THE TYRANNY OF NUMBERS: CONFRONTING THE STATISTICAL REALITIES OF THE EAST ASIAN GROWTH EXPERIENCE*

ALWYN YOUNG

This paper documents the fundamental role played by factor accumulation in explaining the extraordinary postwar growth of Hong Kong, Singapore, South Korea, and Taiwan. Participation rates, educational levels, and (excepting Hong Kong) investment rates have risen rapidly in all four economies. In addition, in most cases there has been a large intersectoral transfer of labor into manufacturing, which has helped fuel growth in that sector. Once one accounts for the dramatic rise in factor inputs, one arrives at estimated total factor productivity growth rates that are closely approximated by the historical performance of many of the OECD and Latin American economies. While the growth of output and manufacturing exports in the newly industrializing countries of East Asia is virtually unprecedented, the growth of total factor productivity in these economies is not.

I. INTRODUCTION

This is a fairly boring and tedious paper, and is intentionally so. This paper provides no new interpretations of the East Asian experience to interest the historian, derives no new theoretical implications of the forces behind the East Asian growth process to motivate the theorist, and draws no new policy implications from the subtleties of East Asian government intervention to excite the policy activist. Instead, this paper concentrates its energies on providing a careful analysis of the historical patterns of output growth, factor accumulation, and productivity growth in the newly industrializing countries (NICs) of East Asia, i.e., Hong Kong, Singapore, South Korea, and Taiwan.

Tables I and II and Figure I present some basic information on growth in the NICs, drawn from national accounts and census sources.[1] As seen in Table I, the extraordinarily rapid and sus-

*This paper was supported by a grant from the MIT-NTU Collaboration Agreement and an NBER Olin Fellowship. I am indebted to Christina Paxson for providing data tapes on Taiwan, to Chan Wing-Kwong, Chao Bi-Tsyr, Ho Kun-Lon, Peter Kisler, John Sharon, and Woo Hyun-Sook for help in gathering and entering data, and, most especially, to Ho Veng-Si and Yang Shin-Kyu for extraordinary research assistance. Thanks are due the governments of Hong Kong, Singapore, South Korea, and Taiwan for providing unpublished data and answering queries.

1. The Appendix provides a full description of sources. All growth rates reported in this paper are logarithmic, rather than geometric, growth rates. The labor force estimates for Korea and Taiwan exclude their large (predominantly conscript) armies, whose measured output (in the form of wages) is comparatively small. Section VI examines the sensitivity of the results reported in this paper to the inclusion/exclusion of military personnel.

The Quarterly Journal of Economics, August 1995

TABLE I
GROWTH RATES (PERCENT)

	Hong Kong (1966–1991)			Singapore (1966–1990)		
	N	D	N − D	N	D	N − D
GDP per capita	7.3	1.6	5.7	8.7	1.9	6.8
GDP per worker	7.3	2.6	4.7	8.7	4.5	4.2
Excluding agriculture	NA	2.8	NA	8.8	4.6	4.2
Manufacturing	NA	1.3	NA	10.2	6.2	4.0
Δ Participation rate		0.38 → 0.49			0.27 → 0.51	
	South Korea (1966–1990)			Taiwan (1966–1990)		
	N	D	N − D	N	D	N − D
GDP per capita	8.5	1.7	6.8	8.5	1.8	6.7
GDP per worker	8.5	2.8	5.6	8.5	3.1	5.4
Excluding agriculture	10.3	5.4	4.9	9.4	4.6	4.8
Manufacturing	14.1	6.3	7.8	10.8	5.9	4.9
Δ Participation rate		0.27 → 0.36			0.28 → 0.37	

N = Numerator; D = Denominator. NA = Not Available, the Hong Kong government has yet to develop constant price estimates of GDP by sector. GDP measures are at market prices, excluding import duties, however. Columns may not add up due to rounding.

tained growth of output per capita in all four economies, averaging some 6 to 7 percent per annum for two and a half decades, is truly remarkable. It is this record of growth, along with its apparent association with the rapid growth of manufactured exports, that has led most economists to believe that productivity growth in these economies must be extraordinarily high, particularly in their manufacturing sectors. This view, however, ignores an equally remarkable record of factor accumulation.

TABLE II
EDUCATIONAL ATTAINMENT OF THE WORKING POPULATION (PERCENT)

	Hong Kong		Singapore		South Korea		Taiwan	
	1966	1991	1966	1990	1966	1990	1966	1990
None	19.2	5.6	55.1	⇓	31.1	6.4	17.0	4.5
Primary	53.6	22.9	28.2	33.7	42.4	18.5	57.2	28.0
Secondary+	27.2	71.4	15.8	66.3	26.5	75.0	25.8	67.6

Self-taught are included under primary. Hong Kong, Korean, and Taiwanese data refer to highest level of education "attended" rather than completed. All percentages are calculated net of those reported as "unknown."

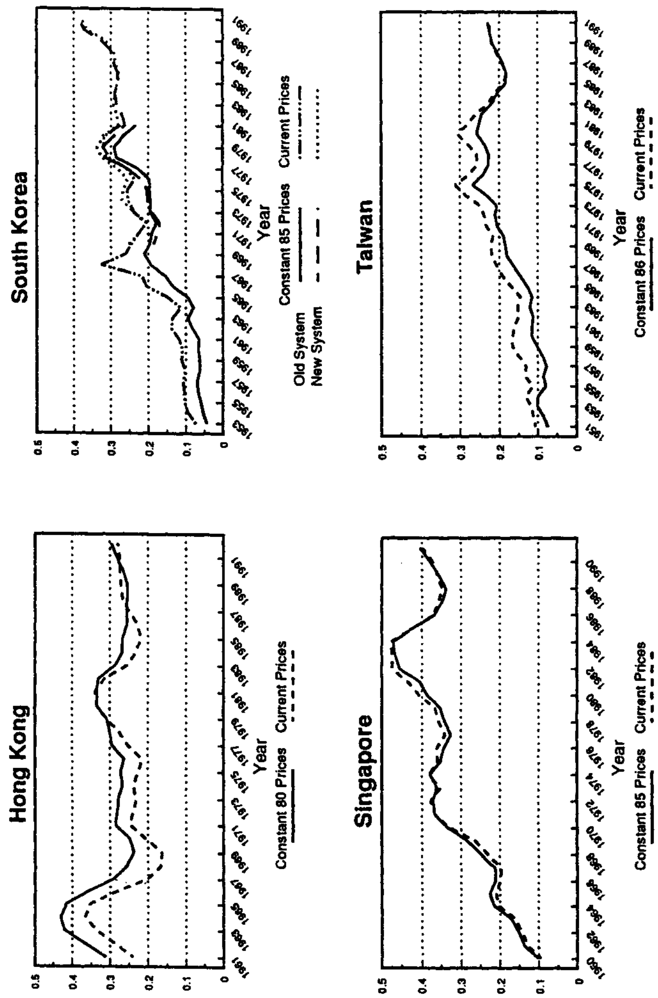

FIGURE I
I/GDP Ratios

As Table I shows, one important area of factor accumulation has been labor input. The rapid postwar decline in birth rates (changing dependency ratios) and rising rates of female labor force participation have led to a substantial rise in the aggregate participation rate in each of the NICs.[2] In moving to measures of output per worker, rising participation rates remove an average of 1 percent per annum from the per capita growth rate of Hong Kong, 1.2 and 1.3 percent per annum from Korea and Taiwan, respectively, and a stunning 2.6 percent per annum (for 24 years!) from the growth rate of Singapore. Intersectoral transfers of labor have also been important. Thus, removing agriculture from the analysis lowers the growth rate of output per worker in Taiwan and South Korea by 0.6 and 0.7 percent per annum, respectively, reflecting the rapid decline in the share of agricultural employment in total employment in both economies.[3] Although the growth of manufacturing output has been unusually rapid in these economies, so has the growth of manufacturing employment. Once one accounts for the transfer of labor into manufacturing, one finds, surprisingly, that, with regard to labor productivity growth, manufacturing in both Singapore and Taiwan actually underperformed the aggregate economy.

Capital input has also grown rapidly in the NICs. As shown in Figure I, although the investment to GDP ratio has remained roughly constant in Hong Kong, in the other NICs it has risen substantially over time. In Singapore the constant price investment to GDP ratio, at 10 percent in 1960 had reached 39 percent by 1980 and an extraordinary 47 percent by 1984, after which it declined substantially, only to begin another rise in the late 1980s. In South Korea, investment rates, which were around 5 percent (in constant prices) in the early 1950s, exploded up to 20 percent in the late 1960s, reached 30 percent by the late 1970s, and were approaching 40 percent by 1991. Finally, in Taiwan the constant

2. Changes in age-specific male participation rates are minimal in all four economies, while, with the exception of Hong Kong and Taiwan (where they declined gradually), reported nonagricultural hours of work have remained roughly constant. This suggests that the increase in participation is genuine, and not some statistical artifact.

3. This intersectoral transfer was greatest in Taiwan during the 1970s, when the difference in the growth of output per worker was 2.1 percent (5.6 versus 3.5), and in Korea during the 1980s, when the difference in growth rates was 1.7 percent (6.7 versus 5.0).

price investment to GDP ratio, at around 10 percent in the early 1950s, grew steadily to a high of 27 percent in 1975, after which it fluctuated around a value of about 22 percent.

Human capital accumulation in the East Asian NICs has also been quite rapid. As shown in Table II above, over the past two and a half decades the proportion of the working population in each economy with a secondary education or more has almost tripled or, in the case of Singapore, even quadrupled. By 1990/1991, some 18 to 20 percent of the working population in each NIC had some tertiary education.[4] In weighting labor input by sex, age, and educational characteristics (discussed further below), I have found that the improving educational attainment of the workforce contributes to about 1 percent per annum additional growth in labor input in each of these economies.

All of the influences noted above—rising participation rates, intersectoral transfers of labor, improving levels of education, and expanding investment rates—serve to chip away at the productivity performance of the East Asian NICs, drawing them from the top of Mount Olympus down to the plains of Thessaly. In a companion paper [Young 1994], I use simple back-of-the-envelope calculations and large international data sets to show that, with regard to productivity growth in the aggregate economy and in manufacturing in particular, the NICs cannot be considered to be strong outliers in the postwar world economy. This paper concentrates on a more careful analysis of these four economies, making use of the extensive statistical record embodied in their national accounts, population censuses, and sectoral, wage, and labor force surveys.

The remainder of this paper is organized as follows. Section II presents a short review of methodology. Sections III–VI then provide a country-by-country analysis of aggregate and sectoral total factor productivity growth. Section VII contrasts this research with earlier work on productivity growth in the NICs, while Section VIII summarizes and concludes. An Appendix provides a description of sources and some of the problems encountered in linking different data series.

4. Defined as junior college and above in Korea and Taiwan and matriculation/A levels and above in Hong Kong and Singapore.

II. Methodology

A. The Translog Index of Total Factor Productivity Growth

Consider the translogarithmic value added production function:[5]

$$(1)\quad Q = \exp\,[\alpha_0 + \alpha_K \ln K + \alpha_L \ln L + \alpha_t t + \tfrac{1}{2}B_{KK}(\ln K)^2 + B_{KL}(\ln K)(\ln L) + B_{Kt}\ln K\cdot t + \tfrac{1}{2}B_{LL}(\ln L)^2 + B_{Lt}\ln L\cdot t + \tfrac{1}{2}B_{tt}t^2],$$

where K, L, and t denote capital input, labor input, and time, and where, under the assumption of constant returns to scale, the parameters α_i and B_{jk} satisfy the restriction:

$$(2)\quad \alpha_K + \alpha_L = 1, \qquad B_{KK} + B_{KL} = B_{LL} + B_{KL} = B_{Kt} + B_{Lt} = 0.$$

First differencing the logarithm of the production function provides a measure of the causes of growth across discrete time periods:

$$(3)\quad \ln\left(\frac{Q(T)}{Q(T-1)}\right) = \overline{\Theta}_K \ln\left(\frac{K(T)}{K(T-1)}\right) + \overline{\Theta}_L \ln\left(\frac{L(T)}{L(T-1)}\right) + TFP_{T-1,T},$$

where

$$\overline{\Theta}_i = [\Theta_i(T) + \Theta_i(T-1)]/2$$

and where the Θ_i's denote the elasticity of output with respect to each input or, equivalently, assuming perfect competition, the share of each input in total factor payments. The translog index of *TFP* growth ($TFP_{T-1,T}$) provides a measure of the increase in output attributable to the time-related shift in the production function. In essence, the translog production function provides a theoretical justification for the use of average factor shares and log differences as a means of extending the continuous time Divisia analysis of productivity growth to data based upon discrete time periods.

