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**Sustainability of Growth in the Korean
Manufacturing Sector**

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SUSTAINABILITY OF GROWTH IN THE KOREAN MANUFACTURING SECTOR

This paper examines Krugman's pessimistic paradigm on East Asian economic growth, using Korean manufacturing data. The initial focus is on a disaggregated growth accounting approach. I found that productivity growth is the largest contributor to output growth in eight of fifteen industries, and that productivity growth explains about 38 per cent of output growth of manufacturing overall. Secondly the theoretical issues, which call into question the theoretical basis of the paradigm, are examined. I found that sequencing of the sources of growth was empirically verified (productivity growth in light industries → capital accumulation in heavy and petrochemical industries → productivity growth through R&D efforts), and that an increasing or constant output–capital ratio (marginal product of capital) was found in ten of the fifteen industries, and that interactions between productivity growth and capital input growth were found in nine of the fifteen industries. These results give a strong indication that criticism of the sustainability of East Asian growth is open to question.

Introduction

The remarkable economic performance in the East Asian NIEs (newly industrialising economies) over the past three decades has been an important issue in the literature on economic growth in recent years. During the past three decades, NIEs have recorded the world's highest growth rates. Growth accounting exercises have been carried out to identify the reason for the high growth in this region, with the expectation that high productivity growth would provide the answer. However, the results show that this is not the case. Instead, these studies arrived at the consensus that resource mobilisation rather than productivity growth was the main source of economic growth in the region. (Young 1992, 1994, 1995; Kim and Lau 1994; Collins and Bosworth 1996). 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 will also inevitably experience a slowdown because of a lack of productivity gains. This low productivity growth, when combined with the view that disembodied technological change driven by innovation is the main contributor to long-run growth, implies that NIEs will not be able to achieve sustainable growth in the long run.

The logic of judging whether growth is sustainable or not 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 are correct to measure technological change as productivity growth.

These earlier empirical findings and their implication of unsustainable growth may not be robust. First, highly aggregated data are used to calculate productivity growth, with resultant aggregation bias. An aggregate production function approach can be justified only if all sectoral production functions are identical (Jorgenson 1990). Second, capital stock data are unreliable because they are constructed from historical investment data using simplistic and arbitrary assumptions (Sarel 1995). Third, some studies using the production function estimation technique are unreliable because of their assumption that the weights of inputs are constant over time. This paper 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 are tested to confirm whether or not the use of disaggregated data gives different results.

Recent theoretical developments in this area have produced some valuable insights into the puzzle of low productivity gains in the East Asian NIEs. These include ideas about sequencing of the sources of output growth, interactions between capital formation and technological change, and the effect of structural adjustment on productivity 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 early stages of development. Later, disembodied technological change becomes a more important source of growth. 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. These hypotheses successfully explain why high growth in the NIEs is explained by capital accumulation rather than productivity growth, and lead to the argument that technological change has played a significant role in the high growth in this region. If these hypotheses can be verified empirically, the argument that East Asian growth is unsustainable may be open to question. I examine these three issues in the later part of this paper using Korean manufacturing data.

The next section reviews the empirical findings of growth accounting studies and their implications for sustainability of growth and reviews the theoretical hypotheses which explain the reasons for low productivity gains. This section questions the logic of judging whether or not growth is sustainable on the basis that disembodied technological change driven by R&D efforts is the sole source of long-run growth, and that capital and technology are independent of each other. The third section tests the validity of the aggregate production function approach, accounts for sources of growth at the disaggregated level, and evaluates Krugman's hypothesis under the standard growth accounting framework. Section 4 tests the theoretical hypotheses that undermine Krugman's hypothesis. The final section summarises the findings and draws some conclusions.

Literature survey: empirical findings and theoretical issues

Resource mobilisation rather than productivity growth

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. Kim and Lau (1994) and Pack (1993, 1992) suggest that the total factor productivity (TFP) gap between developed and developing countries actually widened in the course of East Asia's rapid economic growth.

Young (1995) undertakes the most thorough growth accounting study of growth in the NIEs (see Table 1). The contribution of TFP to the output growth of each country 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. 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 empirical finding has had a strong influence on recent studies of long-run growth and the question of sustainability. However, 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) have established, productivity calculations based on an aggregate production function can be misleading if aggregation bias exists. The aggregate approach requires very stringent

Table 1 Total factor productivity growth in NIEs (per cent)

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

Notes: 1 The values of the upper line in each cell represent whole economies. But in the case of Korea and Taiwan, these values represent the non-agricultural sector.

