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Multilateral Productivity Comparisons of Selected Asian Developing Countries

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I. Introduction

The rapid growth experiences of several Asian countries during the past decade raise the need and interest to measure their performances more accurately, and to make sensible comparisons among these countries and other industrialized nations. This study applies the modern economic theory of index numbers for international comparisons of output, input, and productivity for five ASEAN countries (Indonesia, the Philippines, Thailand, Malaysia, and Singapore) and Hong Kong, Taiwan, and Korea. The comparisons are made for nine outputs and three factors across countries over time.

The method of bilateral and multilateral translog index numbers developed by Caves, Christensen, and Diewert [1982a] along the line of the Tornqvist-Theil approximation to the Divisia index formula (Diewert [1976], Caves, Christensen, and Diewert [1982b]) is employed to perform international comparisons of productivity. Although the methodology used is relatively new, it is used in the growth study of the United States and Japan (Jorgenson and Nishimizu [1978]), and in the study of regional performance of Canadian manufacturing (Denny, Fuss and May [1981]) among others. Multilateral productivity index comparison is extended recently by Pittman [1983] to include the undesirable outputs in the production function.

This paper is an empirical application of index numbers to measure and compare productivity for several developing Asian countries. The focus is on the analysis of productivity growth of aggregate factors and that of technological differences among various output sectors. It is assumed that each of these countries consists of a group of aggregate

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producers who produce commodities and services by employing labor and capital resources. Given a technology level and the prices of all goods and resources, the producer (economy) is assumed to maximize the revenue and to minimize the cost of production. The structure of production technology in different countries at different times can be virtually arbitrary, and the application of translog function to approximate the true production function allows for modeling these diversified technologies up to the second order. This study is the first attempt to apply translog output, input, and therefore, productivity indexes to eight Asian countries at various levels of development within a time frame of twelve years, from 1970 to 1981. Jorgenson and Nishimizu [1978] applied the bilateral indexes to compare the economic growth of U.S. and Japan from 1952 to 1974. In their study, goods and services are divided into two categories, consumption and investment. However, they did not investigate the sectoral breakdowns of aggregate output. In this study, sectoral breakdowns are examined because of concerns over differences in economic structures and in the sources of economic growth among nations in the region. The study emphasizes the international comparisons of sectoral total factor productivity as well as comparisons of individual factor productivity. Both bilateral and multilateral indexes are constructed to evaluate the performance of these Asian nations. Bilateral indexes are used for the chain comparisons of total productivity over time for each country, and multilateral indexes are used for the cross country comparisons of technological differences in the various output sectors and for the comparisons of labor and capital productivities.

The paper, therefore, reports and documents the results of the empirical application of the translog index numbers on the eight Asian countries. As such, the paper does not offer any interpretations of the results, does not highlight the economic issues that emerges from the observed total factor productivity differences, nor does it provide policy implications based on the results. All these are important and perhaps more interesting departures from an initial study that uncovers the prospects for further research. We report these results to stimulate further studies that require detailed investigations of total factor productivity growth of individual countries that may provide insights to important policy issues regarding international competitiveness (for productivity studies of individual countries, see Christensen and Cummings [1981], Tsao [1985], and Wiboonchutikula [1982]).

The theoretical foundation of bilateral and multilateral index number comparisons is presented in the next section. Section III describes the empirical implementation of the theoretical model of index numbers, the procedures of data collection, and the construction of value shares and prices of nine outputs and three factors. Empirical observations on the productivity comparisons of individual countries over time, the total factor productivity comparisons by sectors, and the individual factor productivity comparisons are made in Section IV. Finally, section V suggests extensions of this study into various directions.

II. Theoretical Foundation of Index Number Comparisons

Recent developments in the economic theory of index numbers provide a solid foundation for bilateral and multilateral comparisons of different economic entities over time (Diewart [1976], Caves, Christensen and Diewert [1982a and 1982b], and Denny and Fuss [1983a and 1983b]). Basically, one can specify an aggregator function (production function, utility function, etc.) with desirable properties and derive the corresponding indexes for bilateral and multilateral comparisons. The analysis holds for very general structures of aggregator functions that is also empirically implementable using only observed prices and quantities of outputs and inputs. Discussions of the general methodology used in this study can be found in Caves, Christensen and Diewert [1982a and 1982b], and Denny and Fuss [1983b].

Assume each country at any moment of time uses N factors to produce M outputs. Given a country s ($s = 1, \ldots S$), a general production function can be written as $F^s(X^s, Y^s)$, where $X^s = (X_1^s, \ldots, X_N^s)$, $Y^s = (Y_1^s, \ldots, Y_M^s)$ are the lists on N inputs and M outputs.[1] Given the prices of outputs and inputs, $P^s = (P_1^s, \ldots, P_M^s)$ and $W^s = (W_1^s, \ldots, W_N^s)$, and the classical behavior assumptions of cost minimization and revenue maximization, the Tornqvist-Theil bilateral output and input indexes are as follows:

$$\log Q^{kl} = \log Y^k - \log Y^l = 1/2 \sum_j (U_j^k + U_j^l)(\log Y_j^k - \log Y_j^l) \qquad (1.a)$$

$$\log q^{kl} = \log X^k - \log X^l = 1/2 \sum_i (V_i^k + V_i^l)(\log X_i^k - \log X_i^l) \qquad (1.b)$$

where Y^s and X^s are the translog aggregates of output $Y_1^s, \ldots, Y_M^s$ and factors, $X_1^s, \ldots, X_N^s$; $U_j^s = P_j^s Y_j^s / \sum_j P_j^s Y_j^s$ and $V_i^s = W_i^s X_i^s / \sum_i W_i^s X_i^s$ are the value shares of ith output and jth factor respectively for country $s = k, l$.[2] As usual, productivity comparisons can be

[1] Most industrial analyses emphasizing on the specification of production technology of a particular firm or industry require detailed information on inputs and outputs at the disaggregated level. However, this study looks at the sectoral output distribution and employment of aggregate factors in the economy. The production function $F^s(X^s, Y^s)$ conveys the information of production and distribution technology in the economy transforming aggregate factors X^s into various sectoral outputs Y^s. This analysis eliminates the need for information regarding the sectoral breakdowns of factor inputs which is usually not available for developing countries. Total factor productivity for each sector is, therefore, interpreted as the sectoral output contribution of factors employed in the economy.

