WHAT EXPLAINS THE INDUSTRIAL REVOLUTION IN EAST ASIA? EVIDENCE FROM THE FACTOR MARKETS*

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Abstract

This paper presents price-based (dual) estimates of total factor productivity growth (TFPG) for the East Asian countries. While the dual estimates of TFPG for Korea and Hong Kong are similar to the primal estimates, they exceed the primal estimates by roughly 1 percent a year for Taiwan and by more than 2 percent a year for Singapore. The basic reason for the large discrepancy for Singapore is that despite the high rate of capital accumulation indicated by Singapore's national accounts, the return to capital has remained constant in Singapore. Furthermore, changes in the risk-premium, financial market controls, taxes on capital, and public investment subsidies do not explain why the rental rate of capital in Singapore has not fallen.

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I. Introduction

The industrial revolution in several East Asian countries over the last three decades is one of the most important economic events in the postwar era. Several recent growth accounting exercises have found that their extraordinary rate of output growth was due primarily to an equally impressive rate of factor accumulation, with little due to technological progress. In Korea for example, estimates based on data from the national accounts indicate that the capital-output ratio has increased at an average rate of 3.4 percent a year from 1966 to 1990 while the rate of total factor productivity growth (TFPG) has averaged only 1.7 percent a year. To take another example, the capital-output ratio in Singapore has increased at an average rate of 2.8 percent a year from 1966 to 1990 while the rate of TFPG has averaged 0.2 percent a year.[1] Since these studies suggest that factor accumulation has been the lead actor in East Asia's growth, many economists have reached the conclusion that the industrial revolution in East Asia can largely be explained as transition dynamics in a neoclassical growth framework.[2] More broadly, these studies reinforce the message that a minimalist neoclassical growth model, perhaps augmented with human capital, is sufficient to explain why some countries are rich and others are poor.

The central point of this paper is that if the capital-output ratio in these countries has increased by the extent implied by their national accounts, the return to capital should have fallen dramatically as capital accumulation encounters diminishing returns.[3] It is useful to think about this as an accounting identity. Specifically, by dividing the share of payments to capital in total income by the capital-output ratio, we can obtain the marginal product of capital implied by the national accounts. Since the share of payments to capital in Korea and Singapore has remained roughly constant, the marginal product of capital implied by Korea's and Singapore's national accounts must have *fallen* by 3.4 percent and 2.8 percent a year respectively, the same rate as the increase in the capital-output ratio.

In the case of Korea, there is overwhelming evidence that the marginal product of capital has in fact fallen by the extent implied by the national accounts. Figure 1 plots three alternative measures of the marginal product of capital in Korea. All three measures indicate that the marginal product of capital has fallen dramatically since the 1960s. In the case of Singapore, however, it is highly unlikely that the

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[1] These numbers are from Young (1995), but also see Young (1992), Collins and Bosworth (1996), and Kim and Lau (1994) for similar estimates.

[2] See, for example, Mankiw (1995) and Krugman (1994).

[3] Young (1992) made the same observation about Singapore.

return to capital in Singapore has fallen by the magnitude indicated by the national accounts. First, with no restrictions on capital mobility in Singapore, private investors would not have been willing to continue investing in Singapore if their returns had fallen by such an extent, especially since the opportunity cost of these investments -- world real interest rates -- have more than doubled since the 1960s.[4] More importantly, the three market measures of real interest rates in Singapore presented in Figure 2 do not provide any evidence that the return to capital has fallen. This evidence suggests that while the data on investment expenditures in the Korean national accounts are reasonably accurate, Singapore's national accounts significantly overstate the amount of investment spending.

Of course, this simply reinforces what anybody who has ever worked with national accounts data knows: that the task of computing reliable national income statistics is an impossibly difficult one and that, even under the best circumstances, such statistics are riddled with large errors. As one solution to this problem, this paper presents price-based (dual) estimates of TFPG that do not rely on data from the national accounts. These price-based estimates of TFPG measure the outward shift of the *factor-price frontier* as a share-weighted average of the growth rate of real factor prices. The basic idea is that any improvement in technology that causes an outward shift of the production possibilities frontier will also cause an outward shift of the factor price frontier. In a simple model with two factors, say capital and labor, the outward shift of the factor-price frontier is simply a share-weighted average of the growth rate of real wages and the rental rate of capital. According to the dual growth accounting formula, if real wage growth is entirely due to capital accumulation, the return to capital must fall by the same magnitude as the rate of real wage growth.

These price-based estimates should be identical to the primal estimates as long as the factor price data are consistent with data from the national accounts.[5] For example, if we back out the rental rate from the national accounts by dividing the capital share by the capital-output ratio and use this estimate of the rental rate to measure the dual rate of TFPG, the resulting estimate will be exactly the same as the primal estimate. However, we can use alternative measures of the rental rate to obtain estimates of TFPG that do not rely on data from the national accounts. Again, these estimates of TFPG will be

[4] The estimates of world interest rates cited are GDP-weighted averages of real interest rates of the six major industrialized countries.

[5] See Griliches and Jorgenson (1967) for an early exposition of the equivalence between the primal and dual growth accounting methodologies, and Shapiro (1987) for an application of the dual procedure.

identical to the primal estimates if the alternative estimates of the rental rate are consistent with the rental rate implied by the national accounts. In the case of Korea for example, the paper shows that the dual estimates of TFPG are very similar to the primal estimates since the alternative measures of the rental rate in Korea have fallen by roughly the same magnitude as that indicated by the national accounts. In contrast, the dual estimates of TFPG in Singapore are significantly higher than the primal estimates because the rental rate has remained roughly constant despite the sharp increase in the capital-output ratio indicated by the national accounts.

The paper is organized as follows. Section II develops the methodology of the dual approach to growth accounting. Sections III and IV implement this methodology using data on wages and returns to capital for the four East Asian countries. Sections V and VI assesses whether changes in the risk-premium, capital market controls, taxes on capital, implicit subsidies to private capital, or errors in Singapore's national accounts can explain why the rental rate in Singapore has not fallen despite the high rate of capital accumulation indicated by the national accounts. The last section concludes

II. The Dual Approach to Growth Accounting

This section derives the dual growth accounting procedure from the basic national income accounting identity that national output is equal to payments to the factors of production.[6] The dual growth accounting decomposition can also be derived from the properties of the cost function of any production function. The advantage of using the national income identity rather than the cost function approach is that the national income identity derivation makes it explicitly clear that the equivalence of the dual and primal procedures do not depend on any assumptions about the underlying technology or market structure.

Let's begin with the basic national income accounting identity that national output is equal to the payments to the factors of production, say capital and labor:

$$Y = rK + wL. \tag{1}$$

Differentiating both sides of equation (1) with respect to time and dividing by Y, we get:

$$\hat{Y} = s_K \cdot \left(\hat{r} + \hat{K}\right) + s_L \cdot \left(\hat{w} + \hat{L}\right), \tag{2}$$

[6] I thank Susanto Basu and John Fernald for this derivation.

where $s_K \equiv rK/Y$ and $s_L \equiv wL/Y$ are the factor income shares.[7] By placing the terms involving the growth rates of factor quantities on the left-hand side of the equation, we get:

$$\hat{Y} - s_K \cdot \hat{K} - s_L \cdot \hat{L} = s_K \cdot \hat{r} + s_L \cdot \hat{w}. \quad (3)$$

The primal estimate of the Solow residual is the growth rate of output after subtracting the share-weighted growth in factor quantities:

$$SR_{primal} = \hat{Y} - s_K \cdot \hat{K} - s_L \cdot \hat{L}. \quad (4)$$

The dual measure of the Solow residual is the share-weighted growth in factor prices:

$$SR_{dual} = s_K \cdot \hat{r} + s_L \cdot \hat{w}. \quad (5)$$

It can be seen that SR_{primal} is the expression on the left side and SR_{dual} is the expression on the right side of equation 3. Hence, with only the condition that output equals factor incomes, we have the result that the primal and dual measures of the Solow residual are equal. No other assumptions are needed for this result: we do not need any assumptions about the form of the production function, bias of technological change, or relationship between factor prices and their social marginal products. We do not even need to assume that the data is correct. For example, if the capital stock data is wrong, the primal estimate of the Solow residual will be clearly be a biased estimate of aggregate technological change. However, as long as the output and factor price data are consistently wrong, the dual measure of the Solow residual will be exactly equal to the primal measure and consequently, equally biased.

The two measures of the Solow residual can differ when national output exceeds the payments to capital and labor. Suppose, for example, that the national income accounting identity is given by $Y = rK + wL + \pi$.[8] When this is the case, the difference between the dual and primal estimates depends on how the capital share is measured. Typically, since we have better data on labor income, the capital share is measured as the residual of labor income. When π is positive, this estimate of the capital share is equal to the "true" capital share plus the profit share. When this biased estimate of the capital share is used to calculate the dual and primal estimates of the Solow residual, the primal estimates will exceed the dual

[7] In this paper, a circumflex over a variable denotes the proportional growth rate.

[8] There are (at least) two possible interpretations of π. One interpretation is that firms have market power and π are their profits. An alternative interpretation is that π are the payments to the factors of production omitted from the growth accounting exercise.

estimates by $s_\pi \cdot (\hat{s}_\pi - \hat{s}_k)$ where $s_\pi \equiv \pi/Y$ and $s_K \equiv rK/Y$.[9] Therefore, as long as the data on factor prices are consistent with those from the national accounts, the two sets of TFPG estimates will be the same as long as the growth rate of the capital share is equal to that of the profit share. Since the sum of the capital share and the profit share in all the four East Asian countries has remained roughly constant since the 1960s, it is unlikely that the capital share and the profit share have changed by enough to result in a significant difference between the dual and primal estimates, particularly with a standard estimate of the profit share of roughly 5 to 10 percent of national income.[10] Therefore, any difference between the dual and primal estimates of TFPG is probably not due to imperfect competition or omitted factors of production, but rather due to inconsistencies between the data from the national accounts and the factor price data.

