MISSING A MIRACLE: HOW AGGREGATE TFP ACCOUNTING OVERLOOKS SECTORAL EFFICIENCY GAINS [*]

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ABSTRACT

One-sector aggregate growth accounting does not distinguish capital investments made in response to an economy's newfound ability to produce new goods efficiently from capital deepening in existing industries. This can lead to biased interpretations like Krugman's (1994) paradox that technical progress had been absent in the East Asian economies. This paper introduces a new approach to test for sectoral technical gains even when aggregate growth accounting shows no gains. This methodology is applied to data from Korea, Singapore, and Taiwan. Results suggest sector-specific technical progress may have been present in several episodes from 1972-92. Exports to the U.S. corroborate these findings.

JEL Classification: O47, O53, O3

Keywords: Total Factor Productivity, Technology Growth, Korea, Taiwan, Singapore.

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During the late 1960s and early 1970s, the textiles and apparel industry dominated Korea's manufacturing economy, accounting for one-fourth to one-third of manufacturing value-added (Enos and Park (1988)). In the late 1970's, textiles and apparel was replaced by the metal industry, which in turn made way for the production of motor vehicles and parts in the mid-to-late 1980s which was followed in turn by the emergence of the semiconductor industry in the early 1990s. This rapid industrial change is a common pattern in the industrialization of the East Asian countries whose tales of rags to riches have been well-documented (see, for example, The World Bank (1993)).

One story that could be taken from this is that technological change often comes to an economy one sector at a time. For those countries late to industrialize, it is generally the case that gains are the result of successful emulation of foreign technology from the more advanced countries.[1] This emulation of foreign technology is one important if not the most important factor determining whether a developing country can achieve sustained income growth as was the case in the East Asian countries. Stern et. al. (1995, pp. 184-6) describe how Korea picked 'winners' from 1973 proceeding industry by industry, "[going] to great length to attempt to discern whether Korea had the technical skill needed ... or could expect to acquire these skills quick enough." Through prudent state industrial policies, learning-by-doing, and adaptation of foreign knowledge, a country's comparative advantage can shift like a 'narrow moving band' over successive industries over time (see Krugman (1987) for a discussion of dynamic comparative advantage).[2]

Keeping with the example of Korea, one also recognizes that the progression of industries was from simple, labor-intensive to more sophisticated, capital-intensive production. This pattern is consistent with the model of Stokey (1988) in which 'forward' spillovers of knowledge give rise to the introduction of new goods in production and sustained growth in the economy. The evolution from less to more capital-intensive (sophisticated) industries could account for why past researchers, lacking disaggregated data, and thus employing an aggregate one-sector growth accounting methodology, have found factor accumulation to be the most important reason for growth in the East Asian countries.[3] In a series of influential papers, Young (1992, 1994, 1995) and Kim and Lau (1994a, 1994b) found that the high rates of income growth in the East Asian countries were due almost entirely to high rates of physical and human capital accumulation.

But if technical change is sectoral in nature as the evidence suggests, then technical progress would cause the aggregate production isoquants to change *locally*, as depicted by Atkinson and Stiglitz (1969), with each change occurring in industries of higher and higher capital intensity. An estimated aggregate production function would introduce a systematic bias, misidentifying the effect of technical progress (local in nature) as capital accumulation. This would account for Krugman's (1994) Paradox, based on Young's and Kim and Lau's estimations, that views the East Asian mode of accumulation without innovation to be doomed for failure in the Soviet fashion.

At the core of this apparent paradox is the limitation of one-sector aggregate growth accounting to distinguish those capital investments made in response to an economy's newfound ability to produce new goods efficiently from capital deepening in existing industries. The latter mode of aggregate capital intensification would imply the interpretation of Krugman but the former is more consistent with rapid industrial change in the East Asian economies. Thus, if producing new goods is an important part of a country's industrialization path, the results of aggregate growth accounting would overlook the possibility the country had gotten some things *right* that made it possible to achieve gains in these new industries. On another level, this continual introduction of new goods is essential to the endogenous growth explanations of the East Asian experience — something recognized by Lucas (1988) — for without it, long-run growth will necessarily diminish along with capital's marginal product.

In this paper, we introduce a way to detect the presence of possible technical gains specific to the production of certain goods even where the aggregate growth accounting exercise may overlook such gains as capital deepening.

In simplest terms, the two main methods of growth accounting are (1) to calculate the 'Solow' residual left after the growth of factor inputs is subtracted from growth in aggregate output, and (2) to estimate an aggregate production function for the economy and use the estimated parameters to decompose the output growth into contributions from factor inputs.[4] Both methods assume the existence of an aggregate production function that could adequately represent an economy's production frontier. Atkinson and Stiglitz (1969) showed that each point on the aggregate production function can be thought to represent one industry indexed by its level of capital intensity. In this framework, technical gain in one sector is a movement upward of one point on the production function. And if technical change successively comes to industries of increasing capital-intensity, one can envision the case where there is no shift in an *estimated* aggregate production function but that the capital deepening implied is, in fact, a result of technical gains in the economy, one sector at a time. Growth accounting based on an aggregate production function would identify this case as one of pure capital deepening and no technological change.

Robert Solow (1966) writes: "... I have never thought of the macroeconomic production function as a rigorously justifiable concept ... It is either an illuminating parable, or else a mere device for handling data, to be used so long as it gives good empirical results, and to be abandoned as soon as it doesn't ..." We are certainly not ready to abandon the idea of the aggregate production function and its time-proven usefulness. Instead, in this paper, we offer, as a complement to aggregate growth accounting, a test to detect the presence of localized technical gains to check if the results of the aggregate growth accounting exercise is indeed accurate for the case in question.

We focus on the possibility that technical change in three economies, Korea, Singapore, and Taiwan came one sector at a time. We present a test, using aggregate data, to detect the presence of localized technical gains exploiting the relationship between the marginal rates of technical substitution calculated from parameters of an estimated aggregate production function and the ratio of factor prices. Discrepancies between the rate of factor substitution and factor price ratio would suggest the presence of localized technical gains. In the periods where the two values differ, we also find that the volume of exports to the United States in certain industries increased significantly. Because the U.S. market is widely agreed to be one of the most competitive in the world, an expansion in an industry's exports to the United States is consistent with technical gain in that industry.

