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Korean and Taiwanese Productivity Performance
-- Comparisons at Matched Manufacturing Levels

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Abstract of the Paper

We compare productivity performances of the world's two most rapidly growing countries using matched manufacturing sectors by finding the Malmquist productivity index and its four components, aided by visual methods and correlation analysis. The distance functions are estimated by using category-wise cross-industry meta frontiers from1979 to1996. We find that the overall productivity and technology growth rates of Korea are lower than those of Taiwan, explaining postwar Korea's per capita GDP being less than that of Taiwan. At disaggregated levels, in general, the productivity index is positively and significantly correlated with the technology index, and negatively and insignificantly correlated with the efficiency index. Technology appears to be independent of efficiency in these two countries.

Keywords: Productivity analysis, Malmquist Indexes, Korea and Taiwan, Economic Growth

Contents of the Paper

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I. Introduction

The postwar rapid growth of the Republic of Korea (hereafter Korea) and Taiwan has been a center of studies among the scholars of development economics. Their development experiences began in the early years of the twentieth century (Hsiao and Hsiao, 2002b), accelerated after WWII (Park and Park, 1989; Page, 1994; Hsiao and Hsiao, 2002a, 2002b). Since the late 1960s, they quickly entered the world production process, achieved impressive growth through rapid industrialization and accelerated exports, like two wheels of a cart, with double dependence on Japanese imports (capital equipment and intermediate goods), and the vast US markets (Hsiao and Hsiao, 1996; Hattori and Sato, 1997; Okuda, 1997).

Figure 1 compares long-run GDP per capita levels of 10 Asian countries[1] : Korea (K), Taiwan (T), Thailand (Th), Indonesia (Indo), the Philippines (Ph), Burma (B), China (C), India (Indi), Bangladesh (Ba), and Pakistan (P). The chart is congested and is difficult to distinguish among individual countries. However, the major purpose here is to focus on the general trend of the growth of Taiwan and Korea as compared with other countries. The lines on the upper left-hand side of Figure 1 is enlarged diagrams of the lines below, and should read from the secondary right-hand side Y-axis. It is clear from the chart that the long-run

reason of international politics. Thus, in view of their exceptionally rapid growth after the war, which, as we have shown elsewhere, has been a continuation of prewar rapid growth (Hsiao and Hsiao, 2002b), one may expect a similar pattern of productivity growth in manufacturing industry in these two newly developed countries, and its study may yield useful information about productivity of rapidly growing economies.

While both countries experienced rapid growth, one of the most prominent features is that in the postwar period, in contrast with the prewar period, the real GDP per capita level of Korea has been consistently lower than that of Taiwan, as shown in Figure 1. Curiously, economists in Korea and Taiwan, as well as se in the field of development economics, completely ignore this fact. The difference is not due to the different stage of development between the two countries, nor due to historical differences. Elsewhere we have shown that the situation was reversed before the war, and that, despite the destruction of the economy by Allied air raid of Taiwan during the war (1944 -1945) and the Korean War in Korea (1950-1953) during the early postwar period, Korean real GDP per capita was almost the same as that of Taiwan from 1953 to 1955 (Hsiao and Hsiao, 2002b) that both Korea and Taiwan were on the same development stage by the mid-1950s, and have continued to be so until the mid 1990s, as illustrated in Figure 1. Thus, in this paper, we submit that we may justify one-to-one direct comparison of these two countries, and, as the second purpose of this paper, we would like to explain the difference in the real GDP per capita level and growth rate by examining productivity performance of the two countries.

Section II reviews the overall industrial structure of Korea and Taiwan by comparing the industry composition of GDP in the two countries, and points to the different characteristics of the secondary industry, especially the manufacturing industry, between Korea and Taiwan.

Section III explains the Malmquist output index and its two components, the efficiency change index and the technology change index, and the two component of efficiency change index, that is, the pure efficiency change index and the scale efficiency change index. To help understand the paper, we have illustrated and explained these five indexes in a very simple way diagrammatically.

In Section IV, we explain the sources of data and the method of deriving the five indexes. We use the three-digit matched industry levels of 15 manufacturing industries of the two countries so that the differences in productivity are not due to product composition of each industry. Torii and Caves (1992) also use the matched manufacturing sectors. However, they are more concerned with the different estimation methods of frontier production functions and the determination of the productivity[2] in Japan and the United

This gives rise to the comparisons of the time trend of each index among the three categories (Section VIB), and the comparisons of the time trend of five indexes within each category (Section VIC).

Sections VII and VIII use correlation analysis to examine the difference and similarity of the five indexes in the overall manufacturing industry as well as in each of the three industrial categories of the two countries. The analysis allows us to compare the indexes directly between the countries and the correlations among the indexes inside each country. Section VII compares the whole period. However, in view of the rapidly growing countries like Korean and Taiwan, we expect differences in productivity performances between the early period and the later period during the 18 years of our investigation. Thus, in Section VIII, we divide the data into two periods: Period A, 1979 to 1987, and period B, 1986 to 1996, and compare the productivity performances of the two period.

Section IX is a dynamic version of Section VIII. We ask which of the 15 manufacturing sectors has improved productivity performances, in terms of productivity, efficiency, and technology indexes, in period B over the period A. Section X then finds the innovators among the 15 manufacturing sectors that push the category-wise meta production frontier outward each year. Section XI concludes.

