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Productivity Growth in Newly Developed Countries
-- The Case of Korea and Taiwan

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Abstract of the Paper

Using the Malmquist productivity index, the efficiency change index, and the technical change index, this paper compares the productivity growth of 15 matched manufacturing sectors of Korea and Taiwan. The distance functions are derived by using industry-wide production frontiers from 1979 to1996. We find that the efficiency growth rates for both countries are high and are the predominant component of productivity, and that technology, and thus productivity, growth rates are much higher in Taiwan than in Korea. At a disaggregated level, there is more similarity in technology growth, and less or none in efficiency growth. In both countries, productivity growth is similar, but traditional industries rely more on efficiency, basic industries on technology, and high-tech industries on both. The petroleum and coal products sector is consistently the major innovator of the manufacturing industry in both countries, but the minor innovators differ.

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

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I. Introduction

After the Asian financial crisis of 1997, it has become clear that the "East Asian Economic Miracle" has its limits. The Asian NIEs and the ASEAN countries have fallen into recession, and face the prospect of a productivity slow-down.[1] Taiwan and South Korea productivity measures the value of output when both factors are used. In this paper we discuss both partial and total productivities in the manufacturing industry. Both Taiwan and Korea are manufacturing-oriented countries with a high share of manufacturing goods exports to total exports (Syrquin and Chenery, 1989). The manufacturing industry played a crucial role in the rapid growth of both countries in the postwar period (Timmer, 2000).

The traditional method of productivity analysis is to calculate productivity growth based on production or cost functions with some restrictive neoclassical assumptions.[2] Despite much discussion in the literature, there is no consensus about the size of total factor productivity growth rates (Hsiao and Hsiao, 1998). This paper, instead, proposes to use the recently developed method of the Malmquist productivity index and its composition using non-parametric data envelopment analysis (DEA). There are a few papers that use the Malmquist index methodology to study productivity growth in Korea and Taiwan by decomposing the index into two components: technological change and efficiency change. These include Lee, Kim and Heo (1998) and Kim and Park (2002) for Korea, and Faere, Grosskopf, and Lee (1995) and Lee (1997) for Taiwan. However, so far as we are aware, no one has used this index to make direct comparisons of productivity growth between these two newly developed countries, even though they are so similar in history and stage of development.

In Section II, we first show Korean and Taiwanese economies in the world. Their economic scale in terms of GDP level is large compared with that of many nations with much larger populations or areas. We then point out that in the postwar period, the real GDP per capita level of Korea has been consistently lower than that of Taiwan. Curiously, economists in Korea and Taiwan, as well as those in the field of economic development, completely ignore this fact. We would like to explain this from the productivity performances of the two countries.

The major technical contribution of this paper is to use the Malmquist output index and its composition, the efficiency index and the technology index, in comparing the matched manufacturing sectors of Korea and Taiwan. We derive the composition in a very simple way in

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[1] Recovery is on the way in 2002, although "Growth in the region will continue to be uneven. And there's plenty that can go wrong." (BusinessWeek, 2002).

[2] See Stiroh (2001) for exposition on the restriction and some survey of total factor productivity (TFP) studies. For survey articles, see Hsiao and Hsiao (1998), Dowling and Summers (1998). A recent study of TFP growth in Korea is given in Kwack (2000). There are several papers that compare directly the TFP of Korea and Taiwan, including Oshima (1987), Kawai (1994), Okuda (1997), and Timmer (2000). None, however, use the decomposition of the Malmquist productivity index.

Section III, followed by an explanation of the sources of data in Section IV. We use the three-digit matched industry levels of 15 manufacturing industries so that the differences in productivity are not due to the 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 with determination of the productivity of Japan and the United States.

Section V studies the overall industrial structure of Korea and Taiwan by comparing real output, real capital, the number of workers, and partial productivity of labor and capital between Korea and Taiwan. This is the conventional analysis of productivity in the literature, as may be seen in various papers collected in Wagner and van Ark (1996).

In Section VI, we go beyond traditional analysis and studies and compare efficiency, technology, and productivity indexes of a cross-section of 15 manufacturing sectors, which are grouped into three categories, traditional, basic, and high-tech industries, as well as the time-series of these indexes. We believe our method of presentation and analysis of international comparisons of productivity growth is innovative and unique in the literature. In Section VII, the time-series data are divided into period A, 1979-1986, and period B, 1987-1996. We then compare efficiency, technology, and productivity of the three industrial categories in each sub-period. Section VIII asks an important question: which sectors are the real movers of the manufacturing industry in these newly developed countries each year, the sectors which help form the social meta productivity frontier which serves to measure the efficiency and technology of other industries. We also discuss briefly the effects of industrial policy in both countries . Section IX present the conclusions.

