grew rapidly in the 1970s and early 1980s, reaching a peak of 20.1 per cent of export share in 1985. Thereafter, its share in merchandise export stayed at 15–18 per cent in 1986–96. It was the second largest export industry until 1985. Basic metals (iron and steel) is another interesting case. It was the third largest export industry in 1980–82, but its export share decreased thereafter, reaching 5.8 per cent in 1996 (Table 5.9).

Table 5.9 Industry share of industries in merchandise exports in Korea, 1970–96 (per cent)

	1970	1975	1980	1985	1990	1995	1996
Food, beverages and tobacco	1.98	5.45	2.83	1.00	1.02	0.98	1.15
Textiles and clothing	48.28	43.15	33.23	25.62	24.80	16.11	15.52
Wood	13.55	5.53	3.16	0.49	0.59	0.42	0.40
Paper and printing	0.19	1.38	1.21	0.85	1.11	1.19	1.23
Chemical products	6.26	12.58	16.46	20.69	17.20	16.07	17.60
Non-metallic minerals	0.95	2.33	2.60	1.18	1.09	0.65	0.66
Basic metals	3.05	6.21	11.83	7.43	7.20	6.05	5.80
Fabricated metals and machinery	9.94	18.69	25.40	39.80	43.45	56.61	55.83
Fabricated metals	0.11	0.00	0.03	0.05	0.04	0.04	0.02
Non-electrical machinery	1.15	1.94	3.66	4.69	2.62	3.21	2.34
Electrical/electronic products	0.79	1.43	1.84	3.95	7.75	9.22	10.27
Transport equipment	6.38	11.06	12.26	13.24	22.04	30.11	27.09
Scientific/measuring equipment	1.21	2.72	5.60	16.59	9.68	12.70	14.79
Other manufacturing	0.30	1.54	2.00	1.28	1.32	1.34	1.31

Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

Figure 5.6 Export and production shares of major industries in Korea, 1970–96



Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

The share of major industries in manufacturing production presents a picture similar to the export share. The production share of textiles and clothing decreased rapidly and the shares of transport equipment, electrical and electronic equipment, and scientific and measuring instruments increased rapidly. For example, the production share of electrical and electronic equipment was 4.0 per

cent in 1970, 8.1 per cent in 1980, 15.0 per cent in 1990 and 17.2 per cent in 1995. In contrast, the production share of textiles and clothing was 21.8 per cent in 1973, 19.5 per cent in 1980, 12.0 per cent in 1990 and 10.2 per cent in 1995. Despite similarities in the overall trend, there were slight differences in the production share and the export share of major industries. In part this is because domestic demand played a more important role in Korea than it did in Singapore and Hong Kong. It also arises from the fact that differences in classification between production and export, in particular the classification of electrical and electronic products, and scientific and measuring products. The production share of chemical products was similar to that of textiles and clothing until 1981, when it overtook the latter, even though the overall trend was in decline. The second difference is the high share of electrical and electronic products. This industry became the leading industry in production in 1989, surpassing the share of textiles and clothing. In 1995, the four industries showing the highest production shares are electrical and electronic equipment, chemical products, transport equipment, and textiles and clothing.

The manufacturing sector has been a strong contributor to economic growth in Korea, as has been the case in Taiwan and Singapore. Like other NIEs, Korea's technological niches changed in response to changes in the industrial structure. In the early phase of growth, labour-intensive light industries were Korean technological niches. However, during the next stage, Korean structural adjustment was more thoroughgoing than Taiwan's and its diversification of technological niches was broader than Singapore's, entering new areas such as heavy industry, petrochemicals and electronics.

This analysis has a limited ability to identify structural adjustment within industries, even though it is useful in identifying structural adjustment across industries.

Table 5.10 Industry share of industries in total manufacturing in Korea, 1970–96 (per cent)

	1970	1975	1980	1985	1990	1995
Food, beverages and tobacco	25.75	17.76	16.60	13.85	10.71	8.61
Textiles and clothing	17.12	22.55	19.49	16.50	11.95	10.15
Wood	3.56	2.68	1.74	1.51	1.84	1.94
Paper and printing	5.07	4.00	4.44	4.60	4.64	5.12
Chemical products	22.08	22.28	20.48	18.50	18.25	16.54
Non-metallic minerals	5.97	5.68	5.76	4.81	4.95	4.68
Basic metals	4.02	6.49	7.79	7.73	7.37	6.83
Fabricated metals and machinery	13.54	16.64	21.83	30.56	38.52	44.84
Fabricated metals	2.35	2.40	3.26	4.02	5.13	5.85
Non-electrical machinery	1.77	2.24	3.44	4.73	6.99	9.00
Electrical/electronic products	3.98	7.20	8.13	11.78	15.03	17.15
Transport equipment	5.06	4.04	5.90	9.08	10.22	11.93
Scientific/measuring equipment	0.38	0.76	1.10	0.94	1.14	0.91
Other manufacturing	2.88	1.92	1.88	1.94	1.77	1.29

Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

Future directions

Hong Kong has arrived at a mature stage of growth; the industrial structure has stabilised as a service-oriented economy, featuring the tourism, trade, and banking and finance sectors. Hong Kong's future growth will thus be determined by growth in these industries. Because technological change in the services sector is limited except in some knowledge-intensive industries, Hong Kong's future growth will be dependent on world economic conditions, particularly Chinese economic growth.

Although Singapore and Hong Kong have reached a mature stage of growth, Singapore's manufacturing and knowledge-intensive services are stronger than those of Hong Kong. Moreover, its economic activities are a small subset of the globalised tasks of multinational corporations. Singapore can thus continuously upgrade its economic activities, or secure a more technology-intensive role, as long as the international production of multinational corporations expands. Singapore's services sector may also experience growth as rapid as Hong Kong's if world economic conditions are stable and demand increases.

Taiwan has a stronger manufacturing base than Hong Kong and Singapore. Past history has shown that Taiwan can achieve rapid technological change and growth by upgrading its specialisation in the production of components and parts under the international subcontract and network system. This production interdependence implies that Taiwan's products have a complementary relationship with the final products of developed countries; technological catch-up in the production of parts and components has had a positive effect on the production of developed countries rather than hurting the leader country. In this sense, the growth path of Taiwan is more stable than that of Korea. Taiwan already has a comparative advantage in the production of high-tech parts and components of labour- and technology-intensive goods, such as electronics. Taiwan can expect higher growth rates than developed countries, even though growth rates will be lower than those of the last few decades, unless world economic conditions deteriorate.

Like Taiwan, Korea has a strong manufacturing base. Korea has the potential to undertake rapid technological change and growth as local entrepreneurs diversify their production (by entering new or high-tech industries) and products (by producing higher quality products in the same industry) by organising international capital and intermediate goods transactions. When Korea exported technologically standardised goods, parts, and components, the relationship between Korea and the leader country was complementary rather than substitutive. However, Korean local enterprises have recently begun to compete with innovative leader firms in various industries and products, such as automobiles, electronics, and even in high technology industries. For this reason, the growth path of Korea will be less stable than that of Taiwan as the relationship with leader firms changes into a substitutive one. It also means that the Korean path could become more dynamic than that of Taiwan as strong competition in the world market transforms large Korean conglomerates into multinational corporations. The Korean economy is now at the crossroads: it can achieve sustained higher growth if Korean firms successfully complete their

technological catch-up; otherwise, growth rates will be lowered unless world economic conditions improve and demand increases.

Structural adjustment and productivity growth

The previous section described structural adjustments in NIEs and their effects on changes in technological niches over the last three decades. It was argued that industrialising economies in the process of catching up have substantial potential to lift productivity and technology swiftly by structural adjustments in manufacturing industries. This element of productivity improvement is important in understanding the rapid growth in NIEs, along with the transformation of the economic structure associated with the movement of labour and other resources from the agricultural to the non-agricultural sector in the course of industrialisation.

The objective of this section is to verify empirically the structural adjustment hypothesis within the manufacturing sector. Recognition of structural adjustment as an important source of growth in East Asian economies verifies the argument that it is the driving force behind the interactions between technological change and capital growth. For this purpose, Jorgenson's resource reallocation effect is reviewed, and the negative resource reallocation effect is calculated as an indicator of the structural adjustment effect. Next, Pilat's structural effect, an extension of the standard structural change argument in the manufacturing sector, is reviewed and calculated to verify the argument. Then, applying the model of Bernard and Jones (1996a), the share effect (a proxy for the structural adjustment effect) in connection with the productivity growth effect is calculated and the results are interpreted.

Jorgenson's resource reallocation effect

Jorgenson *et al.* (1987) open the way to derive a method for calculating the effect of structural adjustment across industries by disaggregating whole economies into

many industries. Moreover, Jorgenson and his colleagues express the resource reallocation effect as a component of aggregate productivity growth. They suggest that structural adjustment can be expressed as a component of aggregate productivity growth.

They compute the resource reallocation effect for the purpose of advocating a disaggregation procedure and illuminating the problems of the aggregate production function approach. Under their framework, resource reallocation is a measure of aggregation error. Equation (3-5), which expresses the relationship between productivity growth of aggregate manufacturing (φ_T), the weighted sum of sectoral productivity growth ($\sum w^i \varphi_T^i$) and resource reallocation (RR), is reformatted as equation (5-1). Equation (5-2), (5-3), and (5-4) are the resource reallocations of output (RR_Y), capital input (RR_K) and labour input (RR_L), respectively.

$$(5-1) \quad \varphi_T = \sum w^i \varphi_T^i + RR,$$

where $RR = RR_Y + RR_K + RR_L$

$$(5-2) \quad RR_Y = [\ln V(T) - \ln V(T-1)] - \sum w^i [\ln V_i(T) - \ln V_i(T-1)],$$

$$(5-3) \quad RR_K = \sum w_K^i [\ln K_i(T) - \ln K_i(T-1)] - [\ln K(T) - \ln K(T-1)],$$

$$(5-4) \quad RR_L = \sum w_L^i [\ln L_i(T) - \ln L_i(T-1)] - [\ln L(T) - \ln L(T-1)], \quad (i = 1, 2, \dots, 36)$$

where w^i and φ_T^i represent share of output and productivity growth of industry i , respectively. $V(T)$, $K(T)$, and $L(T)$ represent aggregate indexes of output, capital and labour input at time t , respectively. $V_i(T)$, $K_i(T)$, and $L_i(T)$ represent industry indexes of output, capital and labour input at time t , respectively.

However, if the sums of the resource reallocation in output and inputs (simply resource reallocation) are significantly different from zero, then the aggregate

production function is not credible, and the weighted sum of sectoral productivity growth is preferred to productivity growth of aggregate manufacturing as an alternative measure of aggregated approach. Rearranging equation (5-1) on the basis of the weighted sum of sectoral productivity growth instead of ν_T , we obtain

$$(5-5) \quad \sum w^i \cdot \nu_T^i = \nu_T - RR,$$

$$\sum w^i \cdot \nu_T^i = \nu_T + STR, \quad (i = 1, 2, \dots, 36),$$

where $STR = -RR$.

Equation (5-5) shows that we can obtain productivity growth (the weighted sum of sectoral productivity growth) by adjusting the productivity growth of aggregate manufacturing (ν_T) for structural effects (STR ; resource reallocation with the opposite sign, or $-RR$).

Even though resource reallocation with the opposite sign is a different concept from structural adjustment, it is one indicator of the latter. As long as all industries do not have the same sectoral production function, productivity growth of aggregate manufacturing is not equal to the weighted sum of sectoral productivity growth; resource reallocation³⁷ is not equal to zero. If structural adjustment occurs over time, the weighted sum of sectoral productivity growth may be greater than the productivity growth of aggregate manufacturing, because aggregate output and two aggregate inputs cannot capture the sectoral movements of disaggregated outputs and inputs towards more efficient sectors.

In the case of Korea, the structural effect was positive in the periods 1968–73, 1973–78 and 1978–83, and negative in the periods 1983–88 and 1988–93, as expected (Table 5.11). Note that the structural effect was quite large in the first three sub-periods; it was 1.30 per cent in period 1968–73, 0.61 per cent in 1973–

³⁷ Resource reallocation (RR) is the difference between productivity growth of aggregate manufacturing and the weighted sum of sectoral productivity growth, by definition.

78 and 1.34 per cent in 1978–83. Thereafter, the structural effect became smaller (converging to zero), and became negative: -0.23 per cent in the period 1983–88 and -0.14 per cent in 1988–93. The last column of Table 5.11 shows that the contribution of the structural adjustment effect to the weighted sum of sectoral productivity growth was quite significant. It was 11.1 per cent in 1968–73, 8.5 per cent in 1973–78 and 35.0 per cent in 1978–83.

The large structural effect in the 1968–83 period implies that diversification-style structural adjustment (entering the heavy and petrochemical industries) was an important component of the weighted sum of sectoral productivity growth, but the potential of this diversification effort was exhausted by the early 1980s. Subsequently, the production shift to high-quality products within industries replaced the role of diversification-style structural adjustment, as argued earlier. However, the 36-industry growth accounting scheme cannot identify this effect, so the structural adjustment effect, that is diversification across industries, in the table becomes to negative.

Table 5.11 Structural effect in Jorgenson's framework
(per cent)

	WSSP (A)	Aggregated TFP (B)	Structural effect (C)	Resource reallocation	C/A
68–73	11.66	10.35	1.30	-1.30	11.1
73–78	7.16	6.55	0.61	-0.61	8.5
78–83	3.83	2.50	1.34	-1.34	35.0
83–88	5.35	5.58	-0.23	0.23	-4.3
88–93	4.69	4.83	-0.14	0.14	-3.0
68–93	6.45	5.96	0.49	-0.49	7.6

Note: Resource reallocation of output, labour and capital input was calculated from a 36-industry model.

Source: Table 3.2 in Chapter 3.

Even though the resource reallocation effect of Jorgenson and his colleagues provides some information on the effect of structural adjustment, it has

limitations. By definition, resource reallocation represents the difference between the weighted sum of sectoral productivity growth and productivity growth of aggregate manufacturing. In this regard, the standard calculation of structural change, which focuses on the effect of the movement of labour from agricultural to non-agricultural sectors, is of interest.

Pilat's structural effect

Pilat (1994) accounts for sources of growth in Japan and Korea by disaggregation, even though the manufacturing sector is not disaggregated to the industry level. He calculates the structural effect as the sum of changes in the labour shares of all industries weighted by the output share of industry. He then defines aggregate labour productivity growth (the total sectoral effect: v_{LT}) as the sum of the structural effect and the weighted sum of sectoral labour productivity growths:

$$(5-6) \quad v_{LT} = \sum w^i \cdot v_{LT}^i + \sum w^i \cdot g(s_L^i)^{38},$$

where v_T represents aggregate productivity growth (total sectoral effect), v_{LT}^i is sectoral productivity growth of industry i , w^i is output share of industry i , and $g(s_L^i)$ is growth rate in labour share of industry i .

Table 5.12 Pilat's structural effect
(per cent)

	68-73	73-78	78-83	83-88	88-93	68-93
Sectoral labour productivity growth (A)	12.33	11.33	9.33	9.67	10.50	10.54
Structural effect (B)	-0.67	-1.17	0.67	0.33	1.50	0.19
Total sectoral effect (C=A+B)	13.00	12.33	8.83	9.50	9.33	10.46
B/C	-5.41	-10.29	7.14	3.45	14.29	1.82

Source: Author's calculation.

³⁸ See Pilat (1994: 129) and Syrquin (1986).

According to the table, the structural effect is negative in 1968–73 and 1973–78, and positive in other periods: 0.67 per cent in 1978–83, 0.33 per cent in 1983–88 and 1.50 per cent in 1988–93. Over the whole period, the structural effect increases output by 0.19 per cent. The contribution of the effect to the total sectoral effects are -5.41 per cent in 1968–73, -10.29 per cent in 1973–78, 7.14 per cent in 1978–83, 3.45 per cent in 1983–88 and 14.29 per cent in 1988–93. Over the whole period, the contribution to total sectoral effect is 1.82 per cent.

These results are quite different from those derived from Jorgenson's framework because the focus is on labour productivity growth rather than TFP growth. However, Table 5.12 verifies that structural adjustment played a positive role in lifting aggregate labour productivity.

Bernard and Jones's share effect and productivity growth effect

Bernard and Jones (1996a) make an important contribution to the identification of the structural adjustment effect (share effect in their framework) along with the productivity growth effect. The rationale for separating these two effects from productivity growth is as follows: if individual industries which have different production functions arrive at different levels of technology, changes in aggregate productivity growth can be separated into two components, such as the component caused by structural adjustment across industries and that caused by trends in industrial productivity growth within industries.

They construct an international comparison of productivity growth and technology catch-up, and decompose change in the aggregate TFP (catching up or falling behind) of a country into a share effect and a productivity growth effect. They use relative TFP (a country's TFP level, evaluated by international units, divided by that of the leader country) in their study, so positive TFP growth directly means TFP catch-up. Here the productivity level of Korean manufacturing is indexed by a national unit, so productivity growth does not imply TFP catch-up. Instead, it shows the trend in the weighted sum of sectoral

productivity growth over time. In this respect, the productivity growth effect in this study is different from that in Bernard and Jones.³⁹

Direct application of Bernard and Jones (1996a) to Korean manufacturing leads to the aggregation bias problem again, because they employ aggregate TFP rather than the weighted sum of sectoral productivity growth as an indicator of the productivity level of a country. Thus, the weighted sum of sectoral productivity growth is employed in calculating the share effect and the productivity change effect.

Applying their idea of 'separation procedure', the difference between the weighted sum of sectoral productivity growth at time T and the weighted sum of sectoral productivity growth at time $(T-1)$ is decomposed into the between- and within-industry components. The first component, called the share effect, represents change in the weighted sum of sectoral productivity growth caused by changes in input shares of industries combined with actual industrial productivity growth. Inter-industry production shift to higher productivity growth industries will lead to a positive share effect. The second component, called the productivity change effect, represents change in the weighted sum of sectoral productivity growth caused by changes in industrial productivity growth combined with the actual industry share. A declining trend in industrial productivity growth will lead to a negative productivity change effect, and vice versa. Using equation (5-7), change in the weighted sum of sectoral productivity growth at time T is decomposed into the two components, which are independent of each other by definition.

³⁹ While this approach has a long tradition, productivity growth effect has not yet been fully discussed in a single country setting. Jorgenson and Nishimizu (1978), Jorgenson *et al.* (1987), Jorgenson and Kuroda (1988), Pilat (1994) and Bernard and Jones (1996a) use this terminology in growth accounting studies on international comparisons of productivity growth. In particular, Pilat terms this 'catching-up' and Bernard and Jones (1996a) 'productivity growth effect across countries', a component of catch-up.

Dowrick and Gemmel (1991) also decompose differences in the average growth rates across countries into differences in productivity growth, labour reallocation, and labour and capital growth under the agriculture-industry two-sector model. This study suggests that labour reallocation across sectors within a country (structural change) and productivity growth (technology catch-up between countries) in industry lead to higher average growth rates in upper middle income countries.

$$\begin{aligned}
& (5-7) \sum w^i(T) \cdot \psi_T^i(T) - \sum w^i(T-1) \cdot \psi_T^i(T-1) \\
& \equiv 0.5 \cdot [\{\sum w^i(T) \cdot \psi_T^i(T) - \sum w^i(T-1) \cdot \psi_T^i(T)\} + \{\sum w^i(T) \cdot \psi_T^i(T-1) - \sum w^i(T-1) \cdot \psi_T^i(T-1)\}] \\
& + 0.5 \cdot [\{\sum w^i(T) \cdot \psi_T^i(T) - \sum w^i(T) \cdot \psi_T^i(T-1)\} + \{\sum w^i(T-1) \cdot \psi_T^i(T) - \sum w^i(T-1) \cdot \psi_T^i(T-1)\}].
\end{aligned}$$

The first term on the right-hand side represents the share effect, and the second term represents the productivity change effect. The former is the average of the two measures of share effect, which are evaluated at time T and $(T-1)$. The latter is the average of the two measures of productivity growth effect, which are evaluated at time T and $(T-1)$.⁴⁰

Equation (5-7) is calculated using the growth accounting data from Chapter 3, and summarises the results in Table 5.13. Share effects are positive over all periods except 1978–83. According to the table, share effects are 0.34 per cent in 1968–73, 0.26 per cent in 1973–78, -0.04 per cent in 1978–83, 0.19 per cent in 1983–88 and 0.25 per cent in 1988–93. This means that the production shifts across industries lead to the increase in the weighted sum of sectoral productivity growth. The share effect is 0.16 per cent over the whole period, or 2.54 per cent of the growth in the weighted sum of sectoral productivity growth. This result empirically verifies the hypothesis that structural adjustment leads to an increase in productivity growth and to technological change over time.