To allow consideration of more finely differentiated inputs, one

5. Developed independently by Christensen, Jorgenson, and Lau [1971, 1973], Griliches and Ringstad [1971], and Sargan [1971], and in recent years applied to the study of productivity by, for example, Jorgenson, Gollop, and Fraumeni [1987].

can assume that aggregate capital and labor input are, in turn, constant returns to scale translog indices of subinputs:[6]

$$(4)\quad K = \exp[\alpha_1^K \ln K_1 + \alpha_2^K \ln K_2 + \cdots + \alpha_n^K \ln K_n + \tfrac{1}{2}B_{11}^K(\ln K_1)^2 + B_{12}^K(\ln K_1)(\ln K_2) + \cdots + \tfrac{1}{2}B_{nn}^K(\ln K_n)^2],$$
$$L = \exp[\alpha_1^L \ln L_1 + \alpha_2^L \ln L_2 + \cdots + \alpha_m^L \ln L_m + \tfrac{1}{2}B_{11}^L(\ln L_1)^2 + B_{12}^L(\ln L_1)(\ln L_2) + \cdots + \tfrac{1}{2}B_{mm}^L(\ln L_m)^2].$$

First differencing the logarithms of these translog indices provides a measure of the growth of aggregate capital and labor input as weighted averages of the growth rates of their subinputs:

$$(5)\quad \ln\left(\frac{K(T)}{K(T-1)}\right) = \sum_i \bar{\theta}_{K_i} \ln\left(\frac{K_i(T)}{K_i(T-1)}\right)$$
$$\ln\left(\frac{L(T)}{L(T-1)}\right) = \sum_j \bar{\theta}_{L_j} \ln\left(\frac{L_j(T)}{L_j(T-1)}\right),$$

where

$$\bar{\theta}_i = [\theta_i(T) + \theta_i(T-1)]/2$$

and where the θ_i's denote the elasticity of each aggregate input with respect to each of its component subinputs or, again assuming perfect competition, the share of each subinput in total payments to its aggregate factor. In a manner analogous to the continuous time Divisia analysis, these indices adjust for improvements in the "quality" of aggregate capital and labor input by, to a first-order approximation, weighting the growth of each subinput by its average marginal product.

The appropriate measure of capital and labor input is the flow of services emanating from those inputs. For labor, one can reasonably assume that the flow of services is proportional to total hours of work; i.e., $L_j(T) = \lambda_{L_j} H_j(T)$, with

$$(6)\quad \ln\left(\frac{L(T)}{L(T-1)}\right) = \sum_j \bar{\theta}_{L_j} \ln\left(\frac{H_j(T)}{H_j(T-1)}\right).$$

Since data on capital utilization are rare, it is customary to assume that the flow of capital services is proportional to the measured

6. With similar restrictions on parameter values.

capital stock (denoted by $C_i(T)$), with $K_i(T) = \lambda_{K_i} C_i(T)$ and

$$\ln\left(\frac{K(T)}{K(T-1)}\right) = \sum_i \bar{\theta}_{K_i} \ln\left(\frac{C_i(T)}{C_i(T-1)}\right). \tag{7}$$

Before proceeding further, it is worth considering whether deviations from the restrictive assumptions of the model outlined above might not lead to a downward bias in estimates of total factor productivity growth, and hence explain the low estimates reported in this paper. The absence of perfect competition, in the context of a constant returns to scale production function, could lead to mismeasurement of the elasticity of output with respect to each input, as factor shares need no longer reflect output elasticities. In particular, to the degree that monopoly profits are reflected in capital income, capital's income share will tend to overstate the elasticity of output with respect to capital. The reader can make an easy correction for this factor by adjusting the aggregate shares of capital and labor in the tables presented further below. However, since physical capital accumulation is only a small part of the NIC story, with increases in labor participation and educational attainment and the intersectoral transfer of labor all playing an equally important role,[7] within reasonable bounds adjustments along these lines are not likely to produce spectacular productivity estimates for the NICs.[8]

Relaxation of the assumption of constant returns to scale could either increase or decrease the productivity estimates. If the true aggregate production function is characterized by increasing returns to scale, perhaps due to externalities among factors, then the growth accounting residual actually overstates the true degree of productivity growth, since it captures the increase in production externalities brought about by the increase in factors of production. Conversely, if the true production is characterized by decreasing returns to scale, the growth accounting residual understates the degree of productivity growth.

7. Table XV summarizes the quantitative contribution of each factor toward reducing the estimate of productivity growth.

8. With the exception of Singapore, the NIC labor shares are about two-thirds, i.e., consistent with the standard prior on the elasticity of output with respect to labor. Singapore's share is, however, substantially lower. Raising its share to that of, say, Hong Kong, raises the estimate of average total factor productivity growth from 0.2 to 0.8 per annum, which, while certainly more respectable, is not spectacular. In this regard, I should note that in order to bias my estimates in favor of Singapore I make use of the labor income share reported in the *Singapore Input-Output Tables*, which is substantially greater than that indicated by unpublished data on labor income provided to me by the Singaporean government.

Finally, it is worth addressing a common misconception concerning growth accounting adjustments for the "quality" of labor and capital input; i.e., that these adjustments implicitly incorporate any embodiment of technological change in those inputs. Fundamentally, the growth accounting procedure assumes that input i today is the same as it was yesterday; i.e., that a secondary educated 25-year-old female worker today is identical to a secondary educated 25-year-old female worker yesterday. In so doing, the procedure places any increase in the productivity of that input (whether or not embodied) into the residual. The weighting of capital and labor input in equation (5) above is no more than an extension of the standard two-factor (capital/labor) analysis, in which each factor is weighted by its income share, to the consideration of more numerous inputs which, for analytical convenience, are differentiated into lists of "capital" and "labor" inputs.[9]

B. Measuring Factor Supplies

My analysis focuses on two aggregate inputs, capital and labor, subdivided into finer subinput categories. In general, I divide capital input into five categories: residential buildings, nonresidential buildings, other durable structures, transport equipment, and machinery. With the exception of my analysis of Singaporean manufacturing, I do not include land input, which is difficult to measure. To minimize any error, I focus my analysis of Taiwan and Korea on the nonagricultural economy, where land input accounts

9. This is not to say, however, that the measure of technical progress is independent of the quantity of factors, or the path of factor accumulation. Consider an isoquant that shifts in nonuniformly (i.e., in a non-Hicks-neutral fashion). In this case, the measured improvement in productivity will vary according to the capital-labor ratio of the economy, and the degree to which that capital-labor ratio changes during the period under analysis. If one estimates the production function, one can avoid this problem by describing the full movement of the surface, rather than simply decomposing changes along a particular path of factor accumulation.

One referee queried, if technological improvement led to an improvement in capital goods quality, and hence in a reduction in real capital goods prices, would the increase in capital goods productivity show up in the growth accounting residual? If the capital goods are imported, then the answer is, quite appropriately, no. However, if the capital goods are domestically produced, then if the price indices for capital goods production are quality adjusted, then so are the quantity indices. Thus, the increase in quality in the capital goods sector would show up as a rise in value added per unit of input in that sector and, when aggregated with other sectors, in the aggregate economy. In this regard, it is interesting to note that between 1966 and 1990 the ratio of the capital goods to GDP deflator rose by 1.2 percent per annum in Hong Kong, but fell by −0.2 percent per annum in Singapore, −1.8 percent per annum in South Korea, and −1.1 percent per annum in Taiwan. The decline in relative capital goods prices in South Korea and Taiwan partially offsets the reduction in capital returns induced by the approximately 3 percent per annum rise in the capital-output ratio in those economies.

for only a small percentage of total payments to factors of production.[10] Labor is distinguished on the basis of sex (two categories), age (nine to eleven categories, depending upon the country and time period under consideration), and education (two to seven categories).

I estimate the capital stock using the standard perpetual inventory approach with geometric depreciation.[11] In following this approach, it is customary to initialize the capital stock series using a benchmark survey, such as a national wealth survey. In the case of the NICs, this approach is not productive. Neither Hong Kong nor Singapore has ever conducted such a survey, while, in the case of South Korea and Taiwan, the survey results are greatly at odds with the annual investment flows recorded in the national accounts. Table III reports the ratio of historical cumulative (undepreciated) investment to the value of gross (undepreciated) assets reported in the 1988 National Wealth Survey of Taiwan.[12] As the table shows, the aggregate numbers reported in the survey vastly exceed the *total* cumulative investment in the period 1951–1988.[13] Lest the reader believe that this discrepancy reflects pre-1951 purchases of capital, the survey also reported the date the assets

10. For example, Kim and Park [1985, table 5–13] estimate that during the 1960s and 1970s land input on average accounted for only about 4 percent of Korean nonagricultural nonresidential income.

I also do not include inventories. I have found that the "changes in stocks" series published by most of the NICS are either (i) outright gross fabrications used to conceal large discrepancies between the production and expenditure accounts; or (ii) based upon the flimsiest of data. In Young [1992] I made use of unpublished stocks data provided to me by the Singaporean and Hong Kong governments. Problems with the existence of accurate stocks data for the other economies, combined with a growing suspicion as to the accuracy of the Hong Kong numbers, have led to me to drop consideration of stocks from the analysis.

11. The depreciation rates are based upon Hulten and Wykoff [1981, table 2] and Jorgenson and Sullivan's [1981, table 1] estimates of geometric depreciation rates for detailed asset types (e.g., trucks, autos, mining machinery, service machinery, etc.). I derive the depreciation rate for each of the five broad asset types used in my analysis as the unweighted average of the depreciation rates of the detailed asset types likely to be found in each industry. This approach is crude, but the results are, in any case, not sensitive to moderate adjustments in the depreciation rates (see, for example, Young [1992]).

12. I cumulate the national accounts investment at constant prices of the date of the wealth survey. The gross values reported in the wealth surveys represent, similarly, the product of a purchase price times a price index reflecting asset inflation up to the time of the survey. The price indices for the wealth surveys are drawn from sources similar to those used by the national accounts, e.g., wholesale price indices, and, when reported, as in the Korean national wealth surveys, roughly parallel the national accounts deflators for similar asset types. Thus, the incongruities noted below seem to be more related to differences in the original current price values recorded in the surveys and national accounts, rather than differences in the deflators used to adjust these values to a common standard.

13. In principle, because of scrapping, the wealth survey gross assets should actually be less than the cumulative national accounts investment.

