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PRODUCTIVITY GROWTH IN EAST ASIAN MANUFACTURING: A FADING MIRACLE OR MEASUREMENT PROBLEM?

CHIA-HUNG SUN*
Department of Economics, National Chung Cheng University, Taiwan, R.O.C.

Abstract: Despite the intensive debates on the East Asian economic miracle that persisted during the last decade, the verdict on the source of output growth is inconclusive. There can be no dispute over the importance of total factor productivity (TFP) growth in the process of economic development and raising the level of living standards. But, the question of whether TFP growth played a significant role in East Asian economic growth remains contentious, especially in Singapore's case. This paper provides an updated review on productivity growth in the East Asian manufacturing and that of Hong Kong, Japan, Korea, Singapore and Taiwan, and recommends options for further research to improve understanding on the issue of TFP growth in East Asian manufacturing. Copyright © 2005 John Wiley & Sons, Ltd.

1 INTRODUCTION

To uncover the source of the East Asian economic miracle, the debates on productivity growth in East Asia have been widespread since the 1990s. Due to differences in data, methodology and sample period selected, recent empirical TFP studies have, not surprisingly, revealed mixed results. In an influential paper by Young (1995), he pointed out that the spectacular economic performance in East Asia was not as impressive as previously thought and claimed the economic success was nothing more than intensive factor accumulation. Using growth accounting and breaking down output growth into components that can be attributed to the observable factors of the growth of capital stock and labour force, Young showed that TFP growth (or Solow residual) in East Asian countries was comparable with those of developed economies. Young's finding further predicted that high economic growth is unlikely to be maintained in East Asian economies due to scant progress in the level of TFP.

While the findings of Kim and Lau (1994), Krugman (1994), and Collins and Bosworth (1996) are generally consistent with Young's, Chen (1997) raised concerns over possible

*Correspondence to: Chia-Hung Sun, Department of Economics, National Chung Cheng University, Chia-Yi, 621, Taiwan, R.O.C. E-mail: ecdchs@ccu.edu.tw

difficulties in measuring capital input.[1] Chen also argued that the assumption of disembodied technology in growth accounting appears to be problematic in the case of Singapore, which may have gained more from embodied technological change than disembodied technological change due to the fast-improved quality of its labour force and the adoption of modern technologies. The persuasive conclusion by Chen (1997) states that 'the significance of technological change in economic growth depends largely on how TFP is defined and how factor input data are measured'. Moreover, Felipe (1999) reiterated the theoretical and empirical problems evidenced in recent TFP literature with respect to the application of aggregate production and growth accounting. Given the varied and conflicting results, Felipe urged caution in drawing any conclusions on these TFP estimates because of the problems and limitations associated with the methodology used in these studies. Further discussions of growth accounting can be found in Barro (1999), Rodrigo (2000), and Hulten (2000) and so on.

This paper does not intend to overview measurement of TFP growth as discussion on the parametric (stochastic frontier model) and non-parametric (e.g., Data Envelopment Analysis, DEA) methodology is available in existing literature. For instance, Mahadevan (2003) debated the definition of TFP growth and its relation to the concepts of embodied and disembodied technical change. Mahadevan then raised a number of issues regarding the use of the frontier and non-frontier approaches to measure TFP growth (see Mahadevan, 2003, p. 372, Figure 1). Heshmati (2003) showed the main approaches to the measurement of TFP growth with various degrees of flexibility and then discussed the measurement of inputs and outputs in manufacturing sector, which is crucial for estimating TFP growth but often ignored. For more overviews of TFP measurement, refer to Hulten (2000), Felipe (1999), Nelson and Pack (1999), Chen (1997) etc.

With exception of Mahadevan (1999) on Singapore, earlier survey articles on East Asia concentrated on the economy as a whole. The present paper therefore surveys TFP studies on East Asian manufacturing. Section 2 begins with TFP studies that compared the performance of the manufacturing sectors in Hong Kong, Japan, South Korea (hereafter Korea), Singapore, and Taiwan, followed by country-specific studies on these economies. The focus will be on the estimates of TFP growth rates, sample periods covered, and estimation approaches used by recent studies. Section 3 provides some insights on reconciling differences in TFP growth estimates among existing studies and briefly discusses a recent extension to measure TFP growth. Section 4 summarizes and concludes with a discussion on options for future research.

2 TFP STUDIES ON EAST ASIAN MANUFACTURING

2.1 Review on East Asian Manufacturing

Due to different aggregations and sample periods, the number of manufacturing industries examined varied from study to study. Using growth accounting with translog production function, Young (1995) examined TFP growth in the four East Asian Tigers (Hong Kong, Korea, Singapore and Taiwan) although the results for manufacturing sectors are available

[1]A number of reasons for the possible over-adjustment of factor inputs in East Asia include capacity utilization, depreciation of the capital stock, the deflators of capital input, and so on. For the details of other possible reasons, see Chen (1997, pp. 32–33).

only for the latter three economies. On the one hand, Young found evidence that the Korean manufacturing sector gained TFP at an average annual rate of 3.0 per cent over the 1966–90 period while the average annual TFP growth rate for Taiwan's manufacturing sector was moderate at 1.7 per cent during the same period, mainly due to zero TFP progress in the 1970s. On the other hand, Singapore's manufacturing sector was reported to have had a TFP decline of 1 per cent during the period 1970–90 on an average annual basis.[2]

In a study of manufacturing sectors in Korea, Turkey, Yugoslavia and Japan by Nishimizu and Robinson (1984), the TFP of Korean and Japanese manufacturing sectors measured by the translog TFP index number grew by 3.71 per cent and 2.04 per cent over the periods 1960–77 and 1955–73, respectively. TFP growth in Korea and Japan was attributed to have made a 20.7 per cent and 17.6 per cent contribution to output growth, respectively.