2 The values of lower line in each cell represent the manufacturing sector.

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

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

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. Section 3 examines whether Young's finding is robust in respect of this bias by analysing the sources of growth at an industry level.

The second issue affecting the robustness of Young's finding is the possibility that stage of development or industrial structure strongly affects productivity performance in the case of follower countries. According to Dowrick (1995) and Drysdale and Huang (1995), labour productivity at the initial stage 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. Measured productivity of a country may also depend on the industrial structure. According to Table 1, the higher the labour share, the higher the TFP growth. 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 of a country, contrary to the expectations of the growth accounting theorists.

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. Convergence proponents also make 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) account for the sources of labour productivity (Y/L) in the Korean manufacturing sector. 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,¹ whereas for light industries, TFP convergence is the sole source.² For this reason, Dollar emphasises that the employment structure of Korean manufacturing changed from heavy industry to light industry over the period under review (1963–79), promoting TFP convergence at an aggregated level. However, Korea's industrial structure changed in the opposite direction from the mid-1970s, contrary to Dollar's prediction. 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, even though convergence in labour productivity was evident, contrary to his expectation of catch-up.³ The empirical finding of TFP convergence in these two studies does not appear to be robust.⁴

The fragility of the findings of Dollar, and Dollar and Sokoloff shows the limitations of standard TFP calculations, which ignore the technological characteristics of particular industries and so fail to identify real technological change. Dollar and Sokoloff (1990) argue that the main source of TFP convergence in Korean manufacturing is 'scale economies associated with the transition from craft to modern labor-intensive production'. This finding well describes the characteristic of manufacturing growth in the 1960s and early 1970s, when light industry products, such as textiles, toys, wigs and plywoods, were key export goods. However, their finding is not valid after capital-intensive industries replaced labour-

intensive industries. There was a different mechanism for output growth and productivity growth, lowering standard productivity growth. If different stages of development and/or industrial structure (labour intensity) lead to different productivity growth, as shown in Young (1994), any international comparison of TFP performance will be seriously biased.

Sustainability of growth in NIEs

The earlier empirical work in both growth accounting and convergence studies concluded that economic growth in the NIEs was not based on exceptionally strong productivity growth, and that capital deepening played a crucial role. Standard neoclassical growth theory predicts that capital deepening will not allow sustained growth to continue since long-run growth can only be achieved by technological change. Thus, combining the earlier empirical findings with neoclassical theory leads to a pessimistic prediction about the sustainability of growth in the NIEs because it was a remarkable mobilisation of factors (in particular capital) rather than productivity growth that was the main contributor to rapid growth in East Asia (Krugman 1994).

Krugman (1994) compares the growth performance of NIEs with that of former Soviet Russia. Soviet Russia experienced strong growth in the 1950s and 1960s but growth declined dramatically in the 1970s and 1980s because of a lack of technological change. He warns that the 'little dragons' may turn out to be 'paper tigers'. The question I raise above on aggregation bias is expected to weaken Krugman's pessimistic logic. I test this hypothesis by examining the role of productivity growth in output growth at a disaggregated level in Section 3. Any relationship between industrial structure or stage of development and productivity growth also weakens the pessimistic view of the sustainability of growth. I examine this question in Section 4.

Sequencing of sources of output growth

A key idea is that the main sources of output growth change according to the stage of development. Physical and human capital accumulation is the main source of economic growth in the early stages of development. Later, disembodied technical progress (innovation activity by R&D efforts) becomes the main source of economic growth. Recently the sequencing issue has again attracted interest. Lau (1996) argues:

Much of the economic growth in the United States in the late nineteenth and early twentieth centuries can be similarly [with 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 Abramowitz (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 formally to hypothesise the idea of the sequencing of physical capital, human capital and technical progress in the process of a country's economic growth.⁵ Based on the earlier empirical findings, he explains the hypothesis of the sequencing of the 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.

The hypothesis successfully explains why capital accumulation rather than productivity growth was the main source of growth in the NIEs. These economies have yet to emerge from the earlier stage in which innovative technological change is not important. This hypothesis also questions the logic of judging whether or not growth is sustainable on the basis 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 respect, Krugman's pessimism about the sustainability of growth may be misleading. I validate this hypothesis using Korean manufacturing data in Section 4.