II. Korea and Taiwan in the World Economy

One of the problems with comparisons of productivity among countries is that we may compare the productivity of economies at different stage of economic and social development. This happens in many cross-section analyses when many countries are involved. Fortunately, this is not the case with Korea and Taiwan. We have alluded to the similarity of the long-run real GDP per capita growth rates of the two countries in the introduction. In this section, we examine the levels of GDP in both countries.

According to the World Development Report classification (World Bank, 2000/2001, 275, footnotes), by 1999, ASEAN countries, except Indonesia, belonged to the lower middle-income countries (US$ 755 to 2,996). Korea was an upper middle-income country (US$ 2,997 to 9,265). Taiwan, along with Hong Kong and Singapore, belonged to high-income category, with per capita GNPs reaching US$ 9,266 or more. From 1980 to 1999, the per capita income of Korea increased 5.6 times, and that of Taiwan increased 5.7 times, five times faster than the average for middle-income countries, and twice faster than that of the United States, while GDP per capita of ASEAN-4 increased only slightly above the average rate. The convergence of GDPs per capita of Korea and Taiwan to those of the industrial countries is evident (Hsiao and Hsiao, 2002b).

In terms of the level of GNP in 1999 (WDR, 2000/2001), the contrast is even more dramatic. Few people know that the economic scale of Korea in terms of nominal GNP in US dollars (ranked 13th in the world) is about 40% of that of China (7^{th} at US$ 980 billion). At the GNP level of US$ 292 billion (TSDB, 2000, 13), the economic scale of Taiwan (ranked 17^{th}) is almost the same as that of Russia (16^{th} at US$ 332 billion), as much as 66% of India and 30% of China, and larger than Argentina (18^{th}) and Switzerland (19^{th}).

Figure 1 presents a long-run historical view of the economy of Korea and Taiwan. It shows the ten-year moving average of real GDP per capita in 1990 Geary-Khamis dollars for Taiwan, South Korea, and some OECD countries in the logarithmic scale, since the colonial period (Hsiao and Hsiao, 2002a; Maddison, 1995). It visualizes and confirms the distinctively twin-like relation between the two countries. In the prewar period, both economies grew rapidly and attained the highest real GDP per capita just before WWII, and both then plunged to a level which was even lower than the level of the early 1910s. The diagram shows that the "miracle" of economic growth in both countries started as early as the 1910s, disrupted by WWII and the chaos of the early postwar period for almost 20 years. The economies recovered to their prewar peak during the late 1950s and the mid-1960s, and then continued to show rapid economic growth[3] thereafter.

Place Figure 1 here

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[3] Using the Perron's test of time-series analysis, we have shown that the plunge of GDP per capita in 1944 was indeed very significant in both countries (Hsiao and Hsiao, 2003).

After 1970 both grew faster than any other countries in Asia including Japan, and even faster (the lines are steeper) than all of the advanced countries in the postwar period (Hsiao and Hsiao, 2003). Although, compared with Japan, real GDPs per capita of Korea and Taiwan decreased after the war until 1970, they started to catch up with Japan after 1970 (ibid). If Korea and Taiwan continue their current tracks of progress, it is not inconceivable that both countries may even surpass other developed countries (ibid.). As economic growth is determined by productivity, we may expect that the pattern of productivity growth of these two countries may be similar. This is the first point we would like to explore in this paper.

As Figure 1 shows, for almost a century, the real GDP per capita levels of Korea and Taiwan have grown together hand in hand. It is worth noting that the real GDP per capita of Korea was consistently higher than that of Taiwan in the prewar period, and it became

$= D^t(a^{t+1})/ D^t(a^t)$, 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. Similarly, the MPI at time t+1 when the production set is $P^{t+1}(x)$ is $M^{t+1} = D^{t+1}(a^{t+1})/ D^{t+1}(a^t)$, which refers to the technology at t+1. To avoid ambiguity in choosing the indexes, the output-oriented MPI is then defined as the geometric mean of the MPI in two consecutive periods (Coelli, et al., 1998, 128; Faere et al., 1994):

$$\text{MPI} = (M^t\, M^{t+1})^{1/2} = \left[\left(\frac{D^t(a^{t+1})}{D^t(a^t)}\right)\left(\frac{D^{t+1}(a^{t+1})}{D^{t+1}(a^t)}\right)\right]^{1/2} \qquad (2)$$

where MPI > = < 1 implies productivity growth (or change) is positive, zero, or negative from period t to period t+1. We estimate the four distance functions in (2) by non-parametric linear programs. The method is to construct an annual cross-industry best-practice meta production frontier from the sample, and then compare the observed annual output of each industry with the cross-sector frontier.