Nadiri and Kim (1996) estimated TFP growth for the US, Japanese, and Korean manufacturing sectors. Using the Törnqvist index with labour, capital, materials and research and development (R&D) as factor inputs, the average annual TFP growth for Korea and Japan based on total cost shares as weights was estimated at 0.69 per cent and 1.26 per cent, respectively, over the 1975–90 period. Nadiri and Kim also provided another set of TFP estimates if conditions of perfect competition, constant returns to scale, and instantaneous adjustment of all inputs are assumed to exist. The average annual TFP growth rates based on revenue shares as weights for Korean and Japanese manufacturing sectors were 1.14 per cent and 3.15 per cent, respectively.

Timmer and Szirmai (2000) also applied growth accounting to the four Asian manufacturing sectors of India, Indonesia, Korea and Taiwan, to estimate the aggregate and output-weighted TFP growth, respectively. The difference between the two TFP growth estimates is the result of a total reallocation effect due to the shift from less productive manufacturing industries towards more productive industries. Timmer and Szirmai's results showed that the average annual TFP growth rate of the Korean manufacturing sector was 4.5 per cent over the period 1963–90 regardless of a negative reallocation effect. For Taiwan's manufacturing sector, it was 2.0 per cent for the 1963–93 period, which was partly attributable to the reallocation effect (0.3 per cent).

Han *et al.* (2002) applied the varying coefficients model to investigate TFP growth for 20 manufacturing industries in Hong Kong, Korea, Japan and Singapore. After decomposing output growth into input growth, technical efficiency and technological progress, they suggested that over the period 1987–93 factor accumulation accounted for most of the output growth in the four East Asian manufacturing sectors whereas technological progress played a lesser role during the same period. A summary of these TFP studies on East Asian manufacturing sectors is presented in Table 1.

2.2 Review on Hong Kong's Manufacturing Sector

Compared with other East Asian manufacturing sectors, there have been relatively fewer TFP studies on Hong Kong's manufacturing sector because most TFP studies involving Hong Kong have concentrated on the overall economy, for instance, Dowrick and Nguyen

[2]Apart from Young (1995), none of the TFP studies on East Asian manufacturing sectors made adjustments for quality improvement embodied in capital and labour inputs. Thus, those TFP estimates are likely to be overstated.

Table 1. TFP studies on East Asian manufacturing sectors

Authors	Country	Period	Method	TFPG p. a. (%)
Nishimizu and Robinson (1984)	Japan	1955–73	Translog TFP index	2.04
	Korea	1960–77		3.71
Young (1995)	Korea	1966–90	Growth accounting	3.0
	Singapore	1970–90		–1.0
	Taiwan	1966–90		1.7
Nadiri and Kim (1996)	Japan	1975–90	Törnqvist index	1.26
	Korea	1975–90		0.69
Timmer and Szirmai (2000)	Korea	1963–90	Growth accounting	4.5
	Taiwan	1963–93		2.0

Note: Nadiri and Kim (1996) also provide another set of TFP growth estimates for Japan and Korea if the conditions of perfect competition, constant returns to scale, and instantaneous adjustment of all inputs are assumed to be valid.

(1989), Kim and Lau (1994), Young (1992; 1995), Sarel (1995), Drysdale and Huang (1997), and Hsieh (1999; 2002).

The study most relevant to the topic being reviewed is that by Kwong *et al.* (2000). They used growth accounting with translog gross output function to investigate the TFP growth of Hong Kong's manufacturing industries for the period 1984–93. The study revealed that although 15 out of 29 industries advanced in TFP, the overall manufacturing sector experienced a technology decline of 13.8 per cent during the decade.[3] Stated differently, Hong Kong's manufacturing sector in 1993 could only produce 87 per cent of the 1984 output with the same amount of resources.[4] The implication of this unexpected finding had much to do with the liberalisation in China since 1978 and the style of Hong Kong's existing manufacturing sector (original equipment manufacturing). More specifically, manufacturers in Hong Kong were not willing to invest heavily in R&D to upgrade their technology while profits remained positive and low-cost resource facilities in mainland China could be easily accessed.

Tuan and Ng (1995) examined three major export-oriented industries, namely, garments and wearing apparel, consumer electronics, and electronics parts and components. In applying the Cobb–Douglas production function with regression approach, the study found that there was little change in TFP level in the three industries except for garments and wearing apparel.[5]Imai (2001) did not explicitly estimate TFP growth for Hong Kong's overall manufacturing sector. Instead, he disaggregated Hong Kong's economy into three sectors, non-tradable, tradable services and tradable goods (overwhelmingly dominated by manufacturing). Applying growth accounting, Imai suggested that the tradable goods

[3]Sample periods differ across the 29 industries, for example, the petroleum and coal industry is from 1988–93 and the electronic parts and components industry from 1984–89.
[4]One possible concern is that Kwong *et al.* (2000) use gross output (rather than conventional value added) with the inputs of material, labour, capital, utilities and factory space to estimate TFP growth because they claim that manufacturing value added was overstated as a result of the recent integration with mainland China. An example is provided in Kwong *et al.* (2000, p. 173, footnote 4).
[5]Strictly speaking, the study by Tuan and Ng (1995) is less relevant to the objective of this study. Moreover, it is unclear why there were several negative capital coefficients in their estimates. This indicates that less capital would lead to more output, which basically contradicts the economic theory. No explanations were offered for the huge swing in TFP level and capital coefficients (or elasticities) on an annual basis, say, from 1.6977 to 2.9047 (constant term, represented by TFP) and from 0.2618 to 0.6300 (capital coefficient). Hence, their results must be viewed with care.