Productivity change effects are negative over all periods except 1983–88, which implies that the productivity change of each industry declines over time as a follower country's economic growth moves to a higher level. This effect is -0.49 per cent over the whole period. Negative within-industry effects dominate positive across-industry share effects over all the periods, which decreases the growth rate in the weighted sum of sectoral productivity growth by about 5.2 per

⁴⁰ These measures of share effect and productivity growth effect only consider those evaluated at time T . However, I consider also those evaluated at time $T-1$ to derive the identity relationship between the two effects and the change in productivity growth.

cent over the whole period; the decline in industrial productivity growth overwhelms the share effect.

Table 5.13 Share effect and productivity change effect
(per cent)

	69-73	73-78	78-83	83-88	88-93	69-93
A ($\Sigma w^i(T) - w^i_T(T)$)	12.01	7.16	3.83	5.35	4.69	6.31
B ($\Sigma w^i(T-1) - w^i_T(T-1)$)	12.17	8.62	4.14	4.70	5.72	6.64
Share effect (C)	0.34	0.26	-0.04	0.19	0.25	0.16
TFP change effect (D)	-0.50	-1.72	-0.28	0.47	-1.18	-0.49
A-B = C+D (E)	-0.16	-1.46	-0.31	0.66	-1.03	-0.33
C/A	2.8	3.6	-1.0	3.6	5.3	2.5

Source: Author's calculation.

The limitation of this result is the characteristic of equation (5-6). It is an identity constructed by a mathematical procedure rather than based on economic theory, so separation of the change in productivity growth into the two components makes it difficult to interpret the share effect and productivity change effect.

Summary and Conclusion

The analysis in this chapter suggests a number of conclusions and implications. Section 2 defines structural adjustment across industries after reviewing standard structural change across the agricultural and non-agricultural sectors. In the case of follower countries, structural adjustments are processes which can lead to rapid technological change and economic growth through accumulating new capital embodying technological components.

Section 3 describes the experience of structural adjustment in East Asian NIEs. Focusing on the manufacturing sector, the leading industries in these countries have moved from labour-intensive industries using production technologies which are in a declining stage of the product cycle, to skill- and capital-intensive industries using standardised production technologies in a mature stage.

Subsequently, the production activities of these countries have been moving to capital and technology-intensive industries. They will move again to technology-intensive industries using frontier technologies. Structural change also shapes the direction of economic growth in NIEs. Production and employment in the services sector have been larger, whereas those of the manufacturing and agricultural sectors have been smaller. This is because the demand structure of an economy changes according to increases in per capita income. This section also showed that the East Asian NIEs have different growth paths. Hong Kong's path is characterised by high dependence on the services sector and comparative advantage in labour-intensive industries, whereas Singapore's path is characterised by rapid structural adjustment towards high technology industries with a link to international production of multinational corporations. Taiwan and Korea's paths are similar to Singapore's but the efforts of local entrepreneurs are much more important in Taiwan and Korea.

Section 4 empirically identifies the role of structural adjustment in productivity growth. First, the structural effect in Jorgenson's framework was defined as a resource reallocation effect with a negative sign. This effect explained about 7 per cent of aggregate productivity growth (the weighted sum of sectoral productivity growth) over the whole period. In particular, it was verified that this effect was very large in 1968–83. Second, Pilat's structural effect was calculated. It also confirmed that structural adjustment played a positive role in lifting aggregate labour productivity over the whole period. Then, the share effect, a proxy for the effect of structural adjustment on productivity growth, was calculated using the framework of Bernard and Jones. The share effect was positive over the whole period except 1978–83; its average growth rate was 0.16 per cent per year. These results empirically verified that structural adjustment (in particular entering new industries) has played a positive role in lifting aggregate productivity growth by offsetting the larger declining trend in aggregate productivity growth caused by the large decline in the sectoral productivity growth of each industry.

However, the measured effects were not as strong as expected. This results from the divergence of productivity growth and technological change in the mechanical growth accounting scheme. As expressed in equation (4-4), an increase in capital stock can be separated into two components: capital accumulation without a technological component, such as in former Soviet Russia, and capital accumulation with a technological component, such as in new industries or high-quality process in NIEs. Productivity data used in this chapter did not include the latter component. Thus, the effects of structural adjustment on productivity growth and technological change are not strong because some capital-related effects were mechanically attributed to capital by definition. However, considering the interaction between technological change and capital accumulation in relation to structural adjustment, the effect on technological change is strong.

The puzzle of low productivity gains in NIEs was successfully explained by the sequencing of the sources of growth and interaction between technological change and capital accumulation in Chapter 4. Chapter 5 provided more concrete information for the explanation from another perspective. Structural adjustments are the crux of the link between capital accumulation and technological change and present a new paradigm of low productivity growth and rapid technological change. Two main characteristics, which distinguish the experience of East Asian NIEs from that of developed countries, can be derived from the chapter. First, technological change for a follower country is induced by structural adjustment across industries. Second, productivity growth in new industries or products, where structural adjustments and technological changes occur, is relatively low compared with existing industries because of the mechanical property of growth accounting in treating interaction between capital accumulation and technological change. Thus, it cannot be argued that low productivity growth necessarily entails low technological change for a follower country. Large capital accumulation in a new industry undergoing structural change inevitably decreases productivity growth even though this process results in positive technological change.

Moreover, East Asian economic growth in its earlier stage can be endogenised, as argued by new growth theory, as long as structural adjustment toward high technology industry is pursued and influenced by public policy.

6 Technological Change in the East Asian NIEs

Introduction

Chapters 3 and 4 examined the argument about sequencing of the sources of output growth and interaction between capital accumulation and technological change. In Chapter 5 structural adjustment was characterised as the driving force linking this interaction. Together, these arguments suggest a sequencing of the sources of technological change.

Korea's high productivity growth in 1968–73 resulted from the introduction of the modern factory system in labour-intensive industries with low-level production technologies. This was followed in 1973–83 by low productivity growth as a result of structural adjustment which focused on heavy industry and the chemical industry requiring imports of capital and turn-key plants embodying standardised production technology. Sequentially, economic growth in 1973–83 was said to be fuelled by technological change because some parts of capital accumulation embodied a technological component, even though the mechanical growth accounting scheme does not allocate this role to technology (see Equation 4-4). Slowed productivity growth in 1983–93, characterised by production in capital- and technology-intensive industries, seems to have arisen from undetected structural adjustment (production shifts to high-quality products within industries), and the major source of technological change seems to be technology licensing and R&D investment. Thus, the earlier verification of the sequencing of sources of output growth, the interaction between capital accumulation and technological change, and sequential structural adjustments in Chapters 3–5 suggests that informal methods, capital-related methods, technology licensing and R&D investment were the major sources of technological change over these stages of development.

Another implication of the analysis in previous chapters is that technology can be defined in broad terms in follower countries. Follower countries' technological paths are characterised by sequential structural adjustments and the related import of new capital goods which embody technological components.⁴¹ Thus, allocation of the role of these technological components to technology rather than capital, unlike the framework adopted in the growth accounting scheme, inevitably increases the role of technology and defines technology in broad terms.

After producing sequencing patterns in technological change and defining technology from the follower countries' point of view, this chapter investigates technological development and transfer in the case of Korea to clarify the characteristics of the technological paths followed in East Asian NIEs, with a special focus on the role of R&D investment and technology imports.

The last question considered in this chapter is: What was the main factor that caused NIEs to take a different technological path from that of developed countries? I identify the reason as being linked to the world economic environment after WWII in which the four East Asian NIEs embarked on successful industrialisation and the ways in which they reacted to the particular conditions confronting each of them to establish their own technological niches (Appendix 2).

This chapter is organised as follows. Section 2 introduces the sequencing of the sources of technological change. Section 3 introduces a new definition of technology in broad terms from the perspective of the follower country. Section 4 overviews technological change and changing patterns of technology transfer in Korea as a case study. Section 5 presents a summary. Appendix 2 examines the reason why the technological paths taken in NIEs were quite different from the leader countries.

⁴¹ New industries here are not new at all when viewed from the perspective of leader countries.

Sequencing of the sources of technological change

The argument about sequencing of the sources of output growth and interaction between capital accumulation and technological change is another expression of the mechanical properties of growth accounting in that it attributes technological components of capital accumulation solely to the contribution of capital to output growth. These two hypotheses, combined with a broad definition of technology from the follower countries' perspective, lead to the conclusion that there is a variety of methods of technological change, and that the methods of enhancing the level of technology change according to the stage of development (sequencing of the sources of technological change).

The aim of this section is to investigate what is the sequential source of technological change for follower countries. This section attempts to answer the question, with a special focus on Korea.

Many case studies have found that there are various methods of acquiring production technology, especially in developing countries. They include R&D, technology imports (technology licensing), foreign direct investment (FDI), information embodied in capital goods, information embodied in human capital (for example, newly recruited scientists and engineers), reverse engineering, information from buyers of export goods and suppliers of components and capital goods, informative literature from foreign sources and inspection of foreign production facilities (Kim 1995; 1990; Smith and Jordan 1990; Pack 1994; Amsden 1989; Enos and Park 1988; Dahlman *et al.* 1987; Westphal *et al.* 1985; 1981). I classify these various technology acquisition methods into five groups: informal methods (information from buyers and suppliers, information from foreign journals), capital-related methods (information embodied in physical and human capital, reverse engineering), technology imports (formal licensing of technology from foreign patent holders), FDI and R&D. Follower countries generally acquire production technology from leader countries, instead of through domestic technological innovation efforts.

Case studies emphasise informal methods (including reverse engineering) as a source of technological change for developing countries. Informal methods are also a major means of enhancing the technological capability of developing countries. This emphasis may be driven by the fact that most developing countries are in the early phase of development. In the case of Korea, informal methods were the major source of technological change in the early stages of economic growth in 1960s and 1970s. In this respect, it is noteworthy that Dollar and Sokoloff's finding is that scale economies closely related to the transition from craft to modern labour-intensive production are the main source of technological change in Korea. This kind of technology transfer was prevalent in Korea and Taiwan, when they entered labour-intensive, capital-intensive and skill-intensive industries which employed low-level and standardised production technologies. Developed countries do not seek to block developing countries from entering these labour-intensive activities. The buyers of export goods and suppliers of capital goods and components willingly transfer old production techniques to developing countries, and local entrepreneurs find it easy to obtain information from foreign publications and foreign consultants. Kim (1995: 275–76) summarises this process as follows:

Both buyers and suppliers played an important role in enabling Korean firms to acquire absorptive capability. Informal technical assistance offered by foreign OEM (original equipment manufacture) buyers to ensure that Korean-made products met their technical specifications provided invaluable help to Korean firms in acquiring necessary relevant knowledge. Local buyers of capital goods provided useful information for custom-designed machinery. Technology and capital goods suppliers provided relevant knowledge to ensure successful implementation of their supplies.

The experience of Korea and Taiwan shows that information and knowledge about technologies in the declining and mature cycles lead to technological change in the early stage of development, whereas this is not the case in leader countries.

The other informal method of acquiring technology is reverse engineering, which played a significant role in the second stage of growth, the period which saw the industrialisation of the heavy and petrochemical industries, and interaction with (physical and human) capital imports. However, reverse engineering is classified as a capital-related method of acquiring technology because it works in the same way as capital imports.

Capital-related technology transfers are carried out through FDI, new capital goods, reverse engineering and returning nationals (newly recruited scientists and engineers who have had extensive training and experience in the leader country). According to Kim (1990;1995: 274–75), Korea acquired foreign technology predominantly through capital goods imports. He points out that:

such a policy led to massive imports of foreign capital, which became a major source of relevant knowledge and learning through reverse engineering by Korean firms (Kim, L. and Kim, 1985). Of the four categories of technology transfer [FDI, technology licensing, technical consultancy and capital goods imports]..., capital goods imports were worth 23 times the value of DFI [FDI] and 35 times the value of TL [technology licensing]. The total value of capital goods imports is 14 times that of the other categories combined, suggesting that Korea may have acquired more technology from advanced countries through the importation of capital goods than through any other means. Among NICs, the proportion of capital goods imports to total technology transfer was the highest in Korea (Westphal, Kim and Dahlman, 1985)...Such a policy...has been relatively effective in acquiring technological capability in the mature industries, since Korea's well-trained human resources and their entrepreneurship enabled the country to learn quickly from foreign capital goods.

Pack and Page (1994: 221) argue that returning nationals (information embodied in human capital) also played an significant role by providing important knowledge and information when Korea and Taiwan shifted their manufacturing from labour-intensive sectors to more capital- and technology-intensive sectors, through the introduction of new industries in both countries.

Under the heavy and petrochemical industrialisation program, large Korean conglomerates entered these industries, investing in large-scale capacity (installing turnkey plants), and trying to maximise capacity utilisation so that they could become competitive in the world market.⁴² Korean firms used standardised production technologies embodied in capital goods. As was the case in labour-intensive industries, developed countries willingly transferred standardised production techniques, including the capital goods required to establish new plants.

According to Kim (1995; 1990) and Pack and Page (1994: 218-21), capital imports (physical and human) and related reverse engineering were the major sources of technological change, rather than informal methods of technology transfer, during the second stage of economic growth in Korea (1973–1983), particularly during the period of heavy and petrochemical industrialisation.

There is no evidence that R&D played a significant role in productivity growth or technological change in the first and second stages of growth in Korea. However, technology imports, technical consultancy and R&D efforts increased in the period of high growth in the 1980s, while the growth of capital goods imports slowed. In particular, Hong (1994a: 10–11) concludes that technology imports became the major method of technology transfer in 1980s. This reflects the fact that Korean manufacturing could not secure technology niches using informal or capital-related methods after the mid-1980s, and that technology imports became critical methods of technological change for further growth; structural adjustments over industries could no longer enhance the level of technology, and structural adjustments within industries (the production shift to high-quality products) were required to sustain economic growth. The Japanese experience in the 1950s and 1960s is instructive here. Japan significantly improved its technology by licensing foreign technologies and leapfrogged to a high level of technology during this period. In the 1980s Korea faced a similar situation to

⁴² Scale economies were an important source of productivity growth in that period.

Japan in the 1950s and 1960s in terms of its stage of technology catch-up. Technology imports played the major role in the 1980s in Korea, showing the same evolutionary pattern of technology development as Japan.

Technology imports were an easier and cheaper method of enhancing technology than domestic R&D efforts, because licensing costs were lower than R&D expenses and licensing was seen as safer than R&D. However, there were also some blocking strategies on the part of leader economies to prevent follower countries from obtaining state-of-the-art technology. Pack and Page (1994: 219–20) give some examples:

There is some statistical evidence and a growing subjective sense that arms length licensing is decreasing as an option for closing technology gaps. Potential licensors in the OECD countries have become wary of helping possible competitors, even if contracts preclude exports to third countries for the duration of the licences. Particularly in R&D intensive sectors such as chemicals, machinery, and electronics, firms are increasingly unwilling to license technology as they perceive royalties providing an inadequate return for an action which may impair their own long-term competitiveness. In effect, there is an imperfect or nonexistent market for critical technology transfers. Empirical studies find evidence that sales of licenses to LDCs contain a significant element of rent.

However, these blocking strategies do not appear to have been effective. Korea, having accumulated technological capability and spending large amounts on R&D expenditure after the 1980s, successfully dealt with the blocking strategies of leader countries. Added to this, Korea's industrial structure, characterised by large conglomerates, had the strength to proceed successfully with technology imports. According to Lee (1996: 199),

Technology imports [as well as R&D] take considerable technical, administrative and negotiation costs. Under capital market imperfection, which is often prevalent in LDCs [less developed countries], only firms with relatively strong internal financing ability will be able to afford technology imports. Technology imports also involve more risk, so that it may be undertaken by only firms more willing to take risk.

According to Japan's experience, R&D investments become more important in the final stage of technology catch-up following the third stage of growth in which technology imports play a major role. These two interact with each other and complete the technology catch-up. In the case of Taiwan, there was a relatively low level of local R&D until the 1980s, and the contribution of domestic technology in explaining TFP growth would appear to be limited. This means that Taiwan's economy has yet to arrive at the final stage of technology catch-up. However, Korea's situation is a little different. R&D investments and technology imports were boosted from the mid-1980s. The ratio of R&D to GNP has arrived at the level of developed countries (2.09 per cent in 1993, 2.32 per cent in 1994, 2.71 per cent in 1995 and 2.81 per cent in 1996), and a high level of technology licensing such as strategic alliances has occurred in electronics, computers, automobiles and aerospace.

The relationship between R&D efforts and technology imports is important in determining whether the economies are in the third stage or in the final stage of catch-up. Lee (1996) investigates this relationship in Korea. Korean manufacturing firms importing technology tend to commit themselves to R&D efforts through the establishment of formal R&D institutes. However, technology imports have no complementary relationship with R&D efforts among the firms with R&D institutes. Moreover, when analysed interactively with international innovative activity, technology imports will be shown to have a rather substitutive relationship with R&D efforts (Lee 1996: 206–7).

A substitutive effect rather than a complementary relationship between R&D efforts and technology imports suggests that Korea has not yet arrived at the final stage of technology catch-up, where technology imports and R&D efforts maximise each other's contribution to technological change. However, Lee uses 1984 rather than 1990s data. Thus, his result is not surprising because Korea was at the third stage of growth at that time, where technology imports were the major

vehicle of technological change and R&D investment was more closely related to learning than innovation.

In sum, it can be argued that there are various sources of technological change; informal technology transfer, capital-related technology transfer, technology imports and R&D in turn played significant roles in technological development in Korea (sequencing of technological change). In the initial phase of growth (1962–73), characterised by the transition from craft to modern labour-intensive industries, informal methods were the major avenues for technology transfer. In the second phase of growth (1973–83), characterised by heavy and petrochemical industrialisation, capital imports and reverse engineering were the main sources of technology transfer. Interactions between capital formation and technological change were dominant during this stage. In the third phase of growth (the 1980s), characterised by structural adjustment towards high-quality products within industries, technology imports became the major means of technology transfer. If Korea were in the final stage of growth, its technology imports and related R&D investment would interact with each other and show a complementary relationship. However, this is not yet clear. Innovation efforts become the sole source of technological change after this evolutionary process of technology catch-up is complete. The corollary is that innovative technological change is the major source of growth only for leader countries, for which other means of technological change are limited.

Technological change from follower countries' perspective

Productivity is defined as the degree of efficiency exhibited in the process of turning inputs into output. More specifically, total factor productivity describes the ratio of output to the combination of all inputs used. Meanwhile, technology is defined as a physical concept: the technology of production is a complete specification of the inputs and operations to be performed on them to create output of a given quality (Norsworthy and Jang 1993: 8). According to Tran and Urata (1995: 295), 'technology is often defined as systematic knowledge for the

manufacturing of a product, for the application of a process, or for the rendering of a service, including any integrally associated managerial and marketing techniques’.

Even though technology is closely related to productivity growth, it is not the same thing. To avoid conceptual confusion between them, growth accounting studies use a productivity index to measure technological change. According to this method, technological change is identical to the percentage rate of growth in total factor productivity: technological change is the driving force advancing productivity growth. Griliches (1973; 1979; 1980; 1986) also argues that technology is an output from consciously undertaken R&D investment. Thus, R&D activities play a key role in creating new technology and in enhancing productivity.