Following Faere, et al. (1994, 1995) and Lee, et al. (1998), we use a cross-sector frontier for the whole industry, instead of the sector-specific frontiers,[4] since, in this paper, we are interested in the relative performance among all the sectors, reflecting the social capacity of the economy wide production system (Nishimizu and Hulten, 1978).

The MPI in (2) is the standard definition. It is enigmatic and not intuitively clear. In the literature, the diagram with one-input one-output of Fare et al. (1994) is often reproduced to illustrate the concept. Instead, we will present it and show its decomposition using the familiar diagram of production possibility curves[5] (PPC) (see Figure 2). To avoid the cluttering of superscripts in Figure 2, we denote the observed outputs for periods t and t+1 as y and z, respectively, and the corresponding efficient outputs at time t as y' and z' along the PPC $P'(x)$, and those at time t+1 as y" and z" along the PPC P"(x), respectively. Then, in Figure 2, substituting $D^t(a^t) = y/y'$, $D^t(a^{t+1}) = z/z'$, etc., into the definition of the MPI above, we have

[4] Elsewhere we have constructed the sector-specific frontiers with further decomposition of the efficiency index into the pure efficiency change and the scale efficiency change, based on the variable-returns-scale technology (Hsiao and Park, 2002a).

[5]

$$\text{MPI} = \left(\frac{z}{y}\right)\left[\left(\frac{y'}{z'}\right)\left(\frac{y''}{z''}\right)\right]^{1/2} \quad (3)$$

$$= \left(\frac{z/z''}{y/y'}\right)\left[\left(\frac{y''}{y'}\right)\left(\frac{z''}{z'}\right)\right]^{1/2} = \text{EI*TI} \quad (4)$$

which, in terms of the original distance function (2), is equivalent to

$$\text{M}(\mathbf{a}^{t+1}, \mathbf{a}^{t}) = \frac{D^{t+1}(a^{t+1})}{D^{t}(a^{t})}\left[\left(\frac{D^{t}(a^{t+1})}{D^{t+1}(a^{t+1})}\right)\left(\frac{D^{t}(a^{t})}{D^{t+1}(a^{t})}\right)\right]^{1/2} = \text{EI*TI}$$

The value of MPI may be calcuD(v2 1 1i 0(()--G1324ov.04 225

When 1 is deducted from this ratio, TFPG ≡ (z/y – 1)*100 is the discrete growth rate[6] (or percentage change) of TFP (Faere et al., 1994) between the two consecutive periods. Hence, the TFP growth rate is a special case[7] of the MPI when EI =1. Similarly, MPG ≡ (MPI-1)*100 is the growth rate of productivity, EG ≡ (EI – 1)*100 is the growth rate of efficiency, and TG ≡ (TI-1)*100 is the growth rate of technology. These three indicators will be used in this paper to compare the industrial structures of Korea and Taiwan.

Place Figure 2 here

The output-oriented Malmquist productivity index (MPI), efficiency index (EI), and technology index (TI) are first calculated using the method of nonparametric data envelopment analysis used in Faere, et al. (1994) and programmed in Coelli (1996). The growth rates of the productivity (MPG), efficiency (EG), and technology (TG) are then calculated by subtracting one from the indexes and multiplying by 100. Comparisons of productivity are performed using indexes as well as growth rates, both of which are pure numbers, independent of the units of measurement used in each county.

Differentiating MPI logarithmically, we have the unique relationship

$$M\hat{P}I = \hat{E}I + \hat{T}I\ .$$

That is, the continuous growth rate of MPI is the sum of the growth rates of the efficiency index and the growth rate of the technology index. Since we use discrete growth rates, the relation between MPG, EG and TG is only approximate, that is,

$$\text{MPG} \cong \text{EG} + \text{TG}$$

which may deviate considerably in some empirical studies.

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[6] In conventional notation, since $y = y_t$ and $z = y_{t+1}$, TFPG = (z/y) – 1 is a discrete growth rate, which is compounded once a year. On the other hand, if we define TFPG = ln z – ln y, then it is a continuous growth rate, which is compounded instantaneously. In the continuous case, the sum from period 0 to period 17 will cancel out the middle terms and the average growth rate is $(\ln y_{17} - \ln y_0)/17$. Since some growth rates are negative, we use the discrete growth rate.