sector (manufacturing) experienced high average annual TFP growth rates of 5.6 per cent and 6.0 per cent during 1981–90 and 1991–97, respectively.[6]

2.3 Review on Japan

There are many TFP studies on Japanese manufacturing industries, which enable them to be classified into four categories. The first category concentrated on individual industries, for example, the chemical or automobile industry. Using the translog (Törnqvist) index of cost efficiency growth to measure TFP growth, Fuss and Waverman (1990) investigated productivity growth in the motor vehicle industry of Canada, Japan and the US. They found that the TFP of the Japanese auto industry grew by an annual rate of 3.0 per cent, compared with an average annual TFP growth rate of 1 per cent for the US and Canada.[7] Furthermore, the study found that 80 per cent of TFP growth in the Japanese auto industry during the 1970–84 period was due to technical change and 20 per cent attributed to scale economies.

Kumbhakar *et al.* (2000) discussed the time trend model and the variants of the general index model to accommodate technical change and technological biases in measuring TFP growth. They showed that the average annual TFP growth rates computed by three versions of the general index model appeared to be similar, ranging from 1.553 per cent to 1.716 per cent in the Japanese chemical industry during the period 1968–87.

The second category of studies focused on either the Japanese manufacturing sector as a whole or individual manufacturing industries in Japan. Nakajima *et al.* (1998) used an index number approach to estimate and decompose TFP growth into technical change and scale economy effects for 18 manufacturing industries over the period 1964–88. They found that more than 90 per cent of the gains in TFP were due to technical change and average annual TFP growth rates ranged from 2.167 per cent (food/kindred products industry) to 5.489 per cent (petroleum and coal product industry). Overall, the simple average of TFP growth rate for the entire manufacturing sector was found to be 3.731 per cent per annum.

A study analysing the sectoral shifts in the Japanese economy by Prasad (1997) found that the share of manufacturing output in the real economy GDP remained stable despite the declining share of the manufacturing sector in total employment. According to the OECD sectoral database, the average annual TFP growth rate of manufacturing sector during the 1971–93 period was 2.8 per cent. Sato (2002) held the contraction of manufacturing employment partly responsible for the stagnant economy in the 1990s and estimated the average annual TFP growth rates of the manufacturing sector at 2.5 per cent, 2.6 per cent and 2.2 per cent over the periods 1979–85, 1985–91 and 1991–97, respectively.[8] Yet, the poor performance of the non-manufacturing sector was the main cause that pulled down overall productivity growth in the 1990s.

[6]Note that the qualitative improvement associated with labour and capital inputs was not excluded in Imai's study, which may overstate the actual TFP growth rates. More importantly, the tradable sector cannot be completely viewed as the manufacturing sector; hence, his result should be interpreted with caution.
[7]Because TFP growth measures the improvement in the efficiency of the use of inputs over time, Fuss and Waverman (1990) measure TFP growth by the growth in cost efficiency.
[8]Sato's estimates of TFP growth rates (2002) are taken from the *Annual Report of National Accounts* by the Japanese Economic Planning Agency.

The third category of studies was based on bilateral comparisons between Japanese and US manufacturing industries. Norsworthy and Malmquist (1983) initially rejected the value-added approach to measure productivity growth in the US and Japan due to the failure of separability tests.[9] They next carried out a comparison of the estimates of multifactor productivity growth for US and Japanese manufacturing using the translog production function and gross output approach. Their findings revealed that average annual TFP growth rates for Japanese manufacturing were 0.91 per cent and 1.64 per cent during the periods 1965–73 and 1973–78, respectively.[10]

Jorgenson *et al.* (1987) employed translog quantities indexes of the rates of technical change to compare productivity growth of the Japanese and US manufacturing industries over the period 1960–79. Their results showed that while the average annual TFP growth rates for 21 Japanese manufacturing industries varied widely (from −3.16 per cent in the petroleum and coal industry to 3.07 per cent in the electrical machinery industry), the modest annual TFP growth rate of 0.83 per cent for the overall manufacturing sector was largely due to the TFP slowdown after 1973.

Griliches and Mairesse (1990) used firm-level data to assess the contribution of R&D to productivity growth in the manufacturing sectors of Japan and the US during 1973–80. By assuming that value added and sales vary proportionally and capital input share was constant and equal to 0.25 for all firms in Japan, they found that the electrical equipment and instruments industries experienced the highest annual TFP growth rates of 8.4 per cent and 8.1 per cent, respectively, and the chemical and rubber industry had the lowest annual TFP growth rate of 0.6 per cent.[11]

The final category of studies extended the comparison of Japanese manufacturing industries to that of the US, Canada, and Germany. Using the generalized Leontief cost function, Morrison (1990) provided an alternative measure of TFP growth that allowed for scale economies, subequilibrium, costs of adjustment and mark-up behaviour, as opposed to the conventional TFP growth approach. Morrison demonstrated the comparison of these two approaches using the data of the US, Japanese and Canadian manufacturing sectors and found that the average annual conventional TFP growth rate of the Japanese manufacturing sector was 1.223 per cent over the period 1960–81 whereas the modified TFP growth rate fell to 0.987 per cent.