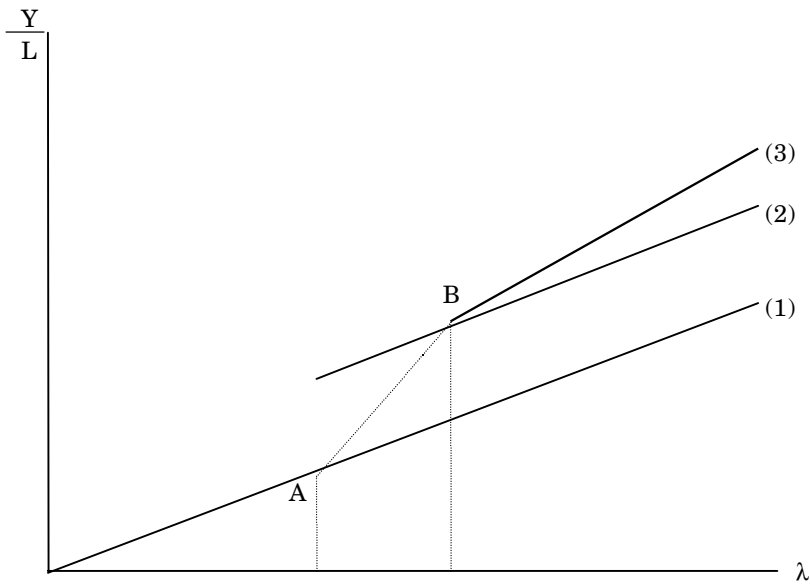
Interaction between capital formation and technical progress

Neoclassical theory and the growth accounting method assume that (physical and human) capital and technology are independent of one another, constituting separate and independent contributors to economic growth. Some economists, however, have raised doubts about this assumption (Landau 1989, 1992; Hulten 1975, 1979).

There are two ways in which the interaction between technological change and capital formation occurs. 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) has 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 Landau (1989; 1992), illustrates this possibility (see Figure 1). 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), and a higher growth rate than the former long-run growth rate, instead of path (2). I test this hypothesis in Section 4. Capital stock data in Section 3 are estimated without considering the embodiment effect. Thus, 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).

The other possibility is induced technological change (from technological change to capital formation); whereby technological change increases capital formation. In this case, capital accumulation appears to have almost no independent role in determining economic growth. Using Figure 2, Hulten argues that the real effect of technical progress is the sum of the shift in the production function plus induced capital accumulation.

Figure 1 Alternative growth paths: technological change and capital formation

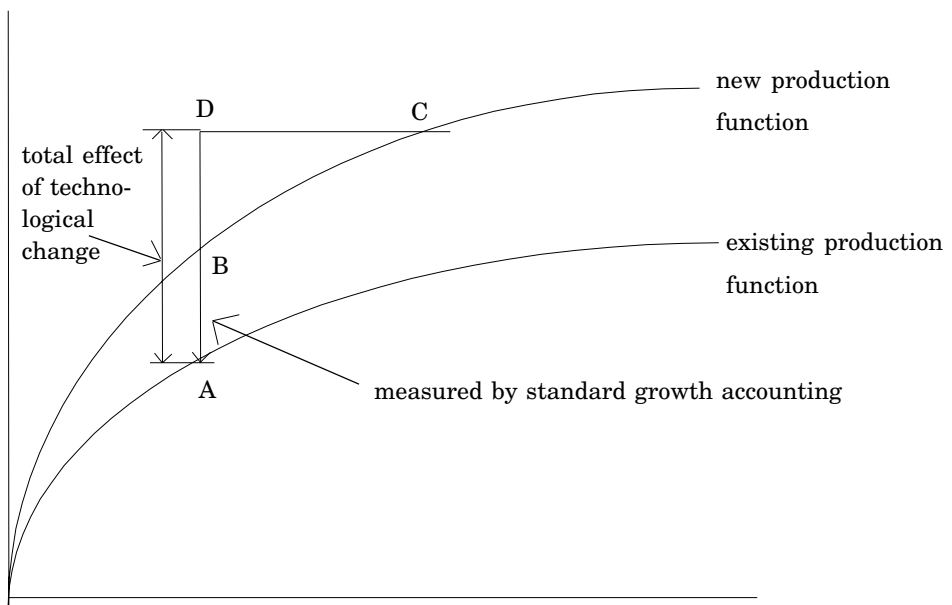


Source: Figure 12.2 in Landau (1989: 487).

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 in Landau 1989: 488–9)

Figure 2 Induced technological change



Source: Figure 12-3 in 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. I also test this hypothesis in Section 4.

Disaggregated growth accounting study

This section seeks to account for the sources of output growth in Korean manufacturing at the disaggregated level, and considers whether or not the earlier findings are valid in a disaggregated industry study. It also tests the sustainability of growth, employing the criteria used by Krugman.