TABLE III
RATIO OF CUMULATIVE INVESTMENT TO WEALTH SURVEY GROSS ASSETS: TAIWAN, 1988

	Residential	Non-residential	Other construction	Transport equipment	Machinery
Economy	0.33	0.60	0.76	0.75	0.86
Mining*	NA	1.37	1.85	25.74	6.23
Utilities*	NA	0.47	0.10	1.23	1.48

NA = Not applicable. *Public enterprises only.

were acquired, indicating that only a small fraction (e.g., 1 percent of machinery and transport equipment) was acquired prior to 1956. As Table III shows, at the sectoral level the discrepancies between the national accounts and the survey values are even greater, with the ratio of cumulative investment to reported gross assets reaching highs of 25.74 and lows of 0.10 for public enterprises in mining and utilities, respectively. In the case of South Korea, three wealth surveys have been taken, which allows for a time series comparison. Table IV compares the gross assets recorded in each survey with an adjustment for cumulative investment in the intervening years.[14] As the table shows, the total nonresidential capital reported in the 1968 wealth survey, plus the ensuing nine years of investment flows, accounted for only two-thirds of the nonresidential capital reported in the 1977 wealth survey, implying that these assets "grew" by 50 percent in the intervening years. In the case of transport equipment, however, fully 76 percent of the gross assets reported in the 1968 survey, plus the ensuing investment, were unaccounted for in the 1977 survey. The incongruity between the stock values recorded in the national wealth surveys and the flow values of the national accounts calls into question any attempt to use the wealth surveys as a means of initializing one's estimates of the capital stock.[15]

As an alternative procedure, I initialize my capital stock series by assuming that the growth rate of investment in the first five

14. The values for each survey and the cumulative investment are converted to common benchmarks using the national accounts deflators.

15. In essence, if one believes the wealth surveys, one has to discard most of the information in the national accounts. I tend to favor the national accounts, since the flow values recorded there are at least subject to some consistency checks (e.g., between the expenditure and production accounts), while the stock values reported in the wealth surveys are basically answers to the open-ended question: what assets do you have, and what did you pay for them?

TABLE IV
RATIO OF GROSS ASSETS FROM SURVEY TO SURVEY: SOUTH KOREA
(ALLOWING FOR CUMULATIVE INVESTMENT)

	Residential	Non-residential	Other construction	Transport equipment	Machinery
1968/1977	0.95	0.65	1.27	1.76	0.89
1977/1987	0.77	0.67	1.00	1.07	0.81

years of the national accounts investment series is representative of the growth of investment prior to the beginning of the series.[16] Given positive rates of depreciation and a sufficiently long investment series prior to the first date of the analysis, the perpetual inventory approach is fairly insensitive to the level of capital used to initialize the series. For Hong Kong the published investment series begins in 1961. I use my own estimates of capital formation, which mimic the methodology of the Hong Kong government, to extend the series on all asset types back to 1947. For Singapore the published investment series begins in 1960. I use data on the construction of one-family equivalent residential units and retained imports of cement[17] to extend the residential and nonresidential durable structures investment series back to 1947.[18] For Taiwan the published investment series begins in 1951 and for South Korea in 1953. In general, I focus my analysis on the

16. Specifically,

$$C_j(0) = \sum_{i=0}^{\infty} I^j_{-i-1}(1-\delta_j)^i = \sum_{i=0}^{\infty} I^j_0(1+g_j)^{-i-1}(1-\delta_j)^i = I^j_0/(g_j+\delta_j),$$

where I^j_0 is the first year of investment data for asset j, δ_j is the depreciation rate for asset j, and g_j is the average growth of investment in asset j in the first five years of the investment series.

An exception is Singaporean manufacturing, where I use the Net Fixed Assets reported in the *Census of Industrial Production* (CIP) to initialize the capital stock in 1969. Prior to 1969 the coverage of the CIP was changing rapidly. Thus, cumulating the annual investment flows prior to that date provides a poor measure of the capital stock of the firms covered by the survey in later periods.

17. Singapore did not produce cement prior to 1961. See the *Malayan Digest of Statistics*.

18. The estimates using retained imports of cement are, admittedly, rather crude. These data, however, suggest a large surge in construction activity in the mid-1950s (which I have not been able to corroborate), with the real value of investment in durable structures in the mid-1950s exceeding the levels recorded in the early-1960s. Although I feel these data are somewhat suspect, I make use of them in order to raise the value of my initial 1966 capital stock estimates, thus biasing the results in favor of Singapore.

post-1966 period, allowing each economy thirteen or more years of investment data to establish the capital stock.[19]

Turning now to the measurement of labor inputs, my task is to estimate the working population, cross-classified by up to seven attributes, i.e., sex, age, education, industry, income, hours of work, and class of worker (i.e., employee, self-employed, etc.). Census and survey data frequently contain information on row and column sums in lower dimensions. Under the assumption that there are no interactions across attributes other than those present in the available subdimensional tables, I derive an approximation of the maximum likelihood estimate of each cell using the iterative proportional fitting technique suggested by Bishop, Fienberg, and Holland [1975]. In general, I make use of the information provided by additional worker characteristics, e.g., occupation, which, in their cross-tabulation with attributes of interest to me provide additional information. Thus, for example, I actually estimate the 1990 Singaporean working population cross-classified by sex × age × education × industry × income × class of worker × occupation, using all available census tabulations.[20] For my TFP estimates, I then sum across occupational categories to derive a reduced six-dimensional table of the variables of interest to me.

All four economies conduct occasional censuses and, on a more regular annual basis, surveys of labor force conditions. With regard to the overall size of the labor force, however, the labor force surveys provide little additional independent information over and above that derived from the census. Each survey is typically based upon a small sample[21] which must then be scaled up to a national estimate. The factors used to accomplish this scaling are usually drawn from the previous census. In essence, the reported survey results are a modified extrapolation of the previous census. Given the rapid transformation experienced by these economies, the results can, on occasion, be grossly inaccurate. Thus, the 1989 Labor Force Survey of Singapore (using scaling factors drawn from

19. To analyze the sensitivity of the results to the value of capital used to initialize the series, I also tried initial values of (i) zero capital and (ii) double the capital implied by the procedure described above. The impact of these (substantial) adjustments on average total factor productivity growth during the 1966–1990 period was (−0.1 percent, +0.1 percent) per annum in Hong Kong, Singapore, and Taiwan, and (−0.4 percent, +0.3 percent) per annum in Korea (where the pre-1966 investment series is shorter).

20. Hours of work data are drawn from other, non-Census, sources.

21. For example, 25,000 housing units in the case of the 1989 Singaporean labor force survey and less than 15,000 households in the case of the 1980 Korean economically active population survey.

the 1980 census) estimated the working population at 1,277,254. The 1990 Census, however, found that the actual working population numbered 1,537,011 (i.e., 20 percent more than reported in the previous survey). The 1991 Labor Force Survey of Singapore (using updated 1990 scaling factors) then estimated the working population at 1,524,315. In the estimates below, I confine myself to census years, treating the census results as the appropriate measure of the "population" and the survey results as a "sample," making use of these, when they contain cross tabulations that are unavailable in the census, by conforming the survey row and column totals to those given by the census. Since, over the long run, the labor force surveys track (with large variance) the census, the long-term average rates of productivity growth reported below are not dependent on this choice of sources.[22]

Finally, I should note that to improve the accuracy of my labor force estimates I have acquired thousands of pages of unpublished census tabulations from the governments of Hong Kong and Singapore, while, in the case of Taiwan, I have made use of the Chinese language area and district census tabulations, which contain additional tabulations over and beyond those reported in the summary English language volumes. These additional tabulations provide valuable information. Thus, for example, unpublished Hong Kong tabulations provide information on income by age, sex, and education cross-tabulated by class of worker (e.g., self-employed, employee, etc.). In contrast, the published tabulations rarely cross-tabulate income with class of worker. Consequently, relying on the published tabulations alone pollutes one's estimates of the returns to different types of labor input with nonlabor capital income.

C. Measuring Factor Shares

In order to estimate the share of labor and capital in total payments to factors of production, it is necessary to measure value added from the point of view of the producer. This requires removing all indirect business taxes on the value of output (including all sales and excise taxes), while retaining all subsidies

22. In fact, during the period emphasized in this paper (1966–1990) the labor force surveys actually imply faster growth in the nonagricultural working population in both South Korea and Taiwan (the labor force surveys for Hong Kong and Singapore began in the mid- to late 1970s and hence do not cover the entire period of analysis).

and taxes on factors of production (such as license fees and profits taxes), a concept of value added midway between GDP at factor cost and GDP at market prices. In the case of Hong Kong, where indirect taxes are minimal, I simply take as my measure of value added the national accounts estimates of GDP at current factor cost. In the case of the other economies, where indirect taxes are more significant, I use published and unpublished data on tax revenues to separate out the "admissible" indirect taxes, i.e., those that are part of the value of output from the point of view of the producer, and allocate them to the different economic sectors.[23]

To estimate the share of labor in total factor payments, I begin by constructing estimates of the hourly incomes of employees cross-tabulated by industry, sex, age, and education. I then use these compensation data, and my estimates of hours of work cross-tabulated by industry, sex, age, education, and class of worker, to estimate the incomes of employees and the implicit labor income of employers, unpaid family workers, and the self-employed, under the assumption that the latter earn an implicit wage equal to the hourly wage of employees with similar sex, age, educational, and industrial characteristics. To determine the share of labor in each sector, I then multiply the sectoral compensation of employees data reported in the national accounts by one plus my sectoral estimates of the ratio of implicit to explicit labor income.[24] Combining my measures of implicit and explicit income provides an estimate of sectoral labor income cross-classified by the sex, age, and educational characteristics of workers and, hence, an estimate of the share of each labor subinput in total payments to labor by sector.

Turning to capital input, under the assumption of perfect competition and constant returns to scale, I take the aggregate share of capital by sector to be simply one minus the estimated share of labor. To allocate capital income by asset type, I note that with geometric depreciation, and perfect foresight, the rental price

23. I should note that while I make this adjustment to value added for the purposes of measuring income shares, I use value added *at market prices* to measure the growth of output, under the assumption that these prices better reflect the relative scarcities and values of the component products of national output. In this sense, my approach parallels that of the national accounts, where income is typically measured at factor cost and output at market prices.

24. This rescaling using the national accounts data corrects for underreporting of income on the part of workers and, also, adjusts for labor taxes and nonmonetary compensation, all of which form a part of the cost of labor input from the point of view of the producer.

of a capital good k_i is given by[25]

$$(8) \quad P_{k_i}(T) = P_{I_i}(T-1)r(T) + \delta P_{I_i}(T) - [P_{I_i}(T) - P_{I_i}(T-1)],$$

where P_{I_i} denotes the investment price of capital good i and $r(T)$ is the nominal rate of return between periods $T-1$ and T. Under the assumption that all assets earn the same nominal rate of return, I vary $r(T)$ until total payments to capital equal my estimate of the aggregate share of capital. This yields estimates of the rental price of each asset category and, by extension, its share of payments to capital.

III. Hong Kong

Table V presents estimates of total factor productivity growth in Hong Kong. With the exception of the 1981–1986 period, when business activity was depressed by the Anglo-Chinese negotiations over the future of the colony, Hong Kong sustained total factor productivity growth rates of 2 percent or more in each of the five-year periods, averaging 2.3 percent over the 1966–1991 period as a whole. As one would expect, given the relative constancy of the post-1966 investment to GDP ratio, there is little evidence of capital deepening, with weighted capital input growing only 0.7 percent faster per annum than output during the 1966–1991 period. As the table shows, the weighting of capital and labor input raises, but only slightly, the estimated growth rate of these factors of production. In the case of capital, weighting raises the growth rate somewhat by placing a greater emphasis on the rapidly growing stock of machinery.[26] In the case of labor, adjustments for sex, hours of work, and age (prior to 1976) lower the growth rate of effective labor input, while adjustments for education and age (after 1976) raise its effective growth rate, with the net effect being slightly positive on average. Weighting is, however, of substantial importance during individual periods, for example during the late 1980s, when the stabilization of female participation rates, aging of

25. This equation can be modified to take into account taxes and depreciation allowances, and one can also relax the assumption of perfect foresight and incorporate a measure of the "expected" change in asset prices. These adjustments, however, are relatively minor compared with the basic concept embodied in equation (8); i.e., that assets with high depreciation rates and declining relative prices (such as machinery and equipment) should command comparatively higher rentals and, by extension, factor shares. In the case of the NICs, where machinery and equipment is one of the most rapidly growing elements of the capital stock, this raises the growth rate of the aggregate (weighted) capital stock.