Using a Törnqvist TFP index, Denny *et al.* (1992) found the evidence that the slowdown of TFP growth was a widespread phenomenon across the manufacturing sectors of Canada, Japan and the US over the 1973–80 period. Their study found that the average annual TFP growth rates for Japanese manufacturing industries ranged from 0.23 per cent in the food industry to 3.28 per cent in precision instruments during the 1954–86 period. Moreover, there was no sign of any improvement in TFP growth in Japan in the 1980s.

[9]Using Norsworthy and Malmquist's data set and non-parametric analysis, Chavas and Cox (1990) suggest the findings of Norsworthy and Malmquist (1983) are sensitive to their parametric specifications. In other words, Chavas and Cox (1990) find little evidence to support the necessity of using the gross output approach and the hypothesis of Hick non-neutral technical change.

[10]If the value-added approach was applied, the corresponding results would be 2.03 per cent and 3.67 per cent, respectively.

[11]The results of the Japanese manufacturing industries in Griliches and Mairesse (1990) are unweighted firm averages and many of multinational firms are also included in the sample, so TFP growth estimates are not comparable to other studies.

2.4 Review on Korea

One of the key issues considered in the series of TFP studies on the Korean manufacturing sector by Jene K. Kwon was the capital utilization rate.[12] After incorporating the capital utilisation rate in the growth accounting framework, Kim and Kwon (1977) demonstrated that the contribution of TFP growth to output growth in the Korean manufacturing sector was significantly reduced from 36 per cent to 8 per cent during the period 1962–71. However, the detailed estimate of TFP growth is not available in their study. Later, Kwon (1986) decomposed TFP growth into technical change, non-constant returns to scale, and change in capital utilisation by linking growth accounting to a cost function. The empirical result showed that during 1961–80, the TFP of the Korean manufacturing sector grew by 2.95 per cent per annum and contributed 15.16 per cent to output growth. More specifically, the shares attributed to TFP growth by technical change, non-constant returns to scale, and change in capital utilisation were found to be 44.6 per cent, 38.1 per cent and 17.3 per cent, respectively.

In employing growth accounting, Dollar and Sokoloff (1990) split labour productivity growth into capital deepening and advances in total factor productivity and analysed the relative contributions to labour productivity growth in 25 Korean manufacturing industries. They found evidence that capital deepening accounted for over 70 per cent of labour productivity growth in heavy industries comprising iron and steel, industrial chemical and others. In contrast, a rapid advance in TFP in light, medium, and natural resource industries on average explained about two-thirds of labour productivity growth.[13] Among TFP studies on Korean manufacturing industries, Dollar and Sokoloff (1990) reported the highest average annual TFP growth of 6.1 per cent for the manufacturing sector over the period 1963–79.

Kang and Kwon (1993) measured the TFP growth of 22 Korean manufacturing industries, using growth accounting associated with a translog cost function and took account of the capital utilization rate. They suggested that TFP growth for the manufacturing sector on average grew at annual rates of 3.43 per cent and 0.16 per cent for the periods 1963–73 and 1973–83, respectively. Input growth accounted for 84 per cent and 99 per cent of the output growth for the corresponding periods, suggesting that the output growth in Korean manufacturing industries was mainly input-driven.

In applying a Cobb–Douglas production function and value added as a measure of output, Pilat (1995) first compared the level of TFP in the Korean manufacturing with that of the United States based on specific industry of origin purchasing power parities. He found the Korean manufacturing sector's TFP had risen from 9 per cent of the US level in 1967 to more than 18 per cent in 1987. Using growth accounting, Pilat found the TFP growth of the manufacturing sector exhibited an average annual rate of 4.3 per cent between 1967 and 1987.

Using the short-run generalized Leontief cost function, Park and Kwon (1995) investigated the TFP growth of 28 Korean manufacturing industries, grouped as heavy and light industries, together with the effects of markups (market power), scale economies and capacity utilization. Their results showed a considerable difference between conventional TFP growth (2.0 per cent) and generalized TFP growth (-1.6 per cent) for the

[12]Other papers on the Korean manufacturing sector's productivity growth by Jene K. Kwon include Kwon (1986), Kang and Kwon (1993), Park and Kwon (1995) and Yuhn and Kwon (2000).
[13]The classification of four major categories (light, heavy, medium and natural resource) can be found in Dollar and Sokoloff (1990, p. 313).

Korean manufacturing over the period 1967–89. This implied that due to the failure of distinguishing the effects of scale economies and capacity utilization in the measurement of TFP growth, the conventional TFP estimates were theoretically biased. Hence, it is argued that the negative TFP growth derived from the generalized TFP measure reflected the true degree of technology decline in the Korean manufacturing sector.

In addition to examining the impact of government intervention (tariff, tax incentives etc.) on the TFP growth of the manufacturing sector in Korea, Lee (1996) also provided TFP growth estimates for 38 manufacturing industries over four separate periods, 1962–67, 1968–72, 1973–76 and 1979–83. Lee did not provide an average annual TFP growth estimate for the manufacturing sector nor for the individual 38 manufacturing industries over the entire period, the results for individual industries over four different periods are available in Lee (1996, p. 408).

In a comparative study involving Korea and Taiwan, Okuda (1997) estimated TFP growth in Korean manufacturing using the growth accounting framework. He found the Korean manufacturing sector as a whole had an average annual TFP growth rate of 3.2 per cent for the period 1970–93 and contributed 22.7 per cent to output growth. Lee *et al.* (1998) applied the non-parametric Malmquist productivity index to 36 Korean manufacturing industries over the period 1967–93. Overall, the TFP of the manufacturing sector increased by an annual rate of 0.286 per cent. The decomposition of TFP growth revealed that technological progress (1.141 per cent per annum) was the major source of TFP progress. However, the moderate technological progress combined with low TFP growth implied that there was deterioration in technical efficiency (−0.855 per cent per annum) over time, which was the case in many Korean manufacturing industries.