Growth accounting methods provide a good tool for calculating technological change for leader countries, which have no way to enhance productivity growth except through innovative R&D investment. However, as illustrated in the previous section, follower countries have ways of accomplishing technological change other than through R&D investment, such as information from buyers of exported goods and suppliers of capital goods, reverse engineering, imported capital goods and technology licensing. Accordingly, technology should be defined in broader terms as consisting of improved methods of doing things. In the words of O’Connor (1995: 57):

It [technology] may permit a more efficient transformation of inputs into outputs, or the production of a wholly new product or range of products. The improvements may be in hardware—for example, in capital equipment—but they may also involve organizational innovations or improvements in the quality of human capital.

When technology is defined in broad terms from follower countries’ point of view, it may be seen to take various forms. It may be embodied in physical capital, such as machinery, or in human capital, such as in the skills of engineers and managers, or it may be disembodied as in product design. These different

forms of technology suggest four channels for technological development in follower countries. First, technology can be developed by the R&D investment of a follower country. Creation of a new design (disembodied technology) generally requires substantial resources, both human and financial. R&D investment is also risky since there is no assurance that these investments will materialise in the form of new technology. The large investment and high risk associated with R&D investment are disadvantageous to follower countries, whose firms are generally characterised by their small scale and limited knowledge accumulation. Moreover, a follower firm has no incentive to concentrate on R&D efforts in the early phase of development since it has cheaper ways to develop technology, namely embodied technology transfer and technology import.

Second, technology can be acquired through importing capital goods such as machinery, in which technology is embodied. In this case the recipient acquires the technology by learning how to operate and utilise the machinery. Reverse engineering may be included in this category. Technology can also be transferred by recruiting foreign engineers or nationals who have experience studying and working abroad. This amounts to the purchase of technology embodied in engineers. Third, technology can be transferred through technology trade such as the sale of patented production processes. Technology transfer through arrangements such as production cooperation, technological cooperation and OEM is classified under this category. This type of technology transfer usually entails a long-term business relationship between the two parties, as remuneration accruing to the supplier usually depends on the performance of the recipient (measured in royalty payments for example). Fourth, technology can be transferred through foreign direct investment. FDI involves international transmission not only of financial capital, but also of technology, including managerial know-how. In the case of FDI, technology transfer takes the form of intra-firm transfer, whereas in other cases it usually takes the form of inter-firm transfer (Tran and Urata 1995: 296).⁴³

⁴³ Tran and Urata (1995) identify the second, third, and fourth means as the three channels of technology transfer. R&D efforts are a fourth source of technology development, even for developing countries.

Solow (1956) treats technology as an exogenously provided public input: a non-rival and non-excludable input. A purely rival good has the property that its use by one firm or person precludes its use by another. A good is excludable if the owner can prevent others from using it. Griliches (1973; 1979) assumes that technology has two components: an excludable component of the benefits of R&D and a non-excludable component, which is created as a side effect of producing the excludable component. This means that technology is accumulated by intentional R&D efforts. Growth accounting studies are based on these formulations of technology, which imply unbounded growth because of the non-rival property of technology.

Romer (1990) argues that technological change is endogenous in large part, and that innovative technology is non-rival, whereas the human capital component is rival. Applying this discussion to the findings in Chapters 2–5, technology has three components: the component embodied in physical capital, the component embodied in human capital, and a disembodied component, such as product design. When applied to a discussion of the properties of technology, embodied components are rival and bounded whereas the disembodied component is non-rival and unbounded. Physical and human capital cannot grow without limit. Thus, the fact that physical and human capital accumulation play a key role in the growth of East Asian NIEs implies bounded growth in this region. In this sense Krugman's criticism of unsustainable growth has some validity. However, his argument that there has been no technological change is more difficult to defend. Exploiting a rival component of technology, entering new industries or high-quality production with significant imports of capital goods, is a cheaper method of achieving technological change for follower countries and that is the reason for the high growth of the East Asian NIEs in the early stages of growth. After these opportunities have been exhausted, Singapore, Taiwan and Korea's firms concentrated on R&D investment to accumulate a non-rival component of technology. In summary, a low level of technological change may have occurred in the East Asian NIEs through the intentional actions of entrepreneurs seeking structural adjustment (diversification and quality change), and this can be seen as

a response to market incentives to exploit the advantages of follower countries. Following from this, the non-rival part of technology, the main concern of standard growth theory, becomes important.⁴⁴

Technology development and technology transfer in Korea

This section overviews technological development in Korea, paying special attention to changes in the vehicles of technology transfer from the 1980s. This section is motivated by the findings in earlier chapters that the technological paths of East Asian NIEs are quite different from those of developed countries.

As mentioned in the introduction, technological development in East Asian NIEs is closely related to structural adjustments. Table 6.1 summarises this feature. The first stage of growth in the 1960s is characterised by a production shift from craft to modern labour-intensive light industries. Declining production technologies were introduced in these industries. Technical assistance and information by foreign buyers and capital suppliers played a role in Korea's learning-by-doing. The focus of the industrial structure changed towards heavy and chemical industries in the second stage of growth in the 1970s and the early 1980s. During this stage, the major means of technology transfer was the import of capital goods and turnkey plants. Learning-by-doing through reverse engineering was also an important means of enhancing productivity. However, technology transfer through licensing increased dramatically in the third stage of growth in 1984–93, characterised by a production shift from low-quality products to high-quality products in established industries. During this period, technology imports were gradually liberalised, and R&D investments became important. Hong (1994a: 10–11) argues that 'technology transfer through foreign licensing increased dramatically to become the important means of technology import'. When

⁴⁴ There is also the question of whether, for some economies, the rival component can be important continuing element, given centres of innovation elsewhere in the world.

technology licensing was recognised not to be useful in transferring frontier technology in the early 1990s, FDI and strategic alliances were emphasised.⁴⁵

Table 6.1 Technology transfer and industrial structure in Korea

	1960s	1970s–early 1980s	mid 1980s– 1993	1994–
Major sources of growth	Productivity	Capital	Capital and productivity	Productivity
Industrial structure	Labour-intensive light industries	Heavy and petrochemical industries; Capital- and skill-intensive	High-quality products in capital- and technology-intensive industries	High value-added industries
Technology policy	Control of FDI and technology imports	Conditional liberalisation of technology imports	Liberalisation of technology imports; Encouragement of R&D in private sector	Encouragement of R&D in private sector; Perfect liberalisation of technology imports
Vehicles of technology transfer	Informal methods	Capital imports, technology imports	Technology imports	FDI, strategic alliances
Technology product cycle	Declining stage	Declining and mature stage	Growing stage	Frontier technology

Source: Compiled by the author using Hong (1994a: 9).

The basic indicators of technology development in Korea are illustrated in Figure 6.1. According to Panel A, the ratios of R&D expenditure to GNP and researchers per one thousand persons show two structural changes. Their growth rates increased in the early 1980s, when R&D investment was encouraged and the liberalisation of technology imports was under way, and in the early 1990s, when transfer of frontier technology was emphasised and the means of technology

⁴⁵ FDI policy was liberalised in 1991; the FDI notification system was changed from a positive list system (listing those industries open to FDI) to a negative list system.

transfer had been diversified from technology licensing to strategic alliances and FDI.

Panel B shows the trends in the indexes of R&D expenditure, technology licensing (technology import) and number of researchers in log values.⁴⁶ R&D expenditure and technology licensing (amount) show a similar trend while the number of researchers and cases of technology licensing follow this trend only until a significant decline in technology licensing takes place in 1991–92.

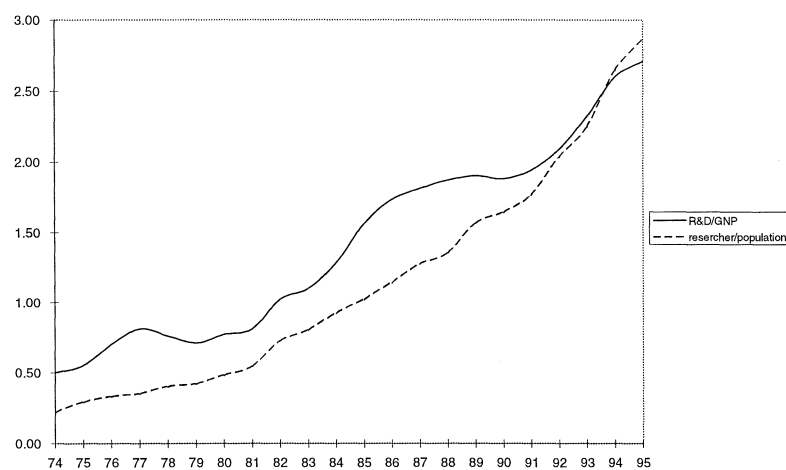
According to Hong (1994a: 16), technology licensing declined in that period because of the domestic recession and increased technological protectionism by developed countries. However, this is not quite accurate when increasing trends in R&D expenditure and number of researchers are considered. The decline in technology licensing from the 1990s may be due to the fact that this became an ineffective means when Korean firms required frontier technologies rather than technologies from mature or growing stages. This is consistent with the rise of strategic alliances with leader firms and increasing trends in R&D expenditure and employment of researchers.

Panel C shows changes in the composition of R&D expenditure over time. The share of private R&D expenditure in total expenditure increased dramatically from the late 1970s, and reached more than 80 per cent in the 1990s. In this regard, Korea is similar to Japan in its emphasis on applied rather than basic research. Korea has already arrived at the technology level of developed countries in terms of the ratio of R&D expenditures to GDP and the number of researchers (see Table 6.2). These facts imply that Korea is at the final stage of growth. However, there is still a big gap between Korea and other developed countries in technology indicators such as amount of R&D expenditure, amount of R&D expenditure per researcher, technology trade and the number of science and technology papers published (Table 6.2).

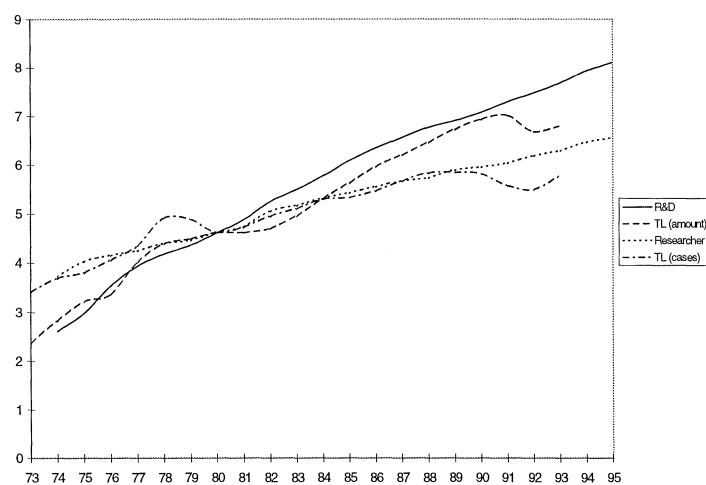
⁴⁶ The index for these data is 1980=100.

Figure 6.1 Korea: basic indicators of technology

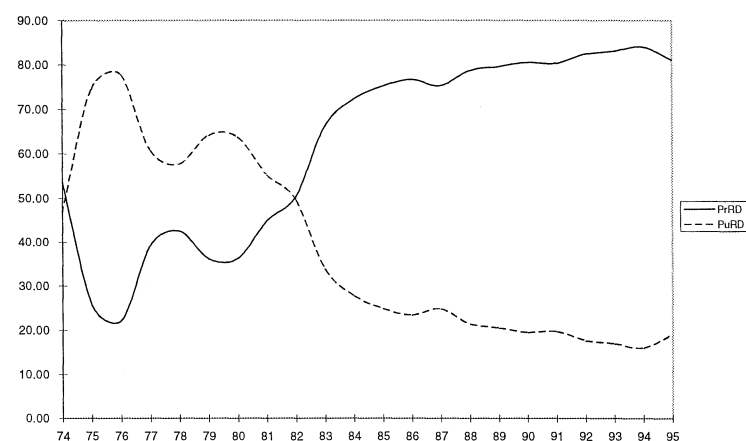
Panel A



Panel B



Panel C



Note: TL: technology licensing, PrRD: private R&D share, PuRD: government R&D share.

Source: Internet: <http://www.most.go.kr/research/>. *Report on the Survey of Research and Development in Science and Technology 1994*, Ministry of Science and Technology, ROK.

Table 6.2 International comparisons of technology indicators

	Korea (1996)	USA (1996)	Japan (1996)	Germany (1996)	France (1995)	U. K. (1995)
R&D expenditures						
Ratio to GDP (%)	2.79	2.54	3.00	2.26	2.34	2.05
Amount (US\$ m)	13522	184665	138619	53070	35954	22610
Multiplier (Korea = 100)	100	1370	1030	390	270	170
Gov't: private:foreign (%)	22:78	34:64	21:79	37:61 ⁹⁵	45:47	32:55
Researchers						
Number of researchers (thousand persons)	132.0	962.7 ⁹³	673.4	229.8 ⁹³	149.2 ⁹⁴	148.0 ⁹⁴
R&D exp. per researcher (US\$ thousand)	102.4	172.3 ⁹³	205.8	201.9 ⁹³	212.0 ⁹⁴	151.1 ⁹⁴
Multiplier (Korea = 100)	100	170	200	200	210	150
Technology Trade						
Payments (US\$ m)	946.4	4748.2	7177.2 ⁸⁹	3041.4 ⁸⁹	2656.7	2734.7 ⁸⁹
Receipts(US\$ m)	45.1	20413.7	3676.8 ⁸⁹	1560.3 ⁸⁹	1801.9	2777.9 ⁸⁹
Number of papers (97 SCI survey, thousand cases)	9.1	284.2	67.5	66.0	46.6	75.5

Note: 1) The ranking of Korea in number of papers is 17th, while Taiwan and Hong Kong's rankings are 20th and 30th, respectively.

Source: Internet: <http://www.most.go.kr/research/>. *Report on the Survey of Research and Development in Science and Technology 1994*, Ministry of Science and Technology, ROK.

An interesting aspect is that the ratio of R&D expenditure to GDP in Korea is rather high in spite of the relatively large technology gap between Korea and developed countries. This arises from the fact that R&D investment for follower countries increased to imitate the frontier technologies essential in the 1990s at a greater rate than in the 1960s. This is also consistent with a slowdown in technology licensing in 1991–93. The large role of R&D and the relatively small role of technology imports in Korea in 1990 differs somewhat from the Japanese experience in the 1960s, when technology licensing was the most important vehicle of transfer for frontier technologies. This may be due to changes in the world economic environment. The United States, a leader country, underwent rapid technological change and related structural adjustments, so technology transfer to Japan was not a big problem in the 1960s. Later, technology catch-up and structural adjustment in developing economies became more difficult as the market for new technology tightened.

The evolutionary pattern of technology transfer in Korea, starting from a lower level of technology and moving towards a more advanced one was similar to the experience of Japan. In particular, technology licensing increased markedly in 1982–91, confirming the fact that it had become a major source of growth in the 1980s. However, Korea has been more dependent on capital imports than Japan for its technology transfer (see Table 6.3). For Japan, technology imports played a major role in the final stage of technology catch-up, but in Korea R&D investment and strategic alliances became important.

Table 6.3 Technology transfer by form to Korea, 1962–91
(US\$ million)

	1962–66	1967–71	1972–76	1977–81	1982–86	1987–91
FDI	47.4	219.0	879.4	720.9	1,767.6	5,636.0
Foreign licensing	0.8	16.3	96.5	451.4	1,184.9	4,359.4
Technical consultation		16.8	18.5	54.7	332.3	1,349.7
Capital goods imports	316	2,541	8,841	27,978	44,705	52,155

Source: Yoo Soo Hong (1994a: 11).

The evolutionary pattern of technology development in Korea can be identified by technology trade data. According to Table 6.4, technology exports increased in the early 1980s and reached a peak in 1983, and then decreased in 1983–88. After 1988, technology exports increased again. These movements in technology exports are quite different from technology imports, which increased until the 1991 recession. The ratio of technology exports to technology imports, a proxy for technology independence, thus shows the same movement as technology exports. The increases in the ratio in 1981–83 are consistent with the transfer of labour-intensive processes, whereas the decreasing trend in 1983–88 was induced by structural adjustments from capital-intensive to capital- and technology-intensive processes. Another increase in 1988–93 marks the end of the structural adjustment of the previous period and signals the fact that capital-intensive processes had been transferred abroad.

Table 6.4 Technology exports and imports, 1981–93

	1981	1982	1983	1984	1985	1986	1987
Exports							
(A, US\$m)	11.8	18.2	18.9	16.9	11.3	11.7	9.1
Imports							
(B, US\$m)	107.1	115.7	149.5	213.2	295.5	411.0	523.7
Ratio							
(A/B, %)	0.11	0.16	0.13	0.08	0.04	0.03	0.02
	1988	1989	1990	1991	1992	1993	
Exports							
(A, US\$m)	8.9	10.5	21.8	35.2	32.5	45.1	
Imports							
(B, US\$m)	676.3	888.6	1,087	1184	850.6	946.4	
Ratio							
(A/B, %)	0.01	0.01	0.02	0.03	0.04	0.05	

Source: *Report on the Survey of Research and Development in Science and Technology 1994*, Ministry of Science and Technology, ROK.

Table 6.5 shows Korea's technology imports by country. Technology imports were valued at US\$ 7906.3 and 8766 cases in 1962–93. The United States' share was 47.0 per cent while its share in total cases was 27.1 per cent. In contrast, Japan's share was 32.0 per cent while its share in total cases was 49.4 per cent. Thus, the United States is the major exporter of technology in terms of value while Japan is the major exporter in terms of cases. Average payment per case from the United States was US\$ 1591 and that from Japan was US\$ 584. This implies that more high-level technologies are imported from the United States than from Japan. According to Yoo (1993: 57–60), this is because technologies from Japan were imported by small and medium-size firms, and that imported technologies were process-related technologies in the mature stage of the product cycle. Technology imports from Japan contrast with the United States, which transfers technologies in the early stage of the product cycle to establish a competitive advantage in the world market.

The leading industry in technology imports is electronics. According to Table 6.6, the share of electronics in total imports is 40 per cent by value and 26.6 per cent by cases. Electronics is followed by machinery industry. Its share is 20.1 per cent by value and 26.2 per cent by cases. The third is chemicals and refining, with 16.5

and 18.5 per cent of shares by value and cases, respectively. These figures are roughly consistent with structural adjustment in the 1980s towards high-quality products in heavy and chemical industries established in the 1970s.

Table 6.5 Technology imports by nation, 1962–93

Panel A (value and number)

	1962 –76	1977 –81	1982 –86	1987	1988	1989	1990	1991	1992	1993	Total
Amount (US\$m)											
USA	29.7	159.2	602.7	239.9	333	415.7	514.1	622.2	452.5	418.4	3784.5
Japan	63.7	139.8	323.7	181.4	214.7	273.9	341.4	372.2	266.2	352.9	2530.2
Germany	8.2	14	49	18.6	22.1	52.8	59.3	60.1	27.1	53.3	364.5
France	1.6	14.3	34.7	25.1	47.9	39.9	29.9	48.9	56.1	32.6	331
Others	10.4	124.1	174.8	58.7	61.6	106.3	142.3	80.4	48.7	89.2	896.1
Total	113.6	451.4	1184.9	523.7	676.3	888.6	1087	1183.8	850.6	946.4	7906.3
Cases											
USA	164	302	515	180	200	244	221	165	163	224	2378
Japan	494	631	1074	307	354	343	333	277	232	285	4329
Germany	23	70	122	35	49	37	55	35	26	31	482
France	7	39	82	40	47	41	25	26	18	23	348
Others	64	183	285	75	101	98	104	79	94	144	1229
Total	752	1225	2078	637	751	763	738	582	533	707	8766

Panel B (per cent)

	1962 –76	1977 –81	1982 –86	1987	1988	1989	1990	1991	1992	1993	Total
Amount											
USA	26.14	35.27	50.87	45.81	49.24	46.78	47.30	52.56	53.20	44.21	47.87
Japan	56.07	30.97	27.32	34.64	31.75	30.82	31.41	31.44	31.30	37.29	32.00
Germany	7.22	3.10	4.14	3.55	3.27	5.94	5.46	5.08	3.19	5.63	4.61
France	1.41	3.17	2.93	4.79	7.08	4.49	2.75	4.13	6.60	3.44	4.19
Others	9.15	27.49	14.75	11.21	9.11	11.96	13.09	6.79	5.73	9.43	11.33
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Cases											
USA	21.81	24.65	24.78	28.26	26.63	31.98	29.95	28.35	30.58	31.68	27.13
Japan	65.69	51.51	51.68	48.19	47.14	44.95	45.12	47.59	43.53	40.31	49.38
Germany	3.06	5.71	5.87	5.49	6.52	4.85	7.45	6.01	4.88	4.38	5.50
France	0.93	3.18	3.95	6.28	6.26	5.37	3.39	4.47	3.38	3.25	3.97
Others	8.51	14.94	13.72	11.77	13.45	12.84	14.09	13.57	17.64	20.37	14.02
Total	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: *Report on the Survey of Research and Development in Science and Technology 1994*, Ministry of Science and Technology, ROK.