The dual procedure can be easily extended to allow for different types of labor and capital. To do this, I assume that the aggregate rental price of capital is itself a weighted average of the rental price of different types of capital:

$$\hat{r} = \sum_{i=1}^{n} s_{k_i} \cdot \hat{r}_i \tag{6}$$

where s_{k_i} is the share of payments and $\hat{r}_i$ is the growth rate of the rental price of type i capital. The aggregate wage is also a weighted average of the wage of different types of workers:

$$\hat{w} = \sum_{j=1}^{m} s_{L_j} \cdot \hat{w}_j \tag{7}$$

where s_{L_j} is the share of payments and $\hat{w}_j$ is the growth rate of wages of a worker of type j. These last two equations adjust for quality improvements in the aggregate capital and labor stocks by separately measuring the real price of *each* factor input before aggregating the prices of the different factor inputs. For example, one possible explanation of higher real wages in East Asia is the improvements in labor quality, particularly due to rising educational levels. Equation (7) adjusts for this by measuring the wages of a *given* quality of labor across time for many different types of workers. Although average real wages in East Asia have increased because the average worker is better

[9] Taking the time derivative of both sides of this new national income accounting identity and dividing by Y yields $\hat{Y} = s_K \cdot (\hat{r} + \hat{K}) + s_L \cdot (\hat{w} + \hat{L}) + s_\pi \cdot \hat{\pi}$, where $s_L \equiv wL/Y$ is the labor share, $s_K \equiv rK/Y$ is the "true" capital share, and $s_\pi \equiv \pi/Y$ is the profit share. When we use 1-wL/Y (instead of s_K) as the capital share for the dual and primal estimates, the relationship between the two estimates of the Solow residual is $SR_{primal} = SR_{dual} + s_\pi \cdot (\hat{s}_\pi - \hat{s}_K)$.

educated, the growth rate of aggregate wages in equation (7) will be zero as long as the real wage of a worker with a given level of education does not change. The difference between the growth rate of average wages and the wage index in equation (7) can therefore be interpreted as the contribution of changes in labor quality.

Finally, the dual framework for estimating TFPG assumes that producers are in a long-run equilibrium in which the quantities of factor inputs are at optimal levels. While this is a reasonable assumption in the long run, adjustment costs due to temporary shocks can drive a wedge between the rental rate and the marginal product of capital and thus bias the dual TFPG estimates in the short run. However, while adjustment costs are clearly important for short run estimates of TFPG, they should not affect estimates of TFPG over the 20 to 30 year time period analyzed in this paper. Therefore, the estimates presented in this paper do not make any corrections for adjustment costs.

III. Measuring Factor Prices and Factor Shares

The dual rate of TFPG is calculated as a weighted average of the growth rate of different types of capital goods and wages of different types of workers, where the weights are the shares of payments to each factor.[11] Real wages of workers are differentiated by sex and by educational attainment (from four to six educational categories, depending on the country) computed from household surveys and the population censuses in the four countries. To compute the growth rate of real wages, I subtract the growth rate of the GDP deflator from the growth rate of nominal wages of each type of worker. The GDP deflator may be an inaccurate measure of the price of aggregate output, but the resulting bias in the growth rate of real wages in the dual calculation has the same effect on the growth rate of real output in the primal exercise.

Turning to the rental price of capital, I calculate the rental price of five categories of capital goods: residential buildings, non-residential buildings, other construction, transport equipment, and machinery equipment. The rental price for capital good j is based on the standard Hall-Jorgenson (1967) rental price formula:

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[10] Since the labor share has remained roughly constant in all four countries, the sum of the capital and profit share (which is one minus the labor share) must have remained unchanged as well.

[11] The appendix provides additional details on the data sources.

(8) $$\frac{r_j}{p} = \frac{p_j^k}{p} \cdot \left(i - \hat{p}_k + \delta_j\right),$$

where p_j^k / p is the relative price, $\hat{p}_j^k$ the inflation rate, and δ_j the depreciation rate of type j capital, and i is the nominal interest rate. This equation states that the rental rate of capital good j is equal to the product of its relative price and the real interest rate plus the depreciation rate. When the relative price of capital is 1, equation (8) reduces to the familiar expression that the real rental price of capital is the real interest rate plus the depreciation rate.

To calculate the real rental price of each capital good j, I need estimates of the relative price of capital (p_j^k / p), the depreciation rate (δ_j), and the real interest rate (i- $\hat{p}_j^k$). The relative price of capital is measured as the ratio of the investment goods deflator of each capital good over the GDP deflator from the national accounts. The investment goods deflator may be inaccurate and result in misleading estimates of the real rental price of capital, but the same error will be reflected in the growth rate of the real capital stock in the primal exercise. Second, the depreciation rates of the five capital goods are taken from Hulten and Wyckoff (1981).[12] The depreciation rate could also be incorrect, but the estimated growth rate of the rental price of capital will be unaffected as long as the gap between the depreciation rate and its true value does not change over time. When this is not the case, the resulting bias in the growth rate of the rental price will be exactly the same as the error in the growth rate of the real capital stock.

Third, I also need estimates of real interest rates to calculate the real rental price of capital. I use two methods to do this. One approach is to assume that that all assets earn the same nominal return and subtract the rate of asset price inflation from this nominal rate. Another approach is to use a market-determined real rate of return such as the earnings price ratio. I discuss each approach in turn.

To estimate the real interest rate by subtracting the rate of asset price inflation from a nominal interest rate, I need the nominal returns of an asset whose returns are perfectly correlated with the returns of the country's capital stock. Since I do not have such an asset, I use the nominal returns of a

[12] The depreciation rates are 1.3 percent for residential buildings, 2.9 percent for non-residential buildings, 2.1 percent for other construction, 18.2 percent for transportation equipment, and 13.8 percent for machinery equipment.

number of different assets.[13] Although the returns on these assets are not perfectly correlated with those of a representative basket of the country's capital stock, as long as their betas and corresponding risk premium do not change over the 20-30 year time period analyzed in this paper, the *growth* rate of their nominal returns will equal the *growth* rate of nominal returns on a representative basket of the country's capital stock. In addition, I have several measures of nominal interest rates for each country, ranging from lending rates of commercial banks to interest rates in informal financial markets, and can check the sensitivity of the dual estimates to these different measures. To calculate a real interest rate from these nominal interest rates, I assume perfect foresight and subtract the average *ex-post* rate of asset price inflation from the nominal interest rate.[14]

I also estimate real interest rates by using market-determined real interest rates. As measures of the real interest rate, I use the earnings-price ratio of firms in the stock markets of Hong Kong and Singapore and direct estimates of the return on equity from the firm-level records in the Singapore Registry of Companies. The earnings-price ratio in Hong Kong and Singapore measure the return to capital of firms listed in the stockmarkets in these two economies, but these firms are clearly not a representative sample of firms in these economies. In contrast, the estimates of the return on equity in Singapore are compiled from annual reports filed by every incorporated business in Singapore, with the exception of partnerships and self-proprietorships, and thus provide a reasonably accurate measure of the aggregate return to capital in Singapore. More generally, the earnings-price ratio and the return to equity are good estimates of the real cost of capital when the companies are only able to invest in projects that yield the market rate of return. However, they will understate the real cost of capital if the firm is expected to make investments that yield returns above the market rate. On the other hand, there are also firms whose investments are expected to yield returns that are below the market rate that should compensate for the firms that have extremely profitable investment opportunities.

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[13] Specifically, I use the loan rate in informal financial markets, the 1-year time deposit rate, the loan rate on secured loans, and the 3-month treasury bill yield in Taiwan. For Hong Kong, I use the call money rate and the best lending rate of the Hong Kong and Shanghai Bank. For Korea, I use curb market loan rate, the 1-year time deposit rate, the discount rate on commercial bills, and the commercial bond yield. In Singapore, I use the average lending rate of commercial banks.

[14] To check for sensitivity, I also estimate the *ex-ante* expected rate of asset price inflation by regressing the realized rate of asset price inflation on lags of the inflation rate and other explanatory variables. The resulting estimates of TFPG using the ex-ante expected real interest rates are very similar to those using ex-post real rates and are therefore not presented in the paper (but are available upon request from the author).

Turning to the factor shares, the share of payments to different types of worker (again, differentiated by sex and education) is calculated as the product of the average wage and the number of workers in each category divided by total payments to labor.[15] To compute the shares of payments to each type of capital, I first estimate the stock of the five types of capital using the standard perpetual inventory method with geometric depreciation. The published investment series begins in 1951 for Taiwan, in 1953 for Korea, in 1960 for Singapore, and in 1961 for Hong Kong. I assume that the growth rate of investment before the beginning of the investment series is equal to its average growth rate in the first five years the data is available. The capital stock at the beginning of the period is thus computed as $K_i = I_i / (g_i+\delta_i)$ where I_i is quantity of investment at the beginning of the period, g_i is the growth rate of investment in the first five years, and δ_i is the depreciation rate. Given a long investment series and a positive rate of depreciation, the estimated capital stock is relatively insensitive to this assumption. I focus my analysis on the post-1966 period, so I have 6 to 16 years of investment data to establish the capital stock. To estimate the share of payments of each type of capital, I take the product of the nominal rental price of capital and the estimated capital stock and divide by the total payments to capital.