In the next section, we present a graphical conceptualization of the argument. That will be followed by section II where we introduce the methodology for detecting localized technology gains using data for Korea, Singapore and Taiwan. Section III describes the variable used in the analysis. Section IV presents the results and section V concludes.

1. A GRAPHICAL CONCEPTUALIZATION OF LOCALIZED TECHNOLOGY GAINS AND GROWTH ACCOUNTING

For an illustration, consider a graphical conceptualization of aggregate growth accounting (see Van and Wan (1997) for a detailed treatment). In Figure I, the curve *aa* is the unit-value isoquant that is the dual of the aggregate constant returns to scale production function representing efficient production in an economy. A movement of the entire isoquant from *aa* to *bb* would represent a technological improvement (less inputs needed for the same unit output). Suppose the economy starts at a level of capital per worker shown as point A. If the economy moves to point C, that would mean that the economy has made technological gains while a movement to point B would mean there was no technological gain, only capital deepening (a higher K/L ratio at point B).

This interpretation is appropriate when there is global technological progress (a movement of the entire isoquant from *aa* to *bb*) but would be inaccurate when the gains are localized to a specific sector. To see this, consider that the unit-value isoquant is really just an envelope of a series of unit-value isoquants each denoting one industry represented by a fixed-coefficient production process indexed by its level of capital-intensity (K/L ratio).[5] In Figure II, the aggregate unit-value isoquant *cc* is shown as the envelope for the isoquants of three sectors: textiles, chemicals, semiconductors.[6] Textiles is the least capital intensive indexed by the point A'; chemicals, indexed by point B', is more capital intensive; and semiconductors, indexed by point C', is the most capital intensive. We can represent a technological gain specific to the textile industry as a movement of point A' to point A, a gain specific to the chemicals sector as a movement of point B' to point B and so forth.

It is conceivable (and verifiable for the countries in question) that technological improvements in the textile industry preceded those in the chemicals industry which preceded those in the semiconductor industry. In fact, the pattern for the Asian NIEs is one of rapid change of the dominant industry following a product cycle. The textile industry dominated these economies for a time, then came chemicals, then semiconductors. Conceptually, we can say that this is represented as an evolution of the envelope isoquants as shown in Figure III. Suppose the economy is producing at point A after having just had a technological improvement in textiles but in no other industry. The envelope unit-value isoquant representing the economy is the thick-set curve

cC'Aa. Now suppose that some years later, there is a technological improvement in the chemicals industry and the economy can now produce chemicals for the world market. The envelope isoquant is now the thick curve **cBAa.** We can imagine technological gain as being some monotonic transformation of the area enclosed by the points c**C'AB**. In contrast, an aggregate growth accounting exercise would fit the economy with the isoquant *aa* and show only capital deepening (no technology gain) as the economy moves up *aa* from point A to B.

Empirically, if we only observed the economy at two points A and B in two different periods, both the localized-technological-progress and the no-technological-progress stories would be plausible. A difference exists, however, as shown in Figure IV, in the relationship between the factor price ratio, w/r (where w is wage; r is the cost of capital) and the marginal rate of technical substitution (MRTS) implied by the isoquant aa. In the localized-technology-gain story, the economy operates at a 'kink' point in the envelope isoquant and thus a whole range of factor price ratios would support production at that point. The factor price ratio will, in general, exceed (not necessarily equal to, as in the case of no technological gain) the MRTS associated with the isoquant aa. We exploit this relationship as an indicator of the presence of sector-specific technical gain.

2. A METHODOLOGY FOR DETECTING LOCALIZED TECHNOLOGY GAINS

When a technology gain has taken place in a sector, and capital investments are made in that sector as a result, then the economy can be thought to be operating at a kink point in the envelope isoquant as in Figure IV. In such a scenario, the MRTS implied by the fitted aggregate unit-value isoquant will either be equal to or less than the factor price ratio, or:

$$\frac{w}{r} \geq MRTS = \frac{MPL}{MPK},$$

where w is the real wage, r is real rental price of capital, MPL is marginal product of labor, and MPK is marginal product of capital. The ratio of marginal products is equal to the MRTS. The one-sided nature of the inequality (i.e., w/r is never less than $MRTS$) is a direct implication of the assumption that technical gains arrive earlier at industries of lower capital intensity. This assumption is consistent with the pattern of industrial change in the three economies studied in this paper.

In order to test this relationship, we need data on factor prices and estimates of the marginal products of labor and capital as implied by an aggregate production function fitted for the economy.

The MRTS between the two aggregate factors, K and L, will simply be the ratio of their two marginal products, MPL/MPK. The marginal products will be derived from parameters of a production function estimated from aggregate data. We start by assuming an aggregate production function of the form:

$$Y_t = F(K_{t-1}, L_t, t),$$

where Y_t and L_t are GDP and labor force in year t, K_{t-1} is capital stock in year $t-1$, and $F(\cdot)$ is an underlying aggregate production function which can shift over time. Further, we assume that this technology shift is Hicks-neutral so that output can be written as:

$$Y_t = A(t)F(K_{t-1}, L_t),$$

where $A(t)$ is a technology shift term.

The production function $F(\cdot)$ is assumed to be a second-order translog form so that the estimation equation can be written as:

$$\begin{aligned}\ln(Y_t) = \bar{\alpha}_0 + \bar{\alpha}_K \ln(K_{t-1}) + \tfrac{1}{2}\bar{\alpha}_{KK}\left(\ln(K_{t-1})\right)^2 + \bar{\alpha}_L \ln(L_t) + \tfrac{1}{2}\bar{\alpha}_{LL}\left(\ln(L_t)\right)^2 \\ + \bar{\alpha}_{KL}\ln(K_{t-1})\ln(L_t) + \bar{\alpha}_T T + \tfrac{1}{2}\bar{\alpha}_{TT} T^2 + \bar{e}_{t,Y},\end{aligned} \tag{1}$$

where we have simplified by taking $\bar{\alpha}_{KL} = \bar{\alpha}_{LK}$, and $\bar{\alpha}_{KT} = \bar{\alpha}_{LT} = 0$ implied by Hicks-neutral technological change.