[7] Thus, it is confusing, if not in error, to refer to MPI as TFP or the TFP ratio.

To calculate the Malmquist Productivity Index of (2), we need four distance functions for the initial two periods for each sector. Each additional period requires three more distance functions (Coelli, 1996). Thus, for 18 years, each sector requires 52 (=3x18-2) distance functions. For 15 sectors and 18 years, we have found 780 linear program solutions of distance functions to construct the time series of the productivity index. The productivity index of each sector in each year is decomposed into indexes of efficiency and technology. At the end, we have generated a sample of 810 (=3x15x18) panel data of the three indexes.

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, the time-series data have been divided into two sub-periods: Period A covers 1979 to 1986 and Period B, 1987 to 1996. Taiwan lifted its 37-year long Martial Law in 1987, and entered a new era of political freedom and economic liberalization and reform (Hsiao and Hsiao, 2001). Similarly, Korea passed the 6.29 Declaration on democratization to change the presidential election method from indirect to direct election by the people, and promulgated seven other laws to democratize the society. One of the consequences of this, as in Taiwan, has been the gain in power of labor unions (Lee, et al., 2001).

Following Hu and Chan (1999), the 15 sectors in the cross-section data set are further grouped into three categories: 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 7 to 15), as shown in the first “Category” (Ca) column in Table 1.

V. Labor and Capital Productivities

The conventional method of comparing the productivity of manufacturing sectors within and between countries is to examine the average labor and capital productivity of the manufacturing industry (Wagner and van Ark, 1996).

Figure 3 draws the time series of real output (Q), real capital (K), and the number of workers (L), labor productivity (Q/L), and capital productivity (Q/K), measured in New Taiwan Dollar for Taiwan and won for Korea, except that labor is given by the number of workers. The units of the data are adjusted to fit the time series in one diagram. They are drawn to show

Within each country, labor is positively and significantly correlated with real output and real capital in period A, but is negatively and rather weakly correlated in period B. For both countries, they are complementary in period A but substitute in period B. A similar relation holds between labor and capital productivity, and labor and labor productivity in both countries in periods A and B, except for the correlation between labor and capital productivity in Taiwan.

Place Table 2 here

VI. Total Productivity Growth, 1979-1996

Having calculated efficiency, technology, and productivity growth rates for Korea and Taiwan covering the cross-section of 15 manufacturing sectors, each of which has a time-series of the three growth rates from 1979 to 1996, we will now discuss their properties separately.

A. Analysis of the Cross-Section Data

Figure 4 shows the average output[10] of each manufacturing sector for the period from 1979 to 1996. EG is shown by an empty column on the left, TG, by a filled dark column on the right, and MPG by a marked line with circles. The number next to the circle mark is the value of MPG. We also calculated the weighted grand average[11] growth rates, EG, TG, and MPG, for the whole manufacturing industry. The weighted grand average and its values are shown after the dotted lines and also in the x-axis label below. The lower section of the chart also indicates whether a sector is in the traditional (T), basic (B), or high-tech (H) category.

At an aggregate level of weighted grand average growth rates of the manufacturing industry as a whole, both countries have almost the same positive efficiency growth, 1.80% for Korea and 1.65% for Taiwan. However, the similarity ends here. The overall technology growth rates are quite different, -1.38% for Korea and 0.72% for Taiwan, resulting in a low MPG for Korea (0.38%) and a much higher MPG for Taiwan (2.23%) (the circle marker of "Grand

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[10] Figure 4 is constructed as follows. We first take the geometric mean of EI (and also TI and MPI) of each manufacturing sector for the period from 1979 to 1996, thus we have 15 means of EI's, each for 15 sectors. Do the same for TI and MPI. We then subtract one from each mean and multiply it by 100 to obtain EG, TG and MPG.

[11] To derive the weighted grand average, we first weight the index EI (and similarly TI and MPI) using the value-

Average" column in Korea and Taiwan sections). Thus, efficiency growth is the dominant factor in productivity growth in both countries, and they are almost the same. However, considering that the manufacturing industry plays a prominent and leading role in a country's industrialization, negative technology growth and the resulting low productivity growth in Korea may, at least partially, explain why GDP per capita of Korea falls behind that of Taiwan in Figure 1. It is rather surprising that technology growth rates, and therefore productivity growth rates, can be so different between these two newly developed countries.