II. Overall Industrial Structure of Korea and Taiwan

We first present an overview of the Korean and the Taiwanese industrial structures, reviewing the position of the manufacturing industry in each economy. Figure 2 shows the overall industrial structures of Korea and Taiwan as the composition of GDP by industries: the primary, secondary, and tertiary industries[3] from 1970 to 1999. We also present the trend of manufacturing and financial sectors, as the manufacturing industry is the prominent factor in a country's industrialization and modernization, and the financial industry is the fast growing sector in both countries in recent years. The extended time period is to put the industrial structures from 1978 to 1996, the range of which our matched data are available, in time perspective.

that Taiwan has experienced de-industrialization (and the rise of the tertiary industry) after lifting of martial law in 1987. Although Auty (1997) pointed out that Korea outpaced Taiwan in macroeconomic performance, Taiwan's trend of de-industrialization is similar to more advanced countries and may be taken as the advancement of industrial society in Taiwan as compared with that in Korea.

Except the secondary industry, especially the manufacturing industry, after mid-1980s, the trend of each pair of the corresponding curves in both countries looks very similar.

III. The Malmquist Productivity Index and its Composition

Unlike most of the current literature on productivity comparisons (Wagner and van Ark, 1996), we now consider total productivity of the manufacturing industry in both countries.

There are several methods of computing productivity growth either at the aggregate level or at industrial levels. Before the mid-1990s, most studies estimated the total factor productivity (TFP) growth rate by using Solow's residual method, or the growth accounting method. There are several papers that compare directly the TFP of Korea and Taiwan, including, Oshima (1987), Kawai (1994), Okuda (1997), and Timmer (2000). Despite the considerable amount of literature (Hsiao and Hsiao, 1998), there is no consensus about the adequate magnitude of TFP growth rates in the process of economic growth (ibid.).

In addition to the strong assumptions of perfect competition and constant returns to scale, the basic problems of the growth accounting method are perfect mobility and divisibility of factors and no distortion due to government regulations. It also assumes that the production activities are always efficient, that outputs are always produced along the production possibility curve. Thus, TFP growth as a measure of technical change is now being considered misleading conceptually and methodologically (Nelson, 1973; Nelson and Pack, 1999).

The recent method of estimating productivity growth rate is the Malmquist productivity index (MPI) method, which has become popular after the mid-1990s. Without using general or specific production function form, this method is based on distance functions and defines productivity as an index of outputs over inputs. Unlike the growth accounting method, it does not require cost and revenue shares to aggregate inputs, nor use cost minimization assumption. We adopt the MPI method in this paper. A comparison of the results using the growth accounting method and the MPI method will be examined elsewhere (Hsiao and Park, 2002a).

Let the pair of observed input vector x_t at time t and the corresponding observed output vector y_t at time t be denoted as $a^t = (x^t, y^t)$. Then the output distance function at time t is defined as

$$D^t(a^t) = \inf_{\delta} \{\delta \mid y^t/\delta \text{ is in } P^t(x^t)\} \qquad (1)$$

$$= [\sup_{\delta} \{\delta \mid \delta y^t \text{ is in } P^t(x^t)\}]^{-1}$$

where $P^t(x^t) = \{y^t \mid x^t$ can produce $y^t\}$ is the production set at time t which is convex, closed, bounded, and satisfies strong disposability of x^t and y^t (Coelli, 1996, 62). The scalar δ is a fraction, $0 < \delta \leq 1$ for all $y^t \geq 0$, and $\delta = 1$ if y^t is in the production set. Then, the MPI at time t when the production set (technology) is $P^t(x^t)$ is defined as $M^t = D^t(a^{t+1})/ D^t(a^t)$, which is the ratio of the maximum proportional changes in the observed outputs required to make each of the observed outputs efficient in relation to the technology at t. Here, $D^t(a^t)$ is applied to the constant-returns-to-scale benchmark. Similarly, the MPI at time t+1 when the production set is $P^{t+1}(x)$ is $M^{t+1} = D^{t+1}(a^{t+1})/ D^{t+1}(a^t$

The MPI in (2) is the standard definition. It is enigmatic and obscure. In Figure 3, we present a simple diagram to illustrate the basic concepts intuitively. To avoid the cluttering of superscripts, we denote (geometric) average of the line segment y’y” and z’z” in Figure 3. It represents new product and process innovation, new management system, or the external shock that shifts the productivity curves.

The 15 sectors in the cross-section data set are further grouped into three categories [9] : The traditional industry category (T, Sectors 1 to 6), the basic industry category (B, Sectors 7 to 11), and the high-tech industry category (H, Sectors 12 to 15), as shown in the first “Category” (Ca) column in Table 1.

We estimate the distance functions in (4) by non-parametric one-output two-inputs linear programs[10] following Faere, et al. (1994), Coelli (1996), and Coelli et al. (1998) for each category. For this paper, our method is to construct a category-wise cross-industry best-practice meta production frontier from the observed outputs each year, as shown by four productivity curves in Figure 3. The best-practice meta frontier is estimated each year from the observed inputs and outputs by linear constraints

$$\{-y_j^t + Y^t w \geq 0,\ -x^{jt} + X^t w \geq 0,\ w \geq 0\}, \tag{7}$$

where for our problem, Y^t is 1xN vector, X^t is 2xN, and w is Nx2, j = 1, 2, … N, and N is the number of manufacturing sectors in each category (see below). We then compare the actual output of each manufacturing sector (like y and z in Figure 3) in the category with the corresponding maximum outputs on category-wise frontier (like y’, y”, a’, a”, etc.), and construct the distance functions $D^t(a^t)$, etc., for consecutive years by maximizing the inverse of the distance δ subject to the frontier technology (7).