Equation (1) can be used to derive the labor share equation:

$$SL_t = \frac{\bar{\alpha}_L + \bar{\alpha}_{LL}\ln(L_t) + \bar{\alpha}_{KL}\ln(K_{t-1})}{\bar{\alpha}_L + \bar{\alpha}_K + \bar{\alpha}_{LL}\ln(L_t) + \bar{\alpha}_{KK}\ln(K_{t-1}) + \bar{\alpha}_{KL}\left[\ln(K_{t-1}) + \ln(L_t)\right]} + \bar{e}_{t,SL}. \tag{2}$$

If we make the additional assumption of constant returns to scale then $\bar{\alpha}_K + \bar{\alpha}_L = 1$, $\bar{\alpha}_{KK} + \bar{\alpha}_{KL} = 0$, and $\bar{\alpha}_{LL} + \bar{\alpha}_{LK} = 0$ and equations (1) and (2) reduce to the following:

$$\begin{aligned}\ln(Y_t) = \bar{\alpha}_0 + (1 - \bar{\alpha}_L)\cdot\ln(K_{t-1}) - \tfrac{1}{2}\bar{\alpha}_{KL}\left(\ln(K_{t-1})\right)^2 + \bar{\alpha}_L \ln(L_t) - \tfrac{1}{2}\bar{\alpha}_{KL}\left(\ln(L_t)\right)^2 \\ + \bar{\alpha}_{KL}\ln(K_{t-1})\cdot\ln(L_t) + \bar{\alpha}_T \cdot T + \tfrac{1}{2}\bar{\alpha}_{TT}\cdot T^2 + \bar{e}_{t,Y},\end{aligned} \tag{3}$$

$$SL_t = \bar{\alpha}_L + \bar{\alpha}_{KL}\left[\ln(K_{t-1}) - \ln(L_t)\right] + \bar{e}_{t,SL}\ . \tag{4}$$

The translog parameters are estimated by jointly estimating (3) and (4) using ordinary least squares so that the error terms $\bar{e}_{t,Y}$ and $\bar{e}_{t,SL}$ are assumed to have all the standard properties.

Based on the estimation results, we can get the estimates of marginal products of capital and labor as follows:

$$MPK = \frac{\partial Y_t}{\partial K_{t-1}} = \frac{Y_t}{K_{t-1}} \cdot \frac{\partial \ln(Y_t)}{\partial \ln(K_{t-1})} = \frac{Y_t}{K_{t-1}}\left(\alpha_K - \alpha_{KL}\left(\ln K_{t-1} - \ln L_t\right)\right), \tag{5}$$

$$MPL = \frac{\partial Y_t}{\partial L_t} = \frac{Y_t}{L_t} \cdot \frac{\partial \ln(Y_t)}{\partial \ln(L_t)} = \frac{Y_t}{L_t}\left(\alpha_L + \alpha_{KL}\left(\ln K_{t-1} - \ln L_t\right)\right). \tag{6}$$

3. Variables used

Capital stock is estimated using the investment series from the gross domestic fixed capital formation (GFCF) data from the national accounts. The GFCF data is divided into five categories: residential buildings, non-residential buildings, other construction, transport equipment, and machinery equipment. A capital stock is calculated for each category and is then aggregated.

The capital stock is estimated using the standard perpetual inventory approach with geometric depreciation where the initial capital stock series is initialized by assuming that the growth rate of investment in the first five years of the national accounts investment series is representative of the growth of investment prior to the beginning of the series.[7] The initial capital stock is thus calculated by the formula $K(0) = I(0)/(g+\delta)$, where $I(0)$ is the first year of the investment data for asset, g is the average growth of investment in assets in the first five years of the investment series, and δ is the depreciation rate for the asset. We use depreciation rates by asset category and the growth rate of investment in the first five years of GFCF data.

For labor inputs, we estimate the working population, classified by industry and hour of work. By multiplying all employees of the nonagricultural sector by average weekly (or monthly) hours of work, we have an estimate of the total amount of labor in these two sector categories.

To estimate the real wage of each country, we use average weekly (or monthly) earnings of nonagricultural employees for each country. The aggregate capital rental price is based on the rental price of five categories of capital goods: residential building, non-residential building, other construction, transport equipment, and machinery equipment. Assuming firms have perfect foresight and geometric depreciation, the nominal rental price of investment good j, r_j, is given as[8] $r_j = p_j^K(i - \hat{p}_j^K + \delta_j)$ where $\hat{p}_j^K$ is the growth rate of the price of investment good j, i the nominal interest rate, and δ_j the rate of physical depreciation. The real rental price for capital goods is nominal rental price divided by the price of the aggregate output:

$$\frac{r_j}{p^Y} = \frac{p_j^K}{p^Y}(i - \hat{p}_j^K + \delta_j),$$

where p^Y is the GDP deflator. The relative rental price of capital goods is measured as the ratio of the deflator of five capital goods over the GDP deflator from national accounts of each country. Depreciation rates for the five capital goods are based on Hulten and Wycoff (1981, table 2) and Jorgenson and Sullivan (1981, table 1) estimates of geometric depreciation rates. Depreciation rates are 1.3% for residential buildings, 2.9% for non-residential buildings, 2.1% for other construction, 18.2% for transportation equipment, and 13.8% for machinery equipment. For the nominal interest rate, we use the curb-loan rate for Korea, the return-on-equity for Singapore, and the informal-market loan rate for Taiwan.

Table I shows the growth rates of output, capital and labor for each country over the sample periods. See Appendix A for a documentation of the various data sources used for the variables in each country.

4. RESULTS

Table II shows the results of OLS estimates of equations (3) and (4) for the nonagricultural sectors in different periods for Korea, Taiwan and Singapore. From the production elasticities calculated from the estimated parameters , we can compute the contributions to output growth of capital and labor, and the resulting residual. These calculations are presented in Table III.

Capital growth accounted for almost all of output growth over the period 1970-95 in Korea and Singapore. The contribution of capital was less in Taiwan but in all three cases, the residual was low, close to zero. These estimates roughly agree with the results of past authors who find that capital accumulation accounted for most of growth in these three countries over this period.

Our interest here, though, is to take the results of the above growth accounting exercise and compare them to factor prices. Specifically, we use the estimated parameters of the production function to calculate implied marginal products of capital and labor and take the ratio of the two to obtain a series for the MRTS for each country and compare to a series of factor-price ratios.

