A Tale of Two Cities: Factor Accumulation and Technical Change in Hong Kong and Singapore
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*A Tale of Two Cities: Factor Accumulation and Technical Change in Hong Kong and Singapore**

1. *Introduction*

Recent years have witnessed an enormous revival of interest in growth theory, stimulated in no small part by the development of innovative models of endogenous growth by Romer (1986, 1990), Lucas (1988), Grossman and Helpman (1991a,b), Jones and Manuelli (1990), Rebelo (1991), and Stokey (1988). The empirical implications of these models have been subjected to extensive regression analysis using cross-national data sets (e.g., Barro 1991; Levine and Renelt 1991). Almost no attempt has been made, however, to link these new theories to the empirical experience of individual economies.[1] Case study analyses provide both the author and the reader with the opportunity to develop a rich understanding of the conditions, processes, and outcomes that have governed the growth experience of actual economies. As such, they provide a means of testing the implications of existing theories and developing one's thinking on the growth process. To this end, this paper presents a comparative study of Hong Kong and Singapore.

My selection of Hong Kong and Singapore as a paired case study is

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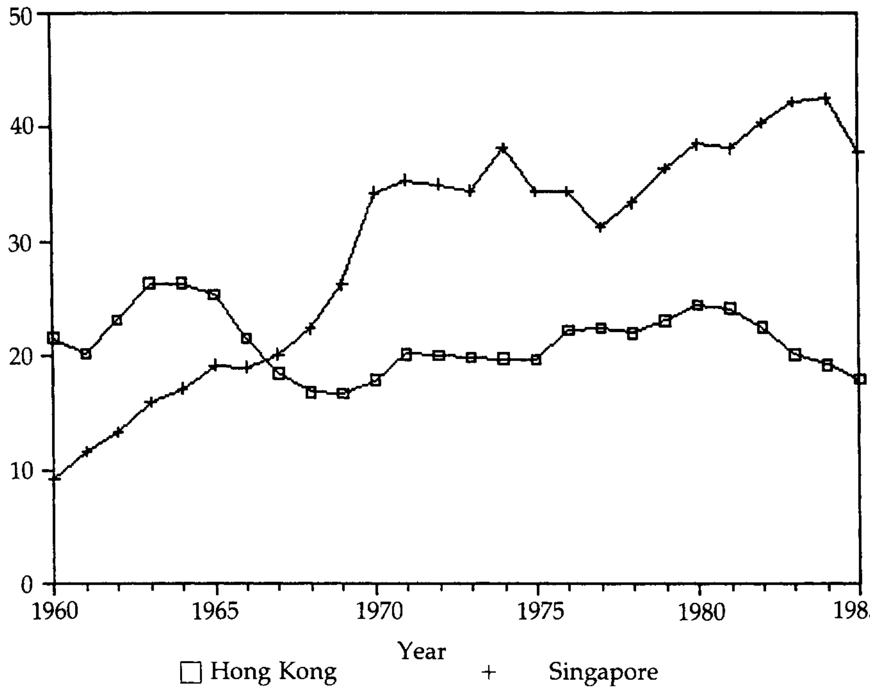
1. An exception is Fischer 1991.

by no means accidental. A combination of broad similarity of institutions and economic structure, and yet striking dissimilarity along critical dimensions emphasized in endogenous growth theory, makes these two economies a useful case study. To begin with the similarities: In the prewar era, both economies were British colonies that served as entrepôt trading ports, with little domestic manufacturing activity. Hong Kong processed trade between Mainland China and the rest of the world, and Singapore served as a conduit for world trade with Malaya and Indonesia. In the postwar era, however, both economies developed large export-dependent domestic manufacturing sectors. Both economies have passed through a similar set of industries, moving from textiles, to clothing, to plastics, to electronics, and then, in the 1980s, gradually moving from manufacturing into banking and financial services. Gross domestic product (GDP) per capita in the two economies was quite close in 1960, and they have subsequently grown at the same remarkable rate.[2] From the political economy perspective, one can note that both economies inherited a fairly efficient and rational administrative structure. The postwar population of both was composed primarily of immigrant Chinese from Southern China.[3] Both economies are really small cities, with no significant agricultural interests, economic or political.

Along many dimensions of interest to growth theorists, the two economies are, however, conveniently dissimilar. The early postwar population of Hong Kong was considerably better educated than that of Singapore, which is of relevance to models of endogenous technical change that emphasize human capital as the critical input in the acquisition of knowledge (e.g., Romer 1990). While the Hong Kong government has emphasized a policy of laissez faire, the Singaporean government has, since the early 1960s, pursued the accumulation of physical capital via forced national saving and the solicitation of a veritable deluge of foreign investment. As Figure 1 illustrates, these policies have been astonishingly successful, with the share of investment in Singapore's GDP rising from 9% in 1960 to a high of 43% in 1984. In

2. According to the Summers & Heston Mark IV data set, real GDP per capita in 1960 in Hong Kong was US$1737 (in 1980 prices) and in Singapore US$1580. Summers & Heston Mark V, however, reverses this ranking, with real GDP per capita in Hong Kong given at US$2323 (1985 prices), and in Singapore at US$2409. According to Mark V, between 1960 and 1985, real GDP per capita grew an average of 6.09% per annum in Hong Kong and 6.03% per annum in Singapore.
3. With, however, a sizeable minority of Malays, Indians, and Pakistanis in Singapore, accounting for 22.2% of the total population in 1957 (Singapore, *Census of Population 1957*, Table 13.3).

Figure 1
I/GDP (%)



stark contrast, Hong Kong's investment rate has fluctuated around some 20% of GDP.[4] This is of relevance to the linear models of Romer (1986), Lucas (1988), and Rebelo (1991), which emphasize the accumulation of factors of production. The Singaporean government has also pursued an active policy of industrial targeting, which has led to rapid structural transformation and allowed the Singaporean economy to catch up and surpass Hong Kong's initial lead in manufacturing. This is of use in exploring the implications of models that emphasize the existence of an explicit technological ladder (e.g., Stokey, 1988; Wan, 1975; Young, 1991a).