Table 6.6 Technology imports by industry, 1962–93
(per cent)

	1962 –76	1977 –81	1982 –86	1987	1988	1989	1990	1991	1992	1993	1962 –93
Amount (US\$m)											
Food	1.76	0.73	1.38	0.82	0.77	1.00	0.87	1.22	1.05	0.88	1.03
Textiles and clothing	8.27	4.03	1.86	1.58	1.23	1.49	1.33	2.13	2.80	2.79	2.14
Pulp and paper	0.09	1.64	0.06	0.06	0.06	0.11	0.11	0.19	0.26	0.16	0.21
Chemicals, refining	29.75	32.79	13.82	12.49	16.58	17.05	19.97	15.81	13.03	12.57	16.54
Ceramic, Cement	0.97	2.33	2.41	1.28	1.01	2.89	1.44	1.54	2.86	1.17	1.88
Metals	21.04	7.09	3.11	2.29	0.89	1.18	0.79	0.58	1.08	1.92	2.08
Electronics	15.67	14.67	30.19	37.66	39.18	43.71	43.03	39.92	52.97	54.28	40.44
Machinery	12.85	19.78	20.11	22.86	17.86	17.39	19.91	27.36	14.82	19.73	20.12
Shipbuilding	4.49	2.48	7.78	2.22	0.89	1.40	1.49	2.88	0.59	2.36	2.73
Electricity	2.46	5.63	14.67	14.32	16.83	9.93	7.35	5.58	8.02	1.07	8.89
Others	2.64	8.84	4.61	4.43	4.72	3.86	3.71	2.79	2.53	3.09	3.93
Total	100	100	100	100	100	100	100	100	100	100	100
Cases											
Food	1.99	2.45	4.86	3.61	2.00	2.88	2.44	2.75	2.25	2.40	3.08
Textiles and clothing	5.05	3.35	6.11	5.81	6.92	7.34	5.96	6.36	3.38	6.22	5.64
Pulp and paper	0.93	0.57	0.14	0.31	0.53	0.39	0.14	0.17	0.00	0.99	0.40
Chemicals, refining	23.40	18.37	17.90	21.19	21.44	19.66	18.70	18.04	13.70	12.87	18.50
Ceramic, Cement	2.79	2.78	2.41	3.92	2.66	2.88	3.52	2.23	2.25	0.99	2.64
Metals	9.84	8.57	5.39	4.87	3.46	3.01	2.85	2.23	2.25	2.12	4.95
Electronics	23.94	18.45	24.11	25.75	28.23	30.28	29.67	30.58	36.40	33.66	26.75
Machinery	23.94	32.90	26.28	23.23	24.10	20.71	23.58	25.95	30.96	28.29	26.23
Shipbuilding	1.46	3.67	4.52	2.04	1.86	1.31	1.90	2.06	2.25	0.85	2.64
Electricity	1.20	3.02	1.15	1.10	0.53	0.66	0.41	0.00	0.56	0.99	1.13
Others	5.45	5.88	7.12	8.16	8.26	10.88	10.84	9.62	6.00	10.61	8.05
Total	100	100	100	100	100	100	100	100	100	100	100

Source: *Report on the Survey of Research and Development in Science and Technology 1994*, Ministry of Science and Technology, ROK.

Table 6.7 contrasts technology imports from Japan and the United States.

According to the table, the leading industries in technology imports from the United States are electronics (38.3 per cent of total imports), chemicals and refining (18.4 per cent) and machinery (16.6 per cent). In the case of Japan, machinery had a much larger share (32.0 per cent) than electronics (24.5 per cent)

or chemicals and refining (19.6 per cent). This difference in the direction of technology imports is another reason that average per case payment from the United States was higher than from Japan.

**Table 6.7 Technology imports from United States and Japan,
31/12/93, cases (per cent)**

	United States	Japan	Total
Food	4.3	2.7	3.1
Textiles and clothing	4.3	3.9	5.6
Pulp and paper	0.5	0.4	0.4
Chemicals, refining	18.4	19.6	18.5
Ceramic, cement	1.7	3.2	2.6
Metals	3.5	5.7	5.0
Electronics	38.3	24.5	26.8
Machinery	16.6	32.0	26.2
Shipbuilding	1.2	1.2	2.6
Electricity	1.9	1.6	1.8
Others	8.8	5.7	8.1
Total	100.0	100.0	100.0

*Source: Report on the Survey of Research and Development in Science and Technology 1994,
Ministry of Science and Technology, ROK*

The role of FDI in technology transfer to Korea had not been large until the 1980s, but FDI rapidly increased from the late 1980s, in particular from 1991. Korean firms realised that frontier technology was difficult to acquire, and diversified their means of technology transfer in the 1990s. According to Table 6.8, Japan far surpassed the United States in FDI to Korea. Japan's share in total FDI is 39.8 per cent by value and 54.5 per cent by cases, whereas the United States' share is 29.2 and 23.9 per cent, respectively. Japan's lead in FDI contrasts with that of the United States in technology imports. The small role of FDI in technology transfer in Korea is due to Korea's industrial and technology policies. Local firms determined which industries and processes to enter and coordinated the import of capital and technology, using foreign capital and domestic savings. This mechanism is the same as FDI in that foreign savings are transferred to a recipient country along with imported capital goods. The difference is that local entrepreneurs rather than multinational corporations organised these production activities in Korea.

Table 6.8 FDI to Korea, 1962–93

	1962 –66	1967 –71	1972 –76	1977– 81	1982– 86	1987– 91	1992	1993	1962– 93	share in total (%)
USA										
Amount (US\$ m)	25	95	134	235	582	1,478	379	341	3,270	29.2
Cases	25	85	78	67	168	463	70	69	1,025	23.9
Japan										
Amount (US\$ m)	8	89	627	30	876	2,122	155	286	4,466	39.8
Cases	5	241	739	132	276	788	72	85	2,337	54.5
Others										
Amount (US\$ m)	14	34	118	185	309	2,046	360	417	3,473	31.0
Cases	9	34	50	52	135	425	94	125	924	21.6
Total										
Amount (US\$ m)	47	218	879	720	1,767	5,636	894	1,044	11,209	100.0
Cases	39	360	867	251	579	1,676	236	279	4,286	100.0

Source: Hong (1994b: 21).

Technology imports, R&D investment and productivity growth

The aim of this section is to verify empirically the relationship between technology imports and productivity growth and that between R&D investment and productivity growth.

Section 2 of this chapter formulated a framework for understanding the sequencing of the sources of technological change, and the earlier part of this section overviewed technological development in Korea. This suggested that technology imports were the major source of technological change in Korea in the 1980s. A linear regression is performed to verify this relationship, using the data on productivity growth in Chapter 3. Formal tests of unit roots and cointegration are performed. Data for the absolute level of TFP and technology import certainly have unit roots but these two variables are not cointegrated. This lack of cointegration may be due to small sample bias: we have only 16 useable observations to test the hypothesis of no cointegration. Expanding the estimation period is not desirable because capital-related and informal methods were major sources of technological change in the early stages of growth. Thus, I focus on the

relationship between two series of differenced data instead of levels of TFP and technology imports. This can be rationalised as follows: the concern of the analysis is to find a variable determining TFP growth rather than a TFP index, and TFP level data are calculated from the TFP growth data. The regression results using differenced data are as follows:

$$\Delta \log(TFP) = 0.029 + 0.078 * \Delta \log(TL)$$

(4.28) (3.37)

$$\text{Adjusted } R^2 = 0.35, D-W \text{ statistic} = 1.11$$

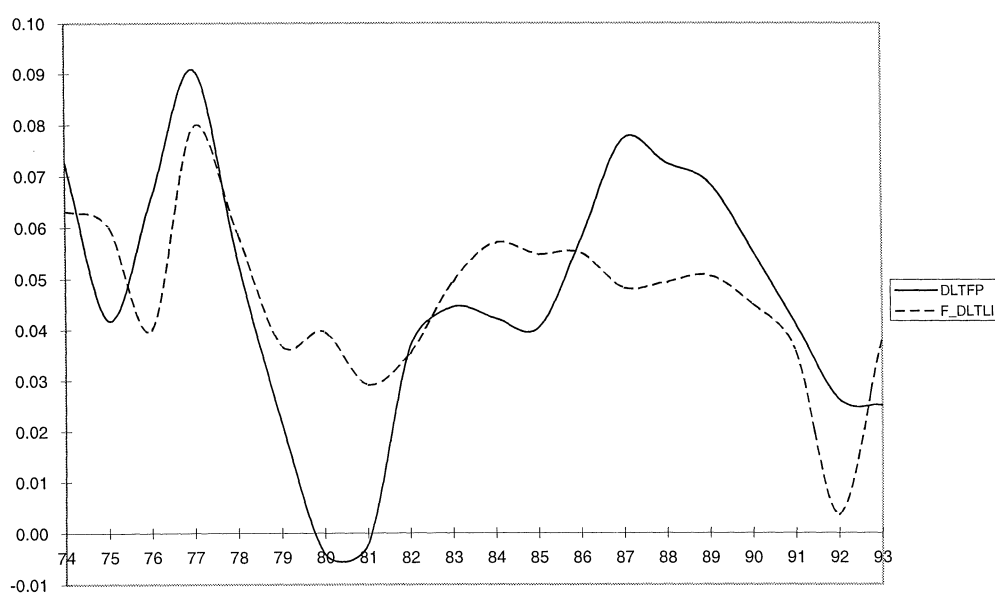
where *TFP* and *TL* represent the indexes of productivity and the value of technology licensing values (amount of technology imports).

Even though the *t*-statistics for the coefficients are good and the sign of the coefficient of technology imports is positive, the low adjusted R^2 and *D-W* statistic present problems, and suggest that another explanatory variable should be included. Inclusion of lagged variables, however, do not improve the regression results: the worsening *D-W* statistic, and the earlier argument of a sequencing pattern in vehicles of technological change suggest no other option. These results can be validated as follows. According to Panel A of Figure 6.2, the fitted value of TFP growth moves along the path of actual TFP growth. The gap between actual and fitted TFP growth arises from three factors. First, the actual value reveals a bigger fluctuation than the fitted value because of the demand factor, as shown in analysing the interaction between capital accumulation and productivity growth. Second, the two values reveal a negative relationship in 1991–93, as shown in the earlier part of this section. Third, the graph shows structural change around 1980 before 1980s: actual TFP lagged behind fitted TFP growth. This phenomenon can also be explained by the earlier part of this chapter: technology imports became a major source of technology transfer from the early 1980s, as outlined in the argument in the earlier part of this chapter. These three factors are reasons for the low R^2 in the above estimation, but they do not constitute a significant theoretical basis for diminishing the link between

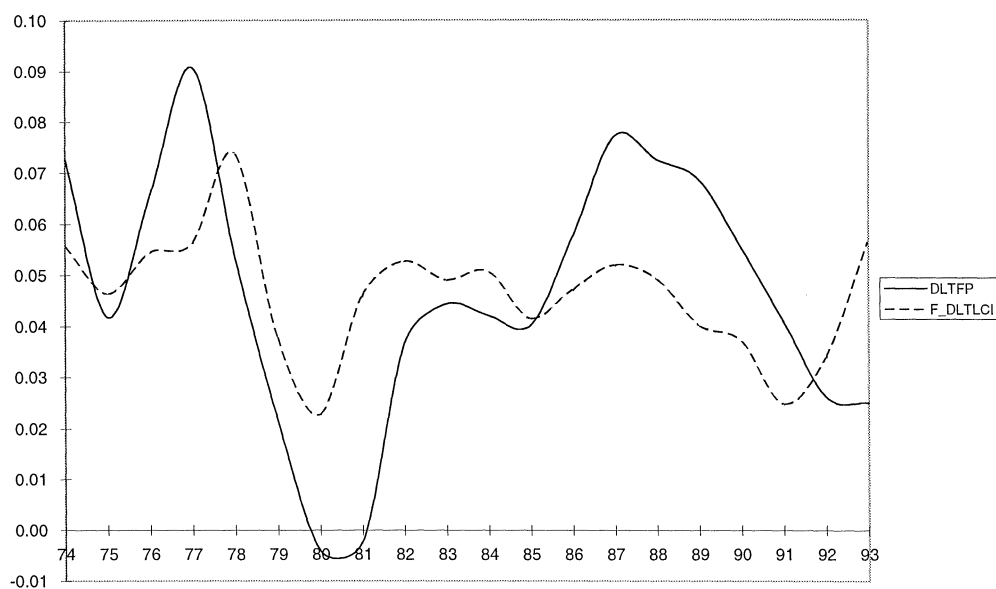
technology imports and productivity growth. In this respect, the estimation result can be validated empirically.

Figure 6.2 Technology imports and productivity growth, 1974–93

Panel A



Panel B



Notes: 1) DLTFP is $\Delta \log(\text{TFP})$.
 2) F_DLTLI is the fitted value of the regression in which the explanatory variable is the amount of technology import, while F_DLTLCI is the fitted value of the regression in which the explanatory variable is the number of cases of technology import.

Source: Author's calculation.

The second panel of Figure 6.2 shows the actual and fitted values of TFP growth when a regression is performed using cases of technology imports instead of value of technology imports. Actual and fitted TFP growth show closer movements than was the case in the first estimation. The regression results are as follows:

$$\Delta \log(TFP) = 0.039 + 0.061 * \Delta \log(TLC)$$

(6.49) (2.23)

$$\text{Adjusted } R^2 = 0.17, D-W \text{ statistic} = 0.82$$

where *TLC* represents the index of cases of technology licensing.

In sum, technology imports are a significant source of productivity growth in Korea in the 1980s.

Griliches (1973; 1979; 1980; 1986) argues that R&D investment is the driving force behind enhanced productivity growth, and this position is explicitly and implicitly accepted by growth accountants. However, earlier chapters of this thesis found that this is not the case. R&D investment become a major source of productivity growth followed by technological change after arriving at the final stage of growth. This suggests that R&D investment does not have a significant effect on productivity growth in the case of Korea. Simple regressions are performed to verify empirically the relationship between R&D investment and productivity growth. As in the case of the regression by technology imports, the number of observations is quite small (the number of useable observations is at most 17), so a formal regression based on unit root and cointegration relationship is impossible. However, the validity of simple regression has been justified theoretically by Griliches (1973; 1979). The best regression results are obtained as follows:

$$\begin{aligned}
\Delta \log(TFP) = & -0.017 - 0.087*RDGP + 0.112*RDGP(t-1) \\
& (-1.05) \quad (-1.96) \quad (1.53) \\
& + 0.096*RDGP(t-2) - 0.094*RDGP(t-3) \\
& (1.23) \quad (-1.32) \\
& - 0.036*RDGP(t-4) + 0.001*RDPR \\
& (-0.88) \quad (1.46)
\end{aligned}$$

$$\text{Adjusted } R^2 = 0.72, D-W \text{ statistic} = 2.01$$

where *RDGP* and *RDPR* represent R&D–GDP ratio and the share of private R&D share in total R&D investment.

Panel A of Figure 6.3 shows the movements of the actual and fitted values of the regression equation. R&D investment seems to explain TFP growth successfully. Exclusion of the share of private R&D from the explanatory variable leads to similar results. The following estimation is the best among them: Panel B shows the actual and fitted productivity growth in this case, confirming a positive but weak relationship between productivity growth and R&D investment.⁴⁷

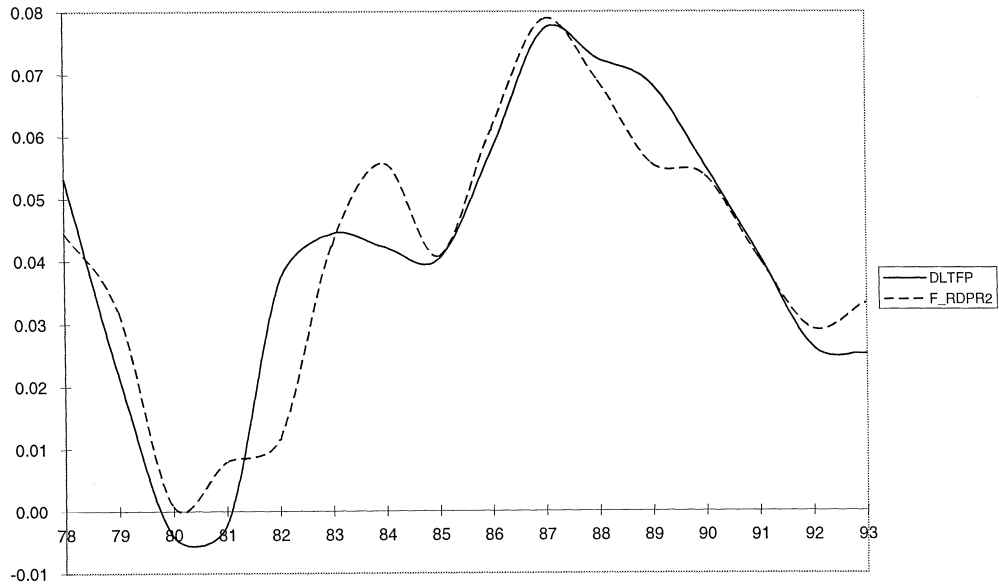
$$\begin{aligned}
\Delta \log(TFP) = & 0.001 - 0.055*RDGP + 0.131*RDGP(t-1) \\
& (0.19) \quad (-1.34) \quad (1.71) \\
& + 0.078*RDGP(t-2) - 0.095*RDGP(t-3) - 0.041*RDGP(t-4) \\
& (0.95) \quad (-1.26) \quad (-0.95)
\end{aligned}$$

$$\text{Adjusted } R^2 = 0.72, D-W \text{ statistic} = 2.01$$

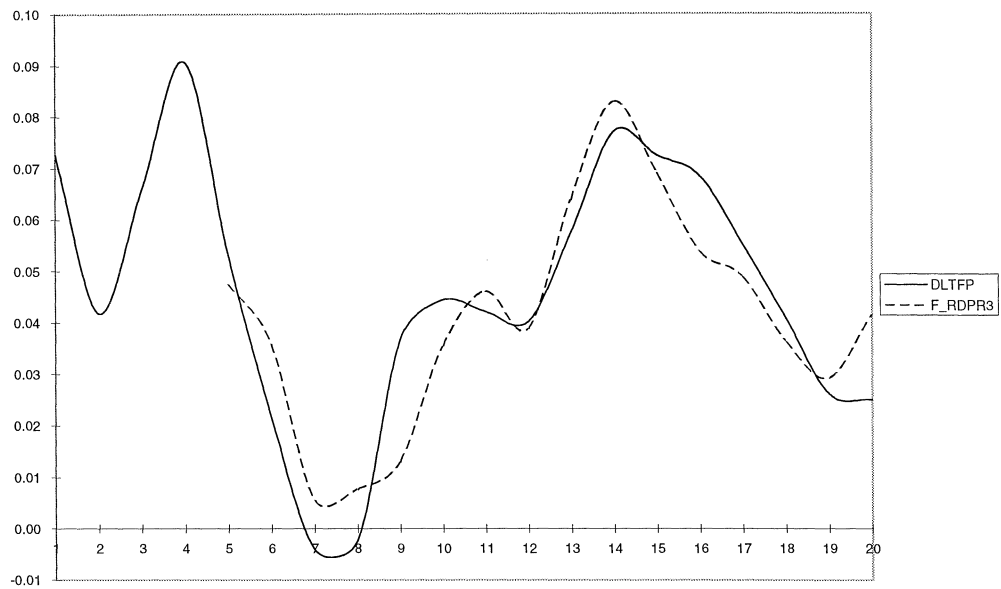
⁴⁷ Because of the complementary relationship between R&D and technology import, it may be that private R&D is important to productivity growth through its interaction with technology import. However, inclusion of a technology import variable in the regression did not improve the empirical result.