Hwang (1998) disagreed with the views of Young (1995) and others who argued that TFP performance in East Asian manufacturing sectors was comparable to that of developed countries. Applying two different approaches (the conventional growth accounting and augmented Solow model), Hwang showed that TFP in Korea's manufacturing sector increased by average annual rates of 2.06 per cent and 2.46 per cent between 1973 and 1993.[14] Further, applying Johansen's cointegration analysis Hwang suggested that the Korean manufacturing sector can be characterized by an endogenous growth model due to increasing returns to scale in production technology or a learning-by-doing effect.

Kim (2000) distinguished the difference between 'standard' TFP growth and 'true' TFP growth for 36 Korean manufacturing industries over the period 1966–88 by considering the incidence of imperfect competition and non-constant returns to scale. Using Korea's *Input Output Tables* and adjusting the growth in labour input for changes in hours worked and education level, the result derived from the traditional growth accounting showed that the unweighted average TFP growth of Korean manufacturing industries was 1.9 per cent per annum. Furthermore, after excluding the effects of imperfect competition and non-constant returns to scale, the true unweighted TFP growth estimate for the manufacturing sector was about 0.5 per cent per annum during the sample period, accounting for only 3 per cent of output growth in the Korean manufacturing sector. The detailed TFP growth rates for 36 manufacturing industries are available in Kim (2000, p. 77, Table 7).

Kwack (2000) measured the TFP growth of Korean manufacturing industries over the period 1971–93. Using the growth accounting approach, the results revealed annual TFP

[14]Hwang (1998) uses the index of manufacturing output as a measure of aggregate output and the total man hours worked in the Korean manufacturing as a measure of labour input.

growth rates of 3 per cent, 4.5 per cent, and 1.1 per cent in the total, heavy, and light manufacturing industries respectively. The contribution of TFP growth to value added growth for the manufacturing sector was 21.6 per cent for the sample period but fell to 9.4 per cent in the more recent period 1989–93.

Yuhn and Kwon (2000) extended the work of Kwon and Yuhn (1990) and questioned the use of value added as a measure of manufacturing output in productivity analysis due to its failure to satisfy the separability hypotheses. They then applied the growth accounting approach to estimate TFP growth of the Korean manufacturing sector and found that TFP grew by an average annual rate of 1.52 per cent between 1962 and 1981 contributing 7.6 per cent to output growth.

Kim and Han (2001) examined the TFP growth of Korean manufacturing industries by using a stochastic production frontier approach and found that the average annual TFP growth rate of the manufacturing sector was 7.3 per cent, despite the decreasing trend. Following Kumbhakar (2000), they decomposed TFP growth into four components: technical progress, changes in technical efficiency, changes in allocative efficiency and scale effects. Using the annual data for 508 manufacturing firms listed in the Korean Stock Exchange from 1980 to 1994, Kim and Han found that technical progress was the key contributor to TFP growth and technical efficiency improvement also played a significant role.

Recently, Mahadevan and Kim (2003) applied the random coefficients model and used firm-level data from 135 firms listed on the Korean Stock Exchange, to estimate the TFP growth in four industries at the two-digit level during 1980–94. Mahadevan and Kim's study showed that output growth in the four manufacturing industries was increasingly productivity-driven since the mid-1980s.[15]

2.5 Review on Singapore

In additional to the present review, a comprehensive survey by Mahadevan (1999) additionally offered comparisons of TFP performance in Singapore's service sector and the overall economy. Notably, Tsao (1985) first argued that the miraculous output growth in Singapore's manufacturing industries was not associated with high TFP growth in the 1970s. Tsao then applied growth accounting with the translog production function and four factor inputs, and discovered that 17 out of 28 Singapore's manufacturing industries experienced negative TFP growth over the period 1970–79. Tsao concluded that on average Singapore's manufacturing sector enhanced its TFP by only 0.08 per cent per annum stemming from annual TFP growth rates of −1.18 per cent for the period 1970–73 and 0.71 per cent for 1973–79.

Wong and Gan (1994) applied the conventional growth accounting approach to examine TFP growth in 28 Singapore manufacturing industries at the 3-digit level. Using gross output and the factor inputs of capital, labour, material and energy, their results indicated that the overall manufacturing sector averaged an annual TFP growth rate of 1.6 per cent over the period 1981–90. Moreover, Wong (1993) investigated the sources of labour productivity growth and found that the TFP growth of Singapore's manufacturing industries accounted for 44 per cent of labour productivity growth in the 1980s.

[15]Note that because the sample size is relatively small and presumably based on large firms, their results may not be comparable with other studies discussed above.

Rao and Lee (1995) explored the sources of output growth in Singapore's manufacturing and services sectors and the overall economy over three distinct phases, 1966–73, 1976–84, and 1987–94. In employing conventional growth accounting, their findings showed that Singapore's manufacturing sector experienced an average annual TFP growth of −0.4 per cent and 3.2 per cent for the periods 1976–84 and 1987–94, respectively. The contribution of TFP growth to output growth increased from −5 per cent to 32 per cent between the two periods. In contrast to Kim and Lau (1994) and Young (1995), Rao and Lee concluded that the sustainability of Singapore's manufacturing sector looked optimistic.