This paper will proceed as follows. Section 2 provides further information on the differences in the growth experience of the two economies, focusing on their initial levels of human capital, the subsequent

4. The data are the investment share at constant international prices, from Summers & Heston Mark V.

policy actions undertaken by their respective governments, and the type and sequence of industries they have traversed in the course of their development. Section 3 then turns to a detailed analysis of total factor productivity (TFP) growth in the two economies. I find that both capital and (human capital adjusted) labor input have grown considerably faster in Singapore. While total factor productivity growth has contributed substantially to economic growth in Hong Kong, its contribution to growth in Singapore is next to nil.

Section 4 suggests some theoretical explanations for these results. Following my (1991a) model, which emphasizes a balance between "invention" (the acquisition of technologies) and "learning" (learning how to use them efficiently), I advance the notion that Singapore is a victim of its own targeting policies, which are increasingly driving the economy ahead of its learning maturity into the production of goods in which it has lower and lower productivity. According to this argument, although Singapore might be experiencing learning-induced improvements in total factor productivity within individual sectors, this is masked at the aggregate level by a movement into industries in which the economy is less productive. As an alternative explanation, I also consider the possibility that embodied technical change may have led to a high rate of capital obsolescence and scrappage. Because Singapore has experienced inordinately rapid structural transformation, much of the "capital stock" measured by standard growth accounting techniques might no longer be in use. I find, however, that although higher depreciation rates increase the contribution of TFP growth to economic growth in Singapore, it remains low and considerably below that of Hong Kong.

Section 5 explores the implications of the TFP results for other models of endogenous growth. The far more rapid rate of total factor productivity growth in Hong Kong as compared to Singapore, when combined with Hong Kong's better-educated labor force, constitutes yet further evidence (in addition to that typically found in cross-national regressions) in favor of models that emphasize the importance of human capital and the acquisition of knowledge (Romer, 1990). The TFP results, however, are somewhat damning of the linear accumulation-driven models, which fall into two groups: those that emphasize externalities (Lucas, 1988; Romer, 1986) and those that do not, but instead achieve linearity directly either by bounding the marginal product of accumulable factors away from zero (Jones and Manuelli, 1990) or by making sectors of the economy linear in accumulable factors (Rebelo, 1991). If externalities make the aggregate production function linear in accumulable factors, then one would expect that the economy that experienced

Table 1 EDUCATIONAL ATTAINMENT OF THE WORKING POPULATION

	Singapore (%)			Hong Kong (%)		
	1947	1966	1970	1961	1966	1971
None	>75	55.1	53.4	20.1	19.2	16.2
Primary	<25	28.2	30.4	52.7	53.6	51.4
Secondary[1]	*	13.2	13.8	24.3	24.7	29.9
Tertiary[2]	*	3.6	2.4	2.9	2.5	2.5

Notes: (*) Included under primary. [1]For Hong Kong, includes postsecondary nondegree courses; [2]fluctuations in this category probably reflect sampling error or migration of educated British expatriates.
Sources: Computed from Hong Kong, 1961, 1966, and 1971 Censuses, and By-Censuses; Singapore, 1947 Social Survey; 1966 Household Survey; 1970 Census.

more rapid accumulation of both physical and human capital would have the larger measure of TFP growth. The results are exactly opposite to this prediction. If externalities are not prevalent, but the marginal product of accumulable factors is bounded away from zero, then the share of the one unaccumulable factor (raw labor) should be diminishing rapidly through time. In Singapore it is almost constant, although in Hong Kong it has fallen dramatically. Nevertheless, with a share of raw labor equal to approximately one-third of national income in both economies in the mid-1980s, there appears to be considerable aggregate concavity in accumulable factors. Overall, the paired case study indicates that the neoclassical growth model was correct in identifying the acquisition of knowledge, rather than the accumulation of raw factors of production, as the principal force driving long-run growth. Section 6 concludes this paper.

2. *Significant Differences in the Postwar Growth Experience of Hong Kong and Singapore*

2.1 INITIAL HUMAN CAPITAL

As Table 1 documents, the early postwar population of Hong Kong was considerably better educated than that of Singapore. The principal cause of this dramatic difference lay in a massive migration from Mainland China to Hong Kong in the immediate postwar era,[5] which cumulatively raised Hong Kong's population from 600,000 in 1945 to 2,237,000 by

5. Instigated by the military struggle between the Nationalists and Communists on the Mainland.

Table 2 DISTRIBUTION OF HEADS OF HOUSEHOLDS ACCORDING TO EDUCATION RECEIVED (HONG KONG–JUNE 1954)

Type of education	*Hong Kong born*	*Prewar immigrants*	*Postwar immigrants*
None	28.6%	23.8%	8.6%
Primary	50.3%	55.3%	34.1%
Secondary	17.8%	14.0%	39.1%
Higher	3.3%	6.9%	18.2%
Total	100.0%	100.0%	100.0%

Note: Of the population of 2.25 million, 600,000 were in Hong Kong-born families, 750,000 in prewar immigrant families, and 900,000 in postwar immigrant families. Some 750,000 refugees from the Sino Japanese War entered Hong Kong between 1937 and 1941, only to leave during the Japanese occupation of the colony. (Davis 1977, pp. 92–94). Thus, most of those classified as prewar immigrants are likely to have arrived during the 1937–1941 period.
Source: Hambro (1955, Table 39).

mid-1950.[6] Available survey data shows that these immigrants came from predominantly urban areas[7] and, as Table 2 shows, were extraordinarily well educated. These migrants included a substantial minority of Shanghainese capitalists, who had run the industrial machinery of what was, outside of Japan, Asia's finest prewar industrial city. Aside from bringing along an enormous amount of gold bullion and other financial assets, the Shanghainese also rerouted existing machinery orders to Hong Kong and, perhaps most important, brought along their technical workers and factory foremen![8] Thus, Hong Kong began the early postwar era with the considerable advantage of what was, for an LDC, an extraordinarily well educated and industrially experienced population.