Our derivation of the category-wise cross-industry meta frontier is different from the current practice of finding the distance functions for all 15 manufacturing sectors by constructing the manufacturing industry-wide frontier (e.g., Faere, et al. (1994), Lee, et al (1998)). Our method takes into account that the meta production frontiers for the three categories in each year are different, for example, the technology used in traditional industries is quite different from that used in high-tech industries. Thus, we submit that technology used in an individual manufacturing sector in an industrial category should be compared with the production frontier of that category, not with the manufacturing industry as a whole.[11]

For each category, we calculated Nx(4x18-2) distance functions using linear programs, where N = 6 for the traditional category, 5 for the basic category, and 4 for the high-tech category, a total of 1050 distance functions. From them, we have constructed five indexes TI, EI, PI, SI and MPI for each sector in each category for 18 years (we lose one year since the indexes start from the second year of the sample), a total of 1350 (=5x15x18) indexes. Since the importance of each sector in each category is different in terms of the value-added share[12] in each category (see Figure 4 below), each index in a year in each category is weighted by the share of the corresponding value-added output in that year and in that category.[13] The sums of the weighted indexes within each category in selected years are presented in Table 2. The column of manufacturing (Mfg) is the geometric mean of the indexes of three categories. The rows of geometric mean (geomean) are the geometric mean of the indexes of 18 years in each category. Note that the decomposition of the MPI indexes (3) and (4) still holds approximately even though the original indexes are weighted by value-added outputs in each category.

Place Table 2 here

In the following analysis, we compare the time-series data as well as the cross-section data for the two countries. Because the years in the mid-1980s are considered a period of transition from traditional industrialization to the high-tech and service-oriented industrialization for both countries, in addition to other factors delineated below, the time-series data have been divided into two sub-periods: Period A covers from 1979 to 1986 and Period B from 1987 to 1996. Taiwan lifted its 37 years long Martial Law in 1987, and entered a new era of political freedom and economic liberalization and reform (Hsiao and Hsiao, 2002b). Similarly, Korea passed 6.29 Declaration on democratization to change the presidential election method from indirect to direct election by people, and promulgated seven other laws to democratize the economy and society. One of its consequences is, like Taiwan, the gain of the power of labor unions (Lee, et al., 2001) and higher wages, stimulating massive outward foreign investment.

V. The Structure of the Manufacturing Industry

Since our Malmquist productivity index and its components are weighted by the value-added output shares in each category, we first examine the differences and similarities of the structure of the manufacturing industry in terms of the output shares of Korea and Taiwan. This is shown in Figure 4. The number after the sector label, like 1Food(94a), shows the sector's correlation coefficient (94% in this case) between Korea and Taiwan. The alphabet after the number shows the level of significance of the student t

As may be expected, there are differences in the importance among the manufacturing sector in each category. In the traditional categories, Figure 4b shows that the food industry is the most important sector in both countries with very high correlation coefficient (94%), followed by textiles, paper, apparel, wood, and leather. The ranking is almost the same between Korea and Taiwan in the mid-1990s, and their patterns are very similar, except the textile and paper sectors, whose correlation coefficients are only 16% and 40%, respectively. The two sectors have opposite trend in the two countries. The textiles sector in Korea is declining, while that of Taiwan stays flat, and the share of paper industry sector is increasing, while that of Taiwan also stays flat.

The value-added output share of the five sectors in the basic category in Figure 4c is quite different. The correlation coefficients are generally low and not significant, and the basic metal sector has negative and low (10%) level of significance between the two countries. In contrast, the ordering of the importance of the high-tech industries in Figure 4d is the same in both countries in the mid-1990s, and is also highly correlated.

Note that the importance of the industries in each category is examined by comparing the industries in the individual category. Since in both countries, the most important industry in each category is the same, that is, the food sector in the traditional category, chemicals in the basic category, and electronics in the hi-tech category, we have plotted these three sectors at the bottom of Figure 4a, in which the comparisons are made for all 15 manufacturing sectors. It turns out that these three sectors are still the largest industries in three column charts) for the period from 1979 to 1996. The growth rates are derived by subtracting 1 from the rows of geometric mean in Table 2 multiplied by 100.

Figure 5 appears that the overall variation of performance indexes in Korea is much larger than that of Taiwan, and the sectional performance is quite different. The overall productivity growth rates (MPG), technology growth rate (TG), scale efficiency growth rate (PG) in Korea are only 40%, 20%, and 60% of those of Taiwan, respectively, and only the efficiency growth rate (EG) is the same as that of Taiwan. According to Kaldor’s first law, the growth of GDP is positively related to the growth of manufacturing output, and his second law states that the growth of manufacturing output is positively related to the growth of manufacturing productivity (Thirlwall, 2002), we can explain from this findings why per capita GDP growth rate of Korea consistently falls behind that of Taiwan, as we have alluded to in the introduction.

Pure efficiency index is low for both countries, but Taiwan registered negative growth rate (-0.3%), due mostly to the large negative growth rate (-0.7%) in the traditional category. Korea has growth rates of 0.1%, mainly due to high pure efficiency growth rate (0.6%) in the high-tech category. The overall scale efficiency growth rate of Korea (0.7%) is lower than that of 3(fa)10.5o. Tw[1-1.4(ow)iclri index. The line with Mfg is the geometric mean of the three categories obtained in Table 2. The manufacturing productivity ranges from 87 to 120 in the case of Korea, and from 102 to 143 in the case of Taiwan. In the sample range, both countries started at almost the same level of the productivity index, but Korea's index increased slowly, and Taiwan's index accelerated until around 1987, leveled afterward, but still kept about 20 points higher than that of Korea.

Place Figures 6 here

The performance of each category is quit different, however. The productivity of Korea's high-tech category accelerated unevenly, while that of Taiwan accelerated at the beginning, but then decelerated after 1989. Taiwan's indexes in the basic category also tend to decelerate after 1987, but still kept about 60 points higher than that of Korea. In Korea, the productivity of the traditional category grew horizontally, and after 1987 it started to decrease. By 1996, Korea's index fell from the high of 97 to 71. But in Taiwan, it accelerated until 1987, and then fell from the high of 147 to 122, still maintained much higher position than that of Korea. Here is the time trend difference in productivity performance in two countries, and also the source of the strength of the Taiwanese manufacturing sector during the years under our studies.