Growth accounting framework

In this section a hybrid of Denison and Jorgenson's framework is constructed, combining the merits of both. Such a model would view productivity growth as a fundamental source of growth on the one hand, and allow the disaggregated approach, where resource reallocation is a component of productivity growth in aggregating procedure. The basic strategies are as follows. First, following Jorgenson's disaggregation procedure, the manufacturing sector as a whole is disaggregated into 15 industries, and the sources of growth in each industry are calculated. This strategy avoids the danger of aggregation bias, and gives detailed information of productivity growth at the industry level. It also makes it possible to test Krugman's hypothesis at the disaggregated level.

Second, following Denison's argument on sustainable and unsustainable factors, I shall not consider embodied technological change and quality change of capital as a component of capital input in the growth accounting framework. They are viewed as components of productivity growth. This strategy makes this study comparable to others, leading to answers about the sustainability question using a standard approach. It also guarantees relatively higher productivity growth than Jorgenson, leaving economies of scale, quality change of capital and others in productivity growth.

I define the sectoral growth rate of productivity for each individual industry, and express the aggregate productivity growth of aggregate manufacturing. In addition I explore the aggregation procedure across all industries, while clarifying the relationship between aggregate productivity growth and growth rates of sectoral productivity.

Suppose that T is time, V is the output, K , L are the capital and labour inputs, and that $\{P_V^i\}$, $\{P_K^i\}$, $\{P_L^i\}$ denote the prices of outputs, and capital and labour inputs, respectively. If we consider data at any two discrete points of time, say T and $T-1$, the average rates of sectoral productivity growth $\{v_T^i\}$, translog rates of productivity growth, can be expressed as follows:

$$(1) \quad \vartheta_T^i = [\ln V_i(T) - \ln V_i(T-1)] - \vartheta_K^i [\ln K_i(T) - \ln K_i(T-1)] \\ - \vartheta_L^i [\ln L_i(T) - \ln L_i(T-1)] \quad (i = 1, 2, \dots, 15),$$

where $\vartheta_K^i = 0.5[v_K^i(T) + v_K^i(T-1)]$, $v_K^i = P_K^i K_i / P_V^i V_i$,
 $\vartheta_L^i = 0.5[v_L^i(T) + v_L^i(T-1)]$, $v_L^i = P_L^i L_i / P_V^i V_i$ and $\vartheta_T^i = 0.5[v_T^i(T) + v_T^i(T-1)]$.

Similarly, we can write the average rate of aggregate productivity growth in terms of the growth rates of aggregate output, aggregate capital and labour inputs as follows:

$$(2) \quad \vartheta_T = [\ln V(T) - \ln V(T-1)] - \vartheta_K [\ln K(T) - \ln K(T-1)] \\ - \vartheta_L [\ln L(T) - \ln L(T-1)]$$

where $V = S V_i$, $K = S K_i$, $L = S L_i$, $\vartheta_K = 0.5 \times [v_K(T) + v_K(T-1)]$,
 $\vartheta_L = 0.5 \times [v_L(T) + v_L(T-1)]$, $v_K = P_K K / P_V V$, $v_L = P_L L / P_V V$.

According to Jorgenson, 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. To test the validity of the aggregate production function approach, Jorgenson derives a relationship between aggregate productivity growth and the weighted sum of sectoral productivity growth (WSSP) as follows.

Multiplying equation (1) by the ratio of value-added in the corresponding sector to value-added in all sectors, and summing over all sectors, we obtain

$$(3) \quad S w^i \times \vartheta_T^i = S w^i [\ln V_i(T) - \ln V_i(T-1)] - S w^i \times \vartheta_K^i [\ln K_i(T) - \ln K_i(T-1)] \\ - S w^i \times \vartheta_L^i [\ln L_i(T) - \ln L_i(T-1)], \quad (i = 1, 2, \dots, 15),$$

where $w^i = 0.5 [w_i(T) + w_i(T-1)]$, $w_i = P_V^i V_i / S P_V^i V_i$.

Subtracting equation (3) from equation (2) and rearranging, we arrive at the rate of productivity growth for the aggregate manufacturing sector.

$$\begin{aligned}
(4) \quad \vartheta_T &= Stt^i \times \vartheta_T^i \\
&- Stt^i [\ln V_i(T) - \ln V_i(T-1)] + [\ln V(T) - \ln V(T-1)] \\
&+ Stt^i \times \vartheta_K^i [\ln K_i(T) - \ln K_i(T-1)] - \vartheta_K [\ln K(T) - \ln K(T-1)] \\
&+ Stt^i \times \vartheta_L^i [\ln L_i(T) - \ln L_i(T-1)] - \vartheta_L [\ln L(T) - \ln L(T-1)], \quad (i = 1, 2, \dots, 15).
\end{aligned}$$

Equation (4) shows that aggregate productivity growth can be defined as the sum of a weighted sum of sectoral productivity growths and three resource reallocations. According to Jorgenson, aggregate productivity growth has a 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.