2.2 ROLE OF THE GOVERNMENT

For most of the postwar era, the laissez-faire colonial Hong Kong government adopted a policy of minimal intervention, with limited policy intervention prompted only by the most enormous popular pressure. Thus, the postwar population inflow and the huge squatter shanty towns it created ultimately led to a public housing program, with the initial allocation of floor space being 24 sq. ft. per adult,[9] or about the size of a coffin. The program has grown steadily and by 1982 housed

6. Fan (1974, p. 2); Lethbridge (1980, p. 47).
7. See the occupational structure cited in Hambro (1955, Table 29).
8. Senior staff and their dependents were sent in chartered planes, while technical workers were moved overland by the hundreds (per company). Wong (1988, pp. 43, 65); Szczepanik (1958, p. 142); Woronoff (1980, p. 164).
9. With half that area for each child under 10. Pryor (1983, p. 24).

40% of the population with, however, as a result of continued immigration, 125,000 families still living in squatter huts.[10] Similarly, widespread riots in 1966 led to an expansion of social services, such as a public assistance scheme covering the elderly, and the passage of labor legislation restricting child labor and mandating 4 rest days per month.[11] In the 1970s microeconomic intervention grew, perhaps because of growing local participation at all levels of government, with the establishment of a (completely unsuccessful) Loans for Small Industry Scheme in 1972 and an Industrial Estates Corporation to encourage industrial diversification in 1977.[12] Despite these significant, and growing, departures from laissez faire, over the postwar era as a whole, Hong Kong government intervention in the domestic economy is best characterized as limited.

Of particular interest to this study is the Hong Kong government's influence on infrastructure development. The Hong Kong government is the sole owner of all of the undeveloped land in the colony. In the absence of government land sales, which are a major source of revenue,[13] private developers have no means of expanding the available living and working space. Government land sales and infrastructure development, however, have been slow and restricted, and only undertaken when demand had reached astronomic proportions. Thus, the overall population density in Kowloon peninsula during the 1960s and 1970s exceeded 200,000 persons per square mile, with individual districts recording densities in excess of 400,000 persons per square mile![14] The *1971 Census of Manufacturing Establishments* found that 69% of all manufacturing establishments were located in domestic premises.[15] Arguably, this reflected the enormous shortage of industrial floor space, as evidenced by the fact that by 1978, when the development of industrial towns in the New Territories was well under way, the share of factories in domestic premises had fallen to 44%.[16] No visitor to Hong

10. *Hong Kong 1983* (pp. 103–104).
11. Rabushka (1979, pp. 70–74).
12. Miners (1981, p. 106); King and Lee (1981, pp. 95–96); Nyaw and Chan (1982, pp. 462–463).
13. Land sales and crown rent accounted for an average of 15% of annual revenue between 1955 and 1975. Sit (1983, pp. 127–128).
14. Sit (1981, p. 14); Leeming (1977, p. 35).
15. Naturally, factories in domestic premises tended to be smaller than those located in industrial premises (accounting for only 27% of total employment). Nevertheless, factories in domestic premises did include 256 factories with 50–99 employees, 89 with 100–499 employees, and 5 with 500–999 employees. *1971 Census of Manufacturing Establishments* (Table 3, p. 494).
16. Accounting for only 12.6% of manufacturing employment. *1978 Survey of Industrial Production* (vol. I, Table 10).

Kong and its New Territories can but marvel at the well-balanced industrial/residential new towns created by the Hong Kong government in the 1970s and 1980s. Nevertheless, given the enormous population pressure,[17] one wonders whether a less minimalist government might not have gotten the job done a little earlier. For most of the period studied in this paper, the rate of infrastructure development was totally out of keeping with the demands of the rapidly growing population.

In stark contrast to the minimalist policies pursued by the Hong Kong government, in the postwar era the government of Singapore has pursued maximalist policies involving widespread state participation in economic activity financed, in the main, by extensive taxation of labor income. The 1950s and early 1960s were a period of economic stagnation in Singapore, as trade, which was the lifeblood of this entrepôt economy, failed to expand.[18] Arguably the stagnation of the 1950s can be attributed to the communist insurgency in Malaysia and the instability caused by racial and anti-British political riots in Singapore. The 1961–1964 development plan actively sought domestic industrialization, erecting trade barriers, providing tax incentives to foreign investors, and initiating a large infrastructure investment program.[19] The early 1960s, however, featured continued political conflict, this time with Singapore's principal trading partners, Malaysia and Indonesia. Consequently, despite the expansion of construction activity, real GDP per capita rose only 2.9% per annum between 1960 and 1965.[20] 1966 witnessed a brief resurgence of trade (as international political relations improved), but in 1967 growth slowed.[21] In July 1967 Britain announced that it would withdraw all of its military forces from Singapore by the mid-1970s. British military bases are believed to have employed, directly

17. By 1986 the resident population equaled 5,495,500, implying a 5.6% average annual rate of growth between 1945 and 1986. *1986 By-Census* (Summary Results, p. 7).
18. The total nominal value of trade (excluding trade with Malaysia) fell from S$7723 million in 1951 to S$4442 million in 1953, rising to S$6081 million by 1957. Total trade (including Malaysia), at S$7570 million in 1957, was still only S$7897 million in 1967. *Malayan Digest of Statistics*, various issues; *Yearbook of Statistics Singapore 1967* (Tables 8.1 & 8.2); *Monthly Digest of Statistics* (June 1962, Table 8.7).
19. Lee (1973, pp. 12, 25–32, 34–36); Mirza (1986, pp. 29–36).
20. *Economic and Social Statistics Singapore 1960–1982* (Tables 2.1 and 4.3).
21. *Economic and Social Statistics 1960–1982*, Table 4.3 indicates that sustained growth began in 1965, when Singapore separated from Malaysia. Authoritative contemporary sources (Goh, 1972, pp. 266–268; Buchanan, 1972, p. 66) strongly disagree. *Economic and Social Statistics* shows that the nominal value of trade increased only 16% between 1965 and 1967. Real GDP is supposed to have increased by 25% (the deflator rose by 2%), with almost half of the increase attributable to a mysterious 37% real increase in "trade" related income (Tables 4.4, 4.5, and 9.1).

and indirectly, 16% of the workforce and accounted for 13–20% of GDP.[22] Meanwhile, Singaporean attempts to industrialize and attract foreign investment drew mixed results, as manufacturing expanded slowly and the giant government-built Jurong Industrial Estate turned into an empty white elephant.[23] Contemporary speeches by Singaporean policymakers convey a palatable sense of desperation.[24]