In terms of the components of the productivity index, the difference is large. Korea and Taiwan have more or less the same level of overall efficiency index over the years (Figures 6b). However, Taiwan's efficiency index in high-tech category grew faster than that of Korea, that in the traditional category decline faster, and that in the basic category fluctuated much widely than that of Korea over the period. On the other hand, Korea has much lower rate of overall technology change than that of Taiwan (Figure 6c), and also in the traditional category. The technology change in Korea is low and uneven, and that in Taiwan is very high and even more uneven. On the other hand, the technology index in the high-tech category in Korea was

1997). The overall pure efficiency index in Korea is slightly higher than that of Taiwan (Figure 6e), and the pure efficiency index in Taiwan's basic category fluctuated much larger than that of Korea.

C. Comparison of Five Indexes in Each Category

Figure 7 provides category-by-category time series performance of the five indexes. It shows the details of the rows of Figure 5 and is extracted from the columns of Table 2. Most of the indexes in each category show a clear turning point at 1987. Figure 7a reveals the history of the indexes in the overall manufacturing industry as a whole. In 1979, both countries started at about the 100 level of the productivity index (MPI), but Korea stumbled and Taiwan grew rapidly and leveled after 1987. So is the technology index (TI), except that Taiwan's TI fell precipitously after 1987, but still maintained much higher position than Korea's.

Place Figure 7 here

In the traditional sector (Figure 7b), all indexes, except the scale index, are decreasing after 1987. However, Taiwan's productivity and technology indexes are still much higher than those of Korea, while Korea's efficiency and scale efficiency indexes exceed those of Taiwan in the early 1990s. In the basic category (Figure 7c), the overall productivity index of Taiwan is consistently much higher than that of Korea, which stagnates during the whole period of study. Note the extremely volatile technology index in Taiwan's basic category: it rapidly increased before 1987 and rapidly fell afterward. Other indexes in both countries are also volatile, especially those of Taiwan. This is in contrast with Korea's rapid but zigzag increases in productivity and technology indexes in its high-tech category (Figure 7d). It appears that the high-tech industries in Korea are rapidly catching up with Taiwan. Here is another warning sign of the future of Taiwanese competitiveness with Korea.

drawn from the same population. This implies that the Pearson correlation coefficients between the indexes and countries can be expected to be high.

Place Table 3

The data are based on the category-wise weighted indexes in columns of Table 2. Table 3 is arranged in terms of whole manufacturing industry and its three categories. In each part, the upper left block shows the correlations among the pairs of data consisting of EIk, TIk, MPIk, PIk, and SIk within Korea, and the lower right block shows the correlations among the pairs of data of EIt, TIt, MPIt, PIt, and SIt within Taiwan. The coefficients along the diagonal elements with bold-faced numbers are the direct cross-country comparison of the five indexes between Korea and Taiwan. The off-diagonal elements are cross-country correlation coefficients. Since we consider that economic relations between Taiwan and Korea are more or less independent to each other, there are less interdependency on technology and efficiency between the two countries at the industrial level, and we could not find meaningful interpretation of the off-diagonal coefficient coefficients. In this paper they are listed for reference only, and will be ignored.

Table 3 presents the correlation coefficients for the whole period, 1979-96.

A. Inter-country comparisons

We first study the bold-faced diagonal elements. This is the analytical version of Figure 7. Curiously, there are only a few strong correlation coefficients between the same indexes in two countries, belying our visual examination in the previous sections.

In Table 3a, only the productivity indexes between Korea and Taiwan are significant at the 5% level. The scale efficiency indexes are even negatively correlated but not significant, implying a possibility of opposite scale efficiency performance of industries in both countries due to different size of the firms in each country. The efficiency, technology, and pure efficiency indexes in the traditional category (Table 3b) are very weakly significant (at the 20% level), but interestingly, the productivity index is not significant. Only the pure efficiency indexes in the basic category (Table 3c) are highly correlated at the 1% level of significance. In the high-tech category (Table 3d), only the productivity indexes are significant at 5% level, which, as no other categories have significant correlations, probably has contributed to the overall significance level of the productivity correlation coefficient in the whole manufacturing industry.

B. Intra-country comparisons

More similar patterns of relationship among the indexes appear within each country. For the basic, high-tech, and whole manufacturing categories in both countries, efficiency and technology indexes are consistently negatively and strongly correlated, except those in the traditional category, in which the coefficients are also negative but not significant. This implies that, although EI and TI are multiplicative

between efficiency and productivity in each country are generally not significant, and the sign also vary. For example, in period A in the overall manufacturing industry, the coefficient is negative but not significant in Korea, but positive and significant at the 5% level in Taiwan. The situation reversed in period B. The coefficient is positive but not significant in Korea, but negative and not significant in Taiwan.

Another similar pattern in both countries in both periods is that technology and productivity are positively correlated among all the categories, mostly significant, especially in period A for Korea and period B for Taiwan. In contrast, technology and scale efficiency are consistently negatively correlated except the traditional category in Korea in both period. The sign of correlation may be negative or positive.

IX. Did Indexes Improve Over Two Periods?

Table 6 shows the comparisons of efficiency, technology, and productivity indexes over the two periods (columns 1 to 3, 5 to 7). These indexes are obtained by taking the geometric mean[17] of the category-wise unweighted indexes, respectively, of the 15 manufacturing sector from 1979-1986 (period A) and from 1987-1996 (period B), and then subtracted one from the mean and multiplied by 100. Thus, unlike the data in Figure 7, we are now dealing with the growth rates of the indexes. The growth rates in each category in petroleum and coal, and non-metallic mineral products, had positive growth in period B, while efficiency growth declined. In Taiwan, both productivity and technology declined, especially in the chemical products, rubber, and plastic industry, but gained considerably in efficiency in the second period. In period B, technology grew faster than efficiency in Korea, while it grew much slower than efficiency in Taiwan. Thus, their pattern of growths are just opposite.