[2] In general, s would be an index of time and/or cross-sectional entity. For time series comparisons, $s = k,l$ refers to $k = t$ and $l = t + 1$ for a given country. On the other hand, in cross-sectional comparisons, k and l represent different countries for a specific time period.

interpreted as comparisons of outputs relative to inputs, and vice versa. Based on the output and input index measurements, the two corresponding productivity indexes are

$$\log Z^{kl} = \log Q^{kl} - \log q^{kl} + \gamma^{kl} \text{ and} \quad (2.a)$$

$$\log z^{kl} = \log Q^{kl} - \log q^{kl} + R^{kl}, \quad (2.b)$$

respectively, where γ^{kl} and R^{kl} are the scale factors of inputs and outputs. The output and input based productivity indexes are identical except for the scale terms γ^{kl} and R^{kl}. For constant and decreasing returns to scale, the productivity measurement can be computed from the observed data. However, for increasing returns to scale, knowledge of the scale factors is required to calculate the productivity indexes.[3]

By substituting equations (1.a) and (1.b) into (2.a) and (2.b) respectively, productivity indexes can be rewritten as

$$\log Z^{kl} = 1/2 \sum_j (U_j^k + U_j^l) (\log Y_j^k/X^k - \log Y_j^l/X^l) + \gamma^{kl}, \text{ and}$$

$$\log z^{kl} = 1/2 \sum_i (V_i^k + V_i^l) (\log Y^k/X_i^k - \log Y^l/X_i^l) + R^{kl}.$$

Under the assumption of constant returns to scale, total factor productivity can therefore be decomposed into various output and factor components. For output j, the corresponding total factor productivity comparison between entity k and l is measured by

$$\log Z_j^{kl} = 1/2(U_j^k + U_j^l) (\log Y_j^k/X^k - \log Y_j^l/X^l), j = 1, \ldots, M \quad (3.a)$$

while the ith factor productivity difference between k and l is

$$\log z_i^{kl} = 1/2(V_i^k + V_i^l) (\log Y^k/X_i^k - \log Y^l/X_i^l), i = 1, \ldots, N. \quad (3.b)$$

It is clear that $\log Z^{kl} = \sum_j \log Z_j^{kl}$ and $\log z^{kl} = \sum_i \log z_i^{kl}$.

The Tornqvist-Theil index numbers are attractive for making base-country invariant binary comparisons. But a set of such binary comparisons does not necessarily satisfy the circularity or transitivity requirement. As a matter of fact, the definition of bilateral index can be modified to obtain a transitive multilateral index. Let a variable with bar be the arithmetic mean of the variable under consideration. For example,

[3] These non-parametric index number constructions were shown in Diewert [1976] and Caves, Christensen, and Diewert [1982a] by assuming constant return to scale translog production function. Later development of Caves, Christensen, and Diewert [1982b] extended the same formulae to the general case which does not require linear homogeneity in specifying production technology. However, equality restrictions on the second-order parameters of the underlying translog function must be imposed. The weakness of this constant share derivative is discussed in Denny and Fuss [1983b].

$$\overline{\log Y} = 1/S \sum_s \log Y^s \text{ and } \overline{\log X} = 1/S \sum_s \log X^s$$

are the arithmetic means of translog output and factor index, respectively. Now,

$$\overline{\log Q^k} = 1/S \sum_s \log Q^{ks} = 1/S \sum_s (\log Y^k - \log Y^s) = \log Y^k - \overline{\log Y}$$
$$= 1/2 \sum_j (U_j^k + \bar{U}_j)(\log Y_j^k - \overline{\log Y_j}).$$

Then the Tornqvist-Theil multilateral output index is defined as

$$\log Q_*^{kl} = \overline{\log Q^k} - \overline{\log Q^l} \tag{4.a}$$
$$= 1/2 \sum_j (U_j^k + \bar{U}_j)(\log Y_j^k - \overline{\log Y_j}) - 1/2 \sum_j (U_j^l + \bar{U}_j)(\log Y_j^l - \overline{\log Y_j}).$$

Similarly, the multilateral input index is

$$\log q_*^{kl} = \overline{\log q^k} - \overline{\log q^l} \tag{4.b}$$
$$= 1/2 \sum_i (V_i^k + \bar{V}_i)(\log X_i^k - \overline{\log X_i}) - 1/2 \sum_i (V_i^l + \bar{V}_i)(\log X_i^l - \overline{\log X_i}).$$

For deriving output-based multilateral productivity measurement, we define

$$\overline{\log Z^k} = 1/S \sum_s \log Z^{ks} = \overline{\log Q^k} - \overline{\log q^k} + \bar{\gamma}^k \quad \text{and}$$

$$\overline{\log Z^l} = 1/S \sum_s \log Z^{sl} = \overline{\log Q^l} - \overline{\log q^l} + \bar{\gamma}^l.$$

Then, the productivity index is

$$\log Z_*^{kl} = \overline{\log Z^k} - \overline{\log Z^l}$$
$$= \log Q_*^{kl} - \log q_*^{kl} + (\bar{\gamma}^k - \bar{\gamma}^l). \tag{5.a}$$

Similarly, the multilateral input-based productivity index is

$$\log z_*^{kl} = \log Q_*^{kl} - \log q_*^{kl} + (\bar{R}^k - \bar{R}^l). \tag{5.b}$$

It is easy to show that these multilateral indexes are transitive, i.e., $\log Z_*^{kl} = \log Z_*^{km} - \log Z_*^{ml}$ and $\log z_*^{kl} = \log z_*^{km} - \log z_*^{ml}$ and that they reduce to their corresponding bilateral indexes when S is equal to 2.

Finally, under the assumption of constant returns to scale, output and factor components of multilateral productivity indexes are obtained the same way as those of bilateral indexes above (equations 3.a and 3.b). They are

$$\log Z^{kl}_{*j} = 1/2(U^k_j + \bar{U}_j)\,(\log Y^k_j/X^k - (\overline{\log Y}_j - \overline{\log X}))$$
$$- 1/2(U^l_j + \bar{U}_j)\,(\log Y^l_j/X^l = (\overline{\log Y_j} - \overline{\log X})), \quad (6.a)$$

and

$$\log z^{kl}_{*i} = 1/2(V^k_i + \bar{V}_i)\,(.\log X^k_i/Y^k - (\overline{\log X}_i - \overline{\log Y}))$$
$$- 1/2(V^l_i + \bar{V}_i)\,(\log X^l_i/Y^l - (\overline{\log X}_i - \overline{\log Y})) \quad (6.b)$$

for output $j = 1, \ldots, M$ and factor $i = 1, \ldots, N$, respectively. Again, $\log Z^{kl}_{*} = \sum_j \log Z^{kl}_{*j}$ and $\log z^{kl}_{*} = \sum_i \log z^{kl}_{*i}$.