1968 witnessed a dramatic expansion of direct Singaporean government investment in manufacturing and the economy. The Development Bank of Singapore (DBS) expanded its financial commitments (loans, equity investment, etc.) from S$45 million in July 1968 to S$340 million in December 1970, by which time its holdings of quoted and unquoted shares amounted to 25% of all shareholders funds in the economy. One-third of all financial commitments were in the electrical machinery and petroleum products industries. It is small wonder that between 1968 and 1970, the number of workers in manufacturing increased 60%, with value added in chemical and petroleum products increasing 87% and value added in electrical machinery increasing seven and a half fold![25]

The early investment commitments of the DBS turn out to have been only the initial steps in the development of a colossal interlocking web of off-budget government corporations and statutory boards. By the early 1980s, the Jurong Town Corporation ran 21 industrial estates and export processing zones (and was building 15 more), while the Housing Development Board housed more than 70% of the population. At this time, the government owned Singapore Airlines, INTRACO (a trading company), Neptune Orient Lines (shipping), Hotel Premier and, in manufacturing, held a 100% or majority equity stake in firms in food, textiles, wood, printing, chemicals and petrochemicals, iron and steel, engineering, and shipbuilding and repair.[26] According to a 1984 *Euromoney* estimate, state-owned corporations and statutory boards earned profits equal to S$10 to 15 billion, or roughly one-third of GDP.[27] The acquisition and expansion of this vast array of properties has been financed by huge government loans to the statutory boards, which aver-

22. Buchanan (1972, p. 87).
23. In 1967, only 2% of the labor force (some 12,000 workers) were employed on the estate's 17,000 acres. Buchanan (1972, p. 69).
24. See Goh (1972, p. 270).
25. Lee (1973, pp. 79, 101–105); Deyo (1981, p. 60).
26. Lim and Fong (1986, pp. 9–10); Mirza (1986, pp. 56–58, 114–119).
27. "How MAS Directs Singapore Inc." *Euromoney* (September 1984, pp. 103–107); *Yearbook of Statistics Singapore 1990* (Table 4.1).

aged 11.4% of GDP between 1981 and 1985, reaching a high of 16.5% of GDP in 1986.[28]

To support its mammoth investment program, the Singaporean government has run prodigious surpluses of current revenue over current expenditure. Total revenue, at some 14% of gross national product (GNP) in 1960, had risen to around a quarter of GNP by 1970, and has remained there ever since. Current expenditure, however, has consistently been less than revenue, averaging, for example, only 58% of the latter during the 1980s.[29] In addition to its own surpluses, the Singaporean government also borrows extensively from the Central Provident Fund. Established in 1955 as a social security program with individualized accounts, the initial contribution rate to the Provident Fund was set at 5% of the employees' salary, with a matching 5% contribution from the employer. By 1975, these rates had been raised to 15%/15%, and by 1984 to a rather impressive 25% apiece.[30] Participants may use their fund balances to purchase housing (usually built by the Housing Development Board) or government shares, but, otherwise have a limited ability to withdraw their balances, even upon retirement.[31] As of 1980, fully 95.1% of the Fund was invested in government securities. At peak, in 1985, CPF contributions amounted to a staggering 14.9% of GNP, or 36% of gross national savings.[32]

1968 also witnessed an intensification of efforts to attract foreign investment. Labor legislation passed in that year standardized basic conditions of employment (e.g., hours of work, holidays) and made issues such as promotion, internal transfer, recruitment, retirement, dismissal,

28. Loans as a percentage of GDP in the year in which the fiscal year begins. *Yearbook of Statistics Singapore 1990* (Tables 4.2 and 13.3).
29. *Economic & Social Statistics Singapore 1960–1982* (Tables 4.2 and 12.1); *Yearbook of Statistics Singapore 1990* (Tables 4.2, 13.1, and 13.2).
30. In 1986 the employer's contribution was reduced to 10% to stimulate investment, but has since crept back up. As of 1989 employers contributed 15% and employees, 23%. Mirza (1986, pp. 54–55); Lim (1988, p. 227); Singapore, Ministry of Labour, *Annual Report 1989* (p. 25).
31. For example, as of 1989, a retiring individual could withdraw his or her contribution, *provided* S$7500 was first transferred to the nominally separate Medisave Account (for health expenditures) and S$30,900 to the fund's Retirement Account. Should an individual, upon retirement, have insufficient funds to meet the Retirement Account's minimum balance requirement, "topping off," i.e., *cash payments* or transfers from the accounts of the individual's children with the CPF were allowed. In 1989 "5310 accounts amounting to $55.5 million were topped off by CPF members." It should be noted that aggregate Singaporean data on "withdrawals" from the CPF do not give an accurate picture of true cash withdrawals. Of the S$4,010.2 million in withdrawals in 1988, S$3225.9 was used for the purchase of housing and shares or transfers to the Medisave and Minimum Sum Scheme. Only S$573.5 million went to retiring Singaporeans over the age of 55. Ministry of Labour, *Annual Report 1989* (pp. 26–27).
32. Mirza (1986, p. 51); *Yearbook of Statistics Singapore 1990* (Tables 4.2 and 12.15).

and allocation of duties all nonnegotiable managerial prerogatives. All disputes were henceforth subject to compulsory arbitration at the Industrial Arbitration Court, which was required to consider "the interest of the community as a whole."[33] Man-days lost because of industrial stoppages fell from an average of some 40,000 per annum in the mid-1960s to *nil* (in all but 2 years) during 1978–1990.[34]

Tax incentives for investors have expanded steadily since 1967. Under Pioneer Status, which was actually first introduced in 1959, firms (selected on the basis of capital expenditure and type of technology) are exempted from the 40% profits tax for a period of 5, 10, or more years. Export incentives, introduced in 1967, provide a 90% tax exemption for 5–15 years for export profits derived from sufficiently large investments. In addition, as of the early 1980s, there was an Expansion Incentive (5-year exemption for profits in excess of the preexpansion level for firms investing more than S$10 million in machinery and equipment) and a Warehousing Incentive (5-year 50% tax exemption on profits in excess of a fixed base for firms investing in warehousing), as well as an Investment Allowance Incentive, an International Consultancy Services Incentive, an Approved Foreign Loan Scheme, and an Approved Royalties provision. In general, all capital equipment can be completely written off in 5 to 10 years, and R&D spending can be double deducted, as can all expenses for export promotion. In principle, these incentives do not discriminate between domestic and foreign investors. In practice, because they are usually linked to sizable investments involving advanced technologies in new (targeted) industries, the overwhelming majority of participants are foreign.[35]