On the other hand, in the high-tech categories, Korea's productivity and efficiency growth rates are higher in the second period, especially in the machinery products and electric, electronic machinery products sectors, but technology of these industries lagged behind greatly in the second period. Taiwan had much larger productivity growth in the second period in the high-tech category. However, its efficiency lagged behind, especially in the machinery products sector, but technology grew much faster in the second period. Thus, the relations between efficiency and technology in Korea and Taiwan in the second period are reversed, and interestingly, the reversed relations are just opposite compared with the basic category. Technology lagged far behind efficiency in Korea in all high-tech industries, but grew much faster than efficiency in Taiwan in all high-tech industries.

Overall, when we take the (arithmetic) average of the indexes of the three categories, we found that the productivity, efficiency, and technology generally declined in the second period, except efficiency in Korea, and the degree of decline is larger in Taiwan than in Korea. Among the 60 indexes in both countries, Korea had 22 positive indexes, and Taiwan had 17. Here is another sign of warning to the Taiwanese economic development. However, if we consider that the high-tech industries are the future of industrialization, as its weight becomes larger and larger (see Figure 4a), and since productivity and technology are positively and highly correlated, the results in the high-tech category in Table 6 may let Taiwan maintain its superiority in the near future.

X. The Innovators

Lastly, we ask which manufacturing sector(s) in each category makes the category-wise best-practice production frontier to shift in each year. Are they the same in Korea and Taiwan? We follow Faere, et al. (1994) to identify the "innovators," which exhibit the following properties:

$$\{TI > 1,\ D^{t}(a^{t+1}) > 1,\ D^{t+1}(a^{t+1}) = 1\}$$

That is, the manufacturing sector that has technology growth at time t, located beyond the previous technology set but inside the current technology set based on the constant-returns-to- scale technology. We find again that Korea and Taiwan have the same pattern as shown in Table 7.

Place Table 7

Table 7 shows that for the traditional category, the most frequent innovator in Korea is the food sector (1), followed by the apparel sector (3). This is the same as Taiwan, except that, in Taiwan, the leather sector (4) also plays as an innovator in period A. It appears that in general Taiwan's meta frontiers shift more often than that of Korea's, indicating more innovation activities in Taiwan's traditional sector.

classified into three categories in two periods, the analysis of the five productivity indexes become quite complicated.

We found there is a clear similarity in the structure of the manufacturing industry in terms of value-added output shares in overall manufacturing industry and traditional and high-tech categories. However, when we examine the productivity performance indexes, the difference appears. Korea's growth rates of overall productivity, technology, and scale efficiency are well below those of Taiwan, and the efficiency growth rate just equals that of Taiwan. This may explain why per capita GDP growth rate of Korea consistently falls behind that of Taiwan in the postwar period.

While we may find much similarity in the time trend of the performance indexes of many of the manufacturing sectors in three categories, the correlation analysis presents more restricted picture. The correlation coefficients of the five indexes indicate that they are generally independent between the two countries, and if they are correlated, they occur most likely in the productivity index, the correlation coefficients of which are only weakly significant.

In the intra-country analysis, we found that, in both countries, efficiency and technology indexes are generally negatively and strongly correlated, however, efficiency and its components, pure efficiency and scale efficiency indexes, are positively and very significantly correlated in both countries. These two indexes are in turn generally independent to each other. Furthermore, the correlation coefficients of the efficiency index and the productivity index in each country are generally negative but not significant in each country. This is in contrast with the technology index, which is positively and highly correlated with the productivity index and negatively and highly correlated with the scale efficiency index in each category in both countries. When the period is divided into two, these characteristics are reinforced generally in the second period.

When the indexes are compared between two period, we found that in high-tech industries,

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Endnotes

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[1] The diagram is taken from Figure 1 of Hsiao and Hsiao (2002b). We also shown that, according to Maddison’s data (1995), the real GDP per capita growth rates of Korea and Taiwan from 1951 to 1992 were highest in the world: Korea 5.8%, Taiwan 6.03%, per annum, exceeding the third ranking Japan, 5.57% (ibid. Table 1)

[2] We plan to examine and compare economic factors that determine efficiency, technology, and productivity of Korea and Taiwan in our future project.

[3] The primary industry consists of agriculture, forestry, and fishery; the secondary industry includes manufacturing, electricity, gas, and water, construction; the tertiary industry includes commerce, transport, storage, communication, finance, insurance, business, government, social and personal service0.1(a)(d4.8c5)22.Srst20 5.72 Tm4(3)Tj11.04 0 0 11.04 68.248093.

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comments of Faere et al. (1997) responding to Ray and Desli (1997) is that the constant returns to scale captures long-run and the VRS is appropriate for the short-run. Since our study analyzes the long-run productivity trend over 1979-96, we use the method of Faere et al. (1994).

[11] We owe Professor Tim Coelli for this point. However, the current literature uses the cross-section frontier rather than category (or sector) specific frontier. See Faere, et al. (1994, 1995), Lee, et al. (1998), and Nishimizu and Hulten, 1978). Elsewhere we also experimented with the industry-wide cross-section frontier method (Hsiao and Park, 2002b).

[12] For example, in Figure 4b, the value-added output in the "food, beverage, and alcohol" sector consistently maintained 41% to 50% of the total value-added output in the traditional category during 1979 and 1997, while that of "leather, Fur, and Products" sector ranged only between 8 to 20%.