26. See footnote 25.

TABLE V
TOTAL FACTOR PRODUCTIVITY GROWTH: HONG KONG

	Annual growth of:						
Time period	Output	Raw capital	Weighted capital	Raw labor	Weighted labor	TFP	Labor share
61–66	0.109	0.169	0.162	0.032	0.025	0.035	0.643
66–71	0.065	0.075	0.078	0.025	0.024	0.023	0.660
71–76	0.081	0.075	0.080	0.033	0.024	0.039	0.662
76–81	0.099	0.093	0.098	0.051	0.064	0.022	0.617
81–86	0.058	0.078	0.079	0.019	0.027	0.009	0.593
86–91	0.063	0.062	0.066	0.005	0.022	0.024	0.609
66–91	**0.073**	**0.077**	**0.080**	**0.026**	**0.032**	**0.023**	**0.628**

Raw inputs are the arithmetic sum of subcomponents, with no adjustment for hours of work. Weighted inputs are translog indices of factor input growth, with labor services measured by hours of work.

the labor force, and rising educational attainment, all served to increase measured labor input. These patterns are repeated in the other economies and, for reasons of space, will, in general, not be commented upon further.[27]

IV. SINGAPORE

Table VI presents estimates of total factor productivity growth in Singapore. Although the late 1960s appear to have been a period of rapid productivity growth, these gains were largely lost during the 1970s and 1980s. With weighted capital input growing an average of 2.8 percent per annum faster than output and output per unit of effective labor input growing only 3.0 percent per annum, the total factor productivity residual for the aggregate economy averages a rather low 0.2 percent per annum. Interestingly, although the growth of capital input has slowed down over time (as the investment rate has stabilized around 40 percent of GDP), the growth of human capital has accelerated. While weighted labor input grew 2.1 percent more slowly than raw labor in the late 1960s, it rose 3.0 percent faster in the 1980s (due to large increases in the age and educational attainment of the workforce). The changing role of physical and human capital accumulation in sustaining growth is reflected in the decline in the growth of output

27. Tables detailing the impact of each adjustment (age, sex, etc.) in each subperiod for the four economies are available upon request from the author.

TABLE VI
TOTAL FACTOR PRODUCTIVITY GROWTH: SINGAPORE

Time period	Annual growth of: Output	Raw capital	Weighted capital	Raw labor	Weighted labor	TFP	Labor share
Economy:							
66–70	0.130	0.119	0.134	0.054	0.033	0.046	0.503
70–80	0.088	0.122	0.140	0.050	0.058	−0.009	0.517
80–90	0.069	0.091	0.084	0.036	0.066	−0.005	0.506
66–90	**0.087**	**0.108**	**0.115**	**0.045**	**0.057**	**0.002**	**0.509**
Manufacturing:*							
70–80	0.103	0.123	0.130	0.086	0.089	−0.009	0.423
80–90	0.067	0.090	0.094	0.021	0.051	−0.011	0.385
70–90	**0.085**	**0.107**	**0.112**	**0.054**	**0.070**	**−0.010**	**0.404**

*Only covering firms recorded in the Census of Industrial Production.

per effective worker, which went from 9.7 percent in the late 1960s, to 3.0 percent in the 1970s, to 0.3 percent in the 1980s.

Although the Singaporean national accounts do not estimate capital formation by sector, it is possible to make use of the annual report on the *Census of Industrial Production* (CIP), which contains data on fixed assets, capital formation, employment, value added, output, and production costs, to derive total factor productivity growth estimates for the manufacturing sector. The CIP is the principal source of information on Singaporean manufacturing and, along with departmental data on prices, forms the basis of Singapore's Index of Industrial Production (IIP), which in turn is the basis of the national accounts estimates of the constant price growth of manufacturing value added. I regret to inform the reader, however, that (i) 40 percent or more of the output recorded in the IIP is *undeflated,* i.e., for many manufacturing subsectors the index is simply the growth of nominal output; and (ii) the Singaporean national accounts use this *undeflated output index* as their measure of the constant price growth of manufacturing value added. Nevertheless, following the lead of the Singaporean statistical authorities, I use the IIP as my measure of the growth of value added in the CIP firms.[28]

28. Although much of manufacturing output is undeflated, the reader should not jump to the conclusion that the IIP overstates the growth of the manufacturing sector. While the undeflated items include many products whose prices have probably been increasing (e.g., printing and transport equipment), they also include

As shown in Table VI, over the 1970 to 1990 period as a whole total factor productivity growth in Singaporean manufacturing averaged −1.0 percent per annum, a performance slightly below that of the aggregate economy during the same period. As in the case of the aggregate economy, the principal source of low productivity growth in Singaporean manufacturing is the combination of a slow growth of output per weighted worker[29] (1.5 percent per annum) and a rapid fall in output per unit of capital input (−2.7 percent per annum). Given the IIP's questionable (i.e., nonexistent) deflators, these estimates are clearly grossly inaccurate and are simply meant to show what can be accomplished at the sectoral level given the current state of Singaporean data.

V. South Korea

Table VII below presents total factor productivity growth estimates for South Korea. Although South Korea exhibits even more capital deepening than Singapore, with output per unit of effective capital input falling 3.4 percent per annum, the larger labor share and faster growth of output per effective worker (3.9 percent) combine to give the economy a considerably larger total factor productivity residual (1.7 percent). Productivity growth in the Korean economy appears to have improved over time, with the average 2.5 percent growth of the 1980s well above the 0.8 and 1.0 percent growth experienced during the 1960s and 1970s, respectively. Turning to the industry level analysis,[30] we see that manufacturing has had the highest average level of productivity growth. Productivity growth in manufacturing fluctuates dramati-

many electronics products, whose prices have undoubtedly been declining. Interestingly, at one point the Singaporean statistical authorities, who were concerned about their methodology, sought the assistance of the Japanese on this issue, but were assured that nondeflation of manufacturing output was also common practice in that economy (!).

29. Since the CIP does not contain any information on the age or educational characteristics of the workers in the firms surveyed, I use census data to adjust for the age and educational characteristics of the workforce under the assumption that the workers in the CIP shared the same age and education characteristics as similar sex persons reported as manufacturing workers in the census.

30. The Korean national accounts include data on capital formation by asset type and by industry, but not by asset type *and* industry. After removing residential investment from service investment (where all residential investment would occur), I estimate each sector's capital stock by cumulating the (indifferentiated) industry investment, using the average nonresidential depreciation rate in the economy (as computed from the asset type data). I then add residential capital back into the service sector. Since I am only able to differentiate capital input in services (where it is subdivided into residential and nonresidential capital), I only compute weighted capital measures for that sector.

TABLE VII
TOTAL FACTOR PRODUCTIVITY GROWTH: SOUTH KOREA

	Annual growth of:						
Time period	Output	Raw capital	Weighted capital	Raw labor	Weighted labor	TFP	Labor share
Economy—excluding agriculture:							
60–66	0.077	0.069	0.070	0.062	0.072	0.005	0.690
66–70	0.144	0.167	0.194	0.095	0.103	0.013	0.690
70–75	0.095	0.121	0.118	0.052	0.055	0.019	0.661
75–80	0.093	0.158	0.178	0.040	0.052	0.002	0.694
80–85	0.085	0.102	0.099	0.031	0.047	0.024	0.729
85–90	0.107	0.105	0.108	0.061	0.072	0.026	0.739
66–90	**0.103**	**0.129**	**0.137**	**0.054**	**0.064**	**0.017**	**0.703**
Manufacturing:							
60–66	0.123	0.105	NA	0.115	0.115	0.013	0.504
66–70	0.204	0.205	NA	0.104	0.108	0.048	0.504
70–75	0.165	0.133	NA	0.084	0.088	0.053	0.477
75–80	0.127	0.207	NA	0.047	0.062	−0.007	0.503
80–85	0.106	0.075	NA	0.019	0.039	0.051	0.547
85–90	0.118	0.147	NA	0.069	0.,082	0.008	0.572
66–90	**0.141**	**0.151**	**NA**	**0.063**	**0.074**	**0.030**	**0.521**
Other industry:							
60–66	0.127	0.188	NA	0.082	0.097	−0.012	0.537
66–70	0.176	0.258	NA	0.165	0.166	−0.033	0.537
70–75	0.085	0.104	NA	0.006	0.014	0.028	0.528
75–80	0.117	0.180	NA	0.051	0.071	0.010	0.672
80–85	0.089	0.131	NA	0.051	0.051	0.014	0.693
85–90	0.119	0.058	NA	0.040	0.050	0.066	0.674
66–90	**0.115**	**0.142**	**NA**	**0.058**	**0.067**	**0.019**	**0.624**
Services:							
60–66	0.059	0.052	0.048	0.040	0.054	0.007	0.804
66–70	0.118	0.142	0.163	0.079	0.089	0.014	0.804
70–75	0.083	0.124	0.131	0.043	0.042	0.022	0.782
75–80	0.073	0.140	0.139	0.033	0.045	0.009	0.796
80–85	0.074	0.107	0.113	0.034	0.047	0.016	0.828
85–90	0.099	0.096	0.098	0.060	0.069	0.025	0.821
66–90	**0.088**	**0.121**	**0.127**	**0.048**	**0.057**	**0.017**	**0.806**

Other industry combines mining, electricity, gas & water, and construction. Services combines wholesale & retail trade, restaurants & hotels, transport, storage & communications, finance insurance, real estate & business services, and community & social services.

cally from period to period, but averages 2 to 3 percent per decade. Productivity growth in other industry and services, while also volatile, has improved on a decade-by-decade basis, with, in particular, a dramatic rise in other industry from −2.0 percent in the 1960s to 1.9 percent in the 1970s and 4.0 percent in the 1980s.

Although the results are not reported in the table, I should note that I have estimated productivity growth in the subsectors of other industry and services, finding average total factor productivity growth rates (during the 1966–1990 period) of −1.1 percent in mining, 5.2 percent in electricity, gas, and water, 2.2 percent in construction, 3.4 percent in transport, storage and communications, and −0.1 percent in finance, insurance, real estate and business services (1970–1990).