III. Empirical Model

Empirical implementation of the above theoretical model requires data on value shares, prices and quantities of outputs and factors for each Asian developing country. Since the real gross output data is either not readily available or is not systematically collected in the region under consideration, we are constrained to apply the concept of real gross domestic product or real value-added to model the production activities of these nations.[4] By applying the concept of GDP in place of output variables Y^s_j for product j and entity (country or time or both) s, U^s_j and V^s_i are now interpreted as the GDP share and factor share of jth product and ith factor, respectively for the economic entity s. Equations (2.a), (2.b), and (6.a), (6.b) are the bilateral and multilateral index comparison formulae used throughout the empirical implementation. Bilateral index comparison is especially useful for own country productivity comparison over time. That is, by setting a base year for each country, the pattern of productivity growth is revealed through chained index numbers over time for the country. On the other hand, multilateral indexes with the desirable characteristics of transitivity are useful for comparing differences in the level of technology across country over time. That is, a particular country at a particular moment of time is treated as the benchmark for comparison. Furthermore, meaningful comparisons are also possible for any pair of countries at any period of time because of the

[4] The use of real GDP or real value-added in the context of production function can be justified if either the underlying production function had a separable functional form with respect to intermediate materials, or if the production function satisfied the Hicks' aggregation condition (Diewert [1978]). Hicks' aggregation can be interpreted as a condition that prices of outputs and intermediate factors vary in proportion. Therefore, many well-known results of production theory may be used in order to characterize the properties of real value-added function (see Khang [1971] and Diewert [1978] for detail discussions on the application of value-added function in modeling producer behavior). See also Hulten and Schwab [1984] for a recent application of real value-added function to compare regional productivity growth in U.S. manufacturing.

transitivity property of the index.

Problems of purchasing power parity conversion always arise in international comparisons because it is necessary to select a common unit of measurement to compare the value of goods and services across countries. The advantage of applying translog bilateral indexes for output, input, and productivity among nations is that these indexes do not necessarily depend on any fixed conversion of local currencies to a common unit of measurement. As a matter of fact, the output and factor indexes (see equations (1.a), (1.b) or (4.a), (4.b) for comparing two countries k and l) contain information of real purchasing power parity for output and factor, respectively. For example, the bilateral output index between k and l can be written as:

$$\log Q^{kl} \doteq \log (Y^k/Y^l) = 1/2 \sum_j (U_j^k + U_j^l) \log (Y_j^k/Y_j^l).$$

Thus, $Y^k = Q^{kl} Y^l$ where Y^s is the translog aggregate of outputs, $s = k,l$. If different currency units are used in measuring the real values of outputs Y_j^k and Y_j^l, $j = 1, \ldots, M$, the resulting index Q^{kl} reflects not only the real output differences but also the differences in units of measurement for outputs in countries k and l. Similarly, the factor index reflects not only the real factor differences but also the differences in units of measurement for factors in countries k and l. Productivity change, defined as the difference of logarithmic output and factor indexes (under the assumption of constant returns to scale), also reflects the parity or price differential in addition to quantity differences.

From equations (4.a) and (4.b), the multilateral output and factor comparisons require the construction of a hypothetical entity representing the average of logarithmic outputs and factors of members in the region. A common unit of currency measurement is needed for computing this regional average before any comparisons can be made between countries. For simplicity, the regional averages of outputs and factors are constructed by converting real outputs and factors of all countries into 1970 constant U.S. dollars via official exchange rates adjusted for inflationary differences between U.S. and the country under consideration. Therefore, the multilateral index comparisons involve a two step procedure. First, the bilateral comparison is made against the regional average, and second, this difference is used to compare against the same difference of the benchmark country.

Data of output and factor series for eight Asian developing countries from 1970 to 1981 are constructed from the following sources: U.N.'s Yearbook of National Accounts, Statistical Yearbook for Asia and Pacific, ILO's Statistical Yearbook, Key Indicators of Developing Member Countries of the Asian Development Bank, and statistical yearbooks of individual countries.[5]

Sectoral GDPs at constant prices are collected as the output series in this study for each country. These sectors are agriculture, mining and quarrying, manufacturing, utilities (electricity, gas and water), construction, trade, transport and communication, finance, and government and others. Output price indexes are the ratios of current and constant values of GDPs. Hong Kong and Malaysia do not report sectoral GDPs in both current and constant terms. The former reports the current values of GDPs at the industry origins only while the latter reports the constant values of sectoral GDPs since 1970. Therefore, their general GDP deflator is used to approximate the prices for outputs of all sectors.

In the context of production studies using real GDP or real value-added as the output proxy, labor and capital are the primary production factors. The concept of production cost used here is similar to the concept of gross domestic product at factor cost that is usually available in the national account statistics of individual countries. GDP at factor cost consists of domestic income (labor compensation and operation surplus—rent, interest and profit) and allowances for fixed capital consumption. To construct factor shares and prices of various factors, GDP at factor cost is decomposed into labor compensation, physical capital services, and working capital services. The latter two forms of capital factors are extracted from operation surplus and allowances for capital consumption. However, not all countries in this study maintain the same definition and procedure for reporting factor series. National account statistics of Korea, Taiwan, and Thailand provide complete information of compensation of employees, operation surplus, and capital consumption allowances. Indonesia and the Phillippines do not separate factor income into labor compensation and operation surplus requiring the use of average wage rate and total employment to approximate the labor cost. Furthermore, due to data unavailability, wage and employment for Indonesia prior to 1976 are approximated from the CPI and the proportion of labor force in the total population, respectively. For Malaysia, the category of operation surplus includes the allowances for fixed capital consumption, but data on labor compensation and operation surplus are incomplete. The missing values of labor cost are filled by using average wage rate and employment. Singapore also does not report detailed breakdowns of gross factor income. Again, labor cost of Singapore is approximated by the average wage rate, average hours of worked, and total employment.

The actual consumption of *total* capital is defined as the residual of GDP at factor cost and labor compensation. This is a well-established approach to estimate the cost of all

[5] We thank Dr. J. M. Dowling, Jr. of ADB in Manila for providing us ADB data and the Philippines statistics.

capital, which includes rent, interest, profit, and depreciation of fixed capital (Griffin and Gregory [1976], Pindyck [1981]). Berndt and Wood [1975], [1979], on the other hand, use a concept of "service cost of reproducible capital" which is defined as the product of serivce price and quantity of *physical* capital in use. Field and Grebenstein [1980] provides a further distinction of total capital by separating it into the "service cost of physical capital" and the "cost contribution of working capital." It is important to separate these two types of capital because their relationships with some intermediate factors (for example, energy) are different (for details, see Field and Grebenstein [1980]).[6] Defining total capital as $K = K1 + K2$ where $K1$ is the service flow of physical capital and $K2$ is that of working capital, the cost of total capital becomes $P_K K = P_{K1}K1 + P_{K2}K2$ where P_K, P_{K1}, and P_{K2} are service price of total, physical, and working capital. Derivations of P_{K1} and P_{K2} are explained in the following paragraph.