Singaporean policies have been extraordinarily successful in attracting a growing deluge of foreign investment. Foreign direct investment in manufacturing, which averaged less than S$30 million per annum during 1960–1965, and only S$73 million during 1966–1967, reached S$151 million in 1968, S$708 million in 1972, and by the late 1970s was well in excess of S$1 billion per annum.[36] According to estimates based upon IMF data, net long-term direct investment in tiny Singapore between 1975 and 1984 (US$11,568 million) vastly exceeded the inflow into either Indonesia (US$2675 million), Malaysia (US$7995), the Philippines (US$720), Thailand (US$1679), South Korea (US$433) or Taiwan

33. Mirza (1986, pp. 38–39); You and Lim (p. 193).
34. *Economic & Social Statistics Singapore 1960–1982* (Table 3.10); *Yearbook of Statistics Singapore 1990* (Table 3.20).
35. Mirza (1986, pp. 88–90); You and Lim (pp. 50–51); Lim and Fong (1986, pp. 19–20); Lim (1988, pp. 257–258, 260).
36. You and Lim (Table 19).

(US$925).[37] By 1990, 35.9% of Singaporean GDP went as payments to resident foreigners and foreign companies.[38]

Before closing this section, it is worth emphasizing that the Pioneer Industries Ordinance, which provides the most significant tax holiday enjoyed by foreign investors,[39] was actually introduced in 1959. By itself, however, it failed to attract much foreign direct investment until after 1968, when the Singaporean government began to expand its own financial participation in manufacturing and other sectors. Both the popular press and academic authors[40] indicate that the Singaporean government uses its involvement in all facets of the economy to subsidize the return to foreign capital (beyond the tax incentives) by, for example, providing preferential loans, leasing land and buildings at reduced cost, shouldering labor-training costs, and assuming large equity positions.[41] As will be seen later, my estimates indicate that by the early 1980s, the real return on Singapore's massive capital stock was below 10% per annum. According to a Business International study, however, U.S. corporations in Singaporean manufacturing in the early 1980s enjoyed a return well over 30% per annum.[42] This suggests that the return on the Singaporean-owned segment of the capital stock is well below the average return estimated further below.[43]

37. Lim (1988, Table 9.4).
38. *Yearbook of Statistics Singapore 1990* (Table 4.1).
39. In 1980 Pioneer establishments accounted for 41% of manufacturing employment and 55% of manufacturing value added in firms with more than 10 workers. *Yearbook of Statistics Singapore 1990* (Tables 6.1 and 6.13).
40. Deyo (1981, p. 68); Mirza (1986, p. 241); "Government pushes Singapore into wafer fabrication," *Far Eastern Economic Review* (18 August 1988, p. 85); "Time to go it alone," *Far Eastern Economic Review* (21 July 1983, p. 61); "Hi-tech vision of a low-growth future," *Far Eastern Economic Review* (14 March 1985, p. 68).
41. I should note that officials of the Singaporean Economic Development Board have assured me that this is not the case, arguing that no subsidy (beyond the tax holidays) is given to foreign firms.
42. The source does not indicate whether these returns were nominal or real. Inflation averaged less than 4% per annum during this period. Lim (1988, Table 9.9). *Yearbook of Statistics Singapore 1990* (Table 4.7). EDB officials have indicated to me that, according to their estimates, the return to foreign corporations exceeds 20%.
43. The Singaporean statutory boards typically report substantial profits. I should note, however, that Lim (1988, p. 224) indicates that by 1984, contributions to the CPF plus the current surplus of the government and the reported profits of the statutory boards equaled 94% of gross national savings (which was approximately equal to gross domestic savings in that year). If one assumes zero saving by all other Singaporeans, this leaves savings equal to only 2.8% of GDP to be accounted for by foreign corporations and residents, which earned income equal to 24% of GDP. This seems rather low. One element of government saving (CPF, current surplus, or statutory board profits) seems to be grossly exaggerated. *Yearbook of Statistics Singapore 1990* (Tables 4.1 & 4.2).

Table 3 PRINCIPAL GROWTH INDUSTRIES BY PERIOD

Hong Kong	
Early 1950s	Textiles
Late 1950s/early 1960s	Clothing, Plastics (Toys)
Late 1960s/early 1970s	Electronics (Watches)
Late 1970s/1980s	Entrepôt Trade, Banking
Singapore	
Early 1960s	Textiles
Late 1960s	Electronics, Refining
Early 1970s	Electronics, Refining, Textiles, Clothing
Late 1970s	Electronics
1980s	Banking, Electronics

2.3 INDUSTRIAL TRANSFORMATION

The postwar economic history of Hong Kong and Singapore is fundamentally one of structural transformation, with each economy moving through a sequence of industries, each of which experienced an initial period of explosive growth followed by slower growth and, ultimately, a relative and, in many cases, absolute decline. Table 3 sketches a brief synopsis of this history of industrial transformation, indicating which were the principal growth industries in each period.

In the case of Hong Kong, the early 1950s witnessed the explosive growth of textiles, as refugee Shanghainese entrepreneurs opened factories in the colony.[44] The imposition by foreign governments of increasingly comprehensive quantitative restraints on imports of Hong Kong textile goods, ultimately constrained the growth of this industry. Accounting for 30.5% of registered manufacturing employment in 1956, the share of textiles had fallen to 14.6% by 1977. Long before textiles had begun to fade, however, entrepreneurs had already moved upstream into the manufacture of clothing, which by 1959 accounted for 17.8% of manufacturing employment. Quantitative restrictions on clothing have been less successful in constraining growth, as Hong Kong producers have constantly changed their specifications, product areas, and quality. Along with clothing, plastics was probably the most important growth industry of the late 1950s and early 1960s, as Hong Kong became one of the leading producers of toys in the world. Accounting for 5.1% of manufacturing employment in 1959, the share of plastics had risen to 12.6% by 1970.[45]

44. The number of cotton spindles went from 6,000 in 1947 to 308,000 in 1955. Wong (1988, p. 9); Szczepanik (1958, pp. 106–109).
45. *Hong Kong Statistics 1947–1967* (Table 4.2); Lethbridge (1980, p. 26).