III. Dual Estimates of TFPG

This section presents the dual estimates of TFPG for the four East Asian countries. As a reminder to the reader, the dual rate of TFPG is calculated as a weighted average of the real rental price of five types of capital and real wages of workers differentiated by sex and education, where the weights are the shares of payments to each factor. As previously mentioned, in the cases in which the real interest rate is computed by subtracting the inflation rate from a nominal interest rate, the estimates presented in this section uses the ex-post realized real interest rate. To calculate the growth rate of rental rate, I divide the point estimate of the time trend of the sum of the real interest rate and the depreciation rate by its average value and add this to the average growth rate of the relative price of capital. Since the point estimates of the time trend are relatively insensitive to different initial and end points, the dual estimates do not significantly change when different initial and terminal years are used for the analysis.

[15] I use Young's (1995) estimates of the aggregate share of capital and labor in total income.

Table 1 presents the estimates of dual TFPG in South Korea. As noted earlier, the dual TFPG estimates in South Korea are roughly the same as the primal estimates. Although real wages (in quality adjusted units) grew at a rate of over 4.4 percent from 1966 to 1990, the dual rate of TFPG is much lower due to the steep decline in the return to capital over this period (see Figure 1). Nominal interest rates have fallen steadily over this period. Without any appreciable decline in the rate of asset inflation, the fall in the nominal interest rates translates into a decrease in real interest rates. The fall in real interest rates was accompanied by a decline in the relative price of capital (averaging 1.4 percent a year from 1966 to 1990), which further decreases the real rental price of capital. Using the one-year time deposit rate as the nominal interest rate, the growth rate of TFP averages 2.3 percent a year from 1966 to 1990. Using the discount rate on commercial bills yields a slightly lower rate of TFPG (2.2 percent a year).

The main problem with using the one-year deposit rate and the discount rate on commercial bills as nominal interest rates is that these rates were set by government fiat for a significant period of time. A solution is to use the interest rate in informal financial markets that were not regulated by the government to calculate the real return to capital. The interest rate in this unregulated market, the curb market loan rate, is always significantly higher than the other interest rates (see Figure 1), but the percentage decline in the real return to capital is only slightly higher (-4.8 percent a year) when the curb market loan rate is used as the nominal interest rate. Therefore, the rate of TFPG (1.7 percent a year) is slightly below the two other dual estimates and almost identical to the primal estimate of TFPG.

Turning to Singapore, the dual estimates of TFPG (shown in Table 2) differ dramatically from existing primal estimates, due mainly to the fact that the rental rate of capital has not fallen. When the average lending rate is used to compute the real return to capital, the rental rate *increases* at an average rate of 1.6 percent a year from 1968 to 1990.[16] Over the same period, quality-adjusted real wages increased by 2.7 percent per year. Since the labor share is roughly 50 percent, this implies that the rate of dual TFPG averaged 2.7 percent a year from 1968 to 1990, which is 3 percentage points higher than

[16] The data on the average lending rate is first available in 1968 from the *Yearbook of Statistics Singapore*, which is why I begin my analysis in 1968 when using the average lending rate to calculate the rental price of capital. The return to capital computed from the average lending rate in Figure 2 combines the data from this source with comparable data on bank lending rates from Lee (1974) for the period prior to 1968 (additional details are provided in the appendix).

the primal estimate. Another measure of the return to capital in Singapore is based on estimates of the return to equity from Singapore's Registry of Companies. As previously mentioned, this measure is compiled from annual reports filed by every incorporated business in Singapore with the Registry of Companies (with the exception of partnerships and self-proprietorships). Using the return to equity from this source as the real interest rate, the (quality adjusted) real return to capital falls by an average of 0.5 percent a year from 1971 to 1990. The combination of an annual 0.5 percent decrease in the real rental price with an increase in (quality-adjusted) real wages by 3.1 percent a year from 1971 to 1990 yields an average rate of TFPG of 1.4 percent a year, which exceeds the dual estimate by 2.1 percentage points. Lastly, we obtain the highest rate of dual TFPG (2.7 percent a year) when the earnings-price ratio of firms in the stock market of Singapore is used as the real return to capital.

I should note that while the three estimates of the time trend of real interest rates in Korea are statistically significant, this is not the case for the three estimates of the time trend of the real interest rate in Singapore. Since the trend of real interest rates in Singapore is not statistically different from zero, an alternative approach is to assume that the sum of the real interest rate and the depreciation rate in Singapore has remained constant. With this assumption, the growth rate of the rental rate is simply the average growth rate of the relative price of capital. Using this as an estimate of the growth rate of the rental rate, we obtain a higher dual estimate of TFPG for one of the three estimates and a lower estimate for remaining two estimates (see Table 2, Panel B). Nevertheless, all three alternative estimates of the dual rate of TFPG are still significantly higher than the primal estimates, and consistently exceed these estimates by about 2 percentage points a year.

Table 3 presents the dual estimates of TFPG for Hong Kong. These estimates are virtually identical to the primal estimates since the rental rate has remained roughly constant over the same period of time in which the capital-output ratio computed from Hong Kong's national accounts has also been constant. Using the prime lending rate (from the Hong Kong and Shanghai Bank) as the nominal return to capital, the real rental price of capital increases by merely 0.3 percent a year from 1966 to 1991. After adjusting for labor quality, real wages increased by 4 percent a year. With a labor share of 0.63, the dual rate of TFPG averages 2.7 percent a year. Turning to stock market indicators of the return to capital, the earnings-price ratio suggests that the rental price of capital fell at an average rate of 0.4 percent a year from 1973 to 1991. Since (quality adjusted) real wages grew by 4.2 percent a year, the

estimated rate of dual TFPG is 2.4 percent a year from 1973 to 1991 when the earnings-price ratio is used as a real interest rate.

Table 4 presents the estimates of TFPG for Taiwan.[17] The average rate of dual TFPG from 1966 to 1990 is the highest of the four countries. The estimated rates of TFPG are relatively insensitive to the choice of nominal interest rates, ranging from a low of 3.5 percent a year (using the interest rate on secured loans) to 3.7 percent a year (using the loan rate in informal financial markets). Although the interest rate on secured loans and the one-year deposit rates were subject to government controls until the early 1980s, the lending rate in informal financial markets yields very similar estimates of TFPG (3.7 percent a year). Lastly, the government issued treasury bills for the first time in 1973. Using the yield on 3-month treasury bills as the nominal return to capital, the estimated dual rate of TFPG averages 3.5 percent a year from 1973 to 1990.

The dual estimates in Taiwan also exceed the primal estimates, albeit by less than in Singapore. In contrast to Singapore, the discrepancy between the dual and primal estimates of TFPG in Taiwan is not due to differences between the measures of the rental price of capital shown in Table 4 and that implied by national accounts. The four estimates of the rental price of capital shown in Table 4 suggest that the marginal product of capital fell from 1966 to 1990, which corroborates the data from the national accounts that indicate an increase in the capital-output ratio over the same time period. Instead, the gap between the two measures of TFPG is entirely due to an inconsistency between the growth rate of real wages computed from household surveys in Taiwan and that implied by the national accounts. Specifically, since the labor share in Taiwan has remained roughly constant, the growth rate of real wages implied by the national accounts is simply the growth rate of output per worker. Table 5 shows that the growth rate of real wages in Taiwan (computed from household surveys) exceeds the growth rate output per worker (computed from the national accounts) by 1.3 percent a year, which explains almost all the discrepancy between the dual and primal estimates of TFPG for Taiwan.[18]

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[17] Young notes that the Taiwan's national accounts incorporate a "quality adjustment" to output of public sector employees. The growth rate of TFP is therefore smaller once an adjustment is made to the measure of public sector output to conform to the standard (zero quality adjustment) measurement technique. To account for this in the dual procedure, I adjust the growth rate of the GDP deflator to remove the "quality adjustment" of public sector output. The growth rate of the adjusted GDP deflator is 0.5 percent higher than that of the unadjusted deflator.

[18] The figures presented in Table 5 are not adjusted for changes in labor quality and thus differ slightly from the figures presented in Tables 1-4 (which do adjust for changes in labor quality).

The natural question is whether the household survey (the *Survey of Personal Income Distribution*) used for the estimates presented in Table 4 overstate the growth rate of real wages in Taiwan. An alternative source of data on wages by educational attainment in Taiwan is the *Survey of Manpower Utilization*, a household survey conducted annually since 1976. I used the *Survey of Personal Income Distribution* for the estimates presented in this paper since it provides more comprehensive and higher quality measures of income than the *Survey of Manpower Utilization*.[19] Nonetheless, the growth rate of real wages from 1976 to 1990 from the *Survey of Manpower Utilization* is similar to estimates from the *Survey of Personal Income Distribution.*[20] The evidence from these two household surveys suggests that the discrepancy between the dual and primal estimates for Taiwan is probably due to an underestimate of real output growth by Taiwan's national accounts.

Finally, it's worth mentioning that the growth rate of output per worker is virtually identical to the growth rate of real wages in Singapore, Hong Kong, and Korea (see Table 5). Since the labor share in these three economies has not changed, this indicates that any discrepancy between the primal and dual estimates for these countries is largely due to the inconsistency between market measures of the rental rate used in the dual analysis and the rental rate implied by the national accounts.[21]

V. Has the Return to Capital in Singapore Fallen?

To recapitulate, the dual estimates for Korea are very similar to the primal estimates since the market measures of the return to capital are consistent with the Korean national accounts -- every estimate of the rental rate shows that marginal product of capital in Korea has fallen very sharply. Similarly, the market measures of the rental rate in Hong Kong and Taiwan are also broadly consistent with the national accounts. In contrast, while the Singaporean national accounts indicate that the marginal product of capital has fallen sharply, the three measures of the rental rate indicate no such

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[19] Specifically, the *Survey of Personal Income Distribution* provides data on income from secondary jobs as well as that from the person's primary job, and also provides data on annual income rather than monthly income.

[20] These estimates are not presented in the paper, but are available upon request.