[13] Thus, for the six MPI's in the traditional category in 1979, we calculated the weighted MPI by $w_i MPI_i$, where $w_i = q_i/\sum q_i$, i = 1, 2, … 6, and q_i is the value-added output of the ith sector in 1979 in the traditional category. The sum of the six $w_i MPI_i$ multiplied by 100 is given as the first number in the "79 row" in Table 2.

[14] The food and textile sectors are the only sectors that have different trend in the whole manufacturing industry as compared with their trend in the category.

[15] See Faere, et al. (1994). Our series is constructed as follows. Let m_i be a Malmquist index. Then, the multiplicative series at time t is defined as $s_t = 100*\Pi_{i=1}^{t} m_i$,where m_i at i = 1 is the index at 1979, and t is 1979, 1980, …, 1996. Note that, $s_{t/} s_{t-1} = m_{t,}$ and the growth rate of s_t , that is, $100*((s_t/s_{t-1})-1)$, is $(m_t – 1)*100$, the growth rate of index m_i defined in Section III.

[16] The correlation coefficient between two indexes is the same as the correlation coefficient between two growth rates of the indexes as defined in Section III.

[17] The difference between the geometric mean and the arithmetic mean are very small.

[18] For example, we constructed 6 weights in the traditional category in period A (the weights sum to one in a category). Then, use each of these 6 weights to multiply the corresponding growth rate of the index in the traditional category. Subtracting the weighted index of period A from that of period B, we obtain the entries in Table 6.

Table 1. Classification of 15 Manufacturing Industries.

Ca	ISIC	No.	Taiwan's 15 Sectors	STAN Industry Category for Korea Combination of Korean Mfg Sectors
T	01	1	Food, Beverage & Tobacco	311, 312, 313, 314
T	02	2	Textiles	321
T		3	Apparel and Ornaments	322
T		4	Leather, Fur, and Products	323
T	03	5	Wood Products & Non-metalic Furniture	331, 332
T	04	6	Paper, Paper Products & Printing	341, 342
B	05	7	Chemical Products, Rubber, and Plastics	351, 352, 355, 356
B		8	Petroleum, Coal, and Products	353, 354
B	06	9	Non-Metallic Mineral Products	361, 362, 369
B	07	10	Basic Metal Industries	371, 372
B	08	11	Fabricated Metal Products	381
H		12	Machinery Products and Repairs	382
H		13	Electric, Electronic Machinery Products and Repairs	383
H		14	Transportation Products and Repairs	384
H	09	15	Precision Instruments and Other Manufacturing	385, 390

Notes:

1 The Korean list includes "#324 Footwear" which may be "wearing apparel" or "leather products." Since we don't have detail information, we divide the numbers in 324 in two: one half puts in Apparel (322), and another half in Leather and Products (323).

2 The title of 385 in the Korean list is "Professional Goods."

Table 2. The Weighted Malmquist Indexes within Each Category

	Korea				Taiwan			
	Mfg	Trad	Basic	Hi-tech	Mfg	Trad	Basic	Hi-tech
Productivity Index (MPI)								
79	0.970	0.972	0.961	0.979	1.020	1.035	1.099	0.931
80	0.896	0.958	0.894	0.838	1.035	1.055	1.060	0.992
81	1.060	1.004	0.978	1.215	1.068	1.092	1.130	0.988
82	0.993	0.979	0.977	1.023	0.986	1.002	0.952	1.005
83	1.073	0.996	1.101	1.125	1.070	1.041	1.071	1.099
8499								

Table 3. Pearson Correlation Coefficients of Manufacturing Industry, 1979-1996

a. Manufacturing Industry

Table 4. Pearson Correlation Coefficients of Manufacturing Industry, 1979-86

a. Manufacturing Industry Number of sample = 8

	EIk	TIk	MPIk	PIk	SIk	EIt	TIt	MPIt	PIt
TIk	-0.423								
MPIk	-0.060	0.930 a							
PIk	0.786 b	-0.333	-0.043						
SIk	0.295	-0.021	0.089	-0.353					
EIt	**0.280**	0.015	0.139	0.575 d	-0.451				
TIt	-0.421	**0.490**	0.362	-0.455	0.131	-0.739 b			
MPIt	-0.178	0.700 c	**0.699** c	0.157	-0.404	0.350	0.371		
PIt	0.048	0.218	0.271	**0.458**	-0.617 d	0.919 a	-0.554 d	0.486	
SIt	0.364	-0.066	0.081	0.598 d	**-0.363**	0.987 a	-0.779 b	0.281	0.844 a

b. Traditional Category

	EIk	TIk	MPIk	PIk	SIk	EIt	TIt	MPIt	PIt
TIk	-0.270								
MPIk	0.257	0.861 b							
PIk	0.830 b	-0.431	0.002						
SIk	-0.120	0.430	0.376	-0.651 c					
EIt	**0.752** b	-0.077	0.318	0.679 c	-0.187				
TIt	-0.422	**0.535** d	0.315	-0.451	0.262	-0.636 c			
MPIt	0.648 c	0.315	**0.656** c	0.520	-0.022	0.796 b	-0.039		
PIt	0.581 d	0.123	0.431	**0.368** d	0.137	0.893 a	-0.435	0.820 b	
SIt	0.669 c	-0.337	0.009	0.843 a	**-0.596** d	0.739 b	-0.676 d	0.421	0.359