Both clothing and plastics managed sustained growth throughout the 1960s and 1970s. As late as 1976, clothing still accounted for a dominating 36.1% of manufacturing employment, and by 1979 Hong Kong had become by far the biggest producer of toys in the world. Nevertheless, the great growth industry of the late 1960s and early 1970s was, without a doubt, electronics. Between 1963 and 1974, the percentage share of manufacturing employment accounted for by electronics increased from 0.4% to 9.1%. Within electronics, digital quartz watches soon became one of the dominant industries, with the value of sales rising from HK$7.7 million in 1965 to HK$4354 million in 1979, by which time, in terms of quantity, Hong Kong had become the world's biggest exporter of watches.[46]

By 1976 domestic manufacturing in Hong Kong accounted for a staggering 44.8% of total employment in the economy.[47] Nevertheless, although it remains the dominant industry to this day, by the late 1970s, manufacturing had begun to decline in relative importance. With the post-1978 economic reforms on the Chinese Mainland, Hong Kong entrepreneurs have invested heavily in construction and manufacturing activities in the Pearl River Delta, leading to a transfer of manufacturing activity to the Mainland. Re-exports, which accounted for only 19.0% of total exports in 1970, provided 30.6% of total exports in 1981, and a dominating 64.7% by 1990.[48] By 1991 manufacturing accounted for only 28.2% of total employment, with employment in almost every manufacturing industry falling in the late 1980s.[49] Along with the decline in manufacturing came a rapid rise in financial, insurance, and business services, which by 1988 accounted for 10.8% of GDP.[50] By the early 1990s, Hong Kong had recovered its prewar role as an entrepôt economy.

As discussed in the preceding section, the postwar Singaporean transition from entrepôt economy to domestic manufacturing occurred some 15 years after Hong Kong's. As late as 1960, manufacturing accounted for only 7.2% of GDP, with 37.8% of employment geared towards traditional production for the small domestic market in industries such as food, beverages, cigarettes, and printing.[51] The import substitution policies of the early 1960s led to some growth in textiles and wear-

46. Lethbridge (1980, p. 26); Woronoff (1980, pp. 168–170).
47. Hong Kong, *1986 By-Census* (Vol. I, Table 33).
48. Lethbridge (1980, p. 48); *Hong Kong Monthly Digest of Statistics* (August 1991, Table 3.1).
49. Hong Kong, *1991 Population Census* (Summary Results, Table 20); Hong Kong, *1983 Survey of Industrial Production* (Table 19); *1989 Survey of Industrial Production* (Table 18).
50. Hong Kong, *Estimates of Gross Domestic Product 1966 to 1990* (Table 10).
51. Lim and Fong (1986, Tables 12 and 14); see also Buchanan (1972, p. 85).

ing apparel, with the share of manufacturing employment accounted for by the two sectors rising from 0.4% and 2.2%, respectively, in 1961 to 2.5% and 10.1% in 1965. Spurred by the interventionist policies chronicled earlier, petroleum refining and electronics exploded in the late 1960s, with the share of manufacturing value added accounted for by capital intensive petroleum rising from 13.6% in 1965 to 19.2% in 1970, while the share of manufacturing employment accounted for by consumer electronics and electrical machinery leapt from 3.3% in 1968 to 11.3% in 1970.[52]

Textiles and clothing in Singapore experienced renewed rapid growth during the early 1970s, with employment rising by more than 50% between 1971 and 1973. However, these two industries never attained the dominance they experienced in Hong Kong. At peak, in 1972, textiles and clothing accounted for 7.3% and 10.6% of manufacturing employment, respectively. By 1980 these shares had fallen to 3.4% and 9.5%. Employment in Singaporean plastics grew rapidly during the 1970s, but still only accounted for 3.2% of manufacturing employment by 1980. Petroleum refining, which expanded to 24.5% of manufacturing value added in 1974, had declined in relative importance to 17.3% of value added by 1980. During the early 1980s absolute employment in plastics, textiles and wearing apparel, and value added in petroleum refining all declined steadily.[53]

Beginning in the mid-1970s, all Singaporean manufacturing sectors were increasingly overshadowed by the thundering growth of electronics. With only 11,847 workers in 1971 (8.4% of manufacturing employment), employment in the production of electronic products and components had risen to 32,780 by 1974 and 71,727 workers, or 25.2% of total manufacturing employment, by 1980. By this time, ISIC sector 38 (fabricated metal products, machinery, equipment, and electronics) accounted for 57.3% of manufacturing employment, as compared to 23.1% in 1967 and 35.8% in 1970. Along with this phenomenal growth came a substantial upgrading of the technical complexity of the products produced. Between 1971 and 1980, annual production of radios increased sevenfold. The number of television receivers produced, however, rose 56-fold. In 1980 Singapore did not produce any computer components or peripherals. By 1983 Singapore was the largest exporter of disk drives in the world.[54]

52. *Economic and Social Statistics Singapore 1960–1982* (Tables 6.5 and 6.6).
53. *Economic and Social Statistics Singapore 1960–1982* (Tables 6.5 and 6.6); *Yearbook of Statistics Singapore 1990* (Tables 6.5 and 6.6).
54. *Economic and Social Statistics Singapore 1960–1982* (Tables 6.6 & 6.8); Lim and Fong (1986, p. 89).

To complete our story, I should note that, much like Hong Kong, financial services were the Singaporean growth industry of the 1980s. Financial and business services developed rapidly in response to the needs of foreign investors in Singapore and the inducements of the Monetary Authority of Singapore, which was established in the early 1970s with the mission of turning Singapore into an international financial center.[55] Accounting for 13.1% of GDP in 1967, the share of financial and business services had reached 19.7% in 1980, and an extraordinary 32.8% by 1990.[56] Manufacturing declined in the early 1980s, with employment falling from 285,250 workers in 1981 to 246,682 by 1986. The late 1980s, however, witnessed a renewed spurt of growth, with employment rising dramatically to 352,489 by 1990, 35.6% of which was accounted for by electronic products and components.[57]

Clearly, in the postwar era, both Hong Kong and Singapore experienced rapid structural transformation, with the relative shares of employment and value added accounted for by different industries changing rapidly over time as the relative importance of each sector rose and then declined. One is left with the indelible impression, however, that, Singapore, which started much later, traversed many of the same industries as Hong Kong, but in a much more compressed time frame. To test quantitatively the hypothesis that Singapore has experienced more rapid structural change, I suggest the use of the sum of the absolute values of the changes in shares of employment or exports accounted for by different sectors as a measure of structural transformation.[58] As a measure of long-term structural transformation, this coefficient suffers from innumerable problems, not the least of which is that business cycle fluctuations, measurement error, and economic calamities will all tend to increase the coefficient without representing any underlying shift in the long-run allocation of factors of production. Nevertheless, as a first cut at measuring rates of transformation, it is not without merit.