[21] Young (1998) argues that the estimates of real wages used in this paper are problematic because they are derived from "different weighting procedures, combining data from different sources, covering different concepts of income in different years." (p. 42). However, these problems are also present in the national accounts. In addition, Table 5 shows that with the exception of Taiwan, the growth rate of output per worker from the national accounts is virtually identical to the growth rate of real wages computed from household surveys and population censuses in these

trend.[22] The large gap between the dual and primal estimates of TFPG for Singapore is due to this inconsistency between the national accounts and the estimates of the rental rate.

This section considers four reasons for why the estimates of the rental rate of capital used in the dual estimates may not be good estimates of the marginal product of capital in Singapore. The two most serious potential problems with the dual estimates are that they do not incorporate changes in taxes associated with capital and that they do not account for implicit subsidies to private investment provided by public investment expenditures. Another potential problem is that there may have been a large risk-premium in Singapore in the late 1960s and early 1970s that are not captured by the estimates of the rental rate. The last potential problem is that nominal lending rates in Singapore were regulated by a bank cartel until the 1970s. Therefore, the rental rate based on the nominal lending rate will be a biased estimate of the marginal product of capital. This section assesses these arguments and ultimately concludes that they do not explain the large discrepancy between the rental rates used in the dual analysis and the return to capital implied by the national accounts in Singapore.

1. Taxes on Capital

I first consider the argument that the dual measures of the return to capital are biased since they do not incorporate changes in taxes on capital income. Many observers have argued that due to a gradual fall in the corporate tax rate, increases in depreciation allowances, and a plethora of other tax incentives over the last two or three decades, the effective tax on capital in Singapore may have fallen since the 1960s.[23] However, while it is true that tax incentives have apparently become more generous over the last few decades, it is unclear whether most firms benefited from these incentives. Tax incentives for

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countries. Therefore, if the growth rate of output per worker is used as an estimate of the growth rate of real wages to calculate the dual rate of TFPG, the resulting estimates will be very similar to those presented in this paper.

[22] Young (1998) points out that the publication *The Singapore Economy: New Direction* (1986, Chart 2-7) presents estimates of the return to capital supplied by Singapore's Department of Statistics that appear to indicate that the marginal product of capital has fallen since the early 1970s. However, these estimates of the return to capital are backed out of the national accounts; that is, they are obtained by dividing the payments to capital in national income by an estimate of the capital stock computed from data on investment expenditures from the national accounts. As previously discussed, since the national accounts indicate that the capital-output ratio has increased sharply, the return to capital implied by the national accounts must have fallen by the same amount.

[23] See for example, Ermisch and Huff (1999) and Young (1998).

most foreign firms are negotiated individually with each firm by the Singaporean government (and details of each agreement are not released to the public). Therefore, while the *maximum* tax rate on capital has fallen over the last few decades, these rates are simply not relevant for many firms in Singapore. In other words, the critical question is whether the tax rate on *aggregate* capital has fallen over the last few decades.

One way to check whether the tax rate on aggregate capital has fallen is to look at aggregate data on the sources of tax revenues in Singapore. If taxes on capital have steadily fallen, then the share of revenues from capital taxation should also have fallen. Instead, the aggregate tax data indicates that the share of revenues from taxes on capital has increased. From 1966 to 1990, the share of corporate taxes in total tax revenues rose from 26 percent to 48 percent while the combined share of corporate and property taxes in total tax revenues increased from 58 percent to 64 percent (see Figure 3). As a fraction of GDP, the share of corporate taxes increased from 2 percent in 1966 to 5 percent by 1990. While the average property tax has fallen, the average corporate tax rate has more than doubled since the 1960s. This evidence suggests that if anything, the tax on aggregate capital has *increased*, not decreased, since the late 1960s.

2. Stalinist Forced Investment

While the tax rate on capital appears to have increased over the last few decades, private investment may have been implicitly subsidized by the large amount of public investment spending.[24] According to this argument, the return to *private* investment may not have fallen thanks to these subsidies, but the return to aggregate capital has fallen due to a decline in the return to *public* capital. This section presents a two-tracked argument against the forced investment hypothesis. First, I show that the government has used only a small fraction of these funds for public investment projects and has largely invested these resources abroad. Therefore, despite the large share of national savings under the government's control, investment spending is primarily by private investors. In turn, since payments to foreign capital are large (roughly 25 percent of GDP in the 1980s), it is clear that private investors are predominantly foreign multinationals. With such a large share of the capital stock owned by private investors, the necessary subsidies to prevent the return to private investment from falling are simply

enormous. A simple calculation shows that the required subsidies would have amounted to 55 percent of GDP by 1990, which is clearly impossible.

I start by analyzing the public sector's control over national savings in Singapore. First, the central government runs large surpluses of current expenditure over current revenue. In addition, a large number of off-budget government corporations and statutory boards also earn large profits. The combined current surpluses of the central government and the main largest statutory boards are large, increasing from 3.6 percent of GDP in 1968 to about 20 percent of GDP by the 1980s (see Figure 6).[25] Second, in addition to its budget surpluses, the government also borrows extensively from the Central Provident Fund (CPF), which is required by law to hold to hold the majority of its assets in the form of government securities.[26] The CPF has become one of the most important vehicles for private sector savings, accounting for 11 percent of GDP at its peak in 1985 (see Figure 4). The CPF, along with the government's budget surpluses, form a large pool of savings the government could have potentially used for public investment projects.

However, despite the large pool of savings under the government's control, the government has used only a fraction of these resources for public investment projects (Figure 5). Figure 6 plots the government's domestic borrowing, primarily from the CPF fund, and the public sector's budget deficit net of public investment expenditures (this is called the *overall* budget deficit by the Singaporean statistical authorities). It can be seen that the government's domestic borrowing is always larger than the overall public sector deficit. In other words, the government has consistently borrowed far more than what it has needed to finance public investment. The government relied most heavily on domestic borrowing to finance public investments from 1967 to 1977, but even during this period, only 40 percent of domestic borrowing was used for public investment (see Figure 6). In the 1980s and

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[24] This is, for example, the argument made by Young (1992).

[25] From 1974 to 1988, the largest statutory boards are the Housing & Development Board, Jurong Town Corporation, Public Utilities Board, Port of Singapore Authority, Telecommunications Authority of Singapore, Urban Redevelopment Corporation, and Sentosa Development Corporation. The estimates also include the surpluses of the Economic Development Board, the Singapore Telephone Board, and the Singapore Tourist Promotion Board from 1967 to 1973 and the surpluses of the Mass Rapid Transit Corporation, the Civil Aviation Authority of Singapore, and the Singapore Broadcasting Corporation from 1989 to 1991.

[26] The CPF is Singapore's Social Security System. It is funded by payroll tax, currently at 40 percent of the employee's income divided evenly between the employee and the employer. Before they retire or leave the country, participants are allowed to use their fund balances to purchase housing or shares in certain government companies, but otherwise are not permitted to withdraw their balances.

particularly after 1983, the current budget surpluses of the government have been large enough to finance its public investment expenditures, eliminating the need to borrow from the CPF. Despite its large budget surpluses, even net of investment expenditures (again, this is the *overall* budget deficit), the government continued to borrow large sums from the CPF in the 1980s.

These large overall budget surpluses, along with the proceeds from the security sales to the CPF, were deposited with the Monetary Authority of Singapore (MAS), Singapore's central bank. To counter this enormous liquidity drain, the MAS purchased foreign assets.[27] Since 1981, these foreign assets have been managed by the Government of Singapore Investment Corporation (GIC). The GIC does not provide the public with any information about its investments, but we can obtain a rough estimate of the government's earnings from the GIC's foreign assets from other data in the national accounts (Figure 7).[28] As can be seen, the earnings from these foreign assets are large, amounting to roughly 14 percent of GDP in 1990. A conservative estimate is that Singapore's public sector's foreign assets were worth 83 billion US dollars in 1991, roughly twice the size of Singapore's GDP that year.[29] As a further check on these figures, we can estimate the rate of return on the GIC's foreign assets in 1990-91 by dividing the estimated earnings on foreign assets by the estimated value of these assets. This calculation results in a rate of return of 7 percent, which is only slightly higher than the earnings-price ratio of the stocks in the S&P 500 in 1990 (6.47 percent).

The bottom line is that while the CPF may have been an instrument of forced savings, it has not necessarily been used for Stalinist-type forced investment. Despite the fact that the government controls

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[27] Curiously, the *Yearbook of Statistics Singapore* stopped publishing a series on the increase in the public sector's foreign assets in 1982.

[28] Singapore's national accounts provides estimates of the so-called *indigenous* GNP and GDP, which roughly speaking, is the GNP and GDP corresponding to Singaporean nationals. Since foreigners play such a large role in Singapore's economy, indigenous GNP and GDP are significantly lower than GNP and GDP. The Singaporean government came up with these measures in the early 1970s to persuade the IMF to continue to classify Singapore as a developing country. The estimated earnings of the government from its foreign assets is calculated as the difference between indigenous GNP and indigenous GDP. Although this measure also includes the wage earnings of Singaporeans abroad and the earnings on foreign assets held by the private sector in Singapore, these are probably quite small, at least until the early 1990s when the private sector in Singapore started to invest abroad.