VI. Taiwan

Table VIII presents total factor productivity growth estimates for Taiwan. With output per unit of weighted capital input falling 2.9 percent per annum, but output per effective worker rising 4.5 percent per annum (the fastest growth in this sample of four economies), Taiwan exhibits an average rate of productivity growth

TABLE VIII
TOTAL FACTOR PRODUCTIVITY GROWTH: TAIWAN

Time period	Annual growth of: Output	Aggregate capital	Weighted capital	Aggregate labor	Weighted labor	TFP	Labor share
Economy—excluding agriculture:							
66–70	0.111	0.152	0.171	0.043	0.044	0.034	0.739
70–80	0.103	0.137	0.144	0.068	0.068	0.015	0.739
80–90	0.078	0.085	0.083	0.024	0.032	0.033	0.749
66–90	**0.094**	**0.118**	**0.123**	**0.046**	**0.049**	**0.026**	**0.743**
Manufacturing:							
66–70	0.168	0.207	0.214	0.078	0.075	0.031	0.558
70–80	0.121	0.145	0.146	0.100	0.101	0.001	0.566
80–90	0.072	0.078	0.079	0.012	0.021	0.028	0.613
66–90	**0.108**	**0.128**	**0.130**	**0.059**	**0.063**	**0.017**	**0.579**
Other industry:							
66–70	0.104	0.177	0.190	0.100	0.096	−0.020	0.702
70–80	0.112	0.165	0.169	0.063	0.066	0.013	0.691
80–90	0.059	0.058	0.060	0.012	0.018	0.027	0.692
66–90	**0.088**	**0.122**	**0.127**	**0.048**	**0.051**	**0.014**	**0.695**
Services:							
66–70	0.087	0.145	0.162	0.018	0.023	0.040	0.828
70–80	0.094	0.134	0.139	0.049	0.050	0.029	0.827
80–90	0.090	0.094	0.092	0.036	0.038	0.039	0.777
66–90	**0.091**	**0.119**	**0.123**	**0.038**	**0.040**	**0.035**	**0.811**

Other industry combines mining, electricity, gas & water, and construction. Services combines wholesale & retail trade, restaurants & hotels, transport, storage & communications, finance insurance, real estate & business services, and community & social services.

comparable to that of Hong Kong (2.6 percent). As Table VIII shows, the sectoral pattern of productivity growth in Taiwan is markedly different from that in Korea. In the Taiwanese economy manufacturing and other industry appear to be productivity laggards (with average growth rates of 1.7 and 1.4 percent, respectively), while services seems to have played the role of the productivity powerhouse (with an average growth of 3.5 percent per annum). Strong differences in the performance of Taiwan and Korea are also apparent within the more detailed sectors of "other industry." Thus, over the 1966–1990 period total factor productivity rose 3.7 percent per annum in Taiwanese mining (as compared with a decline of −1.1 percent per annum in Korea) and fell −0.2 percent per annum in Taiwanese electricity, gas, and water (as compared with rapid growth of 5.2 percent per annum in Korea). Elsewhere, the performance of the two economies was more similar, with productivity in Taiwan rising 1.5 percent per annum in construction (2.2 percent Korea), 4.7 percent per annum in transport, storage, and communications (3.4 percent Korea), and 0.2 percent per annum in finance, insurance, real estate, and business services (−0.1 percent Korea).

It is important to note that part of the extraordinary performance of Taiwanese services is due to the unusual approach taken by the Taiwanese national accounts to the measurement of public sector output. Whereas most national accounts authorities deflate public sector output by the wages of different types of public sector employees, leading to an approximately zero growth in output per effective worker, the Taiwanese national accounts incorporate a "quality adjustment," allowing for the growing (unmeasurable) productivity of public sector employees. According to my estimates, between 1966 and 1990 output per effective worker in the Taiwanese public sector grew 4.4 percent per annum (6.6 percent per annum if one includes military personnel in the denominator.)[31]

31. The reason the Taiwanese national accounts make this adjustment is fairly obvious. With public sector employment stagnating and output per worker in all other sectors of the economy growing rapidly, backward extrapolation (at constant prices of the mid-1980s) using the standard deflation technique implies that the share of the government in total output was about 50 percent in 1966. A similar problem exists in the U. S. national accounts, but is ameliorated by the fact that public sector employment is expanding rapidly, while the growth of the other sectors of the economy is more gradual than in Taiwan. The solution I employ (in Table IX), is to estimate the growth of aggregate output as a Tornqvist index of the growth of the one-digit ISIC sectors (plus the public sector), with the (chain-linked) current price share of each sector taken as its weight. This approach is analogous to that used by Griliches and Jorgenson [1967] for the measurement of the output of the U. S. economy.

Table IX provides additional total factor productivity measures for Taiwan, where I have adjusted the national accounts measure of public sector output to conform to the more standard (zero growth) deflation technique. As the reader can see, this adjustment has a large impact on the aggregate nonagricultural economy, where productivity growth falls to an average of 2.1 percent, and an even stronger impact on services, where productivity growth now appears to have averaged 2.6 percent (which nevertheless remains higher than manufacturing and other industry).[32] Table IX also presents estimates for the nonpublic sector nonagricultural Taiwanese economy, which sidesteps these measurement issues by excluding the public sector from consideration.[33] I find that total factor productivity growth in the nonagricultural private sector Taiwanese economy averaged 2.3 percent per annum between 1966 and 1990. Interestingly, the two sets of estimates for the aggregate economy, both with and without the public sector, show a substantial improvement in productivity growth during the 1980s, which is reminiscent of the results for Korea.

Finally, I remind the reader that in the results reported above I have excluded the large conscript armies of Korea and Taiwan in measuring the growth of labor input in these economies on the grounds that the measured output of these military personnel (i.e., their wages) is a negligible proportion of total output. In the case of Taiwan, census sources provide information on the sex, age, and educational characteristics of military personnel. To analyze the sensitivity of my results, I make use of this information to incorporate military personnel into my estimates. As shown in Table X, including military personnel raises the rate of total factor productivity growth in the aggregate economy by 0.3 percent, to an average of 2.9 percent per annum.[34] However, if one considers

32. The reader may note that, during the 1980s the measures of output growth reported in Tables VIII and IX are identical. The Taiwanese national accounts exaggerate the growth of public sector output in every period, which should lower one's estimate of the growth rate of output. During the 1980s, however, the Tornqvist weighting of the other one-digit ISIC sectors cancels this reduction.

33. This approach is not entirely satisfactory either, since the public sector provides many unpriced services (e.g., roads and bridges) to the private sector. Variations across economies and across time in the quantity of capital and labor services provided (free of charge) by the public sector could potentially bias estimates of private sector productivity.

34. The reader may note that including military personnel lowers slightly the estimated share of labor. This follows from the fact that including the military lowers the ratio of the self-employed to the employed in the economy, implying (for a given aggregate wage bill) a lower implicit wage for the self-employed. The growth of weighted capital also varies between Tables IX and X. Different shares of labor produce different estimates of residual capital income, which changes the estimate

TABLE IX
ADJUSTMENT OF PUBLIC SECTOR OUTPUT: TAIWAN

Time period	Output	Aggregate capital	Weighted capital	Aggregate labor	Weighted labor	TFP	Labor share
	Annual growth of:						
Economy—excluding agriculture and with adjustment of public sector output:							
66–70	0.092	0.152	0.171	0.043	0.044	0.015	0.739
70–80	0.103	0.137	0.144	0.068	0.068	0.015	0.739
80–90	0.073	0.085	0.083	0.024	0.032	0.028	0.749
66–90	**0.089**	**0.118**	**0.123**	**0.046**	**0.049**	**0.021**	**0.743**
Services—with adjustment of public sector output:							
66–70	0.050	0.145	0.162	0.018	0.023	0.003	0.828
70–80	0.094	0.134	0.139	0.049	0.050	0.029	0.827
80–90	0.082	0.094	0.092	0.036	0.038	0.031	0.777
66–90	**0.082**	**0.119**	**0.123**	**0.038**	**0.040**	**0.026**	**0.811**
Economy—excluding agriculture and official public sector:							
66–70	0.120	0.173	0.187	0.069	0.073	0.012	0.699
70–80	0.112	0.141	0.145	0.072	0.073	0.017	0.693
80–90	0.080	0.083	0.081	0.024	0.033	0.033	0.715
66–90	**0.100**	**0.122**	**0.125**	**0.052**	**0.056**	**0.023**	**0.702**

military personnel as part of public sector employment, then the quality adjustment of public sector output in the Taiwanese national accounts appears to be even more exaggerated. Adjusting public sector output to standard deflation techniques yields an average total factor productivity growth rate of 2.1 percent (Table X), i.e., the same as that reported earlier (excluding military personnel) in Table IX. Similar estimates for services yield average rates of productivity growth of 3.7 and 2.3 percent, which are only 0.2 percent greater and 0.3 percent less, respectively, than the comparable figures reported earlier above. In sum, the estimates for Taiwan are not extremely sensitive to the inclusion of military personnel, particularly once one adjusts the growth of public sector output to international norms. The impact of military personnel in Korea, where they constitute a much smaller percentage of the working population, should be even smaller.

VII. Comparison with Earlier Research

This paper is by no means the first rigorous study of total factor productivity growth in the East Asian NICs. Of these, by far

of $r(T)$ (equation (8) earlier) and, by extension, the weights assigned to each capital good.

TABLE X
INCLUSION OF MILITARY PERSONNEL: TAIWAN

Time period	Output	Aggregate capital	Weighted capital	Aggregate labor	Weighted labor	TFP	Labor share
	Annual growth of:						
			Economy				
Excluding agriculture, including military:							
66–90	0.094	0.118	0.122	0.039	0.041	**0.029**	0.709
Exc. agri., inc. mil., with adj. of public sector output:							
66–90	0.086	0.118	0.122	0.039	0.041	**0.021**	0.709
			Services				
Including military:							
66–90	0.091	0.119	0.122	0.029	0.029	**0.037**	0.738
Inc. military, with adj. of public sector output:							
66–90	0.077	0.119	0.122	0.029	0.029	**0.023**	0.738

the most heavily examined has been South Korea, where, as shown in Table XI, different studies have produced a wide range of estimates. A review of the elements underlying the differing results of these studies of the Korean economy can provide some insight into the choices regarding methodology and data selection made in this paper.

The highest estimate of total factor productivity growth in the Korean economy is provided by Christensen and Cummings [1981], who report a private sector growth rate of 4.1 percent for the period 1960–1973. Christensen and Cummings do not separate out the agricultural sector and, consequently, include land input in their measure of the capital stock, which is summarized in Table XII. As the reader can see, land input and agricultural inventories accounted for 68 percent of Christensen and Cummings' measured capital stock in 1959, but only 45 percent in 1973. Thus, while their aggregate capital stock was growing by only 3.4 percent per annum, the components of greatest importance to the nonagricultural economy, i.e., nonresidential structures and equipment, were growing at rates well in excess of 10 percent per annum.[35]

35. According to Kim and Park's [1985, Tables 5-3 and 5-12] estimates, while land input accounted for an average of 87 percent of tangible fixed assets in agriculture during the period 1961–1981, it accounted for only 16 percent of similar assets in nonagricultural nonresidential business.

Unlike this paper, Christensen and Cummings also include consumer durables and nonfarm inventories in their measure of the capital stock. As noted in SectionII, I have found the inventory series published in these economies to be largely fictional. In the case of Christensen and Cummings' estimates, the ratio of nonfarm

TABLE XI
STUDIES OF TOTAL FACTOR PRODUCTIVITY GROWTH: SOUTH KOREA
(ANNUAL RATES OF TFP GROWTH)

	Period	Economy	Manufacturing
This study	1966–1990	1.7	3.0
Christensen and Cummings [1981]	1960–1973	4.1	NA
Kim and Park [1985]	1963–1982	2.7	NA
Pyo and Kwon [1991]	1960–1989	1.6	NA
Pyo, Kong, Kwon, and Kim [1993]	1970–1990	1.3	1.1
Moon, Jo, Whang, and Kim [1991]	1971–1989	NA	3.7
Dollar and Sokoloff [1990)	1963–1979	NA	6.1

NA = Not applicable.

Christensen and Cummings' capital stock estimates, when disaggregated, would probably suggest a record of high productivity growth in agriculture and moderate productivity growth in the nonagricultural economy, which would be in keeping with the results reported in this paper.[36]

Kim and Park [1985] report a somewhat lower estimate of 2.7 percent total factor productivity growth for the aggregate Korean economy during the period 1963–1982. Like Christensen and Cummings, Kim and Park include agriculture and measures of inventories. As they extend their analysis further into the 1970s, however, they derive lower estimates of total factor productivity growth, as the rapidly growing stock of structures and equipment accounts for a growing share of the capital stock. Thus, they estimate total factor productivity growth rates of 4.0 percent for 1963–1972 and 1.5 percent for 1972–1982.[37]

inventories to value added in manufacturing and wholesale and retail trade (at constant prices) falls from 1.01 in 1959 to 0.28 in 1973, i.e., a 9 percent per annum decline in the capital output ratio.