According to Christensen and Jorgenson [1969], the asset price P of fixed capital equals the present value of future services of the asset evaluated at the service price P_{K1}. For simplicity, by disregarding tax structures and assuming that the service from an asset declines geometrically over time, the service price of physical capital can be expressed as the sum of the cost of capital, the current cost of replacement, and the cost of capital loss on the value of the fixed asset. In this study the Christensen and Jorgensons' service cost formula for physical capital has to be modified in order to avoid a result of negative prices during periods of worldwide recession and inflation in the 1970s. In particular, we assume that if the rate of return did not cover the cost of capital loss on the value of the fixed asset, the price of capital is simply the cost of replacement. The service price of physical capital is thus

$$P_{K1_t} = \begin{cases} r_t P_{t-1} + dP_t - (P_t - P_{t-1}), & \text{if } r_t > (P_t - P_{t-1})/P_{t-1} \\ dP_t, & \text{otherwise.} \end{cases}$$

where t is the time subscript, r is the rate of return on fixed capital and d is its replacement rate. For empirical implementation, the asset price P of physical capital is computed from the series of gross fixed capital formation in current and constant values, while physical capital stock is obtained from the perpetual inventory formula by using data of gross fixed capital formation and capital consumption allowances measured in constant values. The implicit average rate of depreciation computed from the ratio of capital consumption

[6] In view of the sample period used, one might suspect that large changes in real energy prices might have significant impacts on the apparent productivity of capital and labor. However, the inclusion of energy as a separate factor in this study is not possible due to the lack of consistent energy consumption data for those countries in the study. The value-added context of model specification also prevents the inclusion of energy factor in the analysis.

allowances and capital stock is then used to approximate the replacement rate of physical capital. However, 10 percent is assumed for d if the data of capital consumption allowances is not available (Malaysia, Hong Kong, and Singapore are examples). Ideally, the long-term government bond interest rate should be used to approximate the rate of return on fixed assets. Unfortunately, this rate is not available for the countries under investigation. Therefore, the central bank discount rates are used as proxy for the variable r except for Singapore, Hong Kong, and Indonesia where the average of 12 months time deposit interest rate is used.

Finally, as discussed above, the service cost of physical capital for each country is obtained by multiplying the service price with the beginning-of-year capital stock. The service cost of working capital and its corresponding price are obtained from the residual of GDP at factor cost, labor compensation, and service cost of physical capital.

IV. Empirical Observations

This section reports the results of three types of productivity comparisons of the countries under study over the period 1970–1981, namely, productivity comparisons of each country over time, total factor productivity comparisons for each sector, and labor and capital factor productivity comparisons among the countries. In summary, total factor productivity is found to increase gradually over time for all countries except during the years of high inflation and recession for Hong Kong and the Philippines. For most of ASEAN countries, however, the total factor productivity growth was minimal. It is also observed that labor productivity increased but physical capital productivity declined during the study period. Total contribution of working capital was relatively stable for all countries, except for Hong Kong in 1974–75. The growth and development of the smaller countries like Hong Kong and Singapore resulted largely from the more productive service sectors such as finance, trade, and transport. Two of the newly industrialized nations, Korea and Taiwan, experienced strong productivity growth in manufacturing, utilities, and construction. Finally, with their rich endowment of natural resources, Indonesia and Malaysia had high performance in the area of mining and quarrying. Below are the detailed discussions of our empirical observations.

A. OWN COUNTRY PRODUCTIVITY COMPARISON OVER TIME

Productivity comparison over time for each country is obtained from equations (2.a) and (2.b) with $k = t$ and $l = t - 1$. The chained indexes $Z^{t,t-1}$ or $z^{t,t-1}$ are constructed by setting 1970 equals to 1.0 for each country under the assumption of constant returns to scale. In general, we observe that the total factor productivity of each country over time showed gradual but increasing trend except for Hong Kong and the Philippines. Productivity of the Philippines over time was variable with sharp declines during 1975–77 and 1978–1979 periods. As for Hong Kong, productivity was quite stable except for the 1973–1977 period when it was highly variable. Further, Hong Kong showed declines in productivity from 1980–81. Within a decade or so of study period, total factor productivity increased more than 15 percent in Taiwan, and about 8 percent in Korea. The strong productivity growth of Taiwan and Korea from early 1970s is believed to be the driving force of economic development in these two countries (See Christensen and Cummings [1981] for a study of Korean productivity). On the other hand, the productivity performance for ASEAN countries was minimal. Malaysia and Indonesia, with their competitive advantage in natural resources, enjoyed a steady but small growth of total factor productivity from 1974 on, while Singapore and Thailand showed little improvement of productivity growth. Economic growth without productivity—Rapid growth of output accompanied with high rate of factors increase—has been characterized as the development experience of the latter two countries and Hong Kong in the 1970s (see also Taso [1985], and Wiboonchutikula [1982]). These comparisons of productivity over time are shown in Table 1 below.

B. TOTAL FACTOR PRODUCTIVITY COMPARISONS

Multilateral comparisons of technological differences among countries are obtained from equation (6.a) by setting Singapore 1970 as the base; that is, the index of Singapore

TABLE 1 Own Country Productivity Comparison Over Time

(1970 = 1.0)

YEAR	INDON.	KOREA	TAIWAN	PHILIP.	THAILAND	MALAYSIA	H.K.	SING.
70	1	1	1	1	1	1	1	1
71	1.007541	0.997406	0.998513	1.042145	0.994409	0.999188	1.054656	1.000984
72	0.993054	0.988489	1.017485	1.014669	0.994630	0.997267	1.091253	1.004459
73	0.982714	1.001186	1.035059	1.076577	0.992756	0.998005	1.026001	1.002193
74	0.976346	0.994456	1.052863	1.019372	1.011342	1.016309	0.922666	0.976199
75	0.983766	1.027053	1.060061	1.024635	0.995880	1.005250	1.279676	0.972092
76	1.005764	1.050700	1.088385	0.870739	1.000583	1.022387	1.129277	0.992828
77	1.015052	1.060862	1.099811	0.826524	1.002704	1.041138	1.020371	0.990837
78	1.011830	1.073609	1.133858	1.105088	1.002556	1.043907	1.026073	0.988919
79	1.014148	1.088061	1.164523	0.962735	1.011968	1.044805	0.999355	0.992462
80	1.010020	1.075661	1.182959	0.975233	1.009963	1.050570	1.007882	0.997118
81	1.020687	1.081971	1.186478	1.071536	0.990880	1.057753	0.945324	1.002332