Figures V, VI and VII graph the wage-to-rent ratios and estimated MRTS over the period 1972-92 for Korea, Singapore and Taiwan respectively. In Korea, we find that the two series follow each other roughly except during the periods of 1972-74, 1978-79, 1986-89, where the factor price ratio is greater than MRTS. In our framework, this evidence suggests that there were localized technology gains in some sectors specific to these three periods. In our theoretical framework, the Korean economy would be operating at kink points in the aggregate unit-value isoquants in these periods. In other periods where the MRTS mirrored the factor price ratio, there is no technology gains, only capital deepening.

We see a similar picture for Singapore in Figure VI where the most notable deviation between the two series occurred beginning at about 1982. For Taiwan, the factor price ratio exceeded the MRTS once in the late 1970's and again from 1986-92.

In some instances, the factor-price ratio exceeded the MRTS by a lot and in others not so much. The theory does not inform us on the meaning of magnitude of difference only that a difference suggests the presence of technology gains in certain specific industries. The extent of the difference would depend on conditions in the specific factor markets.

To find additional evidence to support the story of localized technological gains in the periods mentioned above, we turn to data on exports to the United States. The U.S. market is considered one of the most if not the most competitive market in the world. Therefore, export volume to the United States is one indicator of efficient production. Figures VIII, IX and X graph exports to the United States for certain industries in Korea, Singapore and Taiwan.

For Korea, in the period 1972-74, where the factor-price ratio exceeded the MRTS, there was a big boom in the exports of the apparel industry to the United States; the period 1978-79 saw the beginnings of the increase in exports of the metal industry; and in the period 1986-89, there was a surge in exports of motor vehicles and parts, semiconductors, and electronic computing equipment. This evidence corroborates the story that these industries experienced technological gains in the respective periods mentioned.

In principle, an increase in exports during the periods where w/r exceeded the MRTS could be due to short-run factors such as exchange rate movements or business-cycle effects. This does not seem to be the case here. The Korean won underwent a steady real appreciation against the U.S. dollar over the 1970's and again from 1985 on (see Figure XI). Thus, the mentioned industries were competitve in the U.S. in spite of the strong won. The sustained increase in exports is also not consistent with a business-cycle explanation nor the possibility that subsidies or other export-promotion policies served to prop up these exports. It is likely then that the sharp increase in exports to the U.S. market is attributable to real efficiency gains.

For Singapore, the factor-price ratio deviated from the MRTS first in 1982 and persisted to 1995. In 1982 there was a large increase in the exports of electronic computing equipment, and beginning in 1983 a surge in exports of the chemical industry. There was also a jump in the exports of radios and TVs and semiconductors beginning in 1986. Semiconductor exports continued to increase in 1993.

In Taiwan, the evidence is less clear. However, there does seem to be deviation between the factor-price ratio and the MRTS in 1978-79 coinciding with an export boom in apparel and metal industry exports. Another period of separation occurred from 1986-92 coinciding with an export boom in electronics exports starting in 1986 and semiconductors in 1994.

The pattern is consistent across three countries. Deviations between the factor price ratio and the estimated MRTS seem to coincide with sharp increases in exports to the United States in certain industries. The evidence suggests that these industries may have experienced localized technological gains during those periods.

5. CONCLUSION

Using the graphical framework of the aggregate unit-value isoquant described in this paper, the empirical results suggest that there has been technological gains in South Korea, Singapore and Taiwan for certain industries at different times. This is supported by the increases we see in each industry's exports to the United States in the same respective periods. And since exports make up a large part of these economies, the gains in these industries would mean substantial gains for the economy as a whole.

This result is interesting in that we were able to use the methodology described in this paper to identify meaningful technological gains where the conventional aggregate growth accounting exercise did not. The conventional one-sector exercise only points to capital deepening as the main source for growth. This suggests that there may be complementarity in capital investments and technological progress where efficiency gains in an industry draws capital investments into that industry which could in turn facilitate gains in the next industry. Under such a scenario, decomposing the contributions from accumulation and technological progress can be very difficult using only conventional aggregate growth accounting methods.

We should note again that the methodology proposed in this paper is not meant to be a substitute for growth accounting or as refutation of the method. Indeed, this framework does not offer any concrete measure of technology change that would supplant the Solow residual.[9] We do, however, suggest a complement to growth accounting where one might detect sector-specific technological gains that the aggregate measure may not capture. This should be seen as a check on the existing growth accounting methods.

The results presented here do suggest that it is necessary to exploit disaggregated data to arrive at a more meaningful measure of technical change. Now that microdata is becoming more readily available, it would make sense to explore the information that these datasets might contain.

APPENDIX. DATA SOURCES

SOUTH KOREA

Gross Domestic Product: National Income Statistics Yearbook, The Bank of Korea, annual issues. National Accounts, The Bank of Korea, annual issues.

Gross Domestic Fixed Capital Formation: National Income Statistics Yearbook, The Bank of Korea, annual issues. National Accounts, The Bank of Korea, annual issues.

Paid Employees (in persons): Korea Statistical Yearbook, National Statistic Office, Republic of Korea, various issues. LABORSTA Labor Statistics Database, International Labor Organization.

Average Wages: Korea Statistical Yearbook, National Statistic Office, Republic of Korea, various issues. Report on Occupational Wage Survey, Ministry of Labor, Republic of Korea, various issues for data in 1980, 1982, 1884-1988, 1990. LABORSTA Labor Statistics Database, International Labor Organization.

Average Monthly Hours of Work: Korea Statistical Yearbook, National Statistic Office, Republic of Korea, various issues. LABORSTA Labor Statistics Database, International Labor Organization.

Nominal Interest Rates: CD-ROM of International Financial Statistics, International Monetary Fund, 1998. The Bank of Korea Website (http://www.bok.or.kr). Hsieh's dataset (http://www.wws.princeton.edu/~chsieh/sroe.xls)

Export to the U.S: NBER Trade Database, Disk1 by Robert C. Feenstra.

SINGAPORE

Gross Domestic Product: Singapore National Accounts, various issues. Yearbook of Statistics Singapore, various issues. Alwyn Young's Dataset (http://gsb.uchicago.edu/alwynyoung)

Gross Domestic Fixed Capital Formation: National Income Statistics Yearbook, various issues, Singapore National Accounts. Alwyn Young's Dataset (http://gsb.uchicago.edu/alwynyoung)

Paid Employees (in persons): Report on the Labor Force Survey, various issues. LABORSTA Labor Statistics Database, International Labor Organization.