Place Figure 4 here

At a disaggregate level, the other part of Figure 4 provides sector-by-sector information in detail. Among the sectors, Korea's EG, TG, and MPG fluctuate much more than those of Taiwan. All of Korea's traditional sectors register large negative technology growth rates (TG), as well as negative productivity growth rates (MPG) a(----)(710(an)ndewl)-)ewlncy gra 1(r)4. rates (nP)cn both countries. This is due to the fact that both countries have enforced the development of the electric and electronic sector, machinery, etc. and the high-tech industries are more exposed to the same international market and multinational investment in both countries. In contrast, the traditional category is more local in character and differs considerably between the two newly developed countries.

The similarities and differences among the three categories are clearer if the three indexes are arranged in descending order of productivity growth rates (MPG). This is shown in Figure 5. In all categories, Korea has much larger and more negative growth rates than Taiwan, especially in technology growth. Note the similarity of the shape and location of the columns and lines in all categories, especially the same ranking of sectors in the High-tech category. They are indeed visually similar. ---------

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Place Figure 5 and Table 3 here

To find the degree of relationship among the sectors between Korea and Taiwan, we have calculated Pearson correlation coefficients among EG, TG, and MPG between Korea and Taiwan in Table 3. This table shows the correlation coefficients of weighted indexes[12] for the 15 manufacturing sectors in the two countries, using the data in Figure 4. Table 3a gives the coefficients of the manufacturing industry as a whole, and Tables 3b to 3d give the coefficients for the three categories. In each subtable, the upper left block shows the correlations among the pairs from EGk, TGk, and MPGk for Korea, and the lower right block shows the correlations among the pairs from EGt, TGt, and MPGt for Taiwan. The coefficients along the diagonal line with bold-faced numbers are the direct comparisons of EG, TG, and MPG between Korea and

[12] The correlation coefficient r's of the weighted indexes are taken as follows. For Table 3b to 3d in each country we weigh each of the three indexes EI, TI, MPI in each category by the corresponding value-added output shares within that category for each year. Summing the weighted index in each category, we have the average weighted index for each category, each index containing 18 time-series observations. The correlation coefficients are taken

Taiwan, and the off-diagonal numbers are cross comparisons of growth rates between the two countries.

We submit that if the Korean and Taiwanese economies are at the same stage and the structures of production are similar, then the growth rates of efficiency, technology, and MPI will be more or less similar and of the same magnitude and trend, as the sample may be regarded as drawn from the same population. This implies that the Pearson and rank correlation coefficients between the variables and countries should be high. With this understanding, we may observe some interesting patterns in Table 3.

a. For the manufacturing industry as a whole (Table 3a), along the bold-faced diagonal elements in the small box, the correlation coefficient is high and very significant for productivity growth (MPG), but that of technology growth (TG) is almost zero and not significant, and that of efficiency growth (EG) is negative and not significant. The two newly developed countries are very similar in the pattern of productivity growth, and yet have quite different, or even opposite patterns of efficiency and technology growth at the aggregate level of the manufacturing industry.

Along the diagonal of other subtables (Tables 3b, 3c, 3d), correlation coefficients in the

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icvurestimsimilaiatts bezn the two counl high correlation between MPG and EG or TG, especially in Korea, but low or negative and significant correlation between EG and TG. Thus, even though EG and TG are the components of MPG, they are generally independent of each other inside each country.

c. This relation, however, differs with the industry category. In the traditional sector (Table 3b), EG and TG in both countries, and especially EG, have high and significant correlations with MPG. Thus, for both countries, the main source of productivity growth in the traditional category comes from improvement in efficiency rat her than in technology.

d. In contrast, in the basic category (Table 3c), TG in both countries has a very high and significant correlation (1%) with MPG, but EG has different relation in the two countries. EG is highly correlated with MPG in Korea, but negatively and insignificantly correlated with MPG in Taiwan. Thus, we may consider that the main source of productivity improvement in the basic category comes mostly from technology growth rather than from efficiency growth, as the effects of EG on MPG in these newly developed countries differ.

e. In the high-tech industry category (Table 3d), we notice that, unlike the other two categories, both EG and TG have a very high correlation with MPG at the 1% significance level, although the correlation coefficient between EG and MPG in Taiwan has level of significance of only 10%. Thus, in both countries, the source of growth of productivity in the high-tech industry category comes from both efficiency improvement and technology growth, greatly increasing the output growth of the high-tech industries in both countries.

f. The overall effect of the three categories on the manufacturing industry, as shown in Table 3a, is that in Korea both efficiency and technology improvements contribute to productivity growth (at 1% level of significance), but in Taiwan, efficiency growth does not contribute to productivity growth, and only technology growth does so in all categories.

g. Aside from the bold-faced diagonal coefficients, the off-diagonal coefficients relate one index of one country to another index in the other country. The coefficients may be small or negative and generally not significant, as expected. However, a strange finding is that in the high-tech category, Korea's technology growth and efficiency growth are significantly correlated with Taiwan's productivity growth, and so is Taiwan's technology growth with Korea's productivity

in traditional industries, the “Food, Beverage, and Tobacco”, “Apparel”, and “Leather, Fur, and Products” sectors have negative correlation coefficient in productivity, but the “Food, Beverage, and Tobacco,” “Wood Products” and “Leather” sectors have very high correlation coefficients in TG and low or negative coefficients in EG.