TABLE 2 Multilateral Productivity Comparison Indexes

(SINGAPORE 1970 = 1.0)

	YEAR	Y1/X	Y2/X	Y3/X	Y4/X	Y5/X	Y6/X	Y7/X	Y8/X	Y9/X
INDONESIA	1970	1.824084	1.089527	0.884487	0.978525	0.960816	0.903468	0.924205	0.886165	0.959137
	1971	1.782227	1.109782	0.897324	0.978771	0.964506	0.908863	0.925920	0.887648	0.955020
	1972	1.692541	1.138827	0.897663	0.978773	0.971085	0.910398	0.927209	0.895657	0.957888
	1973	1.679219	1.160317	0.902698	0.979038	0.973339	0.905915	0.928040	0.897677	0.950134
	1974	1.593499	1.243597	0.918596	0.979996	0.979091	0.908014	0.928582	0.903820	0.950441
	1975	1.569693	1.210109	0.927899	0.980302	0.982550	0.910708	0.929184	0.907910	0.961545
	1976	1.562362	1.215952	0.932045	0.980504	0.982170	0.909180	0.932160	0.909158	0.960652
	1977	1.532078	1.219489	0.937644	0.980613	0.987376	0.905667	0.939859	0.914262	0.962719
	1978	1.517587	1.210812	0.949550	0.981740	0.991297	0.906384	0.944828	0.916018	0.965626
	1979	1.503774	1.226098	0.962123	0.983414	0.992059	0.913333	0.946964	0.916934	0.965845
	1980	1.472061	1.243093	0.979525	0.983769	0.994769	0.916364	0.947559	0.920819	0.973394
	1981	1.471256	1.225870	0.986841	0.984425	0.998082	0.921543	0.949673	0.919546	0.975949
KOREA	1970	1.426683	1.030332	1.004784	0.991313	0.987059	0.909174	0.962762	0.921626	0.983210
	1971	1.414103	1.028558	1.026220	0.992861	0.982159	0.923307	0.966575	0.921840	0.982359
	1972	1.388355	1.025999	1.035313	0.993248	0.977494	0.923170	0.966838	0.917682	0.974469
	1973	1.358755	1.026902	1.064479	0.994168	0.982705	0.926078	0.973164	0.931621	0.964783
	1974	1.353380	1.026372	1.082346	0.994478	0.980201	0.922150	0.972433	0.913956	0.959585
	1975	1.354394	1.028121	1.101487	0.996511	0.984097	0.924978	0.976270	0.914454	0.956513
	1976	1.356194	1.026551	1.136898	0.997848	0.985715	0.930261	0.980842	0.916062	0.950537
	1977	1.338412	1.027529	1.153507	0.999236	0.994028	0.931200	0.986681	0.919301	0.946883
	1978	1.302265	1.026551	1.185447	1.000076	1.004652	0.935103	0.992380	0.920853	0.944441
	1979	1.301178	1.024754	1.196201	1.002896	1.002910	0.932420	0.996627	0.919231	0.943525
	1980	1.240123	1.024985	1.204440	1.005483	1.003891	0.933558	1.000844	0.927825	0.948220
	1981	1.275859	1.025840	1.212230	1.005639	0.995238	0.935485	1.004970	0.917743	0.945831
TAIWAN	1970	1.255947	1.029735	1.153072	1.000730	0.974324	0.888197	0.959317	0.953175	0.999670
	1971	1.225616	1.027587	1.175571	1.000046	0.974539	0.885651	0.961826	0.951130	0.992304
	1972	1.207643	1.024847	1.208763	1.000761	0.977322	0.888568	0.964172	0.951466	0.985809
	1973	1.191828	1.021301	1.238574	1.000490	0.978461	0.894929	0.967873	0.953362	0.979910
	1974	1.195152	1.020712	1.216195	1.001780	0.986987	0.898068	0.976731	0.959748	0.976898
	1975	1.173202	1.019326	1.195249	1.002630	0.991127	0.887719	0.981215	0.957921	0.976247
	1976	1.175251	1.020783	1.244488	1.003919	0.997000	0.889561	0.985749	0.961288	0.969840

	YEAR	Y1/X	Y2/X	Y3/X	Y4/X	Y5/X	Y6/X	Y7/X	Y8/X	Y9/X
	1977	1.167128	1.018861	1.259836	1.005240	0.998363	0.890571	0.985451	0.959859	0.971944
	1978	1.149341	1.017674	1.306066	1.006447	0.998532	0.897592	0.987748	0.959069	0.969031
	1979	1.151179	1.015583	1.321972	1.007117	0.999856	0.901612	0.991203	0.965513	0.971515
	1980	1.141677	1.015528	1.320984	1.008241	1.002090	0.903679	0.994881	0.971485	0.969945
	1981	1.125854	1.013201	1.291094	1.009568	0.998329	0.898255	0.994166	0.973000	0.963252
PHILIPPINE	1970	1.445089	1.053103	1.022862	0.982663	0.968893	0.877033	0.939839	0.965465	0.994433
	1971	1.512798	1.060129	1.065161	0.985128	0.977574	0.895265	0.948399	0.978555	1.014684
	1972	1.486094	1.058842	1.056981	0.984459	0.980503	0.882059	0.948843	0.973836	1.007722
	1973	1.550864	1.069141	1.117634	0.986601	0.989194	0.910192	0.959371	0.983878	1.029073
	1974	1.569100	1.068453	1.135544	0.988269	0.996196	0.920834	0.965658	0.989275	1.038517
	1975	1.555411	1.059151	1.128148	0.988014	1.016908	0.914788	0.967919	0.991076	1.037622
	1976	1.508518	1.053922	1.092724	0.987148	1.023570	0.900992	0.966824	0.962427	1.020397
	1977	1.484131	1.055629	1.097566	0.986595	1.021051	0.898033	0.966034	0.955958	1.010722
	1978	1.566851	1.063958	1.171793	0.989869	1.036904	0.936468	0.981263	0.977464	1.040355
	1979	1.521011	1.069846	1.145692	0.989316	1.043871	0.925984	0.974211	0.970615	1.027796
	1980	1.517845	1.073954	1.154831	0.990128	1.043133	0.933628	0.976556	0.976796	1.033052
	1981	1.543378	1.069217	1.179237	0.991876	1.056502	0.949291	0.982996	0.979251	1.046359
THAILAND	1970	1.453683	1.040555	0.959503	0.987227	0.992974	0.950488	0.958657	0.925613	0.968616
	1971	1.465577	1.043667	0.970303	0.988808	0.985802	0.954032	0.959405	0.931542	0.977086
	1972	1.443751	1.040755	0.974143	0.990144	0.978660	0.955076	0.961185	0.929313	0.973761
	1973	1.469413	1.035174	0.979316	0.990997	0.974968	0.946751	0.959721	0.928386	0.973251
	1974	1.449738	1.037277	0.988533	0.991539	0.975038	0.954297	0.962316	0.934577	0.974181
	1975	1.453853	1.030474	0.986387	0.992217	0.977023	0.944535	0.963666	0.933190	0.973641
	1976	1.459904	1.033820	1.008222	0.993534	0.982870	0.951977	0.960920	0.934524	0.978225
	1977	1.424915	1.038696	1.023054	0.994565	0.989248	0.955271	0.962787	0.938261	0.982146
	1978	1.413102	1.039880	1.015183	0.993987	0.989175	0.944764	0.962011	0.938240	0.979043
	1979	1.387154	1.041410	1.024692	0.995174	0.990156	0.944232	0.963986	0.943814	0.984897
	1980	1.369589	1.040817	1.021500	0.995140	0.994029	0.945194	0.964191	0.946376	0.985659
	1981	1.377295	1.038377	1.030675	0.997169	0.989212	0.949956	0.967347	0.951583	0.996315
MALAYSIA	1970	1.478180	1.125519	0.954134	0.994658	0.965446	0.862366	0.951017	0.951355	1.052568
	1971	1.490698	1.115531	0.949105	0.993714	0.976268	0.872068	0.947670	0.951215	1.033172
	1972	1.504812	1.116140	0.961566	0.995802	0.977786	0.878344	0.953062	0.955445	0.051404
	1973	1.484024	1.097376	0.964849	0.994594	0.975891	0.869519	0.951126	0.947728	1.038495