Average Wages: Report on the Labor Force Survey, various issues. LABORSTA Labor Statistics Database, International Labor Organization.

Average Monthly Hours of Work: Report on the Labor Force Survey, various issues. LABORSTA Labor Statistics Database, International Labor Organization.

Nominal Interest Rates: CD-ROM of International Financial Statistics, International Monetary Fund, 1998. Hsieh's dataset (http://www.wws.princeton.edu/~chsieh/sroe.xls)

Exports to the U.S: NBER Trade Database, Disk1 by Robert C. Feenstra.

TAIWAN

Gross Domestic Product: National Income in Taiwan Area of the Republic of China, Directorate-General of Budget, Accounting and Statistics, annual issues. Statistical Yearbook of the Republic of China, Directorate-General of Budget, Accounting and Statistics, annual issues.

Gross Domestic Fixed Capital Formation: National Income in Taiwan Area of the Republic of China, Directorate-General of Budget, Accounting and Statistics, annual issues. Statistical Yearbook of the Republic of China, Directorate-General of Budget, Accounting and Statistics, annual issues.

Paid Employees (in persons): Yearbook of Manpower Survey Statistics, Taiwan Area, Republic of China, Directorate-General of Budget, Accounting and Statistics, annual issues. Statistical Yearbook of the Republic of China, Directorate-General of Budget, Accounting and Statistics, annual issues

Average Monthly Wages: Statistical Yearbook of the Republic of China, Directorate-General of Budget, Accounting and Statistics, annual issues. LABORSTA Labor Statistics Database, International Labor Organization.

Average Monthly Hours of Work: Statistical Yearbook of the Republic of China, Directorate-General of Budget, Accounting and Statistics, annual issues. LABORSTA Labor Statistics Database, International Labor Organization.

Nominal Interest Rates: Statistical Yearbook of the Republic of China, Directorate-General of Budget, Accounting and Statistics, annual issues. Hsieh's dataset (http://www.wws.princeton.edu/~chsieh/sroe.xls)

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NOTES

[1] Korea's total R&D expenditure in 1982 was 1% of the United States' (2.5% of Japan's) in the same year.

[2] There are, of course, many examples of countries that have proactively attempted to emulate foreign technology but with lesser success, for instance, India, Nepal, Sri Lanka, Bangladesh, and the Philippines (Enos and Park (1988)).

[3] See Felipe (1999) for a survey of the literature on growth accounting in East Asia.

[4] Alternatively, Hsieh (1999), citing the problem with the national accounting quantity aggregates, proposes a dual approach where growth in factor prices is used to calculate the Solow residual.

[5] The Lerner-Pearce construction of the aggregate unit-value isoquant is constructed by joining sectoral isoquants of the same output value and the common points of tangency of adjacent sectoral isoquants.

[6] The smoothness of the aggregate unit value isoquant implies that there is a large number of sectors in the economy. For illustrative purposes, isoquants for only three such sectors are drawn.

[7] Past studies have shown that given positive rates of depreciation and a sufficiently long investment series, the perpetual inventory approach is insensitive to the level of capital used to initialize the series.

[8] The rental rate of capital good j is the opportunity cost of using one unit of good j for one period. See Jorgenson (1963).

[9] Lim and Wan (2002) propose a different indicator for future economic performance based on output per capita relative to the technological leader.

Table I
Average annual growth of output and factors.

period	average annual growth of		
	output	capital	labor
	Korea		
70-75	0.080	0.180	0.036
75-80	0.084	0.161	0.074
80-85	0.058	0.117	0.054
85-90	0.086	0.103	0.045
90-95	0.072	0.118	0.032
70-95	**0.076**	**0.136**	**0.048**
	Singapore		
70-75	0.108	0.184	0.059
75-80	0.071	0.108	0.048
80-85	0.082	0.115	0.050
85-90	0.060	0.076	0.008
90-95	0.089	0.071	0.036
70-95	**0.082**	**0.111**	**0.040**
	Taiwan		
70-75	0.085	0.126	0.029
75-80	0.101	0.116	0.055
80-85	0.065	0.092	0.021
85-90	0.087	0.074	0.026
90-95	0.064	0.090	0.020
70-95	**0.081**	**0.100**	**0.030**

NOTE: Calculated from various sources. See Appendix A for a detailed list of sources.

Table II
OLS Estimation Results.

Parameter	South Korea (1966-98)	Singapore (1970-96)	Taiwan (1974-95)
α_0	1.07* (0.038)	0.605* (0.046)	0.879* (0.038)
α_L	0.285* (0.013)	0.22* (0.025)	0.271* (0.013)
α_{KL}	0.115* (0.006)	0.044* (0.007)	0.069* (0.004)
T	-0.06* (0.009)	-0.054* (0.005)	-0.001 (0.007)
T squared	0.003* (0.001)	0.004* (0.001)	0.001** (0.000)
Dep. Var.: lnY			
R-squared	0.997	0.998	0.996
D-W statistic	1.93	2.026	2.027
Dep. Var.: SL			
R-squared	0.929	0.579	0.918
D-W statistic	0.54	0.848	0.807

NOTES:

1. Numbers in parentheses denote standard errors. * denotes significance at 1%, and ** at 5% levels.
2. Estimation equations:

$$\ln(Y_t) = \bar{\alpha}_0 + (1-\bar{\alpha}_L)\cdot\ln(K_{t-1}) - \tfrac{1}{2}\bar{\alpha}_{KL}\left(\ln(K_{t-1})\right)^2 + \bar{\alpha}_L \ln(L_t) - \tfrac{1}{2}\bar{\alpha}_{KL}\left(\ln(L_t)\right)^2$$
$$+\bar{\alpha}_{KL}\ln(K_{t-1})\cdot\ln(L_t) + \bar{\alpha}_T\cdot T + \tfrac{1}{2}\bar{\alpha}_{TT}\cdot T^2 + \bar{e}_{t,Y}$$
$$SL_t = \bar{\alpha}_L + \bar{\alpha}_{KL}\left[\ln(K_{t-1}) - \ln(L_t)\right] + \bar{e}_{t,SL}$$

Table III

Output growth and contributions from factors calculated from estimated production elasticities.