36. I should note that Christensen and Cummings make use of the 1968 National Wealth Survey to initialize their capital stock estimates, using the flow values of the national accounts to cumulate forward and backward. This choice is fortuitous. If, instead, they had used the 1977 National Wealth Survey to initialize their estimates and cumulated backwards, they would have found that, for most depreciation rates, the stock of transport equipment was negative before the early 1970s, since the gross investment in transport equipment reported in the national accounts during the years 1975–1977 alone exceeds the net stock of transport equipment at the end of 1977 as reported in the 1977 wealth survey. As noted in Section II, the stock values reported in the various national wealth surveys are completely incompatible with the flow values of the national accounts.

37. Of the difference, 1.4 percent is due to the more rapid growth in factor input, and 1.1 percent to the slower growth of output during the latter period.

TABLE XII
ESTIMATED COMPOSITION OF THE KOREAN CAPITAL STOCK
(BILLIONS OF 1970 WON)

	Nonresid. structures	Producer durables	Residential structures	Nonfarm inventories	Farm inventories	Consumer durables	Land
1959	168.6	252.0	933.3	298.1	113.1	118.8	3627.3
1973	1495.3	1305.0	1288.8	485.1	341.0	269.0	3632.5
Growth	15.6%	11.7%	2.3%	3.5%	7.9%	5.8%	0.0%

Source. Christensen and Cummings [1981, table 7].

Pyo and Kwon [1991] estimate rates of total factor productivity growth for the private sector Korean economy, 1.6 percent for the period 1960–1989, comparable to those found in this study. Pyo and Kwon also include agriculture and a measure of land input in their estimates. Like Park and Kim, Pyo and Kwon's estimates exhibit a downward trend, as the role of land input in the capital stock declines, finding rates of total factor productivity growth of 2.4 percent for 1960–1973 and 1.0 percent for 1973–1989. Despite the inclusion of land input, Pyo and Kwon's estimates for the 1960s are substantially below those of Kim and Park and Christensen and Cummings. This is largely due to the fact that Pyo and Kwon make use of very early estimates of hours of work, which show a rise of almost 30 percent in hours of work during the 1960–1963 period. Excluding this anomalous period, Pyo and Kwon estimate an average total factor productivity growth rate of 3.5 percent per annum during 1963–1973. In the estimates presented in this paper, I do not make use of these early hours data, assuming that hours of work were constant in the 1960s.[38]

38. Pyo and Kwon draw upon the *Korean Statistical Yearbook* [KSY] for hours of work estimates for 1960–1962 and the Economically Active Population Survey [EAPS] for hours of work thereafter. Between 1960 and 1962 the Ministry of Home Affairs' Labour Force Survey estimated hours of work. In mid-1962 the survey was transferred to the Economic Planning Board, where a new methodology was developed, and the survey was renamed the EAPS. The hours of work reported in the 1960–1961 editions of the KSY are drawn from the Labour Force Survey, while the hours reported in the 1962 edition are from the end-of-year 1962 EAPS. Together with the 1963 EAPS, these data imply a 13 percent rise in private sector hours of work in 1961–1962, and a further rise of 15 percent in 1963 [Pyo and Kwon 1991, table 6]. While GDP grew 9 percent in 1963, the growth of output during 1962 was only 2 percent. Furthermore, subsequent changes in hours of work (in the EAPS) are all quite gradual. It seems highly likely that these early increases are simply a statistical artifact born of linking differing surveys (the increase between 1962 and 1963, drawn consistently from the EAPS, is due to the fact that the 1962 data reported in the KSY concern only the end of the year, when hours of work are seasonally low in agriculture, whereas the 1963 data from the EAPS cover the full year).

Pyo, Kong, Kwon, and Kim [1993] estimate an aggregate rate of total factor productivity growth for the 1970–1990 period of 1.3 percent per annum. This study includes agriculture in the measure of output, but excludes both land and inventories from the capital stock measure. Consequently, Pyo, Kong, Kwon, and Kim record extremely rapid growth in the capital stock, in a manner similar to this paper.[39] Unlike this paper, however, they estimate a considerably lower share of labor, on the order of 53 percent, which explains their lower estimate of total factor productivity growth.[40] Pyo, Kong, Kwon, and Kim assume that the implicit labor income of each self-employed or unpaid worker is only one-quarter that of the average employee. In contrast, I assume that each self-employed or unpaid worker earns an implicit wage equal to that of an employee in the same sector with similar age, sex, and educational characteristics. In general, most studies of Korean productivity growth have been unwilling to make this one-for-one assumption and, consequently, have lower estimates of the share of labor.[41]

39. In both studies mentioned above, Pyo and his coauthors make use of the national wealth surveys to estimate the capital stock. However, rather than selecting any particular year to initialize the series, they, instead, endogenously determine which depreciation rate (for net capital stock) and disposal rate (for gross capital stock) is necessary to reconcile the stock values of the national wealth surveys with the flow values of the national accounts. In practice, this requires that depreciation/disposal rates are substantially negative in one period (say when linking the 1968 and 1977 wealth surveys) and substantially positive in the next (say when linking the 1977 and 1988 wealth surveys) [Pyo, Kwon, and Kim 1993, p. 117]. In essence, this amounts to a rejection of the information in the national accounts in favor of the wealth surveys. As it so happens, this (consistent) approach yields estimates of capital stock growth comparable to those found in my analysis. As noted earlier, the stock values reported in the wealth surveys are incompatible with the flow values in the national accounts. The overall growth in the capital stock implied by the two sources, is, however, roughly the same.

40. Despite the great difference in factor shares, their estimates are only slightly below mine. This is because they draw upon the Establishment Survey for their measure of labor input in the nonagricultural nonmanufacturing sectors, estimating much slower growth in this factor of production. The Establishment Survey, however, is an unscaled survey biased heavily toward manufacturing, with minimal coverage of other sectors. Thus, the 1970 Survey reported that there were only 1 million workers (in an economy with 31 million people), of which 640,000 were in manufacturing (see *Yearbook of Labour Statistics* [1971]). This survey focuses on the distribution of firm sizes, and was not designed to provide estimates of the aggregate number of workers. In Pyo and Kwon [1991] some of the same authors made use of the Economically Active Population Survey, which is the scaled labor force survey (whose results parallel the census). In earlier years, however, this source does not provide the detailed breakdown of employment by industry sought by Pyo, Kong, Kwon, and Kim in their 1993 analysis.

41. Christensen and Cummings [1981, Table 3] use the one-for-one assumption for the self-employed and a four-to-one assumption for unpaid family workers, estimating an average labor share in the private sector economy of about 64 percent. Kim and Park [1985, table 4-1] use a one-for-one imputation, adjusting, however, for wages by firm size. Since, most nonwage labor is in smaller firms, where reported wages are considerably lower, this lowers the estimated share of labor in nonresidential business to an average of 60 percent of national income (i.e., following Denison's

Turning to studies of the manufacturing sector alone, the lowest estimate here, 1.1 percent per annum for the period 1970–1990, is provided by Pyo, Kong, Kwon, and Kim [1993]. The difference between their estimate and the 2.6 percent per annum for the same period reported in this paper stems from Pyo, Kong, Kwon, and Kim's use of the Mining and Manufacturing Survey for data on employment in manufacturing. As compared with the census, the Mining and Manufacturing Survey, which is restricted to firms with five or more workers, reports about 1 percent per annum faster growth in labor input and only a very small number of self-employed and unpaid workers (implying only a small adjustment for implicit labor income). The faster growth in labor input and smaller labor share lead Pyo, Kong, Kwon, and Kim to estimate a considerably lower rate of total factor productivity growth.[42]

Moon, Jo, Whang, and Kim [1991] estimate a 3.7 percent rate of total factor productivity growth in manufacturing for the period 1971–1989. This study, however, does not include adjustments for the age, sex, or educational characteristics of the working population in its estimates of labor input. These adjustments contribute to about 1.3 percent per annum more rapid growth in labor input in my estimates for the period 1970–1990 which, when multiplied by a share of labor of about one-half, explains the bulk of the discrepancy between Moon, Jo, Whang, and Kim's results and those reported in this paper.[43]

[1979]) methods, not counting depreciation as part of factor income). Pyo and Kwon [1991, table 4], drawing upon the estimates of Kim and Park, but including depreciation in factor income, arrive at an average share of labor in the private sector economy of 51 percent. I have experimented with adjustments for implicit wages in Korea based upon firm size. I did not include these adjustments, however, because I found that the substantial impact of firm size adjustments on the labor share was largely dependent upon the relatively low wages of paid workers in firms with less than ten employees. It is unclear, however, whether these low wages reflect the low marginal product of such workers or, instead, an implicit investment by the worker in the capital of the small firm.

42. Pyo, Kong, Kwon, and Kim also make use of data in the *Occupational Wage Survey* on worker characteristics, hours, and incomes to weight by age, sex, and education, which adds about 2.3 percent per annum to their measure of the growth of labor input. The *Occupational Wage Survey* is not, however, a balanced sample. For my estimates I use census data to establish the characteristics of the working population, drawing on the *Occupational Wage Survey* for data on average hours and incomes by worker characteristic, under the assumption that the sample is more representative within cross-tabulated cells. My adjustments add 1.3 percent per annum to the growth of labor input during the 1970–1990 period, or 1.0 percent less than Pyo, Kong, Kwon, and Kim.

43. Moon, Jo, Whang, and Kim also report, separately, adjustments for the characteristics of workers and the quality of capital as a means of explaining total factor productivity growth. After these adjustments, their residual amounts to only 0.6 percent per annum. These adjustments, however, use an unusual methodology,

Finally, Dollar and Sokoloff's [1990] study of Korean manufacturing arrives at the spectacular estimate of 6.1 percent total productivity growth per annum for the period 1963–1979. This study draws its output measures from the Mining and Manufacturing Survey.[44] During the period covered by the study, the output of the firms reported in the Mining and Manufacturing Survey grew some 2.5 percent faster per annum than the output for the manufacturing sector reported in the national accounts. I have repeatedly questioned the Korean national accounts authorities on this issue, and they steadfastly maintain that the Survey is not representative of the entire manufacturing sector. Apparently their adjustment of the survey data, using alternative sources, leads to a considerably lower estimate of the growth of the manufacturing sector. If one subtracts two and a half percent excess output growth from Dollar and Sokoloff's estimates, one arrives at an estimated total factor productivity growth rate of about three and a half percent per annum which, if further adjusted for labor weighting (not included in their study), would yield an estimate close to that reported in this paper.[45]

e.g., the productivity of capital equipment is assumed to be inversely related to its age, and are not comparable to the weighting procedures used in this paper.

44. Dollar and Sokoloff actually make use of the Korean output data reported in the United Nations' Yearbook of Industrial Statistics, which, however, is drawn from the Mining and Manufacturing Survey.

45. Interestingly, the discrepancy between the Survey and the National Accounts largely disappears during the 1980s. It is possible that the earlier inconsistency stems from improvements in the Survey coverage. During the late 1960s and early 1970s, if one benchmarks the capital stock using the net fixed assets reported in one survey year and then cumulates investment, the resulting estimated capital stock is invariably less than the net fixed capital stock reported in a later year. During the 1980s, however, the annual net fixed capital and investment series are broadly consistent. Even if one wishes to restrict one's analysis to the survey firms alone, changes in survey coverage make estimation of the capital stock (which no longer depends upon flow values of investment) quite difficult. I should note that changes in survey coverage are a typical problem in the NICs, e.g., in the Singaporean Survey of Industrial Production, and that the national accounts in those countries make adjustments for this. In the case of my estimates of Singaporean manufacturing, I have restricted my analysis to the period in which the survey coverage appears to have been stable.

With regard to the other NICs, the best study, by far, is Tsao's [1982] analysis of Singapore, which estimates an average total factor productivity growth rate for the economy as a whole of −0.3 percent per annum during the 1966–1980 period and an average rate of −1.2 percent per annum for 28 manufacturing industries between 1970–1979. My earlier estimates for Hong Kong and Singapore [Young 1992] are completely superceded by the numbers reported in this paper, which make use of additional unpublished census and national accounts data.