In the traditional and basic industry categories, the correlation coefficients of TG and EG tend to be opposite; if one is positive, the other will be negative. This is not the case in the high-tech category, in which TG and EG often have relatively strong and positive correlation coefficients, except EG in the “Precision Instruments and Other Manufacturing” sector.

Our diagram confirms our observation in Table 3 that there is more similarity among the indexes in the high-tech categories than the other categories. Thus, whether from the weighted indexes in Table 3 or the un-weighted indexes in Figure 6, we have the same observations and conclusion.

We have also calculated the (arithmetic) average of the correlation coefficients of the 15 sectors. The average EG of the whole manufacturing industry is close to zero (0.05), while the average TG is 0.17, and the average MPG is 0.2. These numbers are indeed small, mainly due to the cancellation effect of the positive and negative correlation coefficients. It also suggests that the aggregated numbers may be misleading.

Place Figure 6 here

Place Table 3 here

B. Analysis of Time-series Data

The right-hand side of Figure 6 presents the time-series of correlation coefficients of unweighted indexes for the 15 manufacturing sectors of Korea and Taiwan,[14] separating period A and period B. The correlation coefficients fluctuate considerably over the years: More

[14] The correlation coefficient r of each year between the two countries is found by correlating the cross-section data of EI (or TI or MPI) of a year in Taiwan with the corresponding cross-section data of EI of the same year in Korea. The same for TI and MPI. In this exercise, the indexes are not weighted.

fluctuating and more negative in the early 1980s, mostly negative in the late 1980s, showing the trend of deviation between the two countries. The correlation in the 1980s is either small but positive or large and negative. The technology growth rates (TG), in particular, have a large and negative correlation (above 0.5). However, in the first half of the 1990s, the industrial structure of both countries seems to converge in all three indexes, as both governments emphasize high-tech industries during this period.

VII. Productivity Growth of Three Categories in Subperiods

We examined the productivity performance of the manufacturing industry of Korea and Taiwan in the 1979-1996 period in the previous section. In this section, we would like to examine sector by sector[15] the performance of three categories, traditional, basic, and high-tech industries, in each subperiod, period A and period B. As we have seen from the analysis of partial labor and capital productivity in Table 2, a much clearer similarity between the two countries in the industrial structure of the manufacturing industry emerges in the subperiods.

Figures 7 and 8 show the three categories of manufacturing industry for period A and period B for Taiwan and Korea, respectively. In Figures 7 and 8, the sectors are arranged in the original order for easy comparison sector by sector. When the sectors in each category are rearranged in accordance with a decreasing order of productivity growth rates (MPG) the similarity is much more striking (not shown). Note the great similarity in terms of the shape, size, and position between the two countries in each period, especially those of the productivity index in period B.

Place Figures 7 to 8 here

In period A, Korea has a mixture of signs of the efficiency growth rates (EG), the technology growth rates (TG), and productivity growth rates (MPG), while Taiwan has mostly positive growth rates for almost all sectors and categories, showing the vitality of the Taiwanese manufacturing industry over Korean industry in period A. Referring to Figure 8, the gain in productivity growth of Taiwanese traditional industries is mostly due to efficiency growth, very

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[15] Since we do not aggregate the data, the indexes are not weighted by the value-added output shares.

little to technology growth, except probably in the Food and Tobacco sector. The Taiwanese basic industry shows strong technical growth, especially in the Petroleum, Coal and Products sector and the Basic Metal sector. Both countries show positive efficiency growth and negative technology growth in Fabricated Metal Products. In the high-tech category, both countries have positive efficiency growth in all sectors, especially in the Transportation sector, and negative technology growth in the "Electric, Electronic Machinery" and "Precision Instruments and Other" sectors. The similarity is almost complete in this high-tech category.