	KOREA				SINGAPORE				TAIWAN			
		Contribution from				Contribution from				Contribution from		
year	output growth	capital	labor	residual	output growth	capital	labor	residual	output growth	capital	labor	residual
1971	0.082	0.143	-0.008	-0.053	0.126	0.125	0.018	-0.016				
1972	0.082	0.121	0.027	-0.066	0.118	0.133	0.025	-0.040				
1973	0.048	0.098	0.014	-0.065	0.125	0.132	0.025	-0.032				
1974	0.116	0.080	0.022	0.015	0.107	0.120	0.025	-0.039				
1975	0.071	0.089	0.020	-0.037	0.065	0.101	0.004	-0.040	0.048	0.067	0.008	-0.027
1976	0.063	0.085	0.030	-0.052	0.039	0.091	0.008	-0.061	0.130	0.073	0.024	0.032
1977	0.106	0.077	0.039	-0.010	0.069	0.072	0.015	-0.017	0.097	0.063	0.039	-0.005
1978	0.095	0.081	0.045	-0.030	0.075	0.067	0.017	-0.009	0.127	0.058	0.016	0.053
1979	0.086	0.088	0.041	-0.043	0.082	0.059	0.024	0.000	0.079	0.060	0.034	-0.015
1980	0.068	0.099	0.015	-0.045	0.089	0.060	0.022	0.007	0.070	0.059	0.013	-0.002
1981	-0.021	0.084	0.029	-0.134	0.093	0.062	0.020	0.011	0.060	0.063	0.000	-0.003
1982	0.063	0.058	0.021	-0.016	0.092	0.070	0.030	-0.008	0.035	0.055	0.017	-0.037
1983	0.070	0.046	0.042	-0.018	0.066	0.072	0.020	-0.026	0.081	0.046	0.013	0.022
1984	0.102	0.046	0.026	0.029	0.079	0.081	0.013	-0.015	0.101	0.038	0.020	0.043
1985	0.079	0.050	0.022	0.007	0.080	0.079	0.009	-0.008	0.048	0.036	0.002	0.011
1986	0.063	0.049	0.030	-0.017	-0.016	0.077	-0.021	-0.071	0.110	0.029	0.025	0.056
1987	0.104	0.045	0.034	0.025	0.023	0.053	-0.003	-0.028	0.120	0.031	0.029	0.060
1988	0.104	0.045	0.033	0.027	0.093	0.037	0.020	0.035	0.075	0.038	0.008	0.030
1989	0.099	0.047	0.016	0.036	0.110	0.033	-0.038	0.115	0.079	0.042	0.010	0.028
1990	0.059	0.048	0.008	0.003	0.092	0.032	0.057	0.003	0.053	0.045	-0.007	0.015
1991	0.086	0.049	0.017	0.020	0.086	0.038	0.038	0.010	0.073	0.043	0.008	0.022
1992	0.088	0.055	0.025	0.008	0.069	0.040	-0.002	0.031	0.065	0.042	0.014	0.010
1993	0.053	0.053	0.011	-0.011	0.063	0.043	0.012	0.008	0.061	0.045	0.011	0.005
1994	0.053	0.043	0.020	-0.009	0.120	0.046	0.007	0.067	0.063	0.043	0.016	0.004
1995	0.079	0.040	0.023	0.017	0.108	0.048	0.015	0.045	0.059	0.040	0.003	0.015
1996									0.055	0.038	0.002	0.015
1997									0.066	0.034	0.011	0.021
entire period	**0.076**	**0.069**	**0.024**	**-0.017**	**0.082**	**0.071**	**0.014**	**-0.003**	**0.076**	**0.047**	**0.014**	**0.015**

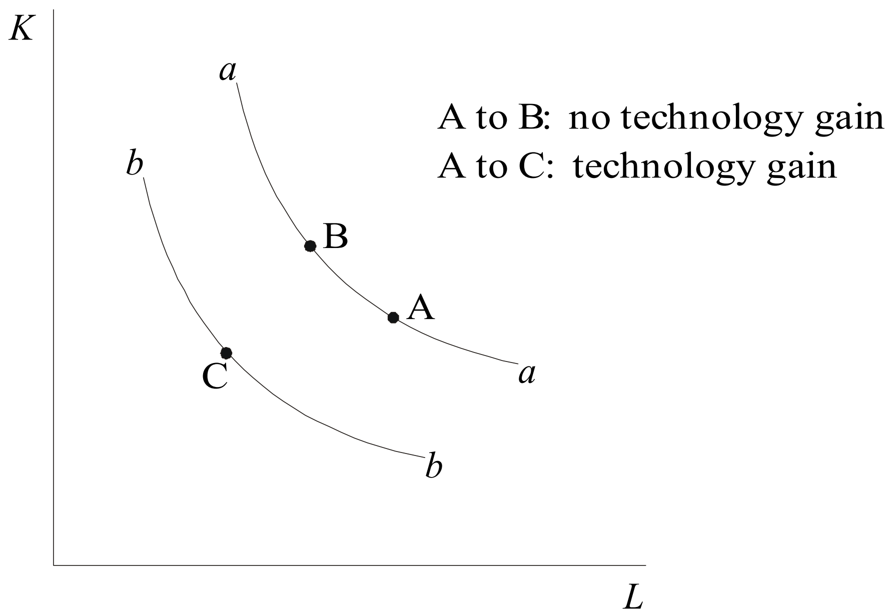

Figure I
Aggregate unit-value-isoquant representation of capital deepening and technical gain.