	YEAR	Y1/X	Y2/X	Y3/X	Y4/X	Y5/X	Y6/X	Y7/X	Y8/X	Y9/X
	1974	1.484060	1.085734	0.971610	0.995374	0.978224	0.872486	0.955006	0.947946	1.046501
	1975	1.463666	1.084725	0.975060	0.996793	0.973527	0.871902	0.961190	0.951495	1.048255
	1976	1.469994	1.091439	0.987081	0.996598	0.973068	0.869922	0.959761	0.947937	1.045351
	1977	1.448397	1.086922	0.994261	0.997345	0.975197	0.871601	0.962647	0.949111	1.055840
	1978	1.428711	1.089084	1.000592	0.998752	0.978646	0.875211	0.964862	0.951510	1.053762
	1979	1.424542	1.092367	1.001315	0.999264	0.979666	0.878162	0.956054	0.949738	1.051091
	1980	1.404944	1.084525	1.003460	0.999437	0.983610	0.882341	0.969834	0.947572	1.053225
	1981	1.401857	1.077660	1.000563	0.999657	0.985082	0.885120	0.970975	0.948834	1.065886
HONG KONG	1970	0.979851	0.983517	1.088779	0.993339	0.972025	0.910753	0.965925	1.001986	1.032718
	1971	0.974853	0.986071	1.071294	0.992598	0.980567	0.915925	0.961470	1.033503	1.048079
	1972	0.968409	0.981256	1.065181	0.992128	0.985629	0.926304	0.957955	1.072026	1.032796
	1973	0.959270	0.973481	1.043034	0.989777	0.983741	0.924854	0.954700	1.045786	1.022285
	1974	0.947326	0.966670	1.010084	0.990191	0.983199	0.900924	0.952581	1.014832	1.023301
	1975	0.987225	0.973088	1.141805	0.997437	1.004532	0.981551	0.984717	1.069876	1.095598
	1976	0.978758	0.974036	1.143777	0.995521	0.998433	0.976490	0.983228	1.065360	
	1977	0.962583	0.967028	1.098482	0.991294	0.997972	0.959593	0.971469	1.078279	1.042046
	1978	0.959276	0.963515	1.086193	0.990775	1.007088	0.950890	0.972648	1.085723	1.021738
	1979	0.943506	0.959774	1.078297	0.988500	1.002654	0.943828	0.970082	1.108246	1.003620
	1980	0.929569	0.959775	1.060276	0.988692	1.006107	0.926691	0.970287	1.149898	0.996129
	1981	0.924755	0.958860	1.047203	0.987971	1.002852	0.917898	0.966837	1.139478	0.989568
SINGAPORE	1970	1	1	1	1	1	1	1	1	1
	1971	0.997566	1.000673	1.009969	0.999140	1.001601	0.991713	1.001700	1.003817	0.988833
	1972	0.994732	1.000843	1.015572	0.998851	1.004402	0.982552	1.006683	1.005741	0.983860
	1973	0.976121	0.999068	1.024125	0.998427	0.990298	0.984821	1.013341	1.009058	0.976060
	1974	0.962246	0.999876	1.011525	0.997211	0.988518	0.989943	1.011448	1.008924	0.965195
	1975	0.962976	1.004749	1.003679	0.998109	0.997360	0.986448	1.019736	1.014087	0.969016
	1976	0.969914	1.005530	1.016646	0.998855	1.001203	0.982041	1.030302	1.016149	0.965235
	1977	0.964726	1.004223	1.021620	0.999814	0.995273	0.985821	1.043025	1.015256	0.962883
	1978	0.958566	1.000438	1.027702	1.001744	0.985863	0.983391	1.052852	1.017342	0.960218
	1979	0.953765	1.001230	1.038278	1.001850	0.984650	0.977198	1.058424	1.027740	0.939944
	1980	0.947497	0.999923	1.042476	1.001875	0.984410	0.970332	1.061657	1.046509	0.923411
	1981	0.941625	1.003529	1.046724	1.000303	0.989399	0.964713	1.064676	1.068105	0.906600

Y1 = Agriculture Y2 = Mining and Quarrying Y3 = Manufacturing Y4 = Utilities Y5 = Construction
Y6 = Trade Y7 = Transport and Communication Y8 = Finance Y9 = Government and Others

1970 is 1.0 for all sectors. In other words, Singapore in 1970 is the benchmark of comparison for all nine sectors of total factor productivity. Here, total factor productivity of a particular output sector is interpreted from the macro viewpoint of the economy. When the output share of a particular sector shrinks, factors employment in the economy may not be affected due to redistribution of resources among different sectors. It is the contribution of total *aggregate* factor in a given output sector that we try to measure and compare. Table 2 reports the total factor productivity for each of nine sectors across eight countries. The indexes Y_j/X (or Q_j^{kl} as denoted earlier with l to be Singapore 1970, and k the country under study) are the measurement of technological differences from the benchmark for the jth sector.