VIII. Summary and Conclusions

Underlying the pervasive influence of the East Asian NICs on both theoretical and policy-oriented research in the economics profession lies a common premise: that productivity growth in these economies, particularly in their manufacturing sectors, has been extraordinarily high. The results of this paper, as summarized in Table XIII, suggest that this premise is largely incorrect. Over the past two and a half decades, productivity growth in the aggregate nonagricultural economy of the NICs ranges from a low of 0.2 percent in Singapore to a high of 2.3 percent in Hong Kong, whereas in manufacturing productivity growth ranges from a low of -1.0 percent in Singapore to a high of 3.0 percent in South Korea. For the purposes of comparison, Table XIV reproduces the results of two detailed cross-country studies of productivity growth, with methodologies similar to that used in this paper. As the reader can see, it is not particularly difficult to find either developed or less developed economies whose productivity performance, despite considerably slower growth of output per capita, has approximated or matched that of the NICs. While, with the exception of Singapore, productivity growth in the NICs is not particularly low, it is also, by postwar standards, not extraordinarily high.[46]

Table XV helps the reader reconcile the moderate estimates of total factor productivity growth found in this paper with the towering record of output growth in the East Asian NICs. The table begins by presenting a "naive" prior estimate of total factor productivity growth in these economies, one based solely upon observation of the growth of output per capita, the statistic most frequently encountered in broad international data sets. Assuming that the analyst's prior was that all other ratios (e.g., participation, capital-output, etc.) had remained constant, the naive estimate of total factor productivity growth would be the labor share (believed to be, say, 0.6) times the growth of output per capita.[47] These, rather extraordinary, estimates of 3.4 to 4.1 percent per annum are presented on line (1) of the table. If, in addition, the analyst was aware that participation rates had risen in these economies, the

46. In this regard it is interesting to note that Lau and Kim [1994], using an econometric approach to the study of productivity growth, find that productivity growth in the NICs over the past few decades was not significantly different from zero.

47. Recall that total factor productivity growth is simply the weighted average of the growth of output per unit of labor and output per unit of capital.

TABLE XIII
AVERAGE TOTAL FACTOR PRODUCTIVITY GROWTH
(PERCENT PER ANNUM)

	Hong Kong (1966–1991)	Singapore (1966–1990)	South Korea (1966–1990)	Taiwan (1966–1990)
Economy*	2.3	0.2	1.7	2.1
Manufacturing#	NA	−1.0	3.0	1.7
Other industry	NA	NA	1.9	1.4
Services	NA	NA	1.7	2.6
Private sector	NA	NA	NA	2.3

NA-not available. *In the case of Korea and Taiwan, agriculture is excluded. #In the case of Singapore, the years are 1970–1990.

naive estimate would be the labor share times the growth of output per worker, or, as shown on line (2) productivity growth rates of between 2.5 and 3.4 percent per annum. Refocusing the analyst's view on the nonagricultural sector (i.e., noting the slower growth of output per worker in that sector) and informing him/her about the unusual Taiwanese approach to the measurement of public sector output,[48] would lead to the estimates presented on line (3). Thus, in simply moving from the common international data on output per capita to country-specific data on output per worker in the nonagricultural sector, the analyst's naive (i.e., still assuming that other ratios remained constant) estimates of productivity growth would fall to between 2.5 to 3.0 percent per annum.

Line (4) of Table XV, which can be considered the starting point of the estimates in this paper, modifies the naive analysis to include the actual, estimated, share of labor. Since these shares are generally estimated to be above 0.6, the starting point of my analysis is somewhat above the figures on line (3). The table then shows the contribution of various factors to lowering this estimate. Weighting of labor input, i.e., taking into account changes in the age, sex, and educational composition of the workforce and adjusting for hours of work, lowers the productivity estimates by a little over half a percent in Singapore and South Korea, but by only a minimal amount in Hong Kong and Taiwan, where the common increases in educational attainment were offset by declining hours of work. With the exception of Hong Kong, capital deepening, i.e., the increase in the crude capital-output ratio brought about by the rapid rise in the investment to GDP ratio, contributes to about 1

48. See Section VI.

TABLE XIV
COMPARATIVE TOTAL FACTOR PRODUCTIVITY GROWTH
(PERCENT PER ANNUM)

Country	Period	Growth	Country	Period	Growth
Canada	1960–1989	0.5	Brazil	1950–1985	1.6
France	1960–1989	1.5	Chile	1940–1985	0.8
Germany	1960–1989	1.6	Mexico	1940–1985	1.2
Italy	1960–1989	2.0	Brazil (M)	1960–1980	1.0
Japan	1960–1989	2.0	Chile (M)	1960–1980	0.7
United Kingdom	1960–1989	1.3	Mexico (M)	1940–1970	1.3
United States	1960–1989	0.4	Venezuela (M)	1950–1970	2.6

M-manufacturing alone; developed economies are from Dougherty [1991]; less developed economies from Elias [1990].

percent per annum reduction in productivity growth. Weighting of capital input, i.e., most specifically placing a greater weight on the rapidly growing machinery stock,[49] has a slight downward effect in all four economies, with the largest effect being in Singapore, where the capital share was greatest.

As Table XV readily shows, the results of this paper derive from a confluence of small effects, each serving to chip away at the performance of the NICs, with no one estimate, in particular, being essential to the argument. One might dispute the estimates for the impact of increases in educational attainment; one might dispute the weighting of capital; or one might dispute the adjustment of Taiwanese public sector output. And yet, one must recognize that participation rates have risen; that output per worker grew more slowly in the nonagricultural sector than in the aggregate economy; that the educational attainment of the working population has risen rapidly; and that investment, particularly in machinery, has skyrocketed. Each of these elements must be taken into account, and each serves to lower one's estimate of total factor productivity growth.[50] While some of these factors have no doubt been present in other economies, in the rapidly growing East Asian NICs they are all, probably fairly uniquely, congruently present.

The results of this paper should be heartening to economists and policy-makers alike. If the remarkable postwar rise in East Asian living standards is primarily the result of one-shot increases

49. See footnote 25 above.
50. In fact, as can be seen from the literature review in Section VII, some estimates of these effects far exceed my own.

TABLE XV

RECONCILING NAIVE AND DETAILED ESTIMATES OF PRODUCTIVITY GROWTH

	Hong Kong	Singapore	South Korea	Taiwan
(1) Naive estimate: $0.6(\hat{Q} - \hat{P})$	**3.4%**	**4.1%**	**4.1%**	**4.0%**
Adjustment for participation: $0.6(\hat{P} - \hat{L})$	−0.6%	−1.6%	−0.7%	−0.8%
(2) Naive estimate: $0.6(\hat{Q} - \hat{L})$	**2.8%**	**2.5%**	**3.4%**	**3.3%**
Focus on Nonagricultural sector: $0.6[(\hat{Q}_{NA} - \hat{L}_{NA} - (\hat{Q} - \hat{L})]$	NA	NA	−0.4%	−0.4%
Adjustment of Public Sector Output: $0.6(\hat{Q}_{adj} - \hat{Q}_{NA})$	NA	NA	NA	−0.3%
(3) Naive Nonagricultural estimate: $0.6(\hat{Q}_{NA} - \hat{L}_{NA})$	**2.8%**	**2.5%**	**3.0%**	**2.6%**
(4) Using actual factor shares: $\overline{\Theta}_L(\hat{Q}_{NA} - \hat{L}_{NA})$	**2.9%**	**2.2%**	**3.5%**	**3.2%**
Weighting of labor: $\overline{\Theta}_L(\hat{L}_{NA} - \hat{H}_{NA})$	−0.3%	−0.6%	−0.7%	−0.2%
Capital deepening: $\overline{\Theta}_K(\hat{Q}_{NA} - \hat{C}_{NA})$	−0.1%	−1.0%	−0.8%	−0.8%
Weighting of capital: $\overline{\Theta}_K(\hat{C}_{NA} - \hat{K}_{NA})$	−0.1%	−0.3%	−0.2%	−0.1%
(5) Estimated total factor productivity growth	**2.3%**	**0.2%**	**1.7%**	**2.1%**

Circumflexes (ˆ) denote logarithmic growth rates. Q, P, L, H, C, and K denote output, population, workers, weighted labor input, aggregate capital, and weighted capital input, respectively. The subscripts NA and adj. denote nonagricultural and "adjusted." $\overline{\Theta}_K$ and $\overline{\Theta}_L$ denote the average (interperiod) share of capital and labor, as in equation (3) earlier.

in output brought about by the rise in participation rates, investment to GDP ratios, and educational standards and the intersectoral transfer of labor from agriculture to other sectors (e.g., manufacturing) with higher value added per worker, then economic theory is admirably well equipped to explain the East Asian experience. Neoclassical growth theory, with its emphasis on level changes in income and its well-articulated quantitative framework, can explain most of the difference between the performance of the NICs and that of other postwar economies.

APPENDIX: SOURCES

Hong Kong. Estimates of Gross Domestic Product 1966 to 1992, Estimates of Gross Domestic Product 1961 to 1975, and unpublished tabulations from the Hong Kong government[51] provided data on Gross Domestic Product (GDP) and Gross Fixed Capital Formation (GFCF) by asset type at current and constant 1980 market prices for the period 1961–1991.[52] Estimates of 1947–1960 investment by asset type were derived from data on retained imports of machinery and equipment, private construction expenditures and government capital expenditure published in *Hong Kong Statistics 1947–1967,* deflated to 1961 prices using the nonfood retail price index (the only price index available) and then linked to 1980 prices using the 61/80 deflators by asset type from the national accounts. Compensation of employees as a percentage of GDP for all years except 1966[53] were taken from current and historical issues of *Estimates of Gross Domestic Product,* data provided by the Hong Kong government, and the pilot national income survey of Hong Kong [Chang, *Report on the National Income Survey of Hong Kong, 1969*].

Estimates of the working population cross-tabulated by class of worker, sex, age, education, income, and hours of work were derived from published and unpublished census tabulations. For

51. The 1961–1975 GDP estimates lacked several components introduced in the later series (e.g., adjustment for the profit margins of real estate developers). The data provided by the Hong Kong government allowed me to adjust the old series.

52. The Hong Kong national accounts measure of GFCF includes the transfer (i.e., transactions) cost of (used and new) buildings and an adjustment for the profit margins of private real estate developers. I exclude the transfer cost from my measures of investment and capital, but include the margins of real estate developers (which I distribute across different types of private sector construction in proportion to their value).

53. Where the value was taken as the average of the 1961 and 1971 percentage shares.

earlier years hours of work and relative incomes by worker characteristic were assumed to be constant at the levels reported in the 1971 and 1976 censuses, respectively, the earliest dates for which detailed data of each type were available.

Singapore. Singapore National Accounts 1987, Yearbook of Statistics Singapore 1991, and *Economic and Social Statistics Singapore 1960–1982* provided data on GDP and GFCF by asset type at current and constant 1968 and 1985 prices for the period 1960–1990. 1947–1959 investment in buildings and structures was estimated from data on the construction of one-family equivalent residential units and retained imports of cement (linked to 1985 prices using the overlap of these data with the 1960–1962 GFCF data) taken from the monthly issues of *Malayan Statistics*. Data on compensation of employees as a percentage of output at basic values (i.e., excluding commodity taxes) for the years 1973, 1978, 1983, and 1988 from the *Singapore Input-Output Tables* were taken as the (unadjusted) share of labor for those years, with values for other years interpolated or extrapolated (at constant levels), as necessary.