[29] This calculation uses the published estimates of the increase in public sector foreign assets before 1982. After 1982, I assume that the annual accumulation of foreign assets is the sum of the operating surplus of the consolidated public sector (central government and statutory boards) and the increase in domestic debt. To arrive at the US$ 83 billion estimate, I also assume that Singapore held no foreign assets in 1966 and that after 1966, the rate of return on Singapore's foreign assets was the average return on long term government bonds in the six largest industrialized countries. These last two assumptions are rather conservative and thus lend a downward bias to the estimated stock of foreign assets.

the largest share of national savings through its budget surpluses and the CPF, investment spending is primarily private investment (see Figure 5). In turn, private investors are predominantly foreign multinationals. In the manufacturing sector, foreign investment accounted for an average 79 percent of total investment between 1972 and 1989.[30] As for aggregate investment, Singapore's published national accounts does not provide a breakdown between investment by foreigners and by Singaporean nationals. However, they do provide estimates of the share of income accruing to foreign nationals from which we can estimate the share of foreign capital in Singapore's capital stock. From 1980 to 1993, payments to foreigners (both labor and capital) averaged 29.1 percent of GDP (see Figure 7).[31] In 1980, payments to foreign labor accounted for a sixth of total payments to foreigners.[32] Assuming that the share of payments to labor in total payments to foreigners remained constant, payments to foreign capital accounted for an average 24.1 percent of GDP from 1980 to 1993, which is roughly one half of total payments to capital and 70 percent of payments to private capital.[33] In effect, the government has been sterilizing the large inflows of foreign capital by accumulating foreign assets.

Since private investors, particularly foreign investors, own the largest share of Singapore's capital stock, the subsidies required to prevent a fall in the return to private investors are simply enormous if the data on Singapore's stock of private capital is to be believed. A simple back of the envelope calculation indicates that if the return to private capital has remained constant since 1968, the share of payments to private capital would have exceeded 50 percent of GDP by 1971 and reached 90 percent of GDP by 1990. Since the share of *total* payments to capital (including public capital) has remained roughly constant at 50 percent of GDP, the necessary subsidy to private capital would exhaust all the payments to public capital by 1971. By 1990, the necessary share of payments to private capital in GDP is 40 percent higher than the share of *total* payments to capital in GDP. Even if the entire public capital stock were used to subsidize private capital, there would still not be enough to pay the required subsidies.

3. Changes in the Risk Premium

[30] This data is compiled by the *Census of Industrial Production*.

[31] The income accruing to foreign nationals is the difference between GDP and so-called "indigenous" GDP.

[32] The estimate of wage income of foreigners takes the estimate of total wage payments to foreigners from the 1980 census and scales the resulting estimate to account for self-employed workers.

[33] This calculation assumes that total payments to capital account for 50 percent of GDP, and payments to private capital account for 34 percent of GDP.

I next consider the possibility that there was a large risk premium in Singapore in the late 1960s and early 1970s that has subsequently fallen. To assess this argument, I measure the risk-premium in Singapore from the interest rate paid on US dollar denominated bonds issued by the Singaporean government in the early 1970s. The Singaporean government tapped international financial markets for the first time on December 1971 by issuing bonds with a face value of 10 million US$ with a 10 year maturity at a 8.5 percent interest rate. In October 1972, the government issued US dollar denominated bonds again, this time with a face value of 20 million US$ and a 15 year maturity at a 7.75 percent interest rate. The interest rate paid by the Singaporean government on its first two issues of US dollar denominated bond was only an average of 195 basis points higher than the interest rate on US Treasury bonds of comparable maturity.[34] Clearly, this indicates that the sovereign risk premium in Singapore in the early 1970s was not very high.

Furthermore, even if the risk premium were high in the early 1970s, this would bias the dual estimates only if the unmeasured risk premium fell since then. One of the measures I use to estimate the marginal product of capital in Singapore is based on the data on the return to equity from the Singapore Registry of Companies. This registry compiles data from *every* incorporated business in Singapore, including government owned enterprises and subsidiaries of foreign companies. If there was a large risk premium in Singapore, this should appear in this measure of the return to capital. While it is true that the return to equity yields a negative growth rate of the rental rate, the rate of dual TFPG calculated from this estimate still exceed the primal estimate by 2 percentage points a year (see Figure 2 and Table 1). In addition, as previously mentioned, the negative trend is not statistically significant. Since the trend of the rental rate calculated from the return to equity is not significantly different from that of the two other measures of the rental rate, this suggests that that the risk-premium in Singapore has not changed significantly since the early 1970s.

4. Financial Market Controls

One of the measures I use to estimate the trend in the real interest rate is the average lending rate of commercial banks in Singapore. A potential problem with the average lending rate is that these rates

[34] The information on maturity and yields of the bonds issued by the Singaporean government is from Tan (1978). The yields on US Treasury bills are from various issues of *An Analytical Record of Yields and Yield Spreads* by

were regulated by a bank cartel until the cartel was disbanded in the early 1970s.[35] According to this argument, lending rates were kept below their equilibrium levels in the late 1960s by ceilings on lending rates. However, after these controls were lifted in the 1970s, lending rates rose to their equilibrium levels. Therefore, the end of the bank cartel in the 1970s could have masked the fall in the marginal product of capital. In support of this argument, Young (1998) shows that the gap between the lending rate (primarily for housing loans) of finance companies, which were not subject to the cartel's regulations, and the average lending rate of commercial banks narrowed in the 1970s. However, the narrowing of this gap was probably due to the housing loan subsidies provided by the Post Office Savings Board (POSB) in the 1970s. Tan (1978, p. 174) states that the POSB established a subsidiary in 1974 specifically to "extend housing loans to depositors at interest rates lower than the prevailing market rates." Thanks to these subsidies, the POSB's share of the housing loan market increased from 5.4 percent in 1975 to over 27 percent in 1986, largely at the expense of the finance companies.[36]

Furthermore, this argument is only valid if the cartel kept lending rates *below* their equilibrium levels. The truth of the matter is that while the bank cartel set ceilings on deposit rates, it set *floors* on lending rates. The cartel set *minimum* lending rates for different types of transactions but the banks were allowed to charge higher rates.[37] After all, the cartel's objective was to increase the gap between lending and deposit rates and thus maximize the profits of its members. If the bank cartel's minimum lending rates prevented banks from offering lower rates to some of their customers, the *average* lending rate in the late 1960s would have been *higher* than their market clearing rates. After the cartel was dismantled in the 1970s, the average lending rate should have fallen to its equilibrium level. Therefore, if the cartel's controls on lending rates had any effect, the estimated rental rate of capital based on the average lending rate would *overstate*, not understate, the fall in the marginal product of capital. Finally, it's remembering that the other two measures of the return to capital (earnings price ratio and the return to equity) that are unaffected by the banking cartel yield results that are broadly similar to that obtained from the average lending rate of commercial banks.

Salomon Brothers.

[35] This cartel (the Association of Banks in Malaysia and Singapore) was finally dissolved in 1975. See Chapter 8 in Lee (1974) for additional details on the cartel's interest rate regulations.

[36] See Luckett, Schultz, and Wong (1994, p. 67).

[37] According to data collected by Lee (1974), the average lending rate for most small and medium sized firms in Singapore was 2.8 percent higher than the minimum loan rate in 1966 (p. 168).

VI. Errors in the National Accounts

What we are left with then are two sets of estimates of TFPG for Singapore that are difficult to reconcile. While one can raise objections to any individual estimate of dual TFPG presented in this paper, it is difficult to see how all three estimates of the rental rate in Singapore could have remained constant over the last few decades if in fact the marginal product of capital has fallen sharply. If the capital-output ratio has increased in Singapore to the extent implied by its national accounts, why hasn't the rental rate fallen as it has in Korea? The natural explanation for this discrepancy is that Singapore's national accounts have overstated the amount of investment spending. In fact, Goh Keng-Swee, one of the founders of modern Singapore and the main architect of its economic policies, has suggested that investment expenditures in Singapore are overstated.[38]

The more general point is that there are idiosyncrasies in how every government compiles their national accounts that make cross-country comparisons problematic. As an example of this, consider the way the statistical authorities in Singapore estimate the rental value of owner-occupied housing.[39] The Singaporean statistical authorities assume that the rental price of owner-occupied housing is the rental price of public rental housing. However, the rental rates of public rental housing are highly subsidized. Since over 90 percent of Singapore's population live in owner occupied housing, this has a significant effect on the national accounts. For comparison, while private consumption expenditures on housing in Singapore account for roughly 5 percent of GDP, they account for 10 to 11 percent of GDP in Hong Kong (see Figure 7). In Hong Kong, official estimates of the value of residential housing do not depend as much on estimates of imputed rent because only 45 percent of Hong Kong's population live in owner occupied housing.

While official statistics indicate that the rental value of residential housing in Singapore is much lower than in Hong Kong, they also indicate that Singapore has invested significantly more resources (8 to 10 percent of GDP) into housing than Hong Kong (about 4 percent of GDP) (see Figure 8). This translates into large differences in the average quality of housing between Hong Kong and Singapore. As late as 1987, a Hong Kong government report estimates that 38 percent of Hong Kong's population

[38] See Goh and Low (1996).

live in inadequate housing.[40] Public housing in Singapore is much better than in Hong Kong. In 1980, public housing in Hong Kong provided between 2.2 to 5.7 square meters per person, while public housing in Singapore provided between 7.7 to 50 square meters per occupant.[41] Taking both public and private housing into account, residential housing space per person was approximately the same in both countries in 1968, but the gap between the two cities widened subsequently. By 1980, Singapore's housing stock per person was roughly double that of Hong Kong and three times that of Hong Kong by 1990 (see Figure 9).[42]

One way to assess the importance of the treatment of owner occupied housing in Singapore is to look at the difference between the rate of TFPG in the aggregate economy and in the manufacturing sector in which the undervaluation of residential housing is not an issue. From 1970 to 1990, the average rate of (primal) TFPG was 0.84 percent a year in the manufacturing sector and -0.7 percent a year for the aggregate economy.[43] The difference between the rate of TFPG in the manufacturing sector and the aggregate economy is rather large, and may be due to other factors in addition to the undervaluation of residential housing. Nonetheless, the treatment of owner occupied housing in Singapore is illustrative of the pitfalls one faces when using national accounts data without first understanding how the data has been put together. Since the task of learning the intricacies of national income accounting for every country is prohibitively time consuming, the dual approach provides a way to bring alternative data to bear to check the consistency of data from a country's national accounts. At a minimum, the large discrepancy between the dual and primal estimates of TFPG in Singapore suggests that we should be very cautious about the data from the Singaporean national accounts and the growth accounting exercises that rely on this data.