(B.1) Agriculture and Mining

Over the period of study, agriculture output contribution of total factor declined in every country except for the small growth observed in the Philippines. Also, large technological differences are observed between Indonesia and Singapore, and between Indonesia and Hong Kong. Although Indonesia's productivity in agriculture showed a declining trend, Indonesia led all the other countries in the level of technology in agriculture.

In the mining sector, total factor productivity for Indonesia increased significantly during 1973–1974 and maintained at a high level into the 1980s. Note that the GDP share of the mining sector in Indonesia grew by a magnitude of 400% in the twelve year period. We suspect that the increases of mining output contribution of total factor in Indonesia were attributable to the higher price of oil during this period. We further observe that Malaysia had the next highest technological level in mining, however, productivity in mining for Malaysia declined over the period accompanied by the decrease of its GDP share from 7% in 1970 to 4% in 1981. The decline of world tin market in the 1970s may be the reason for such decreases in productivity. The technological differences in the mining sector among the rest of the countries were negligible.

(B.2) Manufacturing

As seen from table 2, technological differences (or gaps) in manufacturing among the countries are not as large as the gaps in the agriculture and mining sectors. Over the period, all countries experienced productivity growth in manufacturing with Taiwan, Korea, and the Philippines having the best growth. Although Taiwan had larger GDP shares and a higher level of technology in manufacturing than Korea, the technological gap appears to be closing in the late 1970s and early 1980s. Total factor productivity in manufacturing for Hong Kong appears to be stable except for the 1973–1976 period of highly variable performance. Apparently Hong Kong is more vulnerable to shocks than the other countries, and the GDP shares of this sector decreased from 30% in 1970 to 25% in 1980.

(B.3) Utilities and Construction

The utilities sector consists of gas, water, and electricity. Except for Hong Kong, all countries showed mild productivity growth in this sector. Taiwan, Singapore, Korea, and Malaysia showed the stronger performance while Hong Kong's performance in this sector mirrored the 1973–1976 shock in manufacturing.

Total factor productivity growth in construction was most dramatic in the Philippines over the study period. GDP shares of the construction sector in the Philippines increased from less than 4% in 1970 to more than 8% in 1981. For the other countries, minor differences in technological levels are observed except for the fluctuations for Hong Kong and Singapore during the 1973–1976 period.

(B.4) Trade

The trade sector consists of wholesale, retail, restaurant and hotel services. Singapore with 30% of GDP share in this sector, dominated in the level of technology. However, we also observe that the technological gap is closing for all the other countries. Thailand, with a relatively large and stable GDP share of 22% in this sector, retained its competitive position in productivity with Singapore and Hong Kong. The Philippines exhibited strong but fluctuating productivity growth in the trade sector and Hong Kong continued to show the effects of the 1973–1976 shock. Productivity change in the 1974–75 period was most dramatic for Hong Kong in this sector, even though its GDP share maintained at about 20% throughout the study period.

(B.5) Transport and Communication

With a rapid growth of the GDP share of the transport sector from 11% in 1970 to 20% in 1981, Singapore led in the technological level in this sector. Furthermore, the technological gap appears to be widening against the other countries under study. Even though the technological gap in this sector is widening in favor of Singapore, we observe productivity growth in the transport sector for the other countries. For example substantial productivity increases were seen for Korea and Taiwan since 1978. Hong Kong again showed the variability of total factor productivity in the transport sector during the 1973–76 period.

(B.6) Finance

The finance sector includes banking, real estate, insurance and business services. It is interesting to observe that Hong Kong and Singapore had approximately the same GDP shares for the finance sector. However, Hong Kong led in the level of technology, albeit, with fluctuations during 1973–1975. All countries appear to have stable productivity over the period except for the observed exponential growth of Singapore from 1979–81. The exponential productivity growth of Singapore in the finance sector during the late 1970s, if continued, will surpass the productivity level of the current leader Hong Kong. We further observe that Thailand had closed the technological difference in the finance sector against Malaysia even though the former had a smaller GDP in the sector.

(B.7) Government and Others

This sector consists of government, community, social and other services. Malaysia, Hong Kong, and the Philippines were the leading group in technological differences in this sector with Hong Kong exhibiting substantial variability during 1974–76. Also, Singapore, Hong Kong, Taiwan, and Korea showed declining productivity with Singapore suffering the greatest productivity decline from 1978–81. The GDP share of this sector dropped from 15% in 1970 to a below 10% level in 1981 for Singapore.

C. INDIVIDUAL FACTOR PRODUCTIVITY COMPARISONS

The results of individual factor productivity comparisons based on multilateral index (6.b) are given in Table 3. Three factors—labor, physical capital service, and working capital services—are included for comparisons in terms of their contributions to the total output or real GDP in the economy. The indexes Y/X_i (or q_i^{kl} as denoted earlier with l to be Singapore 1970 for all factors, and k the country under study) are the measurement of factor productivity compared against the benchmark for the factor i.

(C.1) Labor Factor Productivity

In table 3, labor factor productivity for all countries shows an increasing trend with small differences in the level of labor productivity among the countries, except for Hong Kong and the Philippines. Korea and Thailand lead in labor factor productivity, however, the other countries appear to be closing the gap, especially during the late 1970s. The labor productivity index indicates that the gap among the countries, excluding Hong Kong and the Philippines, decreased from a high of 0.25 in 1970 to 0.1 in 1981. We also observe that labor productivity of Taiwan has exceeded that of Singapore since 1978.

The difference in the level of labor productivity between Singapore and Hong Kong increased in favor of Singapore over this period—from 0.25 in 1973 to a high of 0.55 in 1981. Labor productivity differences between Singapore and the Philippines has been maintained at 0.3 over the period.