c. Basic Category

	EIk	TIk	MPIk	PIk	SIk	EIt	TIt	MPIt	PIt
TIk	-0.445								
MPIk	0.203	0.786 b							
PIk	-0.295	0.278	0.099						
SIk	0.979 a	-0.469	0.164	-0.482					
EIt	**-0.083**	0.367	0.346	0.792 b	-0.242				
TIt	-0.048	**-0.176**	-0.229	-0.674 c	0.096	-0.955 a			
MPIt	-0.027	0.154	**0.143**	-0.080	-0.011	-0.508 d	0.694 c		
PIt	-0.027	0.355	0.372	**0.754** b	-0.182	0.993 a	-0.967 a	-0.526 d	
SIt	-0.082	0.349	0.328	0.801 b	**-0.242**	1.000 a	-0.955 a	-0.509 d	0.991 a

d. High-Tech Category

	EIk	TIk	MPIk	PIk	SIk	EIt	TIt	MPIt	PIt
TIk	-0.659 c								
MPIk	-0.153	0.842 a							
PIk	0.953 a	-0.636 c	-0.146						
SIk	0.704 c	-0.331	0.039	0.463					
EIt	**-0.193**	-0.067	-0.241	-0.063	-0.373				
TIt	0.370	**0.312**	0.672 c	0.420	0.187	-0.261			
MPIt	0.290	0.327	**0.630** c	0.390	0.049	0.111	0.930 a		
PIt	0.109	-0.254	-0.280	**0.048**	0.199	0.519 d	0.028	0.213	
SIt	-0.201	-0.059	-0.235	-0.066	**-0.387**	1.000 a	-0.267	0.105	0.493

Notes: Two sides hypothesis testing of r, a = statistical significance at 1% level, b = at 5% level, c = at 10% level, d = at 20% level

Table 5. Pearson Correlation Coefficients of Manufacturing Industry, 1987-96

a. Manufacturing Industry Number of sample = 10

	EIk	TIk	MPIk	PIk	SIk	EIt	TIt	MPIt	PIt
TIk	-0.837 a								
MPIk	0.373	0.193							
PIk	0.692 b	-0.334	0.663 b						
SIk	0.976 a	-0.891 a	0.243	0.520 d					
EIt	**-0.105**	0.087	-0.058	-0.465 d	0.012				
TIt	0.146	**0.050**	0.373	0.512 d	0.026	-0.877 a			
MPIt	0.136	0.207	**0.619** c	0.367	0.059	-0.392	0.785 b		
PIt	0.376	-0.512 d	-0.230	**-0.228**	0.506 d	0.510 d	-0.453 d	-0.185	
SIt	-0.211	0.323	0.171	-0.256	**-0.172**	0.821 a	-0.726 b	-0.355	-0.043

b. Traditional Category

	EIk	TIk	MPIk	PIk	SIk	EIt	TIt	MPIt	PIt
TIk	-0.146								
MPIk	0.610 c	0.695 b							
PIk	0.433	-0.286	0.080						
SIk	0.757 b	0.050	0.595 c	-0.261					
EIt	**-0.045**	-0.313	-0.278	-0.204	0.103				
TIt	-0.403	**0.219**	-0.108	0.220	-0.606 c	-0.183			
MPIt	-0.412	0.060	**-0.240**	0.121	-0.542 d	0.289	0.888 a		
PIt	-0.094	-0.236	-0.252	**-0.160**	0.017	0.945 a	0.007	0.448 d	
SIt	0.182	-0.089	0.057	-0.062	**0.244**	-0.218	-0.502 d	-0.588 c	-0.524 d

c. Basic Category

	EIk	TIk	MPIk	PIk	SIk	EIt	TIt	MPIt	PIt
TIk	-0.900 a								
MPIk	-0.097	0.499 d							
PIk	0.875 a	-0.872 a	-0.385						
SIk	0.983 a	-0.865 a	-0.002	0.775 a					
EIt	**0.078**	-0.119	-0.083	0.208	0.036				
TIt	-0.140	**0.216**	0.198	-0.307	-0.082	-0.975 a			
MPIt	-0.204	0.461 d	**0.648** b	-0.452 d	-0.120	-0.535 d	0.695 b		
PIt	0.637 b	-0.566 c	-0.096	**0.757** b	0.552 c	0.688 b	-0.724 b	-0.465 d	
SIt	-0.157	0.078	-0.062	-0.080	**-0.161**	0.907 a	-0.855 a	-0.432	0.345

d. High-Tech Category

	EIk	TIk	MPIk	PIk	SIk	EIt	TIt	MPIt	PIt
TIk	-0.529 d								
MPIk	0.166	0.748 b							
PIk	0.777 a	-0.202	0.369						
SIk	0.892 a	-0.625 c	-0.026	0.409					
EIt	**-0.022**	-0.066	-0.086	0.114	-0.101				
TIt	0.406	**-0.050**	0.249	0.424	0.273	-0.773 a			
MPIt	0.600 c	-0.115	**0.328**	0.739 b	0.334	-0.267	0.816 a		
PIt	-0.329	0.007	-0.256	**0.035**	-0.501 d	0.131	0.080	0.234	
SIt	0.172	-0.045	0.094	0.060	**0.217**	0.773 a	-0.731 b	-0.404	-0.526 d