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[39] I am grateful to Soon Teck-Wong, the Director of the National Accounts Section of Singapore's Department of Statistics, for bringing the treatment of imputed rent in Singapore to my attention.

[40] Inadequate housing is defined as "temporary structures," "overcrowding by tenants sharing housing units in private housing," and "public housing with structural problems, due for redevelopment." See Table 2.4, pg. 16 in Castells et. al. (1990).

[41] This estimate is from Wong and Yeh (1985), pg. 502. 2.2 square meters is about the area of a coffin.

[42] The stock of residential housing is calculated by a standard perpetual inventory approach from annual estimates of the total area of completed residential housing. See the appendix for further details.

[43] The TFP growth rates for the manufacturing sector for the 1980s are from Wong and Gan (1994) and Tsao (1985) for the 1970s. The estimates for the aggregate economy are from Young (1995). Young's estimates of TFPG for the manufacturing sector are lower than the estimates from Tsao (1985) and Wong and Gan (1994). However, Young's estimates are apparently based on aggregate data for the manufacturing sector, whereas the estimates by Tsao and Wong and Gan are based on 2-digit industry level data.

VII. Conclusion

This paper has shown how the dual exercise can be a useful complement to standard primal growth accounting exercises. Given the enormous difficulties faced in constructing reliable national accounts and capital stock data, the dual approach has the additional advantage of using data on prices instead of quantities. The advantage of using the dual is that factor prices, primarily wages and interest rates, are observed as an equilibrium outcome in a market place. In contrast, a number of tenuous assumptions and estimates have to be made in order to construct the data on quantities of output and capital needed for a primal growth accounting exercise.

In the case of Korea, the dual TFPG estimates are remarkably similar to the primal estimates. Where the dual and primal estimates differ, and dramatically so, is for Singapore. In Singapore, standard estimates of primal TFPG suggest that there has been no technological progress over the last 30 years, and all of the increase in standards of living has been due to factor accumulation, primarily capital accumulation. If this story is correct, then the return to capital should have fallen dramatically. Yet, the evidence suggests that the return to capital has increased in Singapore. The dual estimates of TFPG uses this evidence, along with data showing an increase in real wages over the last 30 years, to obtain estimates of TFPG which suggest that technological progress has played as important a role in Singapore's growth as that in the other East Asian countries.

Appendix: Data Sources

Hong Kong:

Estimates of Gross Domestic Product (1996) provide data on GDP Deflators, rental value of residential housing, and nominal and constant investment in capital goods starting in 1961. Data on wages by sex and education for 1981, 1986, and 1991 are from the datasets of the 1 percent sample of the *Hong Kong Census* for 1981 and 1991 and the *Hong Kong By-Census* of 1986. The 1976 wage data is from the tables in the *Hong Kong By-Census 1976, Basic Tables.* The published tables of the 1966 Hong Kong By-Census (*Report of the By-Census 1966*) provide data on the number of people by sex and education in three income ranges (below 400, 400-600, above 600 Hong Kong dollars per month). I estimated average wage by sex and education by assuming that the average wage for each income range was 200, 500, and 750 respectively.

The best lending rate of the Hong Kong and Shanghai Bank and the money market rate are compiled from various issues of the *Hong Kong Annual Digest of Statistics* and from unpublished data provided by the Hong Kong Department of Census and Statistics. The dividend yield and the earnings price ratio of stocks included in the Hang Seng index was provided by the Hang Seng Bank.

The quantity of residential housing is calculated by a standard perpetual inventory approach from the annual estimates of the area of completed residential housing (from the annual issues of the *Hong Kong Annual Digest of Statistics*). To initialize the series, I take the estimated total area of residential housing from the 1971 Census. I also make the following adjustments to the annual estimates of new residential housing. First, the area of new housing does not include the area of kitchens, bathrooms, and hallways. To make the figures for Hong Kong comparable to that of Singapore (which does include the space occupied by kitchens, bathrooms, and hallways), I add 50 percent to the area of new residential housing in Hong Kong. Second, the figures for the area of new residential housing in Hong Kong does not include certain types of public housing, namely the resettlement estates, housing authority buildings, and the home ownership scheme. It does however include the area of new public housing provided under the private-sector participation scheme, middle income housing program, and the housing society. To estimate the area provided by new public housing not included in the published figures, I calculate the cost per square meter of private housing (excluding the developer's profit) and assume that the cost of a given square meter of public housing is one-third that of private housing. I multiply this cost per square meter by the expenditures on public housing investment from the national accounts to estimate the area provided by new public housing. This adjustment roughly doubles the estimated area of new residential housing each year.

Korea:

Wages by sex and education for 1969-1994 are compiled from the annual issues of the *Report on the Occupational Wage Survey* (in Korean). Prior to 1969, a survey by the Bank of Korea in 1967 (*Report on the Wage Survey*) provides data on wages by sex and education in the manufacturing and mining industries. Data on wages include special payments and monthly equivalent of annual bonuses. Real and nominal expenditures on investment goods, as well as the GDP deflator, are calculated from the annual issues of the *Korea Statistical Yearbook*. The interest rate on secured loans, the 1-year time deposit rate, and the yield on corporate bonds are from the annual issues of the *Economic*

Statistics Yearbook. Lastly, the curb market loan rate is taken from the *Survey of Business Financing and Unregulated Money Markets* (in Korean).

Singapore:

The earliest source of wage data by sex and education is from the 1966 Sample Household Survey. The official publications from this survey (*Singapore Sample Household Survey 1966*) does not have any data on income by worker characteristics, but Rao and Ramakrishnan (1980) obtained previously unpublished data on the number of workers by sex and education in different income ranges from the 1966 Sample Household Survey. I use the tables presented in their book to obtain estimates of average wages. Since their tables only presents the number of workers in each income range, I assume that wages in the top two income groups follow a Pareto distribution and average wage in the other groups is simply the midpoint between the lower and upper wage brackets. The next survey was undertaken in 1972 (*Report on the Household Expenditure Survey 1972/73*) from which the 1972 estimates of wages are obtained. The Labour Force Survey was started in 1973 and has been conducted annually ever since (with the exception of 1980 and 1990). All subsequent estimates on wages by sex and education are from the annual issues of the *Report on the Labour Force Survey*. The exceptions are the data in 1980 and 1990 which are from the publications of the Population Censuses conducted in these two years (*Census of Population, 1980, Singapore, Volume 4: Economic Characteristics* and *Singapore Census of Population, 1990. Economic Characteristics*). The annual Labour Force Surveys only provide data on the number of workers by sex and education in different income groups. To estimate average wages, I again assume that wages in the two top income brackets follow a Pareto distribution and that the average wage in the other income groups is the midpoint of the lower and upper wage brackets.

The return to equity from Singapore's Registry of Companies is an unpublished estimate provided by Singapore's Department of Statistics. The average lending rate from 1968 to 1980 is from the *Yearbook of Statistics Singapore*. To estimate the average lending rate after 1980, I take the prime lending rate and add the average gap between the average lending rate and the prime-lending rate in 1979 and1980. The average lending rate prior to 1968 used to compute the return to capital shown in Figure 2 is the loan rate of commercial banks from Lee (1974, Table 8.2). The earnings-price ratio is from Datastream.

The GDP deflator is calculated from the *Economic and Social Statistics of Singapore, 1960-82* and annual issues of the *Yearbook of Statistics Singapore*. Nominal and real investment spending as well as the breakdown between private and public investment spending, residential housing investment, and private consumption expenditures on utilities and housing are from the annual issues of the *Economic Survey of Singapore* and *Singapore National Accounts 1987*. The annual issues of the *Yearbook of Statistics Singapore* from 1967 to 1972 provides figures of private consumption expenditures on housing. However, later issues only provide an aggregate estimate of private consumption on housing and utilities. To obtain estimates of the residential value of housing after 1972, I assume that the share of rental value of housing in total expenditures on housing and utilities after 1972 is the same as the average share (slightly above two thirds) from 1967 to 1972. The housing stock is estimated by a perpetual inventory approach with annual estimates of the area of new residential housing from the *Yearbook of Statistics Singapore*. To initialize the series, I assume that the growth rate of

new residential housing before 1963 (the first year the investment series is available) is the same as the growth rate from 1964 to 1969.

The data on income tax revenues are from the *Annual Reports* of the Inland Revenue Board. Current and operational surpluses of the central government and statutory boards from 1967 to 1973 are from Low (1985) and from the annual issues of the *Economic Survey of Singapore* for subsequent years. After 1988, the annual issues of the *Economic Survey of Singapore* do not break down expenditures of the statutory boards into current and investment expenditures. I assume that the share of investment spending in total expenditures by the statutory boards from 1989 to 1991 is the same as the average from 1984 to 1988. In addition, the published estimates of the central government's current expenditures do not include debt service payments after 1985. For the figures presented in this paper, I therefore add debt service payments to the published figures of current expenditures by the central government. Lastly, capital receipts are excluded from the estimated revenues of the central government after 1987 and of the statutory boards after 1986. However, I can not adjust for this since I am unable to obtain estimates of capital receipts. Annual net increases in the CPF balances and the public sector's domestic debt are from *Economic and Social Statistics of Singapore 1960-1982* and the annual issues of the *Yearbook of Statistics Singapore*.