Leung (1997) employed growth accounting to study 30 Singapore's manufacturing industries for the period 1983–93. Unlike many existing TFP studies, Leung estimated that the weighted average annual TFP growth was 2.8 per cent for the manufacturing sector whereas the average annual TFP growth rate of the aggregate (unweighted) manufacturing sector was 2.0 per cent. Hence, Leung suggested that an average annual TFP growth rate of between 2 per cent and 3 per cent was plausible for Singapore's manufacturing sector during the decade. Leung's further analysis of the determinants of TFP growth, found that the learning-by-doing effect did not impact on TFP growth.

Bloch and Tang (1999) estimated cost-saving technical progress in 27 of Singapore's manufacturing industries at the 3-digit level in an attempt to distinguish TFP growth derived from conventional growth accounting. Apart from the divergence of eight industries, the findings in the other 19 industries indicated that 11 of them experienced technical progress represented by the elasticity of cost with respect to time whereas the other eight industries suffered technical regression between 1975 and 1994. The estimates of TFP growth rates computed by growth accounting are also available in the Bloch and Tang's study.

Mahadevan and Kalirajan (2000) applied the stochastic production frontier to examine TFP growth in 28 Singapore's manufacturing industries over the period 1976–94. Although input growth emerged as a major factor driving output growth, the Mahadevan and Kalirajan study found evidence of positive technological progress with negative technical efficiency change leading to positive but low and declining TFP growth in Singapore's manufacturing sector. The average annual TFP growth rates for the periods 1976–84 and 1987–94 were 0.92 per cent and −0.52 per cent, respectively. More specifically, the latter was attributable to −0.8 per cent technical efficiency change and 0.28 per cent technological progress.

In contrast to earlier TFP studies, Koh *et al.* (2002) provided the most optimistic TFP estimate for Singapore's manufacturing sector to date. They employed the conventional growth accounting approach in conjunction with Singapore's manufactured-product-price index (output-price deflator) and import-price (material-price deflator) to estimate TFP growth for the manufacturing sector comprising 18 industries at the two-digit level over the period 1975–98. Their finding suggested that TFP growth for the manufacturing sector was 2.7 per cent on an annual basis.

2.6 Review on Taiwan

Before discussing the relationship between export performance and productivity growth, Chen and Tang (1990) applied growth accounting to estimate TFP growth for 16 Taiwan manufacturing industries at the 2-digit level over the 1968–82 period. Unlike conventional growth accounting, TFP growth in their study is defined as 'a change in average cost not accounted for by the changes in input prices', in which the inputs include labour, capital and material. Chen and Tang found that four of the 16 industries experienced negative TFP growth and average annual TFP growth ranged from −0.76 per cent in the lumber and furniture industry to 4.13 per cent in leather and fur industry.

Okuda (1994) explored the impact of trade and foreign direct investment on productivity growth in Taiwan's manufacturing industries and using a Törnqvist index provided TFP growth estimates for 11 industries between 1978 and 1991.[16] He estimated the average annual TFP growth rate for the manufacturing sector was 2.6 per cent during the sample period. Note that the adjustments for quality improvement embodied in labour and capital inputs were not carried out in Okuda's study suggesting a possible overstatement of TFP growth. Okuda (1997) extended his earlier study to compare the TFP performance of the Taiwanese and Korean manufacturing industries. However, the sample period covered for Taiwan's manufacturing industries was only extended by a year so the TFP growth estimates in Table I of Okuda (1997, p. 365) were comparable to his 1994 results; hence, the review of Okuda (1997) is not undertaken.

Liang (1995) stressed the importance of disaggregating factor inputs to avoid measurement errors caused by the heterogeneous inputs, for example, skilled labour, unskilled labour and manager etc. Using the translog index with gross output and four inputs (labour, capital, materials and energy), Liang examined 17 industries comprising the manufacturing sector and found average annual TFP growth rates were 0.12 per cent and 1.41 per cent during the periods 1973–82 and 1982–87 respectively.[17] Extending Liang's (1995) study, Liang and Jorgensen (1999) compared TFP growth estimates for Taiwan's manufacturing industries on the basis of two different output measurements, gross output and value added output. The average annual TFP growth rates computed from value added output for the manufacturing sector were 2.33 per cent, 2.72 per cent and 2.46 per cent over the periods 1961–82, 1982–93, and 1961–93, respectively while the corresponding average annual TFP growth rates calculated from gross output were lower at 0.2 per cent, 0.55 per cent and 0.32 per cent, respectively.

Unlike most TFP studies, Chuang (1996) applied the regression approach to measure TFP growth for Taiwan's manufacturing sector and found that it increased at an average annual rate of 1.9 per cent between 1975 and 1990. After incorporating trade-induced learning, he claimed that over 40 per cent of manufacturing output growth in Taiwan was attributed to a 'trade-induced learning' effect, which he treated as TFP growth. However, detailed TFP growth estimates for individual manufacturing industries are unavailable in his study.

Hu and Chan (1999) applied growth accounting in conjunction with human capital to estimate TFP progress in 15 Taiwan manufacturing industries. On average, TFP in the manufacturing sector grew at 3.1 per cent per annum (employees as labour input) or 3.4 per cent (hours worked as labour input) over the period 1979–96.[18] Because quality

[16]The original 18 industries were combined into 11 industries in order to be consistent with other statistics. The detailed aggregation of industries is available in Table VI of Okuda (1994, p. 433); for instance, the chemicals industry comprised the former chemical material, chemical products, petroleum and coal, and rubber products industries.

[17]The results of manufacturing industries are only available until 1987 in Table 3 of Liang (1995, pp. 22–23).