In period B, the similarity of the two countries is even greater. The advantages of the traditional industry category in EG, TG, and MPG have mostly disappeared, and negative growth rates are registered for almost every sector in both countries. In this category, Korea continues to show negative technology growth, while Taiwan shows negative efficiency growth. Indeed, the change is striking and dramatic in both sets of the figures. In the basic industry category, Korea's Petroleum and Coal sector grows almost five times while the growth of the same sector in Taiwan decreases by half. However, Taiwan continues to show positive growth in efficiency and technology in this category, and Korea also shows improvement in technology in other sectors, except the Fabricated Metal Products sector. In the high-tech industry category, both countries have the same pattern of EG, TG, and MPG in every sector, and there is an increase in EG in the Electric and Electronic Machinery sector in both countries.

VIII. The Innovators of the Manufacturing Industry

In the process of deriving the distance functions in (1), we have compared the actual output of each sector each year with the corresponding maximum output on the manufacturing-wide best-practiced beta frontier of that year (see Figure 3). The two components of the Malmquist productivity index, efficiency change (EI) and technical change (TI) are interpreted as catch-up and shift of production frontier, respectively. Therefore, it is important to identify which industries, called the innovators by Faere, et al. (1994), shift the production possibility curve of the manufacturing industry each year. If we can find the same innovators, that would be additional evidence for the same pattern of manufacturing structure in these two countries.

Faere et al. (1994) define an innovator as

$$\{\mathrm{TI_i} > 1,\ D_i^t(a^{t+1}) > 1,\ D_i^{t+1}(a^{t+1}) = 1\}$$

where TI_i

In both countries, productivity improvement in traditional industry comes from efficiency growth, that in basic industries from technology growth, and that in high-tech industries from both efficiency and technology growth. However, correlation analysis reveals that the processes of efficiency improvement and technology change are different in the two countries. The high-tech industry is an exception, since both efficiency improvement and technology growth are positively and highly correlated between the two countries, showing that both countries have the common factor that they are exposed to the international market and influenced by multinational investment.

The analysis from the time-series data leads to the same conclusion as the analysis from the cross-section data. However, the time-series data do not reveal much about the common trend of the three indexes between the two countries. The correlation analysis shows that the similarity between the manufacturing sectors in period B, 1987-1996, has increased, indicating that due to government policies of emphasizing high-tech industries, there is a sign of convergence in this industry between the two countries. However, the innovator analysis reveals that only the Petrochemical sector dominated the production frontier in both countries, the Electric and Electronic Machinery Products sector played no role or a very minimal one as an innovator. While the future is hard to predict, the policy implication of our analysis is that each country shows similarity in recent years at the aggregate levels and can learn from each other: Korea from Taiwan on technology adoption and Taiwan from Korea on efficiency improvement.

----- and ----- (2001), Economic Liberalization and Development: The Case of Lifting Martial Law in Taiwan," in Change of an Authoritarian Regime: Taiwan in the Post-Martial Law Era, ed. by Taiwan Studies Promotion Committee, Academia Sinica. Taipei, Taiwan: Preparatory Office of Institute of Taiwan History, Academia Sinica.

--------- and -------- (1998), "Miracle or Myth of Asian NICs' Growth—The Irony of Numbers" in The New Industrial Revolution in Asian Economies

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. Correlation Coefficients of Production Factors and Productivity, 1979-1996

a Period, 1979-1996 n = 18

	Qk	Kk	Lk	Q/Kk	Q/Lk	Qt	Kt	Lt	Q/Kt
Kk	0.993 a								
Lk	0.796 a	0.722 a							
Q/Kk	0.985 a	0.996 a	0.690 a						
Q/Lk	0.981 a	0.994 a	0.679 a	0.993 a					
Qt	**0.983** a	0.958 a	0.878 a	0.948 a	0.942 a				
Kt	0.996 a	**0.990** a	0.795 a	0.982 a	0.983 a	0.985 a			
Lt	0.455 c	0.360	**0.838** a	0.345	0.318	0.603 a	0.466 c		
Q/Kt	-0.393	-0.492 b	0.203	**-0.508** b	-0.520 b	-0.229	-0.389	0.581 b	
Q/Lt	0.960 a	0.982 a	0.617 a	0.984 a	**0.993** a	0.909 a	0.964 a	0.235	-0.580 b