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. 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 for each component of capital stock are constructed using the *National Wealth Survey* and *Mining and Manufacturing Survey*; benchmark data of 1968, 1978 and 1987 are from the *National Wealth Survey* and *Mining and Manufacturing Survey* data are used to construct the time series. The capital stock data in this study are more reliable than those constructed from the historical investment data of the National Account, because they do not require arbitrary assumptions about 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.⁶ It is impossible to get 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 of the whole economy in all the 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, which grow more slowly than normal employment. Thus, the growth rate in the labour input index is lower than other cases.

Aggregated results and validity of the aggregate production function approach

The aggregate growth accounting results are summarised in Table 2. During the period 1967–93, the contribution to growth rates⁷ of capital and labour are 7.9 per cent and 2.3 per cent, respectively. The 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 6.0 per cent productivity growth and a 36.9 per cent contribution ratio are not low when compared with the values of developed countries in the same period. This conclusion is very similar to Drysdale and Huang (1995), 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’.

Table 3 decomposes aggregate productivity growth in the Korean manufacturing sector into the weighted sum of sectoral productivity growth (WSSP) and resource reallocations of value-added, capital input, and labour input, using equation (4). Table 3 shows that the sums of resource reallocations are not far from zero over the whole period. However, the sum of resource reallocations by time period (the last column in the table) leads to a different conclusion. The sum of resource reallocations is quite different from zero during the 1968–73, 1973–78, and 1978–83 sub-periods, though not in the 1983–88 and 1988–93 periods. 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. It also means that the sum of sectoral productivity growth weighted by industry share is a better measure

Table 2 Growth in aggregate output and its sources (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 calculations.

of aggregate productivity growth. Further, it indicates that diversification across industries (entering into 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 opportunities for productivity growth by diversification across industries. Thus, the earlier aggregate growth accounting studies such as Young (1995) and Kim and Lau (1994) are somewhat misleading because the aggregate production function up until the early 1980s cannot be defined. This calls their findings into question.

Table 3 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 calculations.

Do these results really mean that the opportunities for productivity growth through diversification are over? Note that follower countries have other opportunities to enhance productivity growth, namely by moving into production of high-quality products within the same industries. This study does not capture within-industry effects because more disaggregation is required. This study simply 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 (heavy and petrochemical industrialisation), 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 entering new industries since the 1980s. To detect this kind of industrial deepening effect, far more disaggregated data are needed.

Disaggregated results and sustainability of growth

Table 4 summarises the growth accounting results of 15 integrated industries which are based on the two-input model. According to the table, productivity growth is the largest contributor to output growth in eight industries: textiles, clothes and leather, wood, paper and printing, chemicals, fabricated metals and machinery, office machinery and medical/precision instruments, motor vehicles, and transportation vehicles except motor vehicles. Krugman's hypothesis is debatable for these industries. Four other industries show that productivity growth is an important source of growth. Their productivity contribution ratios are over 33 per cent. In contrast, capital is the dominant contributor in four industries: food, beverages and tobacco, refined petroleum, steel and non-ferrous metals, and electrical and electronic products. Krugman's criticism is valid only in 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.

Empirical results surrounding theoretical issues

The disaggregated growth accounting study in Section 3 found that productivity growth was an important contributor to output growth in Korea's manufacturing sector. 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 necessar-

Table 4 Growth in sectoral output and its sources, 1968–93

	growth rate				contribution		
	output	product- ivity	capital	labour	product- ivity	capital	labour
Food, beverage, 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 calculations.