Table 4 presents estimates of rates of structural transformation for a variety of economies. Section (a) estimates the rate of structural change in the allocation of labor across two-digit ISIC manufacturing sectors.

55. Mirza (1986, p. 37).

56. These figures probably include real estate services. The comparable 1988 figure for Hong Kong is 19.2%. *Economic & Social Statistics Singapore 1960–1982* (Table 4.4); *Yearbook of Statistics Singapore 1990* (Table 4.3); Hong Kong, *Estimates of Gross Domestic Product 1966 to 1990* (Table 10).

57. *Yearbook of Statistics Singapore 1990* (Table 6.6).

58. In other words, if S_i^t denotes the share of sector i in period t, the measure is given by: $\sum_i |S_i^t - S_i^{t-1}|$.

Table 4 RATES OF STRUCTURAL TRANSFORMATION

(a) Manufacturing employment	*(1967–1986)*		
El Salvador	0.276	Turkey	0.076
Singapore	**0.209**	Ethiopia	0.075
Kuwait	0.206	Switzerland	0.071
Indonesia	0.198	Germany	0.070
Iran	0.189	Egypt	0.069
Malaysia	0.144	Belgium	0.069
Chile	0.126	Sweden	0.065
South Korea	**0.113**	Italy	0.064
Venezuela	0.107	Finland	0.064
Cyprus	0.102	Austria	0.063
Ecuador	0.101	Japan	0.061
India	0.098	Norway	0.059
Dominican Republic	0.093	Yugoslavia	0.056
Malawi	0.091	Australia	0.052
Philippines	0.085	Denmark	0.051
Greece	0.085	United States	0.050
Israel	0.084	Bangladesh	0.045
Hong Kong	**0.082**	United Kingdom	0.041
Spain	0.077	Canada	0.035

(b) Exports	*(1964–1974)*	*(1974–1983)*	*(1962–1984)*
Hong Kong	.454	.432	.045
Singapore	.743	.544	.119

Notes: (a) Employment shifts across the nine two-digit ISIC manufacturing sectors (with, however, subsectors 356 and 385 included in sector 39). Using the average employment shares for 1967–1971, 1972–1976, 1977–1981, and 1982–1986 (minimum of 3 years of data in each 5-year period are required for an economy to be included in the sample), I compute three coefficients of structural change. The reported number is the sum of the three coefficients, representing a measure of total structural change in the period 1967–1986; (b) 1964–1974 and 1974–1983, change in shares of exports accounted for by 190 ISITC categories; 1962–1984 sum of 22 annual coefficients computed on the changes in the shares of exports accounted for by 9 aggregate ISITC categories.

To control somewhat for measurement error, I use the average employment share of each sector across nonoverlapping 5-year periods as the basis for computing the rates of change.[59] As shown in Table 4, Singapore has achieved a rate of structural transformation in the reallocation of labor in manufacturing double that of South Korea and two and a half times that of Hong Kong. Table 4 also includes other economies.

59. The data is from the United Nations data base, which covers well over 100 economies. I have eliminated from the sample all economies that either (a) had data only for a few isolated years, or (b) had data which aggregated across different two-digit sectors or included mining and construction employment under manufacturing categories.

Even if one does not choose to eliminate from the sample economies that have suffered from economic and political disasters, have unreliable data, or have benefited from oil bonanzas, it is clear that Singapore has had one of the most rapid rates of intramanufacturing structural change in the world economy. Section (b) of Table 4 presents a measure of shifts in the shares of exports accounted for by 190 (1964–1974, 1974–1983) or 9 (annual 1962–1984) categories. Once again, Singapore shows a rate of structural transformation far greater than that of Hong Kong.[60] As described earlier, in a short period of time Singapore passed through many of the industries previously traversed, at a somewhat more leisurely rate, by Hong Kong. By the late 1980s, Singapore seems to have surpassed Hong Kong on the technological ladder, with Singaporean finance increasingly dominating Hong Kong finance and Singaporean manufacturing industries producing en masse high-technology electronics goods that have eluded most Hong Kong entrepreneurs.

3. *Total Factor Productivity Growth in Hong Kong and Singapore*

This section presents an analysis of total factor productivity growth in Hong Kong and Singapore. I begin with an explanation of my methodology, which follows that used in recent years by Gollop and Jorgenson (1980) and Jorgenson, Gollop, and Fraumeni (1987), before turning to the actual empirical results.[61]

3.1 METHODOLOGY

3.1.1 The Translog Index of Total Factor Productivity Growth Consider the translogarithmic value added production function:

$$Q = \exp[\alpha_0 + \alpha_K lnK + \alpha_L lnL + \alpha_t t + \frac{1}{2} B_{KK}(lnK)^2 + B_{KL}(lnK)(lnL)$$

$$+ B_{Kt} lnK \cdot t + \frac{1}{2} B_{LL}(lnL)^2 + B_{Lt} lnL \cdot t + \frac{1}{2} B_{tt} t^2] \qquad (3.1)$$

60. In the interest of intellectual honesty, I should note that in earlier work (Young, 1989) I found that Singapore's rate of structural transformation across broad one-digit ISIC GDP aggregates during the late 1960s and early 1970s was high (by world standards), but below that of Hong Kong and South Korea. Because most of Singapore's economic transformation during this period involved intramanufacturing shifts, this is perhaps not terribly surprising.