b Period A, 1979-1986 n = 8

	Qk	Kk	Lk	Q/Kk	Q/Lk	Qt	Kt	Lt	Q/Kt
Kk	0.987 a								
Lk	0.973 a	0.933 a							
Q/Kk	0.979 a	0.981 a	0.911 a						
Q/Lk	0.940 a	0.979 a	0.843 a	0.972 a					
Qt	**0.992** a	0.992 a	0.944 a	0.982 a	0.963 a				
Kt	0.961 a	**0.990** a	0.878 a	0.982 a	0.997 a	0.976 a			
Lt	0.983 a	0.980 a	**0.938** a	0.970 a	0.945 a	0.989 a	0.958 a		
Q/Kt	0.931 a	0.865 a	0.944 a	**0.889** a	0.783 a	0.913 a	0.816 a	0.907 a	
Q/Lt	0.581 b	0.670 b	0.401	0.704 a	**0.799** a	0.641 b	0.765 a	0.573 b	0.385

c Period B, 1987-1996 n = 10

	Qk	Kk	Lk	Q/Kk	Q/Lk	Qt	Kt	Lt	Q/Kt
Kk	0.997 a								
Lk	-0.522 b	-0.566 b							
Q/Kk	0.992 a	0.994 a	-0.600 b						
Q/Lk	0.974 a	0.987 a	-0.680 a	0.984 a					
Qt	**0.995** a	0.991 a	-0.506 b	0.991 a	0.965 a				
Kt	0.993 a	**0.997** a	-0.563 b	0.989 a	0.987 a	0.985 a			
Lt	-0.816 a	-0.849 a	**0.759** a	-0.821 a	-0.897 a	-0.776 a	-0.861 a		
Q/Kt	-0.974 a	-0.980 a	0.554 b	**-0.966** a	-0.971 a	-0.955 a	-0.990 a	0.884 a	
Q/Lt	0.959 a	0.973 a	-0.720 a	0.975 a	**0.992** a	0.946 a	0.976 a	-0.913 a	-0.969 a

Notes: a = significant at 1%, b = significant at 5%, c = significant at 10% of the t distribution for the null hypothesis, H0: rho = 0.

Table 3. Pearson Correlation Coefficients of Mfg Industry, 1979-96
Korea and Taiwan

a **Mfg Industry n = 15**

Mfg	EGk	TGk	MPGk	EGt	TGt
TGk	0.045				
MPGk	0.808 a	0.625 a			
EGt	**-0.106**	0.165	0.022		
TGt	0.514 b	**0.009**	0.408 c	-0.727 a	
MPGt	0.622 a	0.206	**0.619** a	0.133	0.580 b

b **Traditional Category n = 6**

	EGk	TGk	MPGk	EGt	TGt
TGk	-0.444 c				
MPGk	0.671 a	0.365 d			
EGt	**0.061**	0.097	0.158		
TGt	-0.073	**0.151**	0.049	-0.606 a	
MPGt	-0.012	0.266	**0.223**	0.482 b	0.402 c

c **Bsic Category n = 5**

	EGk	TGk	MPGk	EGt	TGt
TGk	-0.121				
MPGk	0.628 a	0.695 a			
EGt	**-0.150**	0.245	0.093		
TGt	0.238	**-0.158**	0.042	-0.885 a	
MPGt	0.292	0.056	**0.258**	-0.297	0.701 a

d **High-tech Category n = 4**

	EGk	TGk	MPGk	EGt	TGt
TGk	0.422 c				
MPGk	0.966 a	0.640 a			
EGt	**0.193**	-0.141	0.128		
TGt	0.488 b	**0.454** c	0.542 b	-0.143	
MPGt	0.572 b	0.348 d	**0.587** b	0.458 c	0.813 a

Notes: a = significant at 1%, b = significant at 5%, c = significant at 10%, d = signifcant at 15%, of the t distribution for the null hypothesis, H0: rho = 0.

Table 4. The Innovators Among the Manufacturing Industry

year	KOREA				TAIWAN				
79	Fd		Pe			Pe			
80						Pe			
81		Ap	Pe			Pe			
82	Fd				Le				Pr
83			Pe	Pr					Pr
84	Fd		Pe			Pe			Pr
85									
86			Pe	Pr					Pr
Count	3	1	5	2	1	4	0	0	4
87				Pr		Pe			Pr
88			Pe						Pr
89								Tp	
90	Fd		Pe						
91			Pe			Pe		Tp	
92	Fd	Ap	Pe					Tp	
93			Pe						
94			Pe			Pe			
95			Pe			Pe	El		
96			Pe			Pe			
count	2	1	8	1	0	5	1	3	2
Total	5	2	13	3	1	9	1	3	6

Notes: Fd = 1Food, beverage & tobacco, Ap = 3Apparel and Ornaments, Pe = 8Petroleum, coal, and products, Le = 4Leather, fur, and products, El = 13Electric, electronic machinery products and repairs, Tr = 14Transportation products an drepairs, Pr = Precision instruments and other manufacturing.