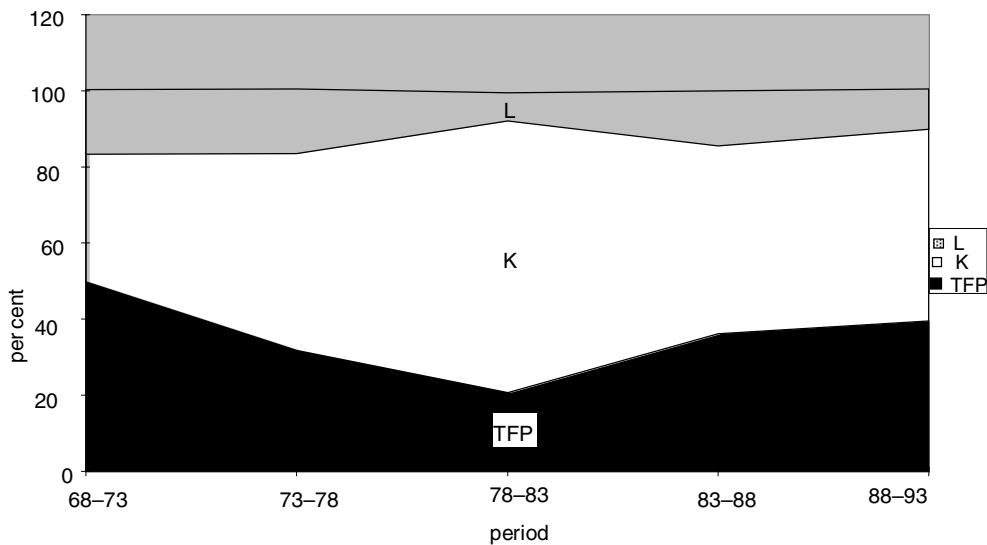
ily mean that technological change has played a minor role in the high growth in this region? The aim of this section is to understand the puzzle of low productivity gains in NIEs. The sources of output growth are not independent of the stage of industrialisation through which an economy is passing. Nor is the rate of technological change independent of the role of capital accumulation, as the discussion in Section 2 suggested. This section tests two hypotheses about these relationships, using Korean data, and examines why productivity has been so high in Korea's manufacturing sector.

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 (through 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 at 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.

Figure 3 shows the contribution ratios of productivity and capital growth to output growth over the period. The major source of output growth appears to have changed 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).

Figure 3 Sources of growth in the manufacturing sector, 1968–93 (per cent)



Source: Author's calculations.

Capital deepening plays the major role in growth but the role of productivity growth increases in 1983–88 and 1988–93.⁸ Figure 3 confirms that the experiences of Korea's manufacturing sector are consistent with the hypothesis of sequencing of the sources of growth, and that the manufacturing sector is in a period of transition from the second to the third stage, where innovation is the sole source of technological change.

The hypothesis is also validated in the industry-level analysis. Sequencing of the major sources of growth is identified in most of the disaggregated industries. Quite different trends are seen in clothes and leather, wood, paper and printing, rubber and plastic and electrical and electronic products, which are characterised by major changes in product items within the same classification.

Figure 3 reveals 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 stage (1973–83) and the 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 with 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 yet to graduate 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.

Interaction between capital growth and productivity growth

In the literature survey in Section 2 I hypothesised that there may be interaction between capital growth and technological change: embodied⁹ and induced technological change. I test this hypothesis employing a Granger causality test to clarify the direction of the interaction between the two.¹⁰

I test whether there is causality between productivity growth and capital input growth in a bivariate environment.¹¹ Capital input growth (productivity growth) is said to Granger-cause productivity growth (capital input growth) if productivity growth can be forecast better using past productivity growth (capital input growth) and past capital input growth (productivity growth), rather than just productivity 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 (5) and (6).

$$(5) \quad Y = \sum \alpha_i Y_{t-i} + \sum \beta_j X_{t-j} + \varepsilon_t$$

$$(6) \quad Y = \sum \alpha_i Y_{t-i} + \varepsilon_t$$

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.¹²

Table 5 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). Causality in the opposite direction is found in food, beverages, and tobacco (three-factor model only), textiles, wood, 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

Table 5 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)

Source: Author's calculations.

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. 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 A1, 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 5) 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, 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 are found in nine of the fifteen industries: food, beverages and tobacco, textiles, wood, 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.

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 means 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 imported capital goods. Interaction 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.

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 (Barro and Sala-i-Martin 1995). 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:

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

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

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

Inserting the average product of capital into the marginal product, the marginal product of capital is expressed as equation (7).