Taiwan:

The *Survey of Personal Income Distribution* contains data on household income by educational attainment. This survey has been conducted since 1964, but published tables on household income by educational attainment of the head of household are only available since 1972. The estimates of wages by education from 1972-1990 are thus from the published tables of the *Survey of Personal Income Distribution*. Fei, Ranis, and Kuo (1979) went back to the original tabulation sheets of the 1966 survey and estimated wages by sex and education. The data from the 1966 survey is not fully comparable to the data presented after 1972 since the 1966 survey presents data on wage income of each worker, and not on household income. The only data on wage income for each worker by sex and education prior to the mid-1970s is from a survey conducted in 1972 by the Ministry of Education (Ganicott, 1972). Therefore, the estimates of the growth rate of real wages from 1966 to 1972 are from the 1966 household survey and from the 1972 survey by the Ministry of Education.

The publication *National Income in the Republic of China* provides data on capital formation in current and constant prices. The GDP deflator is also obtained from the same source. Lastly, the interest rate on loans in informal markets is a simple average of interest rates on post-dated checks in Taipei, Kaohsiung, and Taichung from the *Financial Statistics Monthly* of the Central Bank of China. The 3 month treasury bond yield, the interest rate on short term secured loans, and the 1-year time deposit rate are also from the *Financial Statistics Monthly*.

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TABLE 1—DUAL TOTAL FACTOR PRODUCTIVITY GROWTH: KOREA

Real Interest Rate used	Labor share	Annual growth rate of: Rental price of capital	Wages	Dual TFP	Primal TFP
Curb market loan Rate (1966-1990)	0.70	-4.81	4.38	1.65	1.70
Deposit rate (1966-1990)	0.70	-2.56	4.38	2.32	1.70
Discount rate (1966-90)	0.70	-3.26	4.38	2.16	1.70

Note: All three measures of interest rates are used as nominal interest rates, from which the ex-post inflation rate is subtracted to obtain the real interest rate. For all the estimates, the rate of dual TFPG is the weighted growth rate of quality adjusted real wages and rental price of capital, where the weights are the factor shares. Primal TFPG and aggregate factor shares are calculated from Young (1995).

TABLE 2—DUAL TOTAL FACTOR PRODUCTIVITY GROWTH: SINGAPORE

Real Interest Rate used	Labor share	Annual growth rate of: Rental price of capital	Wages	Dual TFP	Primal TFP
Panel A: Actual Real Interest Rate					
Return on equity (1971-1990)	0.51	-0.49	3.13	1.36	–0.69
Average lending Rate (1968-1990)	0.51	1.64	2.69	2.18	–0.30
E-P ratio (1972-1990)	0.51	1.90	3.46	2.70	–0.68
Panel B: Constant Real Interest Rate					
(1971-1990)	0.51	0.34	3.13	1.77	–0.69
(1968-1990)	0.51	0.60	2.69	1.66	–0.30
(1972-1990)	0.51	0.22	3.46	1.88	–0.68

Note: The growth rate of the rental rate in Panel A is calculated by dividing the point estimate of the time trend of the real interest rate plus the depreciation rate by its average value and adding the average growth rate of the relative price of capital. The estimates in Panel B assumes that the sum of the real interest rate and the depreciation has remained constant. The return on equity and E-P ratio are used as *real* interest rates. The average lending rate is used as a nominal interest rate from which the ex-post inflation rate is subtracted to obtain the real interest rate. See note to Table 1 for further details.

TABLE 3—DUAL TOTAL FACTOR PRODUCTIVITY GROWTH: HONG KONG

Real Interest rate used	Labor share	Annual growth rate of: Rental price of capital	Wages	Dual TFP	Primal TFP
Prime lending rate (1966-1991)	0.63	0.29	4.04	2.65	2.30
Call money rate (1966-1991)	0.63	-0.65	4.04	2.30	2.30
E-P ratio (1973-1991)	0.62	-0.42	4.18	2.41	2.18

Note: The E-P ratio is used as a real interest rate. The call money rate and the prime lending rate are used as nominal interest rates, from which the ex-post inflation rate is subtracted to obtain the real interest rate. See note to Table 1 for additional details.

TABLE 4—DUAL TOTAL FACTOR PRODUCTIVITY GROWTH: TAIWAN

Real Interest rate used	Labor share	Annual growth rate of: Rental price of capital	Wages	Dual TFP	Primal TFP
Curb loan rate (1966-1990)	0.74	-0.75	5.26	3.72	2.10
One-year deposit rate (1966-1990)	0.74	-0.77	5.26	3.71	2.10
Secured loan rate (1966-1990)	0.74	-1.73	5.26	3.46	2.10
3-month treasury bill rate (1973-1990)	0.75	-1.52	5.24	3.52	2.06

Note: All four measures of interest rates are used as nominal interest rates, from which the ex-post inflation rate is subtracted to obtain the real interest rate. See note to Table 1 for additional details.

TABLE 5—COMPARISON OF GROWTH RATE OF REAL WAGES AND OUTPUT PER WORKER

Average Annual Growth Rate of:	Taiwan (1966-1990)	Singapore (1972-1990)	Hong Kong (1966-1991)	Korea (1966-1990)
Output per Worker	4.30	4.20	4.70	4.90
Real Wages	5.62	4.18	4.77	5.12

Note: Growth rates of output per worker and real wages are not adjusted for quality. Growth rate of output per worker calculated from Young (1995), and real wages from the sources described in the appendix.