Figure 6.3 R&D investment and productivity growth, 1977–93

Panel A



Panel B



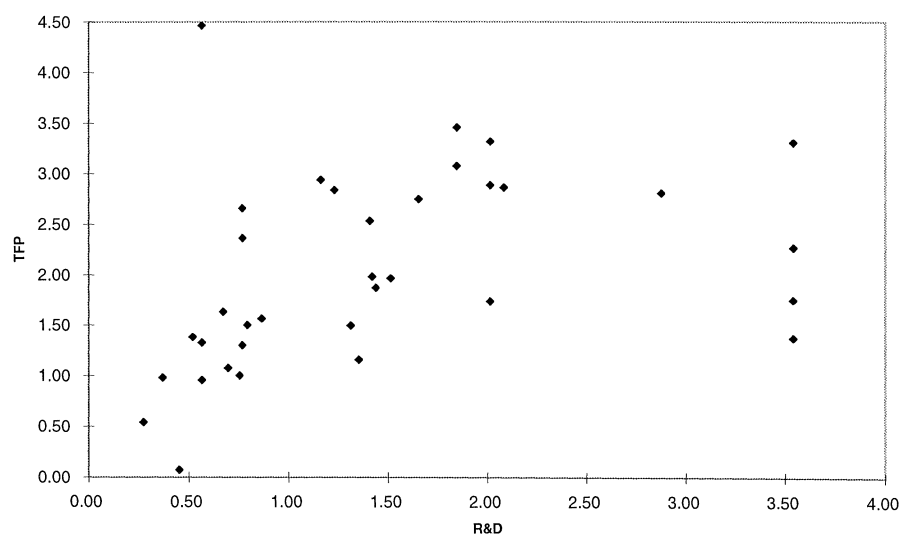
Notes: 1) DLTFP is $\Delta \log(\text{TFP})$.
 2) F_RDPR2 is the fitted value of the regression in which the explanatory variables are R&D–GDP ratio and private R&D share in total R&D, while F_RDPR3 is the fitted value of the regression in which the explanatory variable is the R&D–GDP ratio.

Source: Author's calculation.

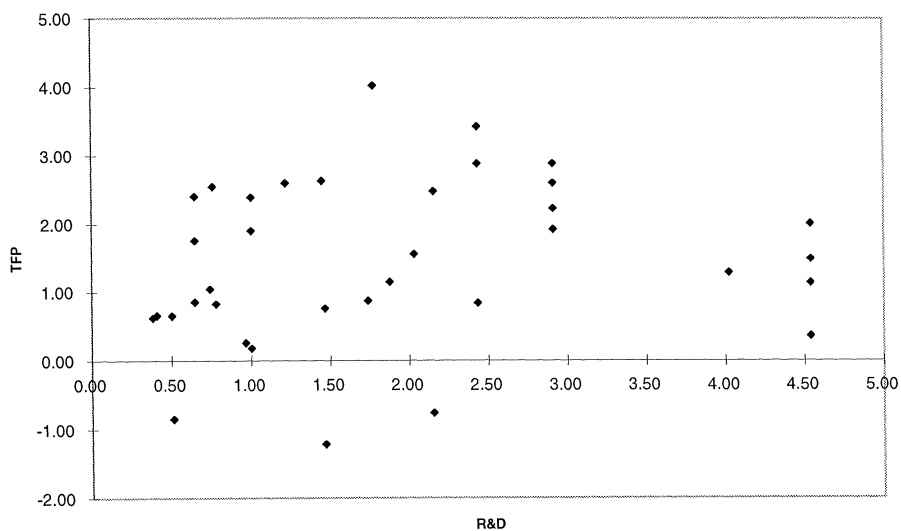
Cross-section analysis, however, rejects the hypothesis of a positive relationship between the two variables. Figure 6.4 plots the scattergram of R&D–sales ratio (horizontal axis) and productivity growth (vertical axis) of 36 Korean manufacturing industries. First the scattergram shows the possibility of a positive relationship between the ratio of average R&D to sales in 1979–93 and average productivity growth in the same period (Panel A), while the Panel B shows the relationship between the ratio of average R&D to sales in 1988–93 and average productivity growth in the same period. Both pictures strongly imply that R&D investment and productivity growth are not correlated with each other in the case of Korea’s manufacturing industries.

Figure 6.4 productivity growth and R&D–sales ratio across industries

Panel A:1979–93



Panel B:1988–93



Notes: 1) TFP means productivity growth calculated under a 3-input growth accounting framework, while R&D means R&D–sales ratio of each industry.

2) The regression result of the Panel A is as follows:

$$\text{TFP} = 1.510 + 0.379 \cdot \text{R\&D}, \text{ Adjusted } R^2 = 0.11.$$

(5.46) (0.16)

3) The regression result of the Panel B is as follows:

$$\text{TFP} = 1.151 + 0.160 \cdot \text{R\&D}, \text{ Adjusted } R^2 = 0.001.$$

(1.15) (0.16)

Source: KDI dataset.

Summary

The discussion about East Asian growth in earlier chapters introduced the importance of two ideas: sequencing of the sources of technological change and a broader definition of technology.

Section 2 introduced the sequencing of the sources of technological change. The major channels of technology development and transfer changed over time. Informal methods of acquiring old technologies were the major source in the initial stage of growth, and capital import followed in the next stage. Then technology imports played the major role in the third stage of growth, characterised by a production shift to high-quality products. This also suggests

that R&D investment becomes a important source of growth from the final stage of technology catch-up.

Section 3 puts forward a definition of technological change applicable to follower countries. It includes rival but bounded embodiment components which have played a crucial role in the growth of East Asian NIEs in the last three decades. This broader definition provides an understanding of why extraordinary growth and technology catch-up is possible, and why the high growth rates will be lowered ultimately unless non-rival components of technology are developed by R&D efforts.

Section 4 investigated technological developments in Korea, with a special focus on the relationship between technology imports and productivity growth and between R&D investment and productivity growth. Basic R&D indicators suggest that Korea may be at the final stage of technology catch-up. This section also identified the major sources of technological change over stages, and concluded that sequencing of vehicles of technological change was correspondent to structural adjustments over stages. The effect of technology imports on productivity growth is positive and significant in linear regression but a regression of productivity growth by R&D investment did not produce significant results, as expected.

Appendix 2 sought to find the reason for the difference between the technological paths of NIEs and those of developed countries. It is argued that follower countries have enjoyed a favourable world economic environment characterised by the rapid technological change and deepening interdependence and roundaboutness of production achieved by leader countries. Under these circumstances, East Asian countries have successfully dealt with technological and marketing barriers in different ways: specialisation in labour-intensive industries characterised by low barriers, participation in small set of tasks for multinational corporations, and local firms' organisation of state-of-the-art production utilising imported capital and intermediate goods. These favourable

world economic conditions and appropriate reactions to these environments were the reason why the technological paths in NIEs were quite different from leader countries.

7 Summary and Conclusion

In previous attempts to identify the reason for the remarkable growth in NIEs, growth accounting exercises have been employed to examine whether productivity growth is the major source of output growth. The results suggested that capital accumulation rather than productivity growth was the main source of economic growth (Westphal, Kim and Dahlman 1985; Chenery, Robinson and Syrquin 1986; Young 1992; 1994; 1995; Kim and Lau; 1993; 1994a; 1994b; 1996; Collins and Bosworth 1996). These results led to the inference that growth in NIEs and other Asian countries is unsustainable.

These studies are deficient in that they lack careful consideration of the ways that growth paths taken in follower countries differ from those of developed countries, and there is no consideration of the implications of the mechanical properties of growth accounting.

According to the growth accounting scheme, productivity growth (ϑ_T) is calculated as residual as follows:

$$(7-1) \quad \vartheta_T = \Delta \ln V(T) - \vartheta_K \Delta \ln K(T) - \vartheta_L \Delta \ln L(T),$$

where ϑ_K , ϑ_L and ϑ_T represent the average value shares of inputs.

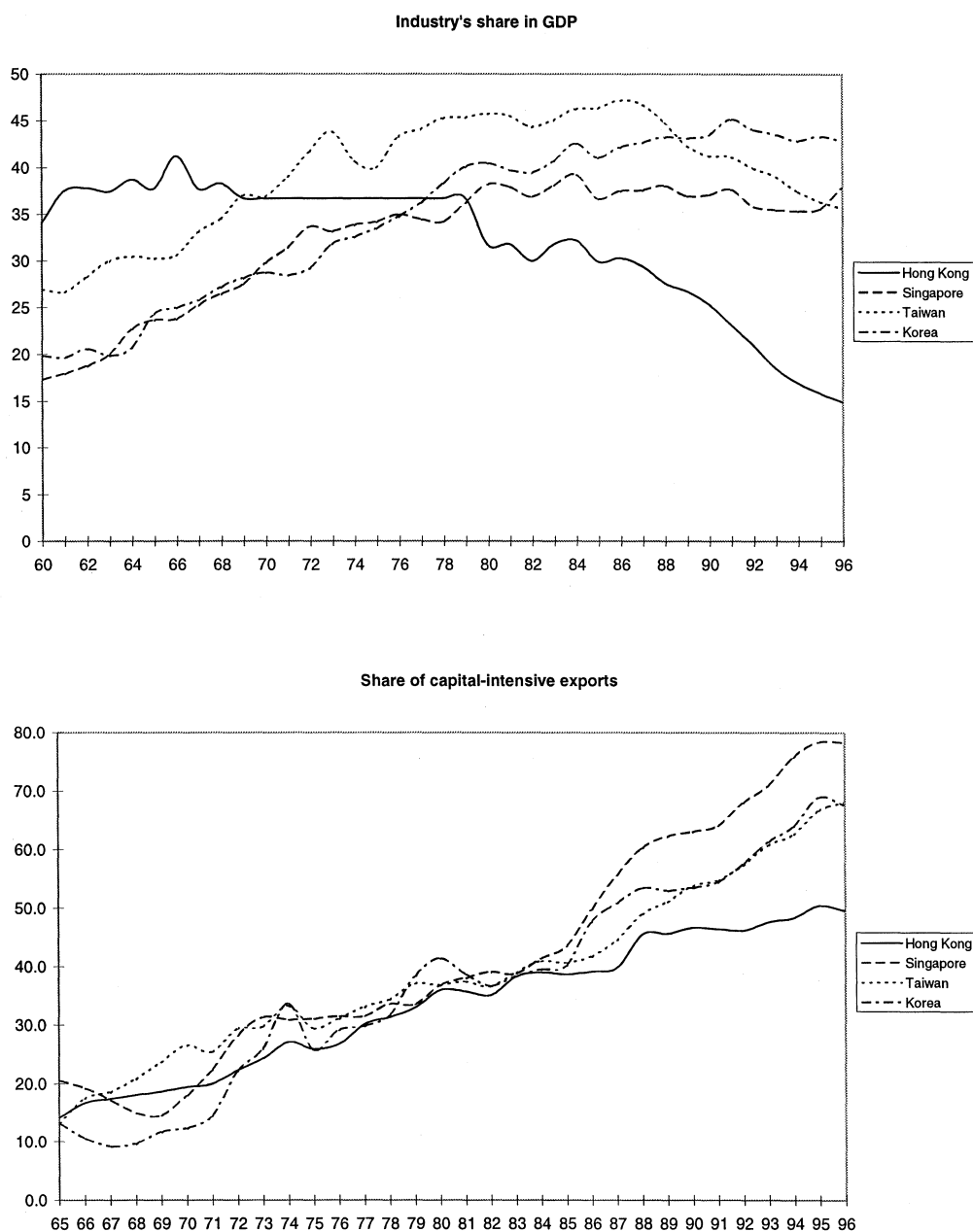
If a linear-homogeneous Cobb–Douglas production function is assumed, the equation (7-1) can be expressed more simply:

$$(7-2) \quad \vartheta_T = \Delta \ln y(T) - \vartheta_K \Delta \ln k(T),$$

where $y = V/L$ and $k = K/L$.

Thus, a high capital share (low labour share) in output leads to low productivity growth, regardless of technological change. Similarly, capital deepening leads mechanically to low productivity growth, regardless of technological change.

Figure 7.1 Structural change and adjustment in NIEs



Note: Data for industry's share in GDP in Hong Kong are not available for 1970–79.

Source: International Economic Data Bank, ANU, *Asia Pacific Profiles 1997*, ANU.

Economic growth in NIEs has been characterised by rapid structural change and adjustment during the last four decades. The production share of industry in GDP increases rapidly, except in Hong Kong (Panel A of Figure 7.1), whereas the production shares of services and agriculture in GDP increased or decreased slowly. This structural change inevitably increases the capital intensity of these economies and results in low productivity growth, in line with the mechanical properties of the growth accounting scheme. Capital intensity in industry is normally higher than that of services and agriculture. Structural adjustment is more important than structural change in explaining low productivity growth in NIEs. The export share of capital-intensive products in total merchandise exports increased rapidly over the last three decades (Panel B of Figure 7.1). It was 10–20 per cent in 1965 but reached 50–80 per cent in 1995. Panel B shows that strong structural adjustment occurred towards capital-intensive industries and away from labour-intensive industries. This inevitably increases capital intensity in the industrial sector and thereby contributes to lowering productivity growth. Structural adjustment and change in NIEs give a clear answer to why growth accounting studies produce low productivity gains in NIEs.

In any consideration of structural adjustment and change in NIEs, a simplistic interpretation of growth accounting results and arguments about long-run growth are problematic. There remain many questions to be answered when seeking to derive implications from the findings. Does disaggregated growth accounting lead to results that differ from the aggregated results? Is the aggregated approach valid? Does high capital accumulation necessarily mean low technological change? Are productivity growth and technological change the same in developing countries?

To answer the first and second questions, a disaggregated growth accounting framework was constructed. First, the manufacturing sector was disaggregated into 36 industries, following Jorgenson, to check the validity of the aggregate analysis. Second, the embodiment effect and quality change of capital in each industry were considered as components of productivity growth, following

Denison, to examine productivity growth as a fundamental source of growth. Disaggregated results show that productivity growth was the largest contributor to output growth in eight of the 15 industries. They are textiles, clothes and leather, wood, paper and printing, chemical products, machinery and fabricated metals, office and medical machinery, motor vehicles and other vehicles. Past and present leading industries are included in this category, with the exception of electrical and electronic products. In these industries, disaggregated growth accounting leads to different conclusions from an aggregated growth accounting approach.

The most important finding of the studies in Chapter 3 is the invalidity of the aggregated approach. The aggregate production function approach was not valid in considering the sum of resource reallocations. It was quite different from zero in 1968–73, 1973–78 and 1978–83, when the Korean manufacturing sector experienced structural adjustments through diversification. The result of no aggregation bias in 1983–88 and 1988–93 is also doubtful. This might arise from the failure of growth accounting to capture structural adjustment within industries (production shift to high-quality products). This finding gives a valuable indication that aggregation bias is systematically linked to sequential structural adjustments, even though the growth accounting scheme failed to identify the real role of technological change owing to its mechanical properties.

Interaction between capital accumulation and productivity growth was investigated in Chapter 4 to clear for the effect of structural change on measured productivity growth. According to a Granger causality test, five of the 15 industries studied supported the embodiment hypothesis, and six of the 15 industries showed induced technological change at the 10 per cent significance level. Growth accounting techniques measure productivity growth as residual under the assumption that technology and capital are mutually independent, and that productivity growth is identical to technological change. However, this is not the case, when verification of the interaction between capital accumulation and productivity growth is taken into account. If an increase in capital stock is separated into two parts: capital accumulation without a technological component

($\Delta \ln Ka$) and with a technological component ($\Delta \ln Kb$), then productivity growth in equation (7-1) and (7-2) is expressed as equation (7-3) and (7-5). At the same time technological change can be defined broadly as equation (7-4) and (7-6):

$$(7-3) \quad \psi_T = \Delta \ln V(T) - \psi_K \Delta \ln Ka(T) - \psi_K \Delta \ln Kb(T) - \psi_L \Delta \ln L(T),$$

$$(7-4) \quad \psi_T + \psi_K \Delta \ln Kb(T) = \Delta \ln V(T) - \psi_K \Delta \ln Ka(T) - \psi_L \Delta \ln L(T),$$

$$(7-5) \quad \psi_T = \Delta \ln y(T) - \psi_K \Delta \ln ka(T) - \psi_K \Delta \ln kb(T),$$

$$(7-6) \quad \psi_T + \psi_K \Delta \ln kb(T) = \Delta \ln y(T) - \psi_K \Delta \ln ka(T),$$

where $ka = Ka/L$ and $kb = Kb/L$.

Growth accounting is mechanical, because the joint contribution of capital and technology to output growth ($\psi_K \Delta \ln Kb$ or $\psi_K \Delta \ln kb$) is solely attributed to capital accumulation, underestimating the role of technological change. Productivity growth and technological change diverged in the case of NIEs. It is therefore misleading to interpret low productivity growth as a sign of the unsustainability of growth on the assumption that measured productivity growth is identical to technological change.

Chapter 4 also found evidence of a predictable sequence in the principal sources of output growth over the period. Productivity growth was a dominant source of output growth due to the labour-intensive nature of the industrial structure in the period 1968–73, after which capital accumulation became the major source of output growth in the Korean manufacturing sector. Subsequently, productivity growth played a more important role in output growth from the late 1980s, lowering the contribution of capital to output growth. Verification of the sequencing of the sources of output growth and interactions between capital and productivity growth explain the reason for the low productivity gains in NIEs. These countries have not yet arrived at the third stage of development, where

innovation by R&D investment is the sole means of technological change. Rapid growth in these economies has been driven by utilising low-level technology, such as technology in a declining product-cycle in labour-intensive light industries and standardised technology embodied in capital goods in capital-intensive industries.

Chapter 5 identified structural adjustments as the driving force behind the link between capital accumulation and technological change in follower countries. This is because structural adjustments were associated with accumulation in new industries or in the manufacture of high-quality products sequentially. East Asian NIEs exhibited strong structural adjustment over the last four decades. The leading industries in these countries moved from labour-intensive industries using production technologies which are in a declining stage of the product cycle, to skill- and capital-intensive industries using standardised production technologies in a mature stage of economic development. Subsequently, production activities in these countries have been moving to capital and technology intensive-industries. They will move again to technology-intensive industries using frontier technologies. This chapter also showed that each of the East Asian NIEs has a different growth path. Hong Kong's path is characterised by high dependence on the services sector and comparative advantage in labour-intensive industries, whereas Singapore's path is characterised by rapid structural adjustment towards high technology industries with a link to the international production of multinational corporations. Taiwan and Korea's paths are similar to Singapore's but local entrepreneurs' efforts are much more important in Taiwan and Korea.

This claim was verified as follows. First, the structural effect in Jorgenson's framework was defined as a resource reallocation effect with a negative sign. This effect explained about 7 per cent of the weighted sum of sectoral productivity growth in 1968–93. Second, Pilat's structural effect was calculated. It also confirmed that structural adjustment played a positive role in lifting aggregate labour productivity over the whole period. Then, the share effect, a proxy for the effect of structural adjustment on productivity growth, was calculated using the

framework of Bernard and Jones. The share effect was positive over the whole period except 1978–83; its average growth rate was 0.16 per cent per year. These results empirically verified that structural adjustment (in particular entering new industries) has played a positive role in lifting aggregate productivity growth by offsetting the larger declining trend in aggregate productivity growth caused by the large decline in sectoral productivity growth of each industry. In sum, structural adjustments led to rapid technological change and economic growth through the accumulation of new capital embodying technological components.