$$(7) \quad MP_K(t) = \beta(t) \times Y/K(t)$$

Hence, a stable output–capital ratio directly means a stable marginal product of capital, on the condition that b 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 7) but also productivity growth. Rearranging equation (1), which calculates productivity growth in terms of growth rates in output, and effective labour and capital input, we arrive at

$$g(Y) = v_T + v_K g(K) + v_L g(L)$$

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

$$(8) \quad g(Y/L) = v_T + v_K g(K/L) + (v_K + v_L - 1) g(L)$$

$$\text{or} \quad g(Y/L) = v_T + v_K g(K/L), \quad \text{if } v_K + v_L = 1$$

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

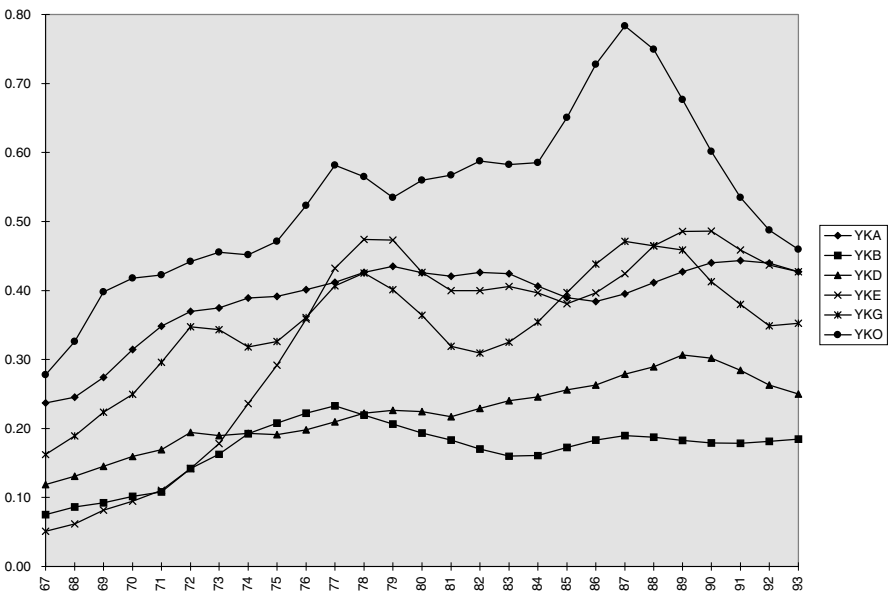
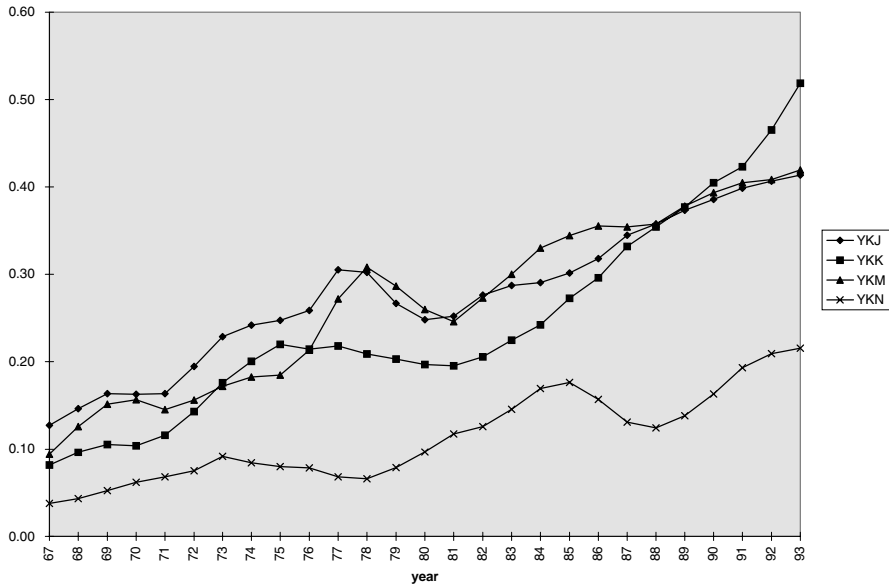
The rate of growth in output per effective labour unit can be expressed by the sum of the growth rates in the output–capital ratio and the capital–labour ratio, because $Y/L = (Y/K) \times (K/L)$. Inserting this relationship into equation (8) and rearranging, we obtain

$$(9) \quad v_T = g(Y/K) + v_L g(K/L) - (v_K + v_L - 1) g(L)$$

$$\text{or} \quad v_T = g(Y/K) + v_L g(K/L), \quad \text{if } v_K + v_L = 1.$$

Equation (9) means that productivity growth is the sum of growth of the output–capital ratio and the contribution growth rate in the capital–labour ratio. 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 Section 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. It is noteworthy that these industries showed the lowest productivity growth in the growth accounting study in Section 3.

Figure 4 Output-capital ratio at industry level, 1968–90



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

Source: Author's calculations.

The increasing output–capital ratios 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.

Conclusion

Aggregate growth accounting studies find that productivity growth is not an important source of growth in East Asia. This result leads to the implication that the NIEs will not be able to sustain growth in the long run, combined with the view that productivity growth is the main contributor to long-run growth. This paper examined this paradigm.