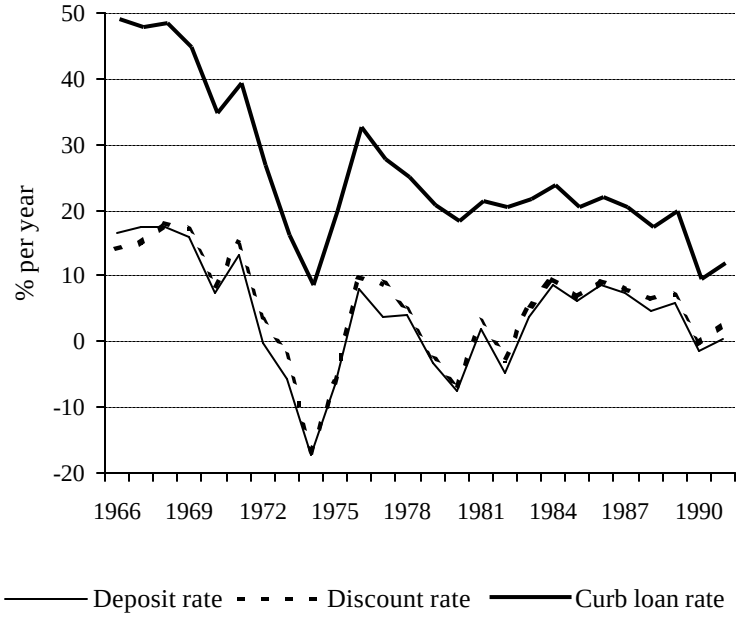

FIGURE 1. RETURN TO CAPITAL IN KOREA

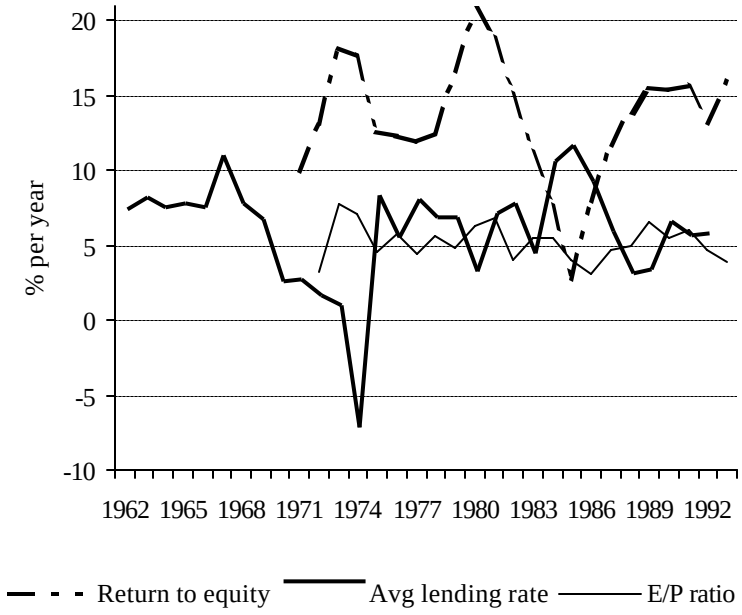

FIGURE 2. RETURN TO CAPITAL IN SINGAPORE

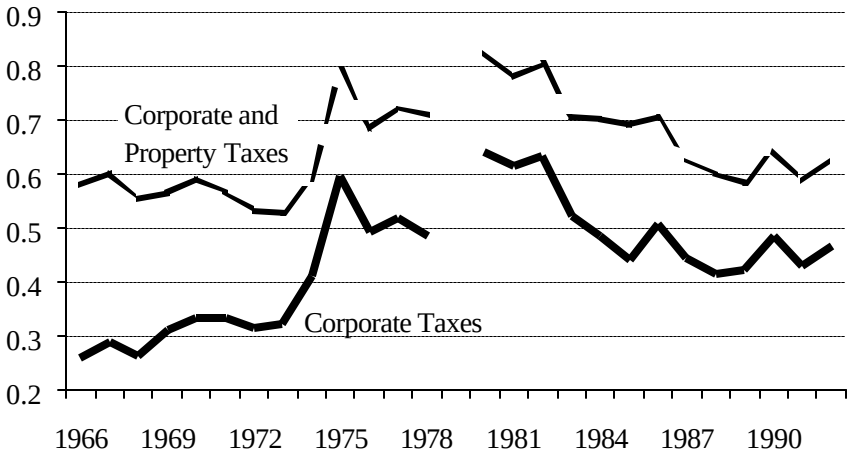

FIGURE 3. CAPITAL TAX REVENUES/
TOTAL INCOME TAX

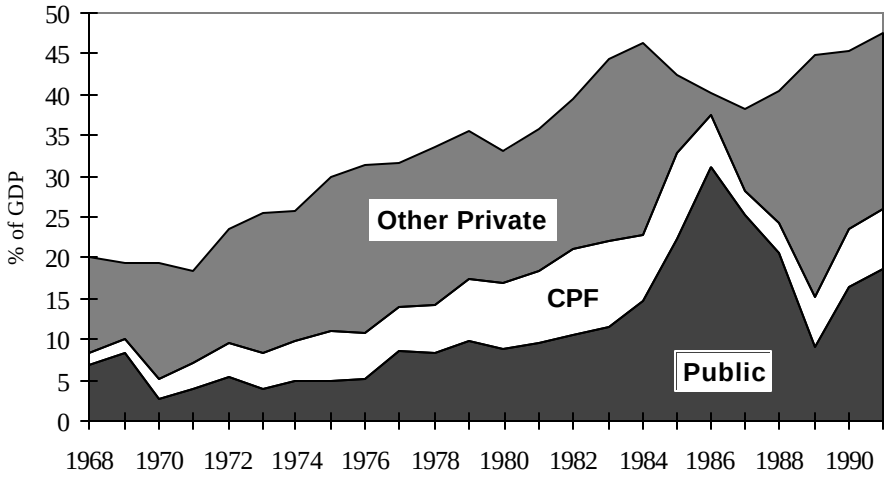

FIGURE 4. COMPOSITION OF NATIONAL SAVINGS IN
SINGAPORE

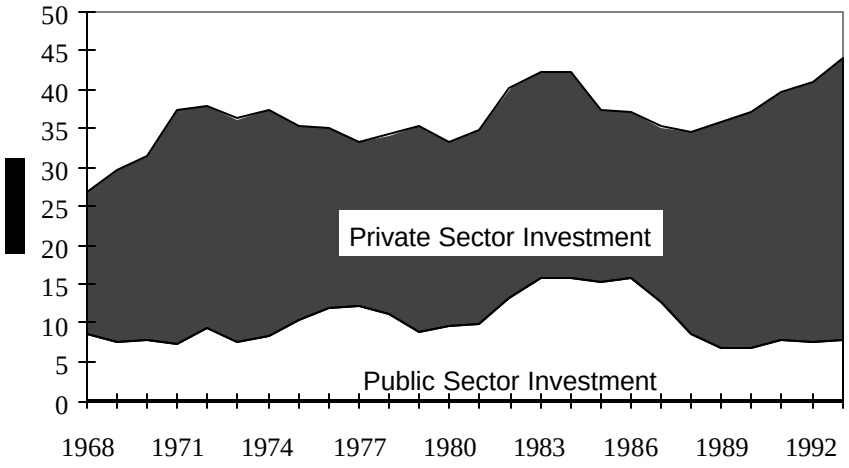

FIGURE 5. COMPOSITION OF INVESTMENT SPENDING IN SINGAPORE

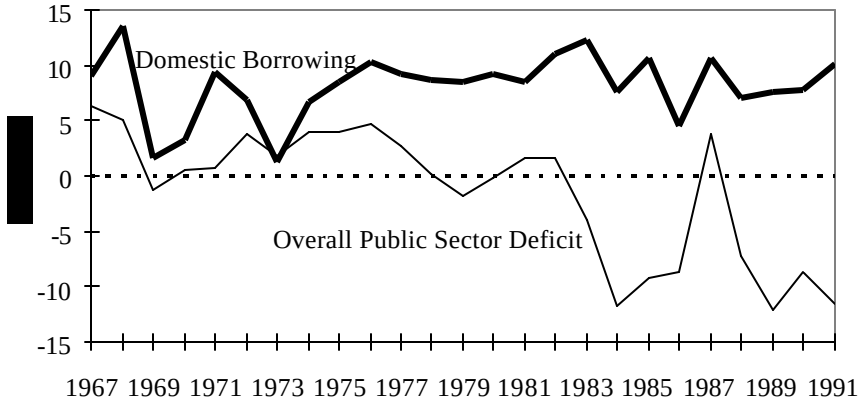

FIGURE 6. SINGAPORE'S PUBLIC SECTOR BUDGET BALANCE AND FINANCING

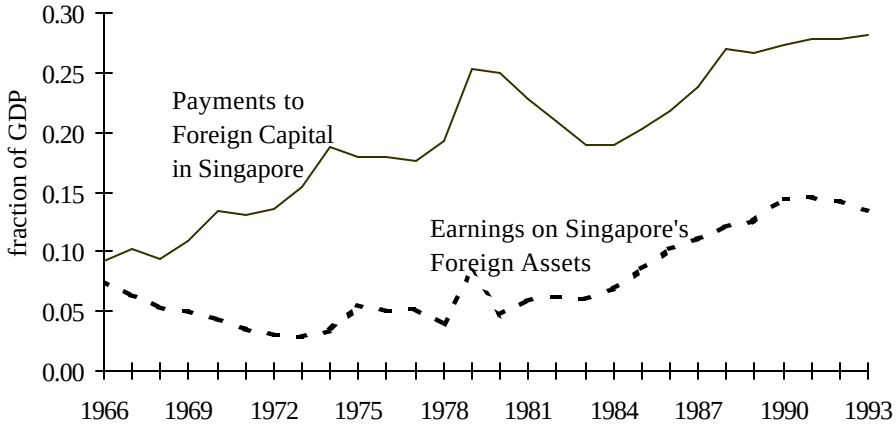

FIGURE 7: PAYMENTS TO FOREIGN CAPITAL IN SINGAPORE AND TO SINGAPORE'S FOREIGN ASSETS

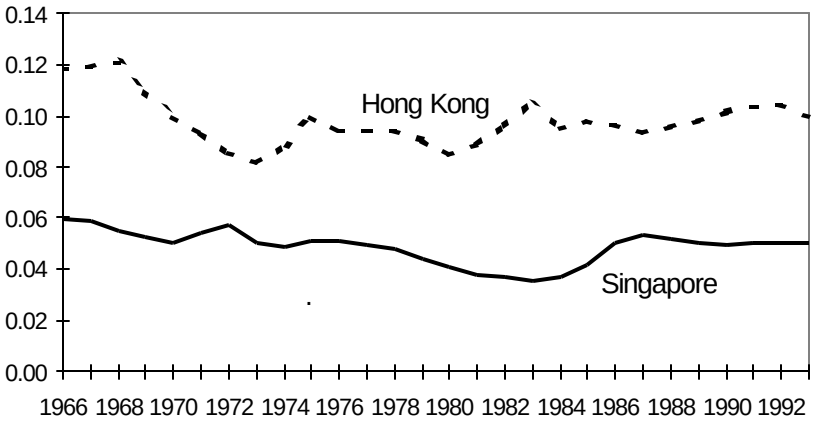

FIGURE 8. PRIVATE CONSUMPTION EXPENDITURES ON HOUSING/GDP

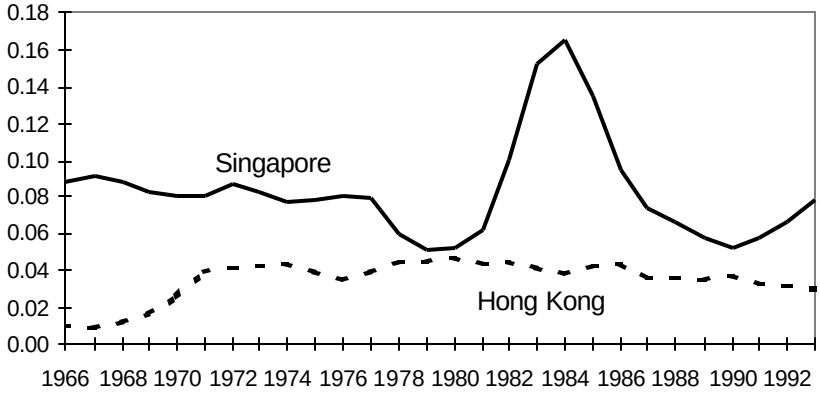

FIGURE 9. RESIDENTIAL HOUSING INVESTMENT/GDP

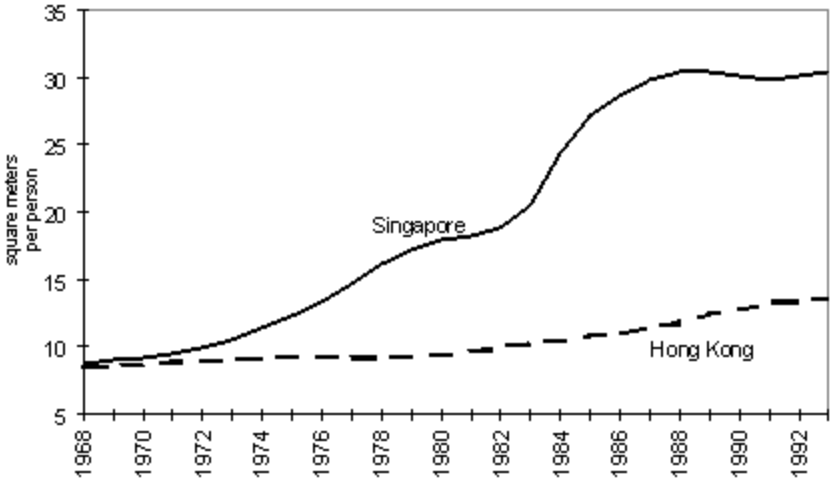

FIGURE 10. RESIDENTIAL HOUSING SPACE PER PERSON