[18]Hu and Chan (1999) also reported that human capital adjusted TFP growth rates in the manufacturing sector were correspondingly higher at 5.5 per cent and 6.0 per cent during the sample period.

improvement embodied in capital and labour inputs was not adjusted, Hu and Chan's TFP growth estimates overstate the extent of actual TFP growth.

Using a Törnqvist TFP index, an official publication '*The Trends in Multifactor Productivity, Taiwan Area, Republic of China*, 2000' published by the Directorate-General Budget, Accounting and Statistics (DGBAS) provided annual TFP growth estimates as well as TFP levels for the manufacturing sector and 18 manufacturing industries from 1978 to 1998. Over the period, the average annual TFP growth in the manufacturing sector was reported to be 1.9 per cent. However, the DGBAS (2000) did not allow for the effect of imperfect competition; so these official figures unavoidably overestimate the real TFP growth rates for Taiwan's manufacturing industries.

Aw *et al.* (2001) applied the multilateral TFP index proposed by Caves *et al.* (1982) to three sets of Industrial and Commercial Census data in 1981, 1986 and 1991 in order to investigate the TFP differentials in Taiwanese firms. By defining industry productivity as the market-share of the weighted sum of the firm productivity levels, Aw *et al.* subsequently computed TFP growth for the nine manufacturing industries at the 2-digit level. At the manufacturing level, the weighted TFP growth was estimated to be 32.4 per cent during the decade (or 3.2 per cent per annum).[19]

Färe *et al.* (1995) focused on four major Taiwanese industry groupings, comprising essential goods, chemicals, metal machinery and electrical precision. Using the non-parametric DEA approach, they claimed that TFP in the manufacturing sector measured by the Malmquist TFP index progressed at 3.59 per cent annually solely due to technological progress during the period 1978–89. Subsequently, Färe *et al.* (2001) extended their study and calculated Malmquist productivity indexes for 16 of Taiwan's manufacturing industries between 1978 and 1992. They suggested that Taiwan's manufacturing sector had on average enhanced TFP by 2.89 per cent per annum largely due to technological progress (2.56 per cent) and 0.33 per cent attributed to technical efficiency improvement. A brief summary of the TFP studies on the five East Asian manufacturing sectors reviewed in this chapter is presented in Table 2.

3 COMPARISON AND FUTURE AGENDA

As seen from Table 2, the results of the TFP studies reviewed differ significantly. Even for the same country, TFP growth estimates varied extensively; for instance, the average annual TFP growth estimates for the Korean manufacturing sector ranged from −1.6 per cent in Park and Kwon (1995) to 7.3 per cent in Kim and Han (2001). So, what has contributed to these discrepancies?

First: the use of different methodologies or specifications. Taking Taiwan as an example, the methodologies used varied from study to study. They included growth accounting, regression, DEA (or Malmquist productivity index) and multilateral TFP index approaches etc. Although growth accounting was widely applied in many TFP studies, different specifications for the production function could have led to different outcomes. For instance, Hu and Chan (1999) incorporated human capital into the growth accounting framework, whereas in a series of TFP studies on Korean manufacturing

[19]The details of the variables involved in the estimation are available in Aw *et al.* (2001, pp. 82–84). With the exception of the transportation equipment industry, all other industries gained TFP growth between 7.8 per cent (clothing) and 36.6 per cent (chemicals) over the period 1981–91.

Table 2. TFP studies on the manufacturing sector in the five East Asian economies

Author	Period	Method	TFPG
Hong Kong			(per cent)
Kwong *et al.* (2000)	1984–93	Growth accounting	−1.53
Imai (2001)	1981–90	Growth accounting	5.6
	1991–97		6.0
Japan			
Norsworthy and Malmquist (1983)	1965–73	Translog function with gross output	0.91
	1973–78		1.64
Jorgenson *et al.* (1987)	1960–79	Translog quantities index	0.83
Morrison (1990)	1960–81	Generalised Leontief cost function	0.987
Prasad (1997)	1971–93	Not available	2.8
Nakajima *et al.* (1998)	1964–88	Index number approach	3.731
Sato (2002)	1979–85	Not available	2.5
	1985–91		2.6
	1991–97		2.2
Korea			
Kwon (1986)	1961–80	Growth accounting with a cost function	2.95
Dollar and Sokoloff (1990)	1963–79	Growth accounting	6.1
Kang and Kwon (1993)	1963–73	Growth accounting with a cost function	3.43
	1973–83		0.16
Pilat (1995)	1967–87	Growth accounting	4.3
Park and Kwon (1995)	1967–89	Generalised Leontief cost function	−1.6
Okuda (1997)	1970–93	Growth accounting	3.2
Lee *et al.* (1998)	1967–93	Malmquist productivity index	0.286
Hwang (1998)	1973–93	Growth accounting	2.06
		Augmented Solow model	2.46
Kim (2000)	1966–88	Traditional growth accounting	1.9
		Modified growth accounting	0.5
Kwack (2000)	1971–93	Growth accounting	3.0
Yuhn and Kwon (2000)	1962–81	Growth accounting with a cost function	1.52
Kim and Han (2001)	1980–94	Stochastic frontier approach	7.3
Singapore			
Tsao (1985)	1970–79	Growth accounting	0.08
Wong and Gan (1994)	1981–90	Growth accounting	1.6
Rao and Lee (1995)	1976–84	Growth accounting	−0.4
	1987–94		3.2
Leung (1997)	1983–93	Growth accounting	2.8
Mahadevan and Kalirajan (2000)	1976–84	Stochastic frontier approach	0.92
	1987–94		−0.52
Toh and Ng (2002)			
Koh *et al.* (2002)	1975–98	Growth accounting	2.7
Taiwan			
Okuda (1994)	1978–91	Growth accounting	2.6
Liang (1995)	1973–82	Growth accounting	0.12
	1982–87		1.41
Chuang (1996)	1975–90	Regression approach	1.9
Liang and Jorgensen (1999)	1961–93	Growth accounting	2.46
Hu and Chan (1999)	1979–96	Growth accounting	3.1
DGBAS (2000)	1978–98	Törnqvist TFP index	1.9
Aw *et al.* (2001)	1981–91	Multilateral TFP index	3.24

(1986, 1993, 1995, 2000), Kwon used the rate of capital utilisation to estimate the growth of capital input.