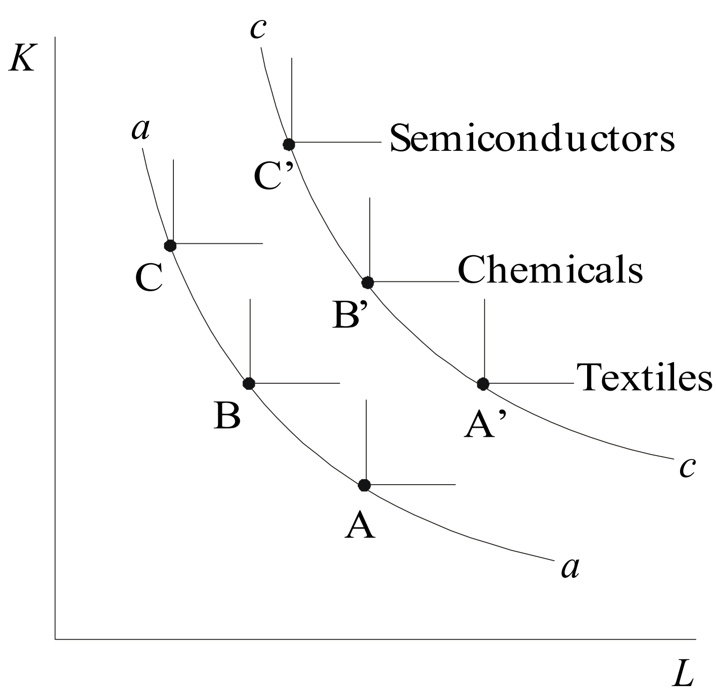

Figure II
Global technical gain in a multi-sector economy.

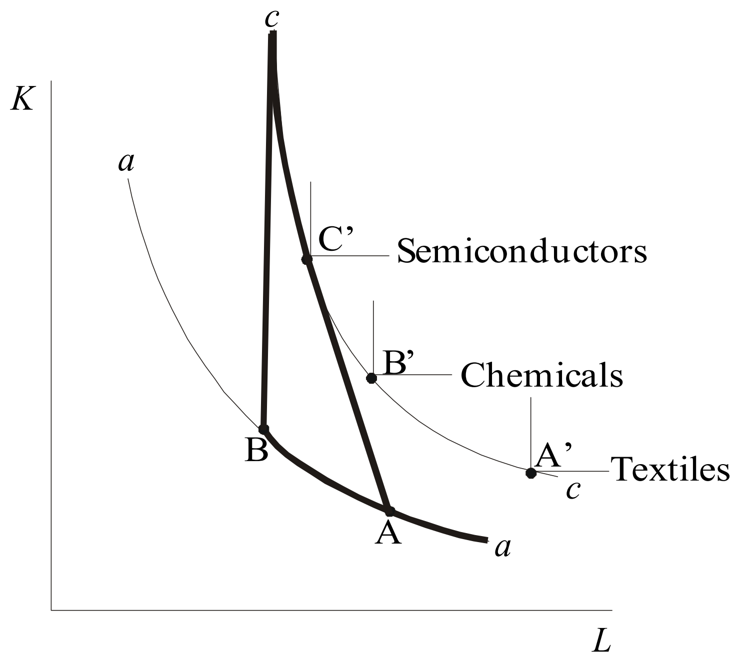

Figure III
Movement of the envelope unit-value isoquant when technical change is sectoral.

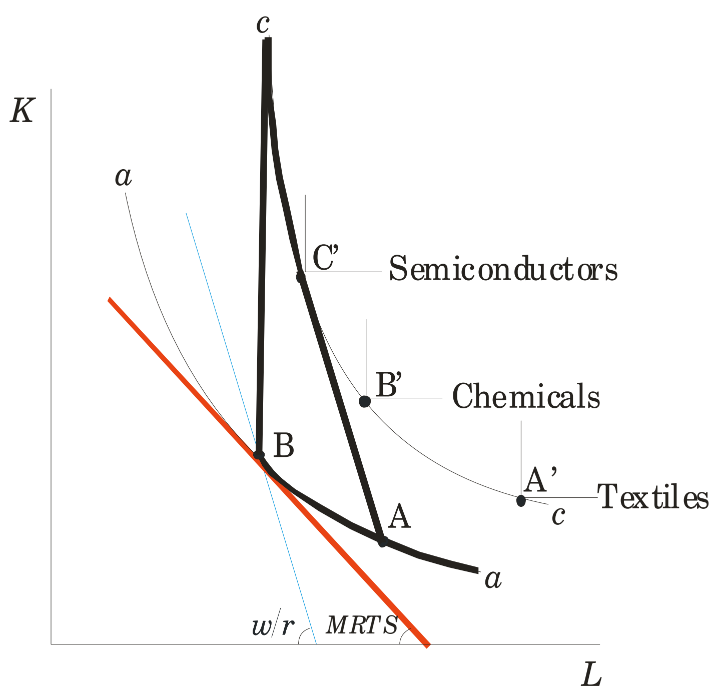

Figure IV
The estimated rate of factor substitution need not equal the factor price ratio in the presence of sectoral technical gain.

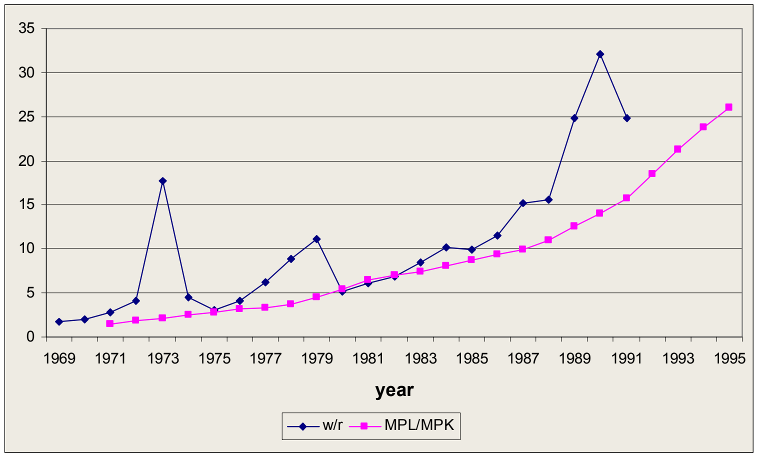

Figure V
Factor price ratio and Marginal Rate of Technical Substitution for Korea.

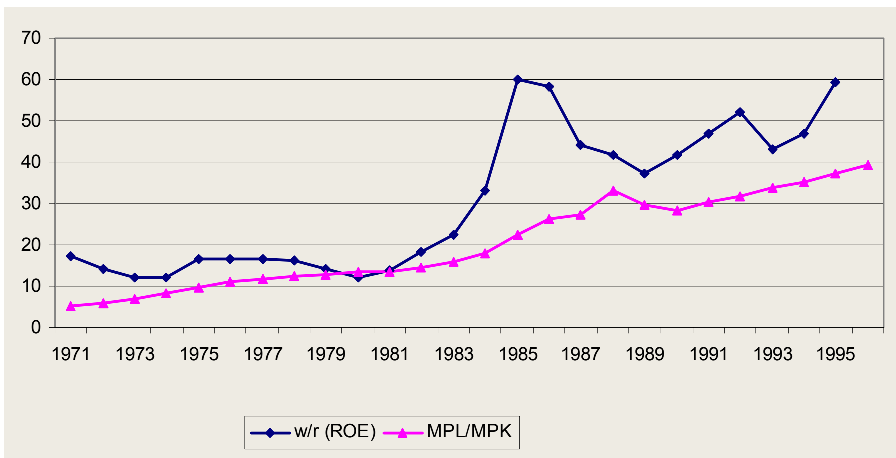

Figure VI
Factor price ratio and Marginal Rate of Technical Substitution for Singapore.