The initial focus was on disaggregated growth accounting approach. According to the results, the earlier finding that the contribution of capital to growth is relatively high in the case of NIEs cannot be denied for Korean manufacturing. However, productivity growth is the largest contributor to output growth in eight of the fifteen industries, and the contribution of productivity growth to output growth is not low, at about 37 per cent. The aggregate production function approach is not acceptable in considering the sum of resource reallocations. It is quite different from zero.

This led to an examination of the theoretical hypotheses, which explain the puzzle of low productivity gains and call into question the unsustainability of growth in NIEs. The empirical results of these hypotheses are as follows. First, the sequencing of sources of growth was empirically verified (productivity in light industries → capital accumulation in heavy and petrochemical industries → productivity growth through R&D efforts). Second, interaction between productivity growth and capital input growth was apparent in nine of the fifteen industries. Third, an increasing or constant output–capital ratio (marginal product of capital) was found in ten of the fifteen industries.

Verification of the hypotheses explains 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 hypotheses is also inconsistent with Krugman’s unsustainability hypothesis derived from 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.

A crucial component of the logic of sustainability of growth is that disembodied technological change is the main contributor to long-run growth. This view is generally accepted in the case of a leader country, which achieves higher productivity growth mainly by accumulating new knowledge through innovation. However, this study suggests that the growth process of a follower country is different.

Appendix: Comparison with earlier studies

Earlier growth accounting studies on Korean manufacturing show a wide range of estimates of productivity growth, 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. It 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). Growth rate in capital stock estimated from the *Mining and Manufacturing Survey* or the *National Wealth Survey* is also higher than the estimate from 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 the case of KDI dataset decreases its growth rate because growth rates in other types of capital stock, machinery and non-residential structures, grow faster. In this case productivity growth will be higher than in the other case. 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 applied a one-to-one rule in treating self-employed and unpaid family workers. This would surely decrease labour input growth, and so increase productivity growth.

Table A1 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)*

Source: Author's calculations.

However, the one-to-one rule has an offsetting force by decreasing productivity growth through lowering the share of labour.

According to Table A2, this study is within the higher productivity group, as noted by Kim and Park (1988) and Dollar and Sokoloff (1990). In contrast, the other studies show lower productivity growth (1.1–3.7 per cent). Table A3 finds the causes of difference in productivity

Table A2 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: Compiled by the author.

growth between this study and Young (1995). According to the table, capital stock data in two studies do not make any difference in calculating productivity growth, even though the growth rate in Young is 2 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)¹³ and differences in data source (1.01 per cent). However, most of the difference in productivity growth, about 70 per cent (2.04 in 2.95 per cent), is simply a result of the difference in output growth. KDI output data are estimated from the *Input Output Table* and the *Mining and Manufacturing Survey*, whereas Young uses National Account data.¹⁴

Table A3 Productivity growth comparison with Young (1995)

	This study (1968–93)	Young (1966–90)	Difference
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: Compiled by the author.

Notes

- 1 This directly predicts that we can find no evidence of productivity growth when decomposing output (Y) growth into input growth, capital (K) and labour (L), and productivity growth.
- 2 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. In this way, they conclude that TFP convergence occurred.
- 3 On this point, Dollar finally arrives at the same conclusion as the growth accountants.
- 4 As shown in section 3 (growth accounting studies), capital deepening (increase in K) explains more than 70 per cent of economic growth in Korean manufacturing in the period 1978–83. Thus, extending the time span to the early 1980s probably weakens Dollar's TFP convergence argument.
- 5 Strictly speaking, the idea of sequencing has a long tradition. Rostow's stage theory and Baumol's growth analysis are examples.
- 6 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.
- 7 The contribution growth rate is calculated by multiplying the growth rate in an input by its share in output.
- 8 At the third stage, the capital contribution share decreases while the productivity share increases.
- 9 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).
- 10 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.
- 11 I performed a bivariate cointegration test using the Johansen procedure for capital and productivity levels. According to I_{\max} and I_{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.
- 12 Optimal lag length is chosen where the Akaike statistic (equation 1) or 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.

- 13 Young's weighting scheme for labour is more stringent than the KDI dataset. 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. However, these different weighting schemes result in a 0.58 per cent difference of labour input growth.
- 14 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 (1995), capital share and the specific estimation period results in different productivity growth in the East Asia. In contrast the *Input Output Table* does not require strong assumptions in calculating productivity growth, and allows a disaggregated approach.

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