On the basis of the discussion of sequencing of the sources of output growth, the interaction between capital accumulation and productivity growth, and structural adjustment as a driving force of the interaction, two implications were drawn out in Chapter 6. These were the need to incorporate the sequencing of the sources of technological change and a broader definition of technology into analysis of technological change and productivity growth. The major channels for technology development and transfer change in different stages of economic development. Informal methods of acquiring old technologies were the first major source in the initial stage of growth, and capital imports followed in the next stage. Subsequently, technology imports played the major role in the third stage of growth, characterised by a production shift to high-quality products. This also suggests that R&D investment becomes an important source of growth from the final stage of technology catch-up. The effect of technology imports on productivity growth in Korea's manufacturing sector was positive and significant in the linear regression but regression of productivity growth by R&D investment did not produce significant results, as expected. Chapter 6 also put forward a definition of technological change applicable to follower countries. It includes rival but bounded embodiment components which have played a crucial role in the growth of East Asian NIEs in the last four decades. This broader definition is consistent with an understanding of why extraordinary growth and technology catch-up occurred in NIEs.

The other findings of this thesis are as follows.

First, differences in productivity growth in several growth accounting studies arose from the data source. The *National Wealth Survey* and the *Mining and Manufacturing Survey* allow a disaggregated approach, and result in relatively high productivity growth. In contrast, National Income Account data only allow an aggregated approach, and require some arbitrary assumptions to estimate capital stock and productivity growth.

Second, Sarel's (1995a: 246–47) argument that estimates of productivity growth are very sensitive to a specific estimation period is quite right. Productivity growth and its contribution to output growth are very high in 1968–73 but very low in 1978–83. Thus, extending the estimation period to the 1960s and/or to the 1990s leads to relatively high productivity growth, whereas focusing on the late 1970s and 1980s leads to low productivity growth.

Third, the trends in productivity growth in 1970s and 1980 are quite different from the picture put forward by Dollar (1991) and Dollar and Sokoloff (1990), who emphasise changes in manufacturing structure from heavy industry to light industry and resulting TFP convergence. What really happened in Korea is a change in the manufacturing structure from light industry to heavy industry and TFP convergence.

Fourth, output–capital ratios at the aggregate and sectoral level have increased with decreasing growth rates in the past three decades. These trends lifted the marginal product of capital. These findings support the argument that low-level technology played a significant role in rapid growth, even though they do not appear in mechanical growth accounting exercises.

Fifth, the measured effects of structural adjustment on productivity growth were not as strong as expected. This results from the fact that productivity data used in empirical verification did not include the interaction technological component of capital accumulation. However, in the light of the interaction between

technological change and capital accumulation in relation to structural adjustment, the effect on technological change might be strong.

Sixth, two main characteristics which distinguish the experience of East Asian NIEs from that of developed countries can be derived from the discussion. One, technological change for follower countries was induced by structural adjustment across industries. Two, productivity growth in new industries or products, where structural adjustments and technological changes occur, is relatively low compared with existing industries because of the mechanical property of growth accounting in treating the interaction between capital accumulation and technological change.

Seventh, East Asian economic growth in the earlier stage can be endogenised, as argued by new growth theory, as long as structural adjustment towards high technology industry is pursued by economic growth agents and encouraged by public policy.

Eighth, the sequencing of the vehicles of technological change was related to structural adjustments over the stages of economic development.

Ninth, a favourable world economic environment and appropriate responses to these conditions were the reasons why technological paths in NIEs were quite different from those in leader countries. East Asian NIEs have enjoyed a favourable world economic environment characterised by rapid technological change and deepening interdependence and roundaboutness of production achieved by leader countries. East Asian countries have successfully dealt with technological and marketing barriers in different ways: specialisation in labour-intensive industries characterised by low barriers, participation in a small set of tasks for multinational corporations, and local firms' organisation of state-of-the-art production utilising imported capital and intermediate goods (Appendix 2).

However, this study has some limitations and further research is clearly required. First, the thesis argues that technological change played an important role in economic growth in NIEs by broadening the definition of technology into rival and bounded technologies, which are considered as parts of physical and human capital in the standard growth model. On this point, the definition of technology is quite different from that of the neoclassical growth model, focusing on the nonrival and unbounded properties of technology (innovative technology), and predicting permanent effects of technological change on growth. Thus, deeper discussion of on technology and growth theory is necessary to reduce the gap between the arguments of this thesis and the neoclassical model.

Second, this thesis conceptualised the technological components of capital accumulation ($\Delta \ln Kb$) induced by a production shift to new industries and high-quality products. However, data for these components were not constructed, so the role of technological change in growth was not measured empirically.

Finally, the relationship between productivity growth and technology import was investigated at the aggregated level. Cross-sectional industry data would be a useful addition to the time-series estimations undertaken in this study. This would allow a more detailed analysis of the relationship between technology import and the productivity growth which occurred in Korean manufacturing.

Appendix Tables

Table A3.1 Classification of manufacturing industries

A. Thirty-six industries

Number	Industry	Number	Industry
1	Food products	19	Glass and glass products
2	Beverages	20	Non-metallic mineral products
3	Tobacco	21	Steel
4	Spinning, weaving, bleaching, and dyeing	22	Non-ferrous metals
5	Knitted and crocheted fabrics and articles	23	Fabricated metal products, except machinery and equipment
6	Other textiles except clothes	24	Engines and turbines
7	Wearing apparel	25	Industrial purpose machinery and machine-tools.
8	Leather and leather products (footwear included)	26	Office machinery and tools (service purpose machinery and tools included)
9	Wood and products of wood (furniture included)	27	Electric and industrial machinery and apparatus
10	Paper and paper products	28	Radio, TV and communication equipment and apparatus, and other electric components
11	Publishing, printing and related processing	29	Domestic purpose electric appliances
12	Chemicals for industry	30	Other electric, electronic machinery and apparatus
13	Other chemical products	31	Building and repairing of ships
14	Refined petroleum products	32	Railway locomotives
15	Other refined petroleum products and coal products	33	Motor vehicles
16	Rubber products	34	Motor cycle, aircraft, and other transport equipment
17	Plastic products	35	Medical, precision, and optical instruments
18	Ceramic products and clay products	36	Other manufacturing

B. Integrated industries (15 sectors)

	Classification	Industry
A	Food products, beverages, and tobacco	1, 2, 3
B	Textiles	4, 5, 6
C	Clothes and leather	7, 8
D	Wood, paper and publishing	9, 10, 11
E	Chemical and chemical products	12, 13
F	Refined petroleum	14, 15
G	Rubber and plastic	16, 17
H	Non-metallic mineral	18, 19, 20
I	Steel and non-ferrous metals	21, 22
J	Fabricated metals and machinery	23, 24, 25, 27
K	Office machinery, and medical/precision instruments	26, 35
L	Electric and electronic products	28, 29, 30
M	Motor vehicles	33
N	Transportation vehicles except cars	31, 32, 34
O	Other manufacturing	36

Notes: 1) Panel A is from Kim and Hong (1992: 38).

2) Panel B is aggregated from Panel A.

Source: Kim and Hong (1992)

Table A3.2 Sources of growth (three-input model), 1968–93

A. Growth rate (%)

	Output	TFP	Intermediate input	Capital	Labour
Food, beverages, tobacco	12.73	1.25	9.01	2.27	0.19
Textiles	13.94	1.72	10.40	1.35	0.47
Clothes, leather	10.94	1.29	8.00	1.11	0.53
Wood, paper, printing	12.54	1.65	9.06	1.21	0.62
Chemicals	19.38	3.08	12.93	2.54	0.82
Refined petroleum	11.21	0.63	7.76	2.75	0.08
Rubber, plastic	17.45	1.67	13.00	1.92	0.86
Non-metallic minerals	14.16	1.85	8.77	2.76	0.79
Steel, non-ferrous metals	18.63	0.97	15.12	2.06	0.49
Machinery, fabricated metals	18.96	2.44	13.08	2.02	1.42
Office, medical machinery	24.90	3.34	16.90	2.61	2.05
Electrical/electronic products	23.52	1.76	16.47	3.66	1.64
Motor vehicles	22.16	2.93	15.02	2.91	1.30
Other vehicles	17.07	2.57	11.51	1.87	1.12
Others	14.81	1.59	10.23	1.89	1.10

B. Contribution to output growth (%)

	Output	TFP	Intermediate input	Capital	Labour
Food, beverages, tobacco	100	9.84	70.79	17.85	1.51
Textiles	100	12.37	74.58	9.71	3.34
Clothes, leather	100	11.76	73.19	10.19	4.87
Wood, paper, printing	100	13.17	72.27	9.63	4.93
Chemicals	100	15.90	66.75	13.13	4.22
Refined petroleum	100	5.58	69.21	24.52	0.69
Rubber, plastic	100	9.59	74.48	11.02	4.91
Non-metallic minerals	100	13.06	61.92	19.47	5.55
Steel, non-ferrous metals	100	5.20	81.13	11.03	2.64
Machinery, fabricated metals	100	12.84	68.98	10.68	7.50
Office, medical machinery	100	13.42	67.88	10.48	8.21
Electrical/electronic products	100	7.47	70.01	15.54	6.98
Motor vehicles	100	13.22	67.80	13.12	5.86
Other vehicles	100	15.07	67.43	10.92	6.58
Others	100	10.71	69.08	12.79	7.41

Source: Author's calculation.

Table A3.3 Productivity growth by time period (three-input model), 1968–93
(per cent)

	1968– 73	1973– 78	1978– 83	1983– 88	1988– 93	1968– 93
Food, beverages, tobacco	2.75	1.52	0.77	0.32	0.85	1.25
Textiles	3.43	2.49	0.07	1.37	0.84	1.72
Clothes, leather	1.78	1.14	0.88	1.46	1.14	1.29
Wood, paper, printing	2.51	1.22	1.52	1.74	1.07	1.65
Chemicals	6.42	6.46	0.92	1.31	0.82	3.08
Refined petroleum	2.22	0.23	-0.85	0.84	0.89	0.63
Rubber, plastic	3.06	1.55	0.70	2.92	0.13	1.67
Non-metallic mineral	3.60	3.26	-1.09	1.21	2.66	1.85
Steel, non-ferrous metals	2.37	0.95	0.33	0.71	0.54	0.97
Machinery, fabricated metals	3.10	3.94	1.68	2.44	1.41	2.44
Office, medical machinery	4.52	4.20	2.19	3.45	2.55	3.34
Electric and electronic products	2.74	2.08	1.88	1.80	0.91	1.76
Motor vehicles	3.55	4.43	2.29	2.45	2.13	2.93
Other vehicles	4.25	2.39	2.69	1.20	2.50	2.57
Others	2.23	2.62	1.88	2.55	-1.43	1.59
Total	10.36	6.53	2.49	5.57	4.80	5.95

Source: Author's calculation.

Table A4.1 Sources of growth over time period (two-input model), 1968–93
(per cent)

	68–73	73–78	78–83	83–88	88–93
Food, beverages and tobacco					
TFP	49.85	30.91	24.62	12.18	35.94
K	41.4	62.16	72.65	81.9	64.86
L	8.75	6.93	2.73	5.91	-0.8
Textiles					
TFP	57.45	49.57	4.61	46.79	49.11
K	21.69	34.17	91.52	42.97	62.87
L	20.86	16.26	3.87	10.24	-11.97
Clothes and leather					
TFP	41.26	22.38	63.4	63	125.18
K	30.44	50.33	37.51	20.13	39.18
L	28.3	27.29	-0.91	16.87	-64.36
Wood, paper and printing					
TFP	55.03	32.5	64.33	50.71	34.97
K	23.64	39.75	34.09	31.07	48.98
L	21.34	27.75	1.58	18.22	16.05
Chemicals					
TFP	72.07	62.52	21.69	29.04	20.73
K	16.44	26.49	68.23	55.1	66.15
L	11.49	10.99	10.08	15.86	13.13
Refined petroleum					
TFP	40.44	15.06	-118.1	33.07	23.74
K	58.98	82.64	207.97	64.02	72.55
L	0.59	2.31	10.13	2.91	3.71
Rubber and plastic					
TFP	50.85	27.49	25.29	51.26	5.6
K	26.58	41.73	65.33	33.26	91.41
L	22.57	30.78	9.38	15.49	2.98
Non-metallic minerals					
TFP	50.56	44.93	-33.35	23.54	54.85
K	40.35	34.69	112.65	62.19	30.56
L	9.09	20.39	20.7	14.27	14.6
Steel, non-ferrous metals					
TFP	41.83	21.57	13.18	32.73	26.34
K	50.45	66.01	72.61	41.78	51.14
L	7.71	12.42	14.21	25.49	22.52

Table A4.1 Sources of growth over time period (continued)

	68-73	73-78	78-83	83-88	88-93
Machinery and fabricated metals					
TFP	53.16	45.73	30.27	41.71	32.68
K	19.93	32.98	47.9	36.23	37.06
L	26.91	21.29	21.83	22.06	30.25
Office and medical machinery					
TFP	52.92	36.25	33.24	42.54	46.11
K	23.22	36.93	43.29	30.71	27.29
L	23.86	26.82	23.47	26.75	26.6
Electrical and electronic products					
TFP	27.61	21.34	34.86	26.08	25.59
K	39.09	56.97	57.79	52.07	50.52
L	33.3	21.69	7.35	21.85	23.9
Motor vehicles					
TFP	48.04	50.85	38.83	31.39	33.84
K	29.6	28.89	43.85	49.89	53.18
L	22.36	20.26	17.33	18.72	12.98
Other vehicles					
TFP	70.75	1.04	57.53	67.63	58.72
K	18.11	54.96	27.77	43.58	21.41
L	11.14	44.01	14.7	-11.21	19.88
Others					
TFP	34.09	43.13	44.51	44.44	260.33
K	30.12	38.09	47.66	34.04	-207.43
L	35.79	18.79	7.83	21.51	47.11

Source: Author's calculation.

Table A4.2 Sources of growth over time period (three-input model), 1968–93
(per cent)

	68–73	73–78	78–83	83–88	88–93
Food, beverages and tobacco					
TFP	14.97	10.43	7.64	2.93	8.54
X	70.31	67.76	63.35	76.37	76.43
K	12.16	19.61	27.98	19.29	15.22
L	2.56	2.2	1.03	1.41	-0.18
Textiles					
TFP	15.46	11.72	0.96	13.25	12.15
X	72.91	76.48	77.67	71.18	75.38
K	5.93	7.93	20.48	12.5	15.38
L	5.7	3.87	0.88	3.07	-2.91
Clothes and leather					
TFP	9.84	5.36	39.98	16.04	28.49
X	74.52	74.43	35.93	74.8	77.58
K	8.11	13.12	24.98	5.01	8.57
L	7.53	7.09	-0.9	4.15	-14.63
Wood, paper and printing					
TFP	15.04	8.76	19.24	14.55	9.28
X	72.66	73.01	69.84	71.19	73.42
K	6.42	10.74	10.42	9.01	13.02
L	5.88	7.49	0.5	5.25	4.28
Chemicals					
TFP	25.87	21.71	6.71	8.14	5.63
X	63.21	64.12	66.48	71.95	73.12
K	6.41	10	23.36	15.47	17.72
L	4.51	4.17	3.44	4.45	3.52
Refined petroleum					
TFP	12	2.37	-20.09	9.45	6.8
X	63.57	68.64	84.22	69.09	69.99
K	24.19	28.13	34.17	20.55	22.08
L	0.23	0.86	1.69	0.92	1.13
Rubber and plastic					
TFP	11.73	6.44	6.8	15.34	1.61
X	76.79	76.51	73.54	69.91	72.09
K	6.19	9.82	17.24	10.05	25.47
L	5.29	7.23	2.41	4.7	0.83
Non-metallic minerals					
TFP	19.74	17.17	-12.82	8.84	20.6
X	61.03	61.84	61.83	62.38	62.62
K	15.7	13.21	43.1	23.41	11.36
L	3.53	7.78	7.89	5.38	5.42
Steel, non-ferrous metals					
TFP	8.31	3.76	2.11	5.56	4.26
X	77.62	81.41	83.99	82.98	83.87
K	12.19	12.49	11.62	7.13	8.25
L	1.88	2.34	2.28	4.34	3.62

Table A4.2 Sources of growth over time period (continued)

	68-73	73-78	78-83	83-88	88-93
Machinery and fabricated metals					
TFP	16.68	13.78	9.66	12.97	9.97
X	68.48	69.83	68.17	68.9	69.48
K	6.3	9.96	15.22	11.27	11.32
L	8.54	6.42	6.96	6.86	9.24
Office and medical machinery					
TFP	18	11.42	10.57	13.42	14.35
X	65.77	68.51	68.13	68.45	68.81
K	8.01	11.62	13.82	9.69	8.55
L	8.22	8.44	7.48	8.44	8.3
Electrical and electronic products					
TFP	8.83	6.32	9.86	7.34	7.03
X	68.2	68.78	71.59	71.83	72.46
K	12.41	18.02	16.45	14.68	13.94
L	10.56	6.89	2.1	6.16	6.57
Motor vehicles					
TFP	16	14.95	13.34	10.23	10.95
X	66.77	70.6	65.54	67.68	67.73
K	9.73	8.48	15.18	16.03	17.15
L	7.5	5.98	5.94	6.05	4.17
Other vehicles					
TFP	22.08	7.1	16.37	51.19	15.53
X	66.87	73.03	60.31	8.68	73.66
K	6.82	11.04	15.25	49.49	5.63
L	4.23	8.84	8.06	-9.36	5.18
Others					
TFP	9.08	13.85	14.3	14.93	91.23
X	71.45	67.79	67.89	66.62	64.23
K	8.89	12.29	15.27	11.36	-71.63
L	10.57	6.07	2.54	7.1	16.17

Source: Author's calculation.