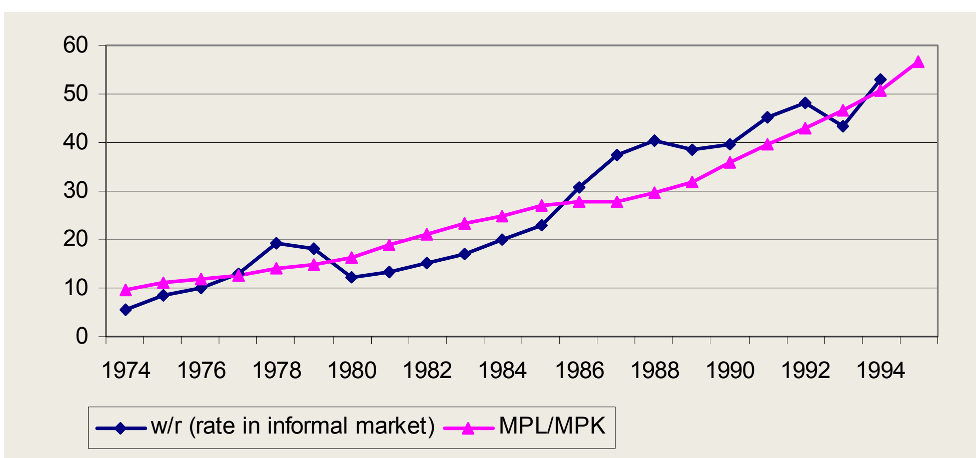

Figure VII
Factor price ratio and Marginal Rate of Technical Substitution for Taiwan.

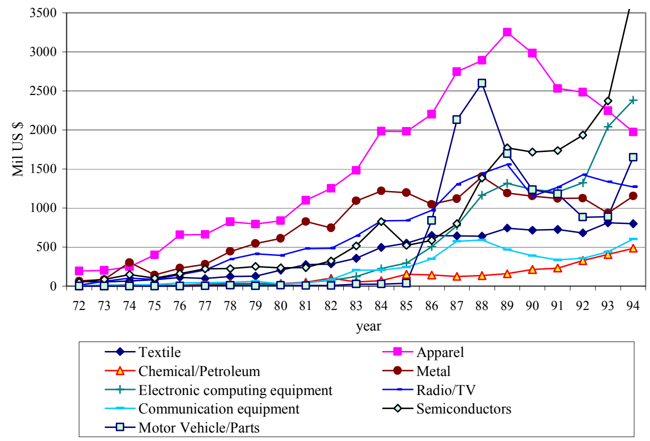

Figure VIII
Exports to the United States of major industries for Korea.

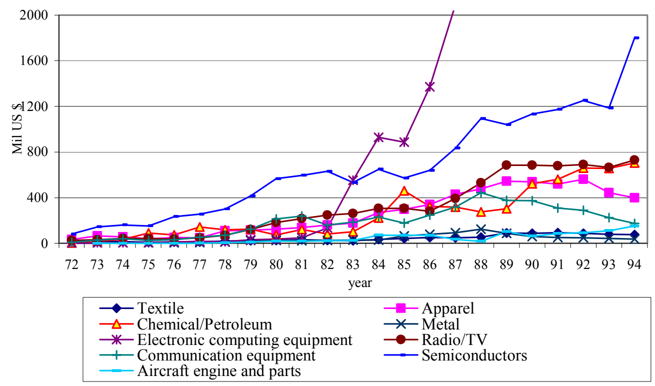

Figure IX
Exports to the United States of major industries for Singapore.

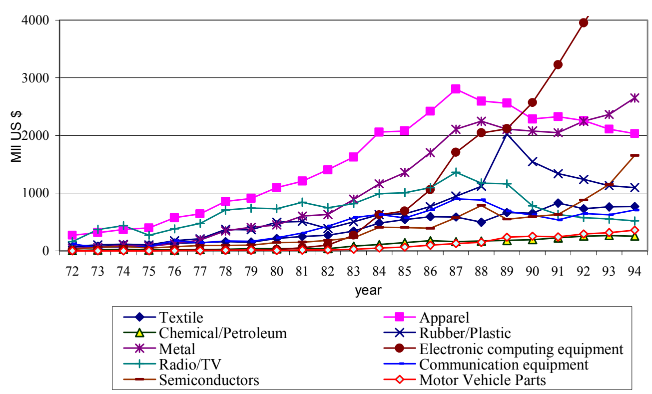

Figure X
Exports to the United States of major industries for Taiwan.

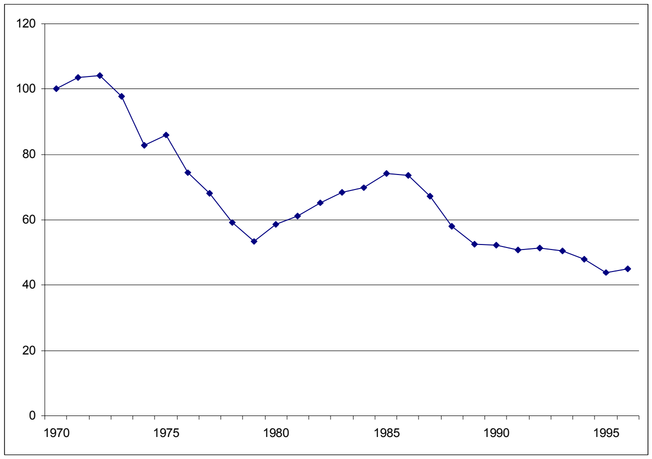

Figure XI
Real Exchange Rate (won/US$; 1970=100).