TABLE 3 Multilateral Factor Productivity Comparison Indexes

(Singapore 1970 = 1.0)

	YEAR	Y/X1	Y/X2	Y/X3
INDONESIA	1970	0.837012	0.982608	1.426105
	1971	0.861345	0.984019	1.410205
	1972	0.890869	0.961946	1.389796
	1973	0.928572	0.957291	1.352045
	1974	0.966423	0.953717	1.372580
	1975	0.969532	0.941987	1.373226
	1976	0.993936	0.930752	1.364349
	1977	1.023148	0.918544	1.352199
	1978	1.026443	0.913739	1.371421
	1979	1.060864	0.907822	1.376453
	1980	1.100152	0.905026	1.371151
	1981	1.080835	0.895936	1.418351
KOREA	1970	0.983046	1.057922	1.102228
	1971	1.008673	1.060741	1.099435
	1972	1.018287	1.018432	1.102010
	1973	1.053261	1.016837	1.076300
	1974	1.070274	1.009506	1.066762
	1975	1.093585	0.999261	1.087207
	1976	1.122686	1.005320	1.095913
	1977	1.164649	0.991733	1.091080
	1978	1.207574	0.978081	1.087991
	1979	1.229485	0.958845	1.096809
	1980	1.198157	0.927110	1.143584
	1981	1.225608	0.914999	1.155553
TAIWAN	1970	0.871230	0.972809	1.392885
	1971	0.905417	0.960532	1.333909
	1972	0.941885	0.951266	1.312321

	YEAR	Y/X1	Y/X2	Y/X3
	1973	0.965975	0.944927	1.308379
	1974	0.956843	0.927733	1.359067
	1975	0.968315	0.884206	1.351368
	1976	1.017727	0.895262	1.340802
	1977	1.035809	0.887934	1.338439
	1978	1.079444	0.893378	1.311758
	1979	1.107491	0.890608	1.322703
	1980	1.132108	0.880909	1.314483
	1981	1.153246	0.827237	1.302283
PHILIPPINE	1970	0.667777	0.977726	1.796375
	1971	0.650605	0.964823	2.209491
	1972	0.673038	0.959668	2.041503
	1973	0.684679	0.957975	2.437804
	1974	0.727442	0.954022	2.467229
	1975	0.730575	0.946627	2.458540
	1976	0.768078	0.934035	2.093182
	1977	0.791947	0.922422	1.987612
	1978	0.758556	0.912557	2.706662
	1979	0.796799	0.901827	2.411257
	1980	0.806744	0.886574	2.500978
	1981	0.805597	0.870745	2.779619
THAILAND	1970	1.070882	1.021298	1.062758
	1971	1.093544	1.030134	1.069917
	1972	1.126214	0.998980	1.047315
	1973	1.136589	0.999528	1.040111
	1974	1.153434	0.995374	1.046611
	1975	1.155478	0.993148	1.032419
	1976	1.184560	1.011177	1.037443
	1977	1.172814	1.017025	1.058551
	1978	1.185847	0.995600	1.037199
	1979	1.221830	0.984081	1.026430
	1980	1.215813	0.979366	1.028372
	1981	1.198673	0.999207	1.057635
MALAYSIA	1970	0.966987	1.001934	1.292129
	1971	0.999111	1.005724	1.237611
	1972	1.000181	1.054794	1.253467
	1973	1.014132	0.987912	1.239072
	1974	1.039771	0.977851	1.239283
	1975	1.027923	0.959508	1.273177
	1976	1.064248	0.957041	1.247511
	1977	1.073008	0.952226	1.252802
	1978	1.078683	0.945732	1.263047
	1979	1.077977	0.943333	1.269024
	1980	1.086970	0.937945	1.259071
	1981	1.107744	0.928069	1.258479
HONG KONG	1970	0.691900	0.992960	1.342364
	1971	0.715905	0.993971	1.343631

	YEAR	Y/X1	Y/X2	Y/X3
	1972	0.748061	0.992714	1.309497
	1973	0.774742	0.986663	1.171157
	1974	0.735057	0.965974	1.130311
	1975	0.556760	0.961497	2.325966
	1976	0.575450	0.967085	2.138322
	1977	0.605219	0.971922	1.801283
	1978	0.605958	0.972829	1.743486
	1979	0.639379	0.977607	1.576759
	1980	0.657484	0.979159	1.505386
	1981	0.676517	0.974820	1.396020
SINGAPORE	1970	1	1	1
	1971	1.017145	0.987353	0.990626
	1972	1.044023	0.975726	0.974592
	1973	1.034630	0.960836	0.976353
	1974	1.037294	0.945122	0.954156
	1975	1.051351	0.927236	0.980231
	1976	1.063771	0.921259	1.004103
	1977	1.073525	0.910573	1.012748
	1978	1.079160	0.908225	1.004397
	1979	1.087380	0.911950	0.985484
	1980	1.100142	0.913823	0.964568
	1981	1.120318	0.907325	0.957823

X1 = Labor
X2 = Physical Capital
X3 = Working Capital

(C.2) Capital Factor Productivity

Capital contribution to output, as noted in Section III is divided into two parts, physical capital productivity and working capital productivity. The contribution of physical capital service for all countries is observed to be decreasing over time. This observation, together with the observation of increasing trend in labor productivity reflect increasing capital intensity in the production technology for all countries over the study period.

Singapore, the Philippines, and Indonesia had very similar productivity of physical capital, from an index of 0.9 to 1.0 over the period. Physical capital productivity of Korea has decreased as significantly as that of Taiwan, except that Taiwan was at the lower level. The index for Korea, which at 1.05 in 1970 was much higher than Singapore declined to 0.9 in 1981, the same level for Singapore in that year. Furthermore, Hong Kong, Thailand, and Malaysia are observed to have similar levels of physical capital productivity and the most gradual declines in productivity.

In terms of the relative contribution of working capital to output, we observe that all countries had similar and stable index of working capital productivity—between 0.95 and 1.45—except for Hong Kong and the Philippines. Hong Kong exhibited a very sharp increase in this index for 1974–1975, and then the index declined to the level compatible with other countries in 1981. The Philippines, on the other hand, showed an increasing trend in working capital productivity at a high but unstable level—from 1.8 in 1970 to 2.8 in 1981. Hong Kong and the Philippines appear to be more vulnerable to shocks than the other countries.

V. Conclusion

This study applies the economic theory of index numbers to compare technological differences and productivity performances of eight Asian countries from 1970–1981. Extensions of this study can be made in various directions. First, as mentioned earlier in this paper, sectoral comparisons of output, factor, and productivity for individual countries may be important information in terms of a country's development policy. Productivity studies of individual countries based on multilateral index numbers are particularly useful because comparisons can be made either within the country or across competitive countries over time. If data permits, national and regional productivity analyses grounded on Tornqvist-Theil bilateral and multilateral indexes for major sectors should be taken.

As pointed out by Denny and Fuss [1983b], the use of nonparametric measurement of bilateral and multilateral output, factor, and productivity implies some very restrictive assumptions on the general specification of production technologies for each economic entity involved. In particular, the increasing returns of output and factor cannot be measured without econometric estimation. The current study is limited by the assumption of competitive markets and of constant returns to scale in technologies. These assumptions will be relaxed in future studies by structurally estimating the production technologies explicitly. The bias from economic scale effect can, therefore, be corrected in measuring output, factor, and productivity performance among these countries.

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