Estimates of the working population cross-tabulated by industry, class of worker, sex, age, education, and income were derived from the published and unpublished tabulations of the *Sample Household Survey 1966* and 1970, 1980, and 1990 censuses. The 1966 Sample Survey and 1970 Census provide little data on the income of workers.[54] Average incomes by worker characteristic, for use in computing the income weights for these years, were derived from the *Household Expenditure Survey 1972/1973* and *Labour Force Survey 1973*. Average hours of work by industry for 1972–1990 were taken from annual issues of the *Yearbook of Statistics*, with hours of work prior to 1972 assumed to be constant at the level reported in 1972.

South Korea. National Accounts 1990 and *National Accounts 1991* provided data on GDP and GFCF at current and constant 1985 prices for the period 1970–1990 (the "New System" accounts), while *National Income in Korea 1982* provided the same data (at 1975 constant prices) for the period 1953–1981 (the "Old System" accounts). Although the (revised) New System accounts should be superior to the Old System accounts in their measures of

54. The 1966 Sample Survey collected some data on the employee income of heads of households, but the published tabulations only cross tabulate this with occupation, which is of little use in estimating the full array by industry, sex, age, and education.

output and capital formation, they unfortunately follow the 1968 United Nations System of National Accounts (SNA) in classifying capital formation by industry of ownership, rather than by industry of use (as was the case in the Old System accounts, which followed the 1953 SNA). Provided that the ratio of ownership to use remains roughly constant over time, the New System accounts still provide a reasonable measure of the growth of capital input by industry. A problem arises, however, in linking the Old and New System accounts, when the change in definition induces a dramatic change in measured capital input by sector. To ameliorate this problem, I use the Old System accounts to measure the growth of capital and output by industry for the 1960–1975 period and the New System accounts (initializing the capital stock with the 1969 Old System values) for the period 1975–1990.[55] Measures of indirect taxes, and their distribution by type, were taken from the national accounts sources and the annual issues of the *Economic Statistics Yearbook*. Data on compensation of employees by economic sector are provided in *National Accounts 1990*. Since the Old System accounts do not provide data with similar detail, I assume that the share of labor by sector in 1960 and 1966 equaled the ratio estimated for 1970.

Estimates of the working population cross-tabulated by class of worker, sex, age, and education were derived from published census tabulations, supplemented with data from the *Economically Active Population Survey* (where this contained tabulations unavailable in the census). Incomes and hours of work by worker characteristic were estimated from the published tabulations of the *Occupational Wage Survey* for the period 1971–1990. For earlier years hours of work and relative income's by worker characteristic were assumed to be constant at the levels reported in 1971.[56]

Taiwan. Unpublished data provided by the Taiwanese government included information on capital formation and output in current and constant 1986 prices, as well as compensation of

55. For the analysis of the aggregate nonagricultural economy, where the distinction between user and owner is less significant, I use the Old System for 1960–1970 and the New System (initialized with the Old System values of 1969) for 1970–1990.

56. Both the Economically Active Population Survey and the Monthly Wage Survey (reported in the *Yearbook of Labour Statistics*) contain data on hours of work (in the former case extending back to the early 1960s). The hours of work data reported by both sources, however, are uncorrelated with movements in output (and with each other), which is not the case with the occupational wage survey, which also provides considerably greater detail. In any case, no source shows any substantial trend in nonagricultural hours of work since 1966.

employees and indirect taxes. The publication *National Income in Taiwan Area of the Republic of China* summarizes much of these data. Estimates of the working population by class of worker, industry, sex, age and education were derived from English and Chinese language census sources.[57] Employee incomes by worker characteristic for the years 1976, 1980, and 1990 were estimated from the data tapes of the *Survey of Personal Income Distribution* (summarized in the publication of the same name), with labor force estimates prior to 1976 weighted with the relative wages of that year. Hours of work data from 1970 on were estimated from the results of the monthly labor force survey,[58] with hours of work for earlier years assumed to be constant at the levels reported in 1970.[59]

SLOAN SCHOOL OF MANAGEMENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

REFERENCES

Bank of Korea, *Economic Statistics Yearbook,* (Korea: Bank of Korea), annual issues.

———, *National Accounts 1991* (Korea: Bank of Korea, 1991).

———, *National Accounts 1990* (Korea: Bank of Korea, 1990).

———, *National Income in Korea 1982* (Korea: Bank of Korea, 1982).

Bishop, Yvonne M. M., Stephen E. Fienberg, and Paul M. Holland, *Discrete Multivariate Analysis* (Cambridge, MA: MIT Press, 1975).

Chang, E. R., *Report on the National Income Survey of Hong Kong* (Hong Kong: Government Printer, 1969).

Christensen, Laurits R., and Diane Cummings, "Real Product, Real Factor Input, and Productivity in the Republic of Korea, 1960–1973," *Journal of Development Economics,* VIII (1981), 285–302.

Christensen, Laurits R., Dale W. Jorgenson, and Lawrence J. Lau, "Conjugate Duality and the Transcendental Logarithmic Production Function," *Econometrica,* XXXIX (1971), 255–56.

Christensen, Laurits R, Dale W. Jorgenson, and Lawrence J. Lau, "Transcendental Logarithmic Production Frontiers," *Review of Economics and Statistics,* LV (1973), 28–45.

57. Since the national accounts data cover only the "Taiwan Area," I excluded those listed as working in Fujian province from my estimates of the working population.

58. Most recently published in the *Yearbook of Manpower Statistics,* but previously appearing in publications such as the *Monthly Bulletin of Labor Statistics.*

59. The labor force survey extends back to 1966 (the beginning of my analysis), but the reported hours of work data are in extremely crude categories (e.g., "49 hours or more"), which makes estimation of average hours of work difficult. For 1970, hours of work by detailed category are only available for the second half of the year. For the purposes of estimating changes in hours of work between 1970 and 1980, I link these data to 1980 data for the latter half of the year. I should note that the industry level earnings survey has, historically, also produced data on hours of work, reported, for example, in the *Yearbook of Earnings and Productivity Statistics* and in the *Taiwan Statistical Data Book.* These data, however, have been subject to enormous revisions, as the survey was expanded and industry definitions were changed. It is difficult to construct a consistent series from this source.

Denison, Edward F., *Accounting for Slower Economic Growth* (Washington, DC: The Brookings Institution, 1979).
Dollar, David, and Kenneth Sokoloff, "Patterns of Productivity Growth in South Korean Manufacturing Industries, 1963–1979," *Journal of Development Economics,* XXXIII (1990), 309–27.
Dougherty, John C., "A Comparison of Productivity and Economic Growth in the G-7 Countries, Ph.D. thesis, Harvard University, 1991.
Elias, Victor J., *Sources of Growth: A Study of Seven Latin American Economies* (San Francisco, CA: Institute for Contemporary Studies Press, 1990).
Griliches, Zvi, and Dale W. Jorgenson, "The Explanation of Productivity Change," *Review of Economic Studies,* XXXIV (July 1967), 249–80.
Griliches, Zvi, and V. Ringstad, *Economies of Scale and the Form of the Production Function* (Amsterdam: North-Holland Publishing Company, 1971).
Hong Kong, Census and Statistics Department, *Hong Kong Statistics 1947–1967* (Hong Kong: Government Printer, 1969).
——, *Estimates of Gross Domestic Product 1961 to 1975* (Hong Kong: Government Printer, 1977).
——, *Estimates of Gross Domestic Product 1966 to 1992* (Hong Kong: Government Printer, 1993).
Hulten, Charles R., and Frank C. Wykoff, "The Measurement of Economic Depreciation," *Depreciation, Inflation, and the Taxation of Income from Capital,* Charles R. Hulten, ed. (Washington, DC: Urban Institute Press, 1981).
Jorgenson, Dale W., Frank M. Gollop, and Barbara M. Fraumeni, *Productivity and U. S. Economic Growth* (Cambridge, MA: Harvard University Press, 1987).
Jorgenson, Dale W., and Martin A. Sullivan, "Inflation and Corporate Capital Recovery," *Depreciation, Inflation, and the Taxation of Income from Capital,* Charles R. Hulten, ed. (Washington, DC: Urban Institute Press, 1981).
Kim, Kwang-suk, and Joon-kyung Park, *Sources of Economic Growth in Korea: 1963–1982* (Seoul: Korea Development Institute, 1985).
Lau, Lawrence J., and Jong-il Kim, "The Sources of Economic Growth of the East Asian Newly Industrializing Countries," *Journal of the Japanese and International Economies,* VIII (1994), 235–71.
Moon, Hee-wha, Byung-tahk Jo, Ihn-ho Whang, and Kyung-buhm Kim, *Total Factor Productivity in Korea: An Analysis of 27 Manufacturing Industries* (Seoul: Korea Productivity Center, 1991).
Pyo, Hak-kil, and Ho-young Kwon, "Estimation of Real Factor Input and Factor Productivity in the Korean Private Sector," *Korean Economic Journal,* XXX (1991), 147–94.
Pyo, Hak-kil, Byung-ho Kong, Ho-young Kwon, and Eun-ja Kim, *An Analysis of the Causes of Growth and Productivity by Industry for the Republic of Korea, 1970–1990* (Seoul: Korean Economics Research Institute, 1993).
Republic of China, Council for Economic Planning and Development, *Taiwan Statistical Data Book* (Republic of China: Council for Economic Planning and Development), annual issues.
Republic of China Directorate-General of Budget, Accounting and Statistics, *Monthly Bulletin of Labor Statistics, Republic of China,* monthly issues.
——, *National Income in Taiwan Area of the Republic of China,* annual issues.
——, *Report on the Survey of Personal Income Distribution in Taiwan Area of the Republic of China,* annual issues.
——, *Yearbook of Earnings and Productivity Statistics, Taiwan Area, Republic of China,* annual issues.
——, *Yearbook of Manpower Survey Statistics. Taiwan Area, Republic of China,* annual issues.
——, *1988 National Wealth Survey of Taiwan Area of the Republic of China.*
Republic of Korea, Economic Planning Board, *Korea Statistical Yearbook,* annual issues.
——, *National Wealth Survey of Korea,* 1968, 1977, and 1987 issues.
Republic of Korea, Ministry of Labour, *Report on Occupational Wage Survey,* annual issues.
——, *Yearbook of Labour Statistics,* annual issues.
Republic of Korea, National Statistical Office, *Annual Report on the Economically Active Population Survey,* annual issues.
Sargan, J. D., "Production Functions," *Qualified Manpower and Economic Perfor-*

mance, P. R. G. Layard, J. D. Sargan, M. E. Ager, and D. J. Jones, eds. (London: Penguin Press, 1971).
Singapore, Department of Statistics, *Economic and Social Statistics Singapore 1960–1982* (Singapore: National Printers, 1983).
——, *Report on the Household Expenditure Survey 1972/1973* (Singapore: National Printers, 1974).
——, *Report on the Labour Force Survey* (Singapore: National Printers), various issues.
——, *Singapore Input-Output Tables* (Singapore: National Printers), 1978, 1983, and 1988 issues.
——, *Singapore National Accounts 1987* (Singapore: National Printers, 1988).
——, *Yearbook of Statistics Singapore* (Singapore: National Printers), annual issues.
Singapore, Registrar of Malayan Statistics, *Malayan Statistics* (Singapore: Government Printer, monthly issues.
Singapore, Economic Development Board, *Report on the Census of Industrial Production* (Singapore: National Printers), annual issues.
Singapore, Ministry of National Development, *Singapore Sample Household Survey 1966* (Singapore: National Printers, n.d.).
Tsao, Yuan, "Growth and Productivity in Singapore: A Supply Side Analysis," Ph.D. thesis. Harvard University, 1982.
Young, Alwyn, "A Tale of Two Cities: Factor Accumulation and Technical Change in Hong Kong and Singapore," *NBER Macroeconomics Annual 1992,* Olivier J. Blanchard and Stanley Fischer, eds. (Cambridge, MA: The MIT Press, 1992).
——, "Lessons from the East Asian NICs: A Contrarian View," *European Economic Review,* XXXVIII (1994), 964–73.