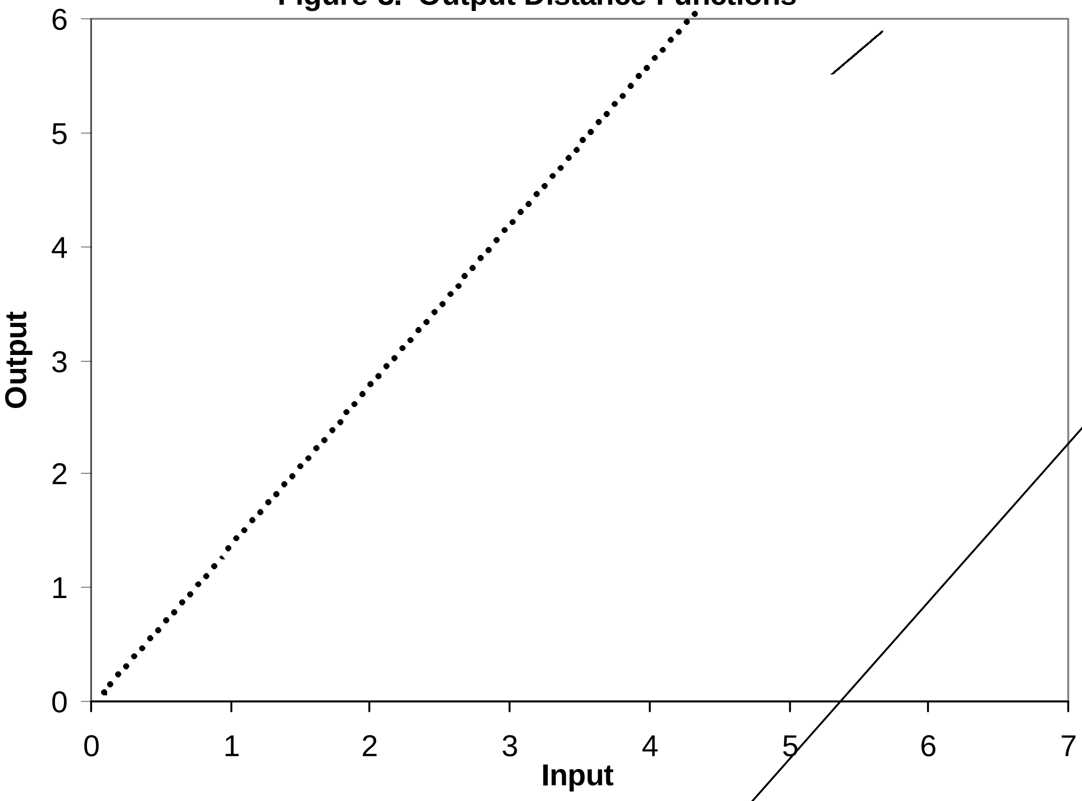
Notes: Two sides hypothesis testing of r, a = statistical significance at 1% level, b = at 5% level, c = at 10% level, d = at 20% level

Table 7. The List of Innovators by Category Each Year

	Korea								Taiwan						
	Tradition		Basic		High-tech				Tradition			Basic	Hig-tech		
79	Fd		Pe				Tp				Le	Pe			
80									Fd			Pe			
81	Fd	Ap	Pe	Fm			Tp	Pr		Ap		Pe		Tp	
82	Fd								Fd	Ap	Le			Tp	Pr
83			Pe	Fm				Pr	Fd					Tp	Pr
84	Fd		Pe				Tp		Fd	Ap	Le	Pe		Tp	Pr
85									Fd						
86	Fd		Pe	Fm			Tp	Pr	Fd	Ap	Le			Tp	Pr
87		Ap		Fm				Pr	Fd	Ap		Pe		Tp	Pr
88	Fd	Ap	Pe				Tp							Tp	Pr
89	Fd			Fm						Ap				Tp	
90	Fd		Pe	Fm	Ma		Tp		Fd					Tp	
91	Fd		Pe			El	Tp		Fd	Ap		Pe		Tp	
92	Fd	Ap	Pe				Tp		Fd					Tp	
93	Fd		Pe					Pr	Fd						
94			Pe			El		Pr	Fd			Pe			
95			Pe			El	Tp	Pr	Fd			Pe	El	Tp	
96			Pe				Tp		Fd	Ap		Pe			
Count	11	4	13	6	1	3	10	7	14	8	4	9	1	12	6

Note: See Table 1. Fd=Food, etc., Ap=Apparel; Pe=Petroleum, Coal, etc., Fm=Fabricated Metal, Ma=Machinery, El=Electric, Electronic Machinery, Tr=Transportation.

Figure 3. Output Distance Functions



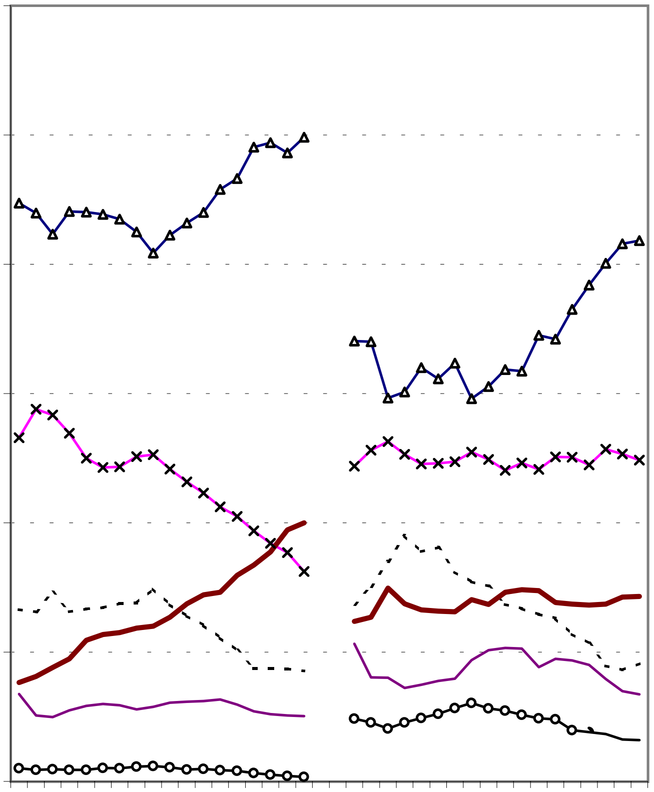


**Figure 5. Growth Rates of the Components of Output Indexes
Mfg Overall and 3 Categories, 1979-1996**