Second: differences in sources of data sets and sample periods covered generated various outcomes that made it difficult to compare outcomes. For example, Aw *et al.* (2001) used firm-level data while other studies used aggregate data at the industry level.

Third: disparity in the number of industries and industrial classifications or aggregations used. In the case of Singapore, 27 industries were investigated in the Bloch and Tang (1999) study, 28 in the studies by Tsao (1985), and Mahadevan and Kalirajan (2000), and 30 in Leung (1997). In the case of Taiwan, the classifications or aggregations were even more diverse and the number of industries examined ranged from 11 to 17. Furthermore, Chuang (1996) estimated TFP growth of manufacturing sector rather than that of individual industries.

Fourth: differences in the construction and adjustment of variables. Quality improvements embodied in labour and capital inputs were frequently been ignored and may have led to an overestimation of the extent of TFP growth, for instance, in the studies by Dollar and Sokoloff (1990) and Kim and Han (2001). The use of 'hours worked' or 'number of employees' to measure labour input would have led to different conclusions, as in Hu and Chan (1999), as would the use of gross output or value added to measure firm or industry performance (e.g. Wong and Gan, 1994; Kwong *et al.*, 2000; Liang and Jorgenson, 1999; Yuhn and Kwon, 2000).

In view of the discrepancies evidenced in existing studies, this paper makes three recommendations to improve existing understanding of TFP growth in East Asian manufacturing. First, it recommends the adoption of the stochastic frontier approach (SFA) proposed by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977) to measure TFP growth. This can avoid the strict assumptions of constant returns to scale and perfect competition imposed by the growth accounting. Following the decomposition approach introduced by Nishimizu and Page (1982), the stochastic frontier approach can demonstrate the role of technical efficiency in enhancing TFP and output growth in East Asian manufacturing. Regardless of its wide popularity, growth accounting has been seriously questioned as an appropriate means of explaining the role of technological progress in the East Asian economic miracle (Chen, 1997; Felipe, 1999; Nelson and Pack, 1999) because it does not distinguish the difference between TFP growth and technological progress.

Second, the paper recommends the use of Kalirajan and Obwona's (1994) varying coefficients frontier model to calculate TFP growth because it avoids the assumption of the homogeneity of firms in applying frontier production technology made by the conventional stochastic frontier approach. As a result of this assumption, the conventional stochastic frontier approach captures the variations in intercept only and leaves the estimated coefficients of factor inputs constant, this is, a neutral shift of production frontier. However, the assumption is unwarranted if firms utilize the frontier production technology differently for a variety of reasons regardless of best practice technology being available to all. In practice, it is empirically observed that firms with the same level of inputs can achieve different levels of output while facing the same production technology. Hence, it is vital to take account of the heterogeneity of firms' behaviour and estimate the variations in both intercepts and slope coefficients across firms and over time for the same firm, namely, reflecting a non-neutral shift in production frontier.

Finally, it is recommended that studies use a uniform data set, such as the United Nations Industrial Development Organization (UNIDO) database, which covers manufacturing industries at the 3-digit level and has a consistent industrial classification for each country. This will facilitate investigation of the sources of output growth in the East Asian manufacturing sectors.[20] More importantly, the adjustment of quality improvement embodied in labour and capital inputs and construction of variables can be consistently undertaken and an accurate comparison of TFP growth for manufacturing industries in East Asia can be ascertained.

4 CONCLUSION

Research on productivity in East Asia is essential because impressive economic growth cannot be sustainable without improvement in TFP. From a policy perspective, the assessment of TFP growth is important as it serves as a guide for allocating resources and investment decisions. Existing TFP studies have questioned the role of TFP progress in the East Asian economic miracle because they have predominantly focused on the performance of the overall economy and paid scant attention to the manufacturing sector. However, the World Bank (1993) reinforced the significant role played by the manufacturing sector in the East Asian economic miracle, and this has induced increasing interest about its rate of TFP growth.

This paper offers an updated review of recent studies on East Asian manufacturing as a whole and the manufacturing sectors in Hong Kong, Japan, Korea, Singapore and Taiwan to stimulate future research on relevant issues. As seen the empirical findings of these studies varied considerably, even for the same country. This paper offers four reasons for the discrepancies. These include the use of different methodologies, differences in sources of data sets and sample periods covered, disparity in the number of industries and variations in industrial classifications or aggregations, and differences in the construction and adjustment of variables used.

The paper expects that the varying coefficients frontier model will provide the best framework for estimating TFP growth in the East Asian manufacturing sectors and recommends the use of a uniform data set such as the UNIDO database to facilitate an accurate comparison of TFP growth. As for future research, it should be directed at explaining why some manufacturing sectors can achieve high TFP growth while others cannot. It is expected that differences in R&D, human resources, trade openness, industrial policies, and capital investment will determine cross-country differences.

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[20]Due to missing data and changes in industrial classifications some industrial aggregations have been used in the studies on Hong Kong, Singapore and Taiwan.

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