Table A6.1 R&D expenditure and researchers, 1966–93

	1966	1971	1976	1981	1986	1990	1991	1992	1993
R&D expenditure									
Amount (US\$ m)	12	29	200	526	1,865	4,676	5,466	6,328	7,615
GNP ratio (%)					1.73	1.88	1.94	2.09	2.33
R&D researchers									
Number (thousand)	3.0	5.3	11.7	20.7	47.0	70.5	76.3	88.8	98.8
per 10 thousand population (%)	1.0	1.7	3.3	5.4	11.4	16.4	17.6	20.3	22.0

*Source: Report on the Survey of Research and Development in Science and Technology 1994,
Ministry of Science and Technology, ROK.*

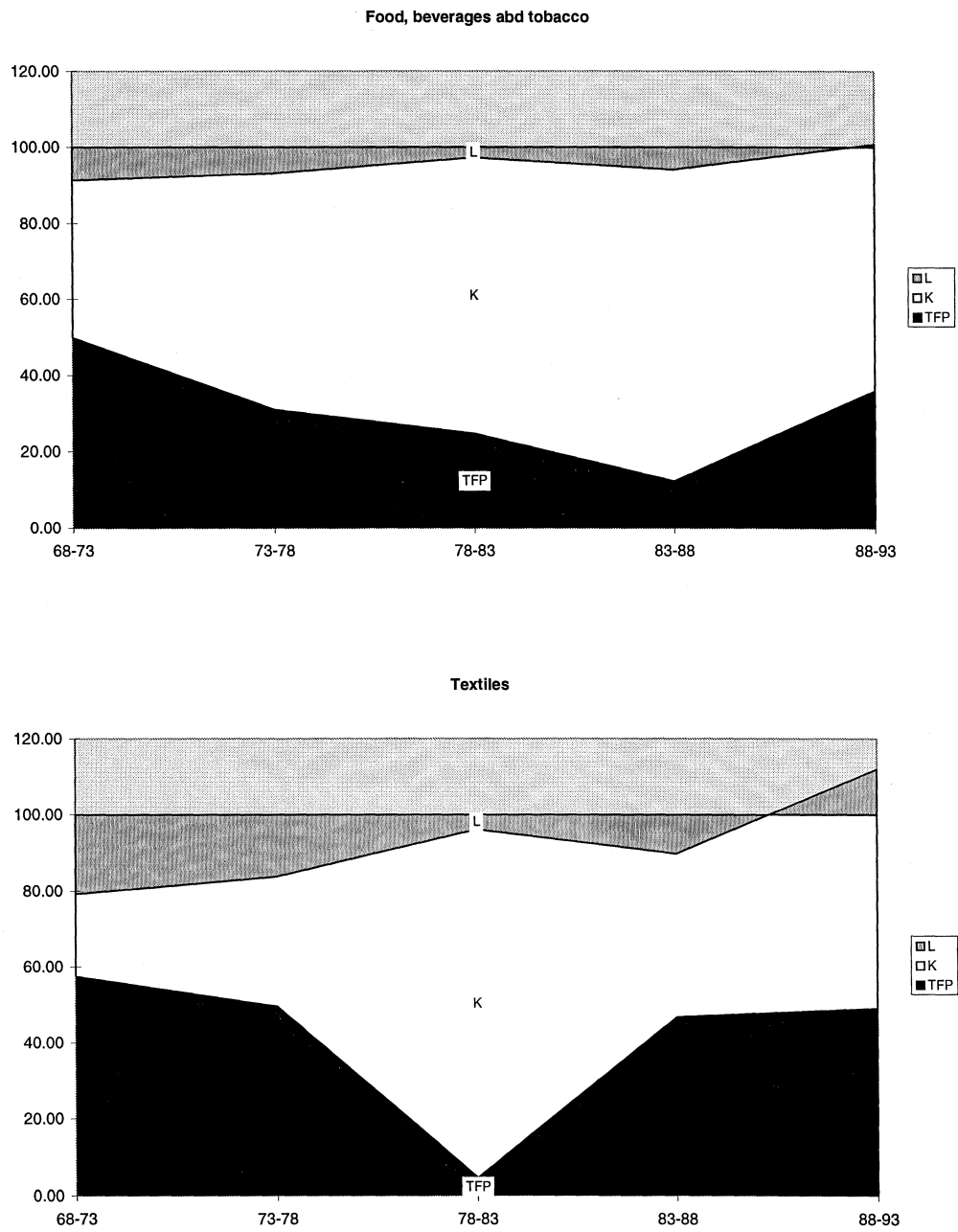
Table A6.2 Technology imports by industry, 1962–93

	1962– 76	1977– 81	1982– 86	1987	1988	1989	1990	1991	1992	1993	1962– 93
Amount (US\$ m)											
Food	2	3.3	16.4	4.3	5.2	8.9	9.5	14.4	8.9	8.3	81.2
Textiles and clothing	9.4	18.2	22	8.3	8.3	13.2	14.5	25.2	23.8	26.4	169.2
Pulp and paper	0.1	7.4	0.7	0.3	0.4	1	1.2	2.3	2.2	1.5	16.9
Chemicals, refining	33.8	148	163.8	65.4	112.1	151.5	217.1	187.2	110.8	119	1307.8
Ceramic, Cement	1.1	10.5	28.5	6.7	6.8	25.7	15.6	18.2	24.3	11.1	148.4
Metals	23.9	32	36.9	12	6	10.5	8.6	6.9	9.2	18.2	164.3
Electronics	17.8	66.2	357.7	197.2	265	388.4	467.7	472.6	450.6	513.7	3197
Machinery	14.6	89.3	238.3	119.7	120.8	154.5	216.4	323.9	126.1	186.7	1590.4
Shipbuilding	5.1	11.2	92.2	11.6	6	12.4	16.2	34.1	5	22.3	216.1
Electricity	2.8	25.4	173.8	75	113.8	88.2	79.9	66	68.2	10.1	703.2
Others	3	39.9	54.6	23.2	31.9	34.3	40.3	33	21.5	29.2	310.9
Total	113.6	451.4	1184.9	523.7	676.3	888.6	1087	1183.8	850.6	946.4	7906.3
Cases											
Food	15	30	101	23	15	22	18	16	12	17	270
Textiles and clothing	38	41	127	37	52	56	44	37	18	44	494
Pulp and paper	7	7	3	2	4	3	1	1	0	7	35
Chemicals, refining	176	225	372	135	161	150	138	105	73	91	1622
Ceramic, Cement	21	34	50	25	20	22	26	13	12	7	231
Metals	74	105	112	31	26	23	21	13	12	15	434
Electronics	180	226	501	164	212	231	219	178	194	238	2345
Machinery	180	403	546	148	181	158	174	151	165	200	2299
Shipbuilding	11	45	94	13	14	10	14	12	12	6	231
Electricity	9	37	24	7	4	5	3	0	3	7	99
Others	41	72	148	52	62	83	80	56	32	75	706
Total	752	1225	2078	637	751	763	738	582	533	707	8766

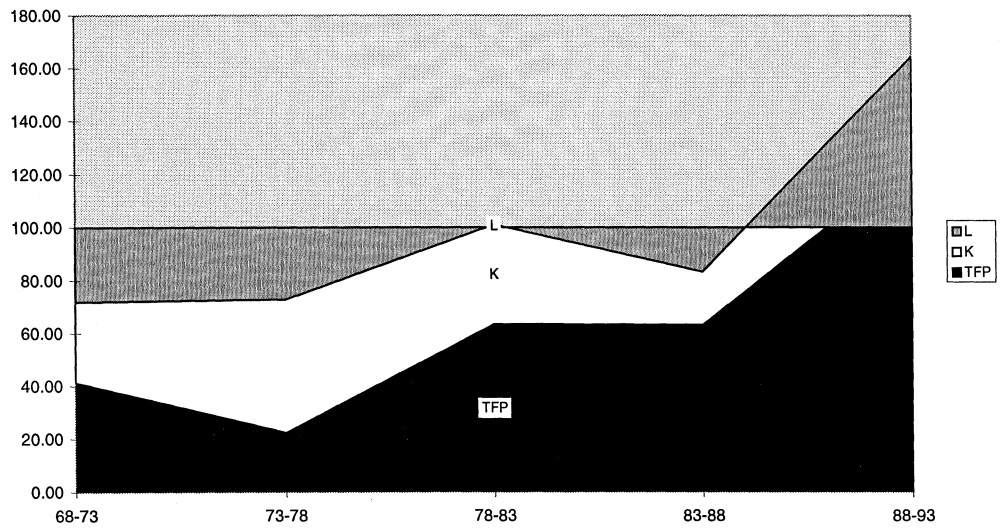
Source: Report on the Survey of Research and Development in Science and Technology 1994, Ministry of Science and Technology, ROK.

Appendix Figures

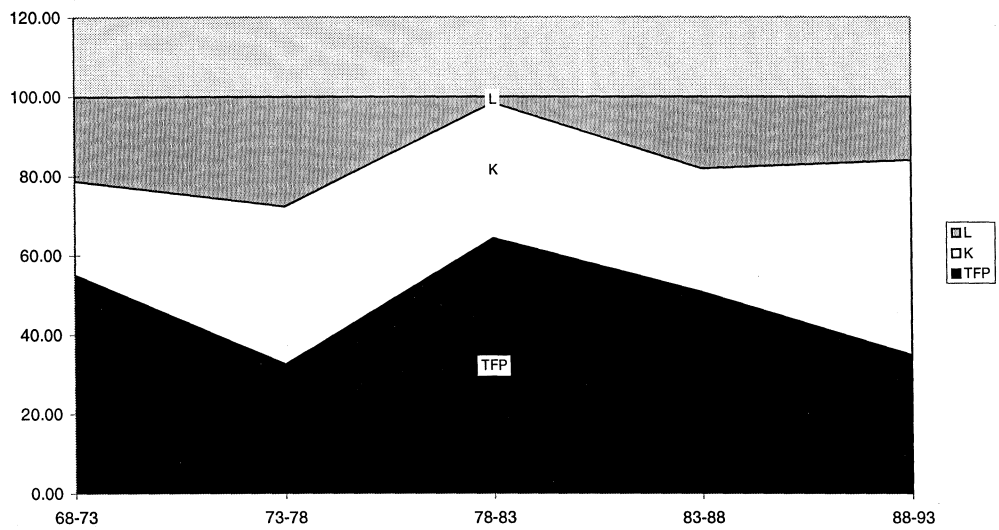
Figure A4.1 Sources of growth in industries, 1968-93



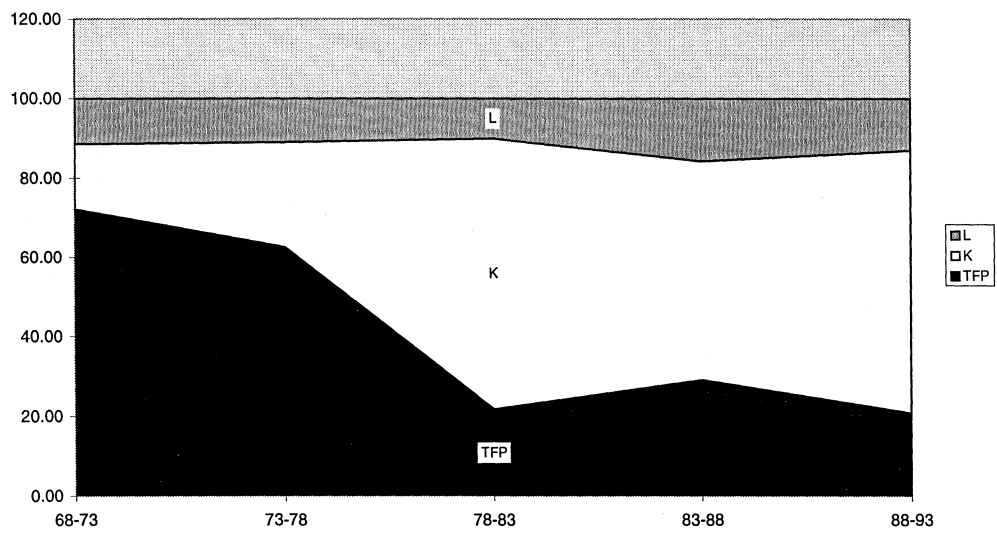
Clothes and leather



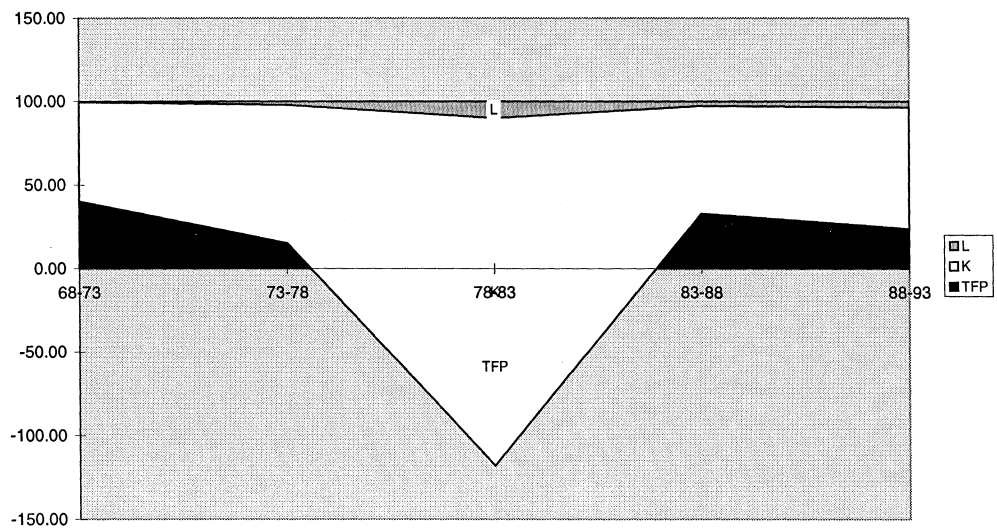
Wood, paper and printing



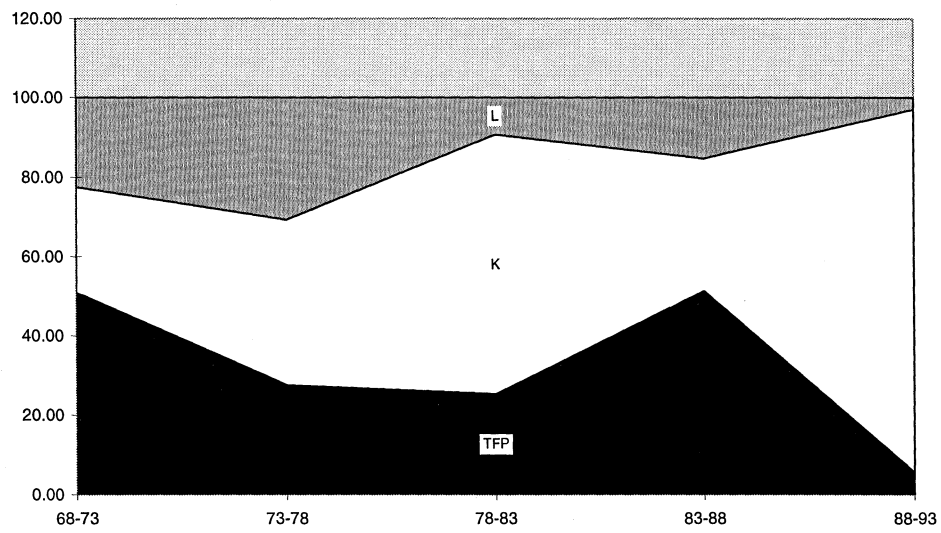
Chemicals



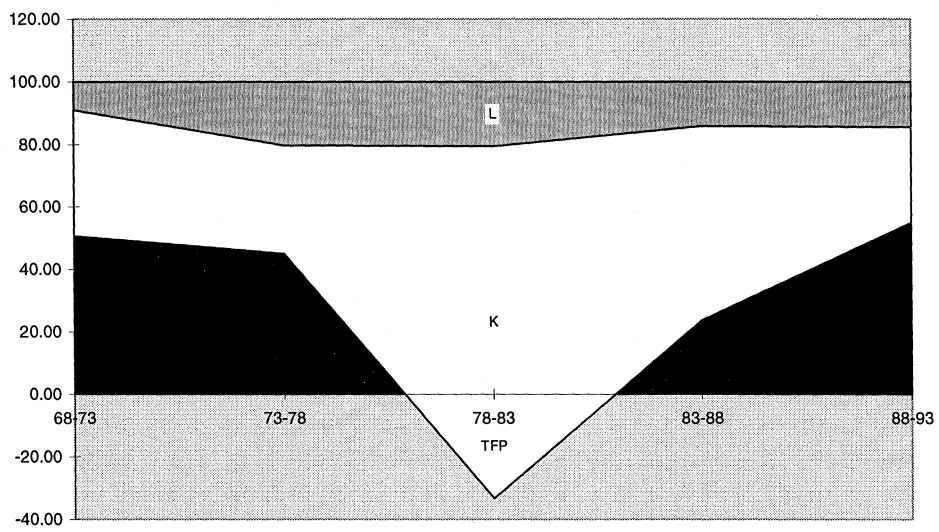
Refined petroleum



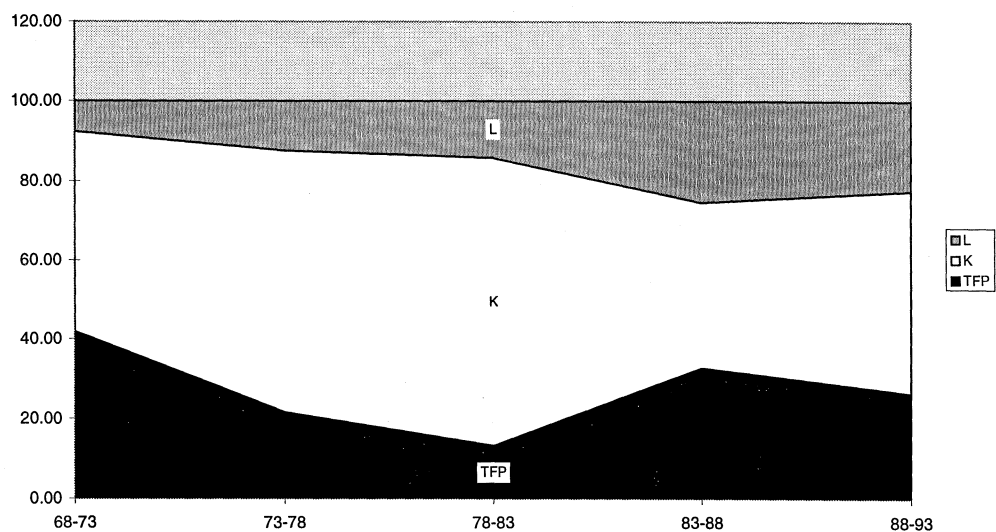
Rubber and plastic



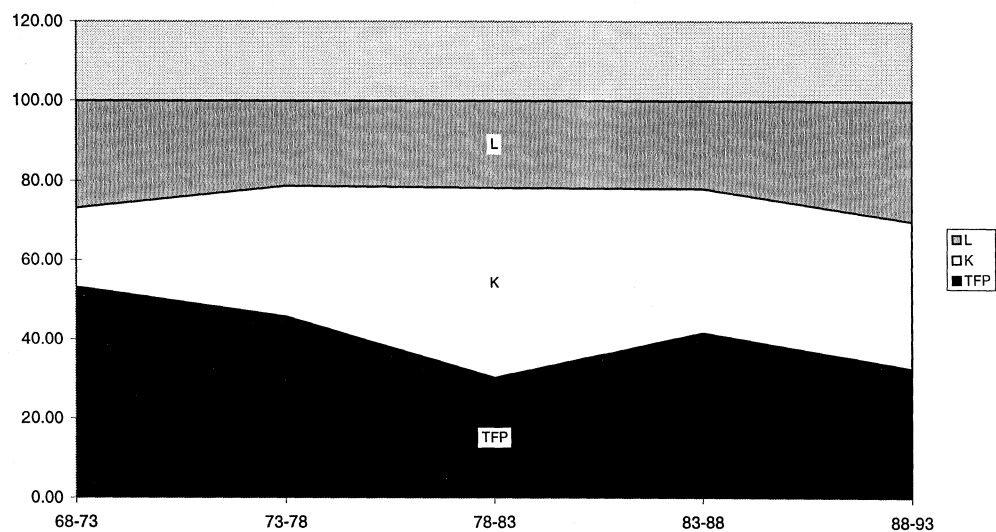
Non-metallic minerals



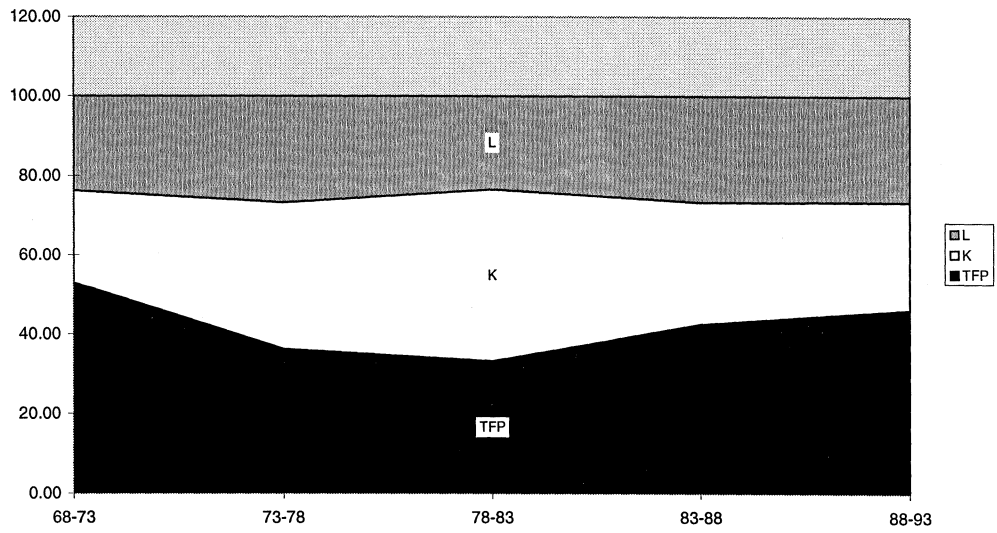
Steel and non-ferrous metals



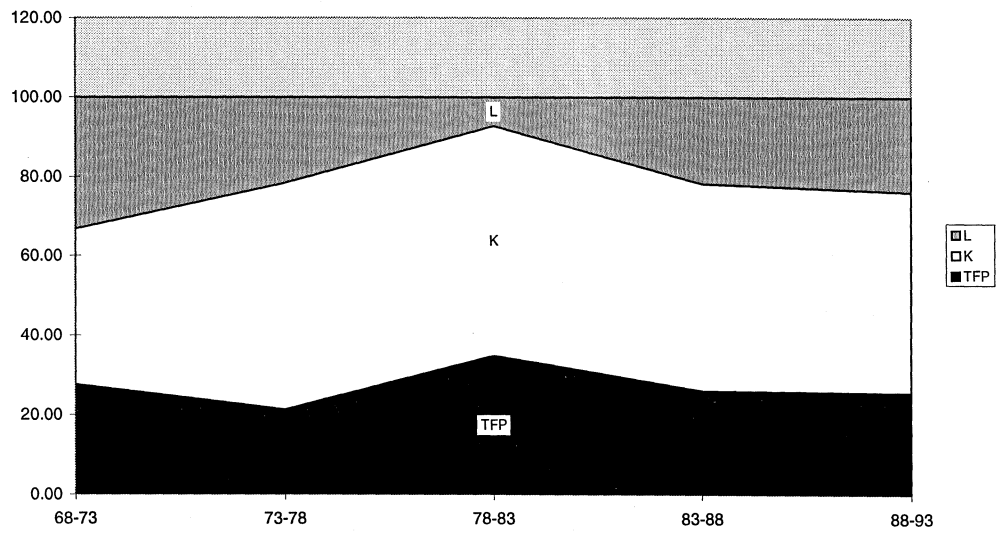
Machinery and Fabricated metals



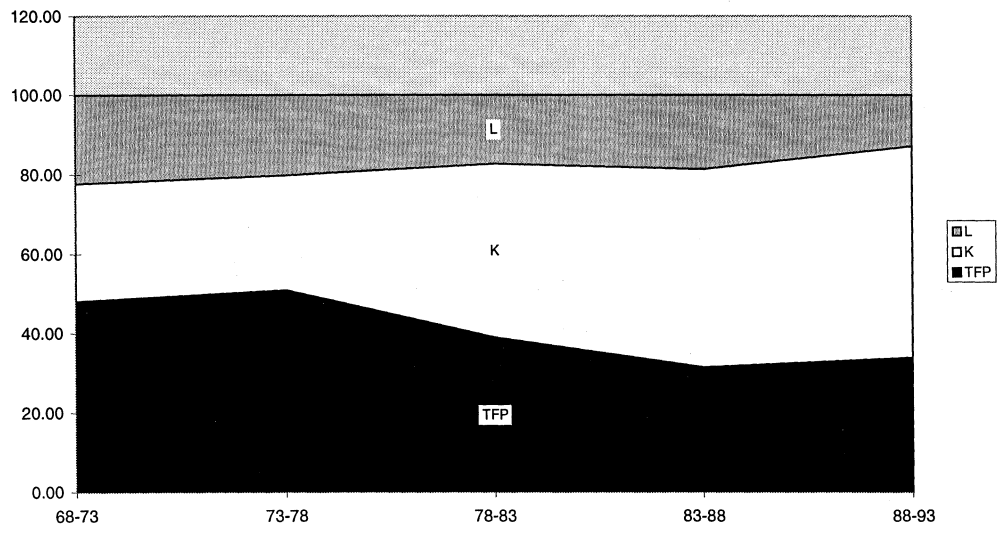
Office and medical machinery



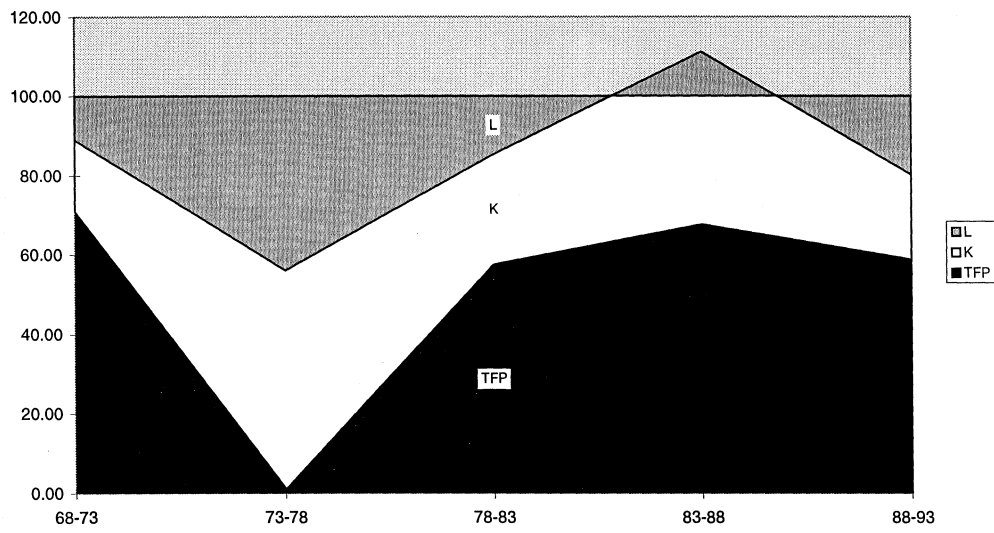
Electrical and electronic products

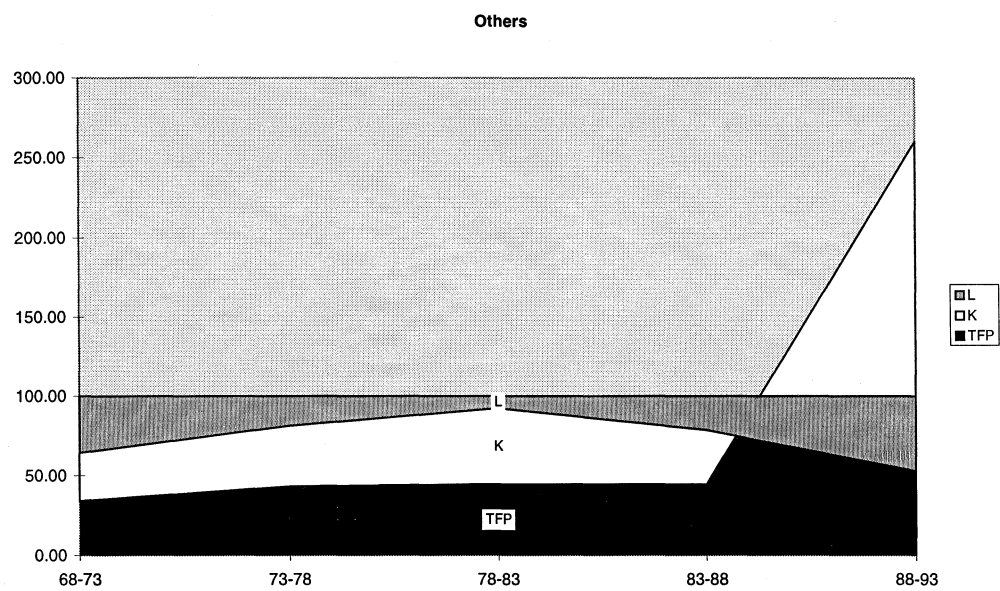


Motor vehicles



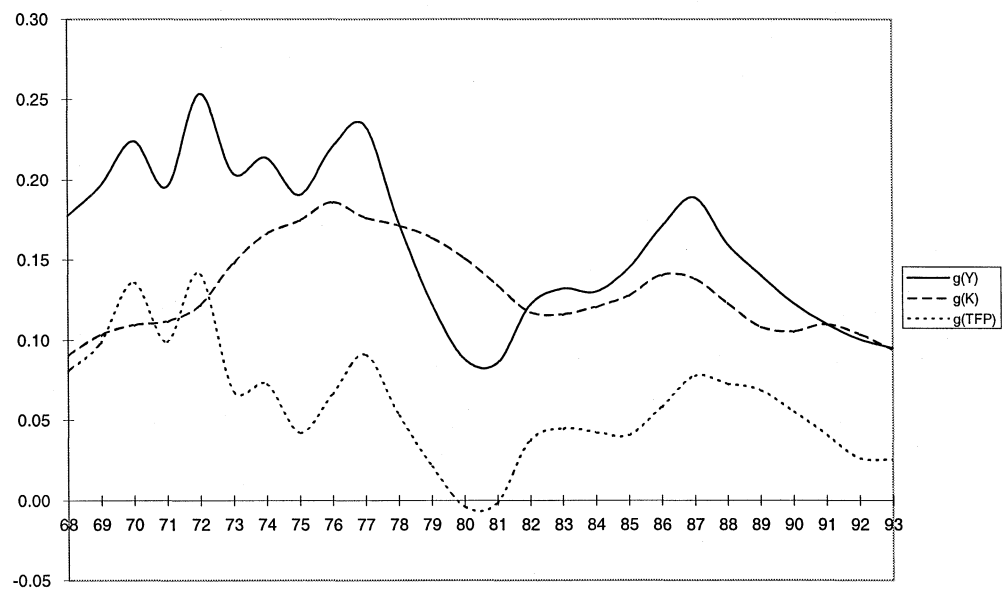
Other vehicles





Source: Author's calculation.

Figure A4.2 Productivity and output growth, 1968–93



Source: Author's calculation.

Appendix 1 Technology Catch-Up

The TFP index of Korea is calculated from the aggregate productivity series while United States data is from BLS, which takes Denison's approach in estimating productivity trend. The following table shows that Korean productivity growth is much higher than in the United States. According to the table, the difference in productivity growth between the two countries is 4.84 per cent during the whole period. It is specially high during the 1968–73 period, when Korean manufacturing had comparative advantages in light industries. The table implies that the technology gap between the two countries has been narrowing, contrary to the prediction of cross-country analysis.

Table A1.1 Productivity growth comparison: Korea and United States

	68–73	73–78	78–83	83–88	88–93	68–93
Korea	10.36	6.53	2.49	5.57	4.80	5.95
United States	1.98	0.49	0.88	2.11	0.58	1.11
Difference	8.37	6.04	1.62	3.46	4.22	4.84

Note: United States growth rates are calculated from multifactor productivity index of United States manufacturing (BLS data) after changing the basis year from 1987 to 1980.

Source: Table 3.2 and BLS.

Appendix 2

Reasons for Asian Technological Paths: the Economic Environment after WWII and Three Options for Follower Countries

The thesis constructs a new paradigm of Asian growth: low productivity growth but high technological change. Low productivity growth is an artefact of the mechanical properties of growth accounting, which fails to attribute the technological components of capital accumulation, both rival and bounded, to the residual. Structural adjustment is another expression of the paradigm, resulting in sequential changes in technological niches over time. Accordingly, the earlier section of Chapter 5 produced a definition of technology in broad terms and a hypothesis about the sequencing of sources of technological change (transfer), illustrating the difference between the technological paths of NIEs and those of developed countries. What is the main reason that NIEs took a different technological path? I seek an answer for that in the world economic environment after the Second World War.

The remarkable growth of the East Asian NIEs has been driven by large domestic and overseas investments in the region and by exports to the United States and Japan under favourable world economic conditions after the Second World War. As noted by Krugman (1979; 1994), rapid growth in this region is highly dependent on the international economic environment. The economic environment following WWII shaped the experience of East Asian growth; the same set of economic circumstances after WWII resulted in the same set of characteristics for growth in the region; yet different responses on the part of the four countries to these conditions may have led each of them down different growth paths. The objective here is to identify the characteristics of the world

economic environment after WWII, and to discover how the four East Asian NIEs reacted to these different conditions to secure their own technological niches.

Economic environment after World War II

Economic growth after WWII is exceptional in economic history in terms of growth rates in GDP, GDP per capita, and exports. In particular, the period 1950–73, termed ‘a golden age of unparalleled prosperity’ by Maddison (1995), records the highest growth rates in the history of capitalism. Table A2.1 also shows that the economic performance of the next period (1973–92) is even better than the first. Performance over these years is comparable to that of 1870–1913, a relatively peaceful and prosperous era. Overall, economic performance after WWII surpasses that of all other eras.

Table A2.1 Phases of growth of the world, 1820–1992
(annual average compound growth rate)

	1820– 70	1870– 1913	1913– 50	1950– 73	1973– 92
GDP	1.0	2.1	1.9	4.9	3.0
GDP per capita	0.6	1.3	0.9	2.9	1.2
Merchandise Exports	4.2	3.4	1.3	7.0	3.7

Source: Maddison (1995: 41, 74).

Table A2.2 Phases of Growth in the Leader Countries, 1820–1992
(annual average compound growth rate)

	1820–70	1870–1913	1913–50	1950–73	1973–92
GDP					
UK	2.04	1.90	1.19	2.96	1.59
USA	4.22	3.94	2.84	3.92	2.39
Japan	0.31	2.34	2.24	9.25	3.76
Labour productivity (GDP per hour worked)					
UK	1.16	1.13	1.66	3.12	2.18
USA	1.10	1.88	2.48	2.74	1.11
Japan	0.09	1.89	1.85	7.69	3.13
TFP					
UK	0.15	0.31	0.81	1.48	0.69
USA	-0.15	0.33	1.50	1.72	0.18
Japan	n.a.	-0.31	0.36	5.08	1.04

Source: Maddison (1995:41).

What were the reasons for high world-wide growth after WWII? First, there were rapid technological changes in the developed countries, causing an increasing technology gap between developed and developing countries. According to Table A2.2, technological change in developed countries in the 1950–73 period was exceptionally high. In this period, the TFP growth rate of the United States, the leader country, was 1.72 per cent and its labour productivity growth was 2.74 per cent. Technologically new industries evolved, leading to structural adjustment from old to new industries. In particular, electronics innovations in the information-related industries were important. As Chandler (1990: 607) explains:

the electronic revolution not only brought into existence a number of new industries but also transformed the processes of production and distribution, as the coming of electricity had before the turn of the century. In the 1960s and 1970s a wide variety of industries shifted from electromechanical to electronically controlled processes of production that began to transform the work place and alter the materials used in production. They realigned the economies of scale and scope, often reducing minimum efficient scale and at the same time expanding the opportunities for exploiting the economies of scope.

The other industries which displayed high rates of technological change were transportation and communications. The commercial introduction of the jet plane, and cable and satellite communication encouraged the internalisation of markets by diminishing the effects of distance.

The second significant characteristic of the economic environment after WWII has been greater economic interdependence between countries triggered by an increase in the roundaboutness of production. The rapid increase in world exports is a good indicator of this phenomenon. Growth rates in merchandise exports in 1950–73 and 1973–92 were 7.0 and 3.7 per cent, respectively. These growth rates are higher than those of other periods (see Table A2.1). The expansion of the international production activities of multinational corporations was the result of this interdependence and roundaboutness of production. Why did this occur? One explanation may be that leader countries transformed their firms into more

vertically and horizontally integrated structures to exploit economies of scale and scope (Chandler 1990). The other may be the economics of transaction costs. Market failure in intermediate product markets and the need for firms to exploit the economies of interdependent activities led them to replace the market mechanism of cross-border transactions with internal hierarchies (Dunning 1988: 17). Whatever the reasons, the importance of international production marked a change in the organisational structure of firms towards the formation of large conglomerates after WWII. Dunning (1993: 14) explains the significance of activities of multinational corporations in the mid-1980s:

MNEs accounted for between 25% and 30% of the gross domestic product of the world's market economies in the mid 1980s. They were also responsible for around three-quarters of the world's commodity trade, and four-fifths of the trade in technology and managerial skills of these economies.

East Asian NIEs accomplished rapid growth in a world economic environment characterised by rapid technological change and deepening interdependence triggered by roundaboutness of production. How did these two factors affect the growth paths of East Asian countries? The first factor had a positive effect on East Asian economic growth. This was because structural adjustment from the low technology sector to the high technology sector in leader countries necessitated more imports from follower countries in the low technology sector. A follower country could target industries which were in decline in leader countries. Thus, as observed by Krugman (1979), Dollar (1986), Segerstrom *et al.* (1990), and Grossman and Helpman (1991a), follower countries could enjoy sustained growth by entering the declining industries of leader countries sequentially, as long as technological change in leader countries created new industries or new processes of production. Thus, the structural adjustment of the leader countries is directly linked to that of follower countries, and this link increased the efficiency of production world-wide.

The effect of the second factor was positive in one way but negative in another, because exploiting economies of scale and scope or deepening interdependence

acted as technological and marketing barriers as well as opportunities for follower countries. For example, countries which pursued an inwardly-oriented industrialisation strategy experienced bad performance because they entered industries with technological and marketing barriers, such as the capital goods sector at the starting point of industrialisation. Michael E. Porter called this phenomenon an error in the technological dimension of competitive strategy. Simply put, follower countries' firms were not competitive in the world market in producing high technology products at the initial stage because the firms were not able to coordinate various production activities based on the roundaboutness of modern production and thus failed to benefit from development in modern technology. By contrast, East Asian countries experienced successful performance by first entering industries with low barriers, then moving to industries with higher barriers. Only when they moved into industries with higher technology barriers in the later stage, did they benefit from developments in modern technology by linking domestic production activities with those of developed countries via imports of capital and intermediate goods. Because of this kind of internationally coordinated production, the second feature of the world environment, deepening interdependence and roundaboutness of production, became an opportunity rather than a barrier.

Three alternatives

Given rapid technological change and deepening of roundaboutness of production, East Asian follower firms had three alternatives in dealing with technological and marketing barriers. The first option was to specialise in labour-intensive products with no technological and marketing barriers in which follower firms had a comparative advantage. This strategy can be typically seen in Hong Kong before it reached a mature stage of development and services became the major industry. Labour-intensive light industries were also the most competitive industry in other East Asian NIEs and Japan in the early phase of development before they entered the electronics, and steel and iron industries. These labour-intensive products were the major Japanese exports of the 1950s. Products from

these industries were also the major exports for Korea and Taiwan in the 1960s, 1970s and early 1980s before electronics and/or heavy industry replaced them from the late 1980s. It is noteworthy that all the developing countries began their industrialisation in this labour-intensive sector.

The second alternative in dealing with technological and marketing barriers was to specialise in small subsets tasks of the international production activities of large conglomerate MNEs. In this case, there were no entry barrier problems because follower production activities depended on the technological and marketing ability of the MNEs. Moreover, there was no cooperation problem. The parent company organised all the transactions of the state-of-art capital and intermediate inputs, as well as providing organisational skills. This strategy was typically seen in the growth path followed by Singapore.

The third alternative was for local firms to organise state-of-the-art production of a target industry's products in accordance with world-wide structural adjustments triggered by technological change in developed countries. Under this alternative, market transactions rather than internalisation of production in multinational corporations solved the coordination problem. Local firms organised imports of capital and intermediate inputs in the international market to keep up with international production technology until the technological gap disappeared. They were also responsible for the development of their own organisational and marketing skills. Under this scenario, access to information is very important in making rapid adjustments to changes in the international industrial structure. This was the path taken in Japan, Korea and Taiwan.

The second and third options are the same from the technological point of view. The follower firms entered target industries in which the technological entry barrier had been lowered through world-wide structural adjustment. They also organised transactions of state-of-the-art capital and intermediate goods embodying modern technological developments based on the deepening of the roundaboutness of production. The difference lies in who organises production

and how it is organised. In the case of the second alternative, multinational corporations organise it through internalisation. In the latter case, local entrepreneurs organise by means of market transactions.

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