61. I have come across only one rigorous study of total factor productivity growth in either of these economies: Tsao's 1982 study of Singapore during the 1970s. Her results are qualitatively similar to those I report later. Early estimates by Riedel (1974) and Chen (1979) were considerably handicapped by a lack of data and, consequently, are not particularly informative.

where the assumption of constant returns to scale implies that the parameters satisfy:

$$\alpha_K + \alpha_L = 1 \quad B_{KK} + B_{KL} = B_{LL} + B_{KL} = B_{Kt} + B_{Lt} = 0. \tag{3.2}$$

To allow consideration of more finely differentiated inputs, one can assume that aggregate capital and labor input are, in turn, constant returns to scale translog indices of subinputs:[62]

$$K = \exp[\alpha_1^K lnK_1 + \alpha_2^K lnK_2 + \ldots + \alpha_n^K lnK_n + \frac{1}{2}B_{11}^K(lnK_1)^2 + B_{12}^K(lnK_1)(lnK_2) + \ldots + \frac{1}{2}B_{nn}^K(lnK_n)^2]$$

$$L = \exp[\alpha_1^L lnL_1 + \alpha_2^L lnL_2 + \ldots + \alpha_m^L lnL_m + \frac{1}{2}B_{11}^L(lnL_1)^2 + B_{12}^L(lnL_1)(lnL_2) + \ldots + \frac{1}{2}B_{mm}^L(lnL_m)^2]. \tag{3.3}$$

First differencing the logarithms of these translog production functions provides a measure of the causes of growth across discrete time periods:

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

$$\text{where } ln\left(\frac{K(T)}{K(T-1)}\right) = \sum_i \bar{\theta}_{k_i} ln\left(\frac{k_i(T)}{k_i(T-1)}\right)$$

$$ln\left(\frac{L(T)}{L(T-1)}\right) = \sum_j \bar{\theta}_{l_j} ln\left(\frac{l_j(T)}{l_j(T-1)}\right)$$

$$\bar{\Theta}_i = \frac{\Theta_i(T) + \Theta_i(T-1)}{2} \qquad \bar{\theta}_i = \frac{\theta_i(T) + \theta_i(T-1)}{2}, \tag{3.4}$$

where the Θ_i's denote the share of each aggregate factor in total factor payments and the θ_i's the share of each subfactor in payments to its aggregate factor. The translog index of TFP growth ($TFP_{T-1,T}$) provides a measure of the amount the log of output would have increased had all inputs remained constant between the two discrete time periods.[63]

62. With similar restrictions on parameter values.
63. In essence, the translog production function, which can be viewed as a second order approximation of any given production function, provides a theoretical justification for the use of average factor shares and log differences as a means of extending the standard Divisia analysis of productivity growth to data based upon discrete time periods.

3.1.2 Measuring Factor Supplies My analysis focuses on two aggregate inputs, capital and labor, subdivided into finer subinput categories. I divide capital input into five categories: inventories, residential buildings, nonresidential buildings and works, transport equipment, and machinery.[64] Labor is distinguished on the basis of sex (two categories), age (five categories), and education (four to eight categories, depending upon the time period under consideration). I also adjust for hours of work by sex.[65]

The stock of each capital input is measured using the perpetual inventory method with geometric depreciation,[66] where I assume that the capital stock was zero at some early date and then cumulate investment flows forward. Given positive rates of depreciation and a sufficiently long investment series prior to the first date of the analysis, this approach should yield reasonably accurate estimates.[67] Because neither the Hong Kong nor the Singaporean government have estimates of investment prior to 1961 or 1960 (respectively), I have constructed my own estimates for earlier years using available data. For Hong Kong I mimic the published methodology[68] of the Hong Kong government in the post-1961 era to derive estimates of residential, nonresidential, machinery and transport equipment investment for the years 1947–1960. I

64. I have not included land as a capital input because the price series for Hong Kong (estimated by me from government data on land sales) shows extraordinary variation from year to year. These movements coincide with that of the Hong Kong stock market index (which is dominated by real estate development companies). Hong Kong's property market seems to suffer from bubbles.
65. I do not believe that dividing labor on the basis of occupation (e.g., professional worker, laborer, etc.) is meaningful, because, given the rapid growth of both economies, the type of work encompassed by each definition is likely to have changed dramatically over time.
66. Based upon the Hulten–Wykoff estimates of geometric rates of capital depreciation, I use depreciation rates of 1.3% for residential buildings, 2.9% for nonresidential buildings and works, 18.2% for transport equipment, 13.8% for machinery, and 0% for inventories. I derive these by taking the unweighted average of estimated depreciation rates for asset types which are likely to be found in these economies. Jorgenson, Gollop and Fraumeni (1987); Tsao (1982).
67. In the case of inventories (which do not depreciate), for Hong Kong I use government estimates of the level of inventories in 1980 and then cumulate changes in stocks (at 1980 prices) backward and forward to estimate the constant price inventory stock at other times. In the case of Singapore, the statistical authorities have informed me that the discrepancy between their production and expenditure GDP estimates is frequently on the order of 5%, most of which, however, is added to "changes in stocks" rather than the "statistical discrepancy" in the national accounts. Consequently, I do not use the "changes in stocks" data. Instead, I use data from the annual government surveys of the current price level of stocks in different sectors, deflating to a constant price series using the sectoral GDP deflators.
68. See Hong Kong, *Estimates of Gross Domestic Product* (1966–1990 and 1961–1975 issues).

also use survey data to estimate the prewar residential and nonresidential capital stocks.[69] For Singapore, I have not been able to find any detailed description of methodology. I use crude data on cement imports[70] and the number of one-family equivalent residential units constructed to derive measures of real residential and nonresidential capital formation in 1947–1959. My TFP analysis of Singapore begins in 1966. Thus, I have 6 years of government data on all types of capital and 13 earlier years of my own rough estimates of residential and nonresidential investment. To the degree that I have underestimated the capital stock in 1966, the contribution of capital in the subsequent time periods is overestimated. Given cumulated depreciation, however, by the early 1970s there should not be much bias.

In the case of labor, my task is to estimate the working population, subdivided by three attributes, i.e., a three-dimensional matrix. Census and survey data frequently contain information on row and column sums in lower dimensions. Using all available subdimensional matrices, 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). I also make use of the biproportional matrix model[71] (Bacharach, 1965) to expand subsample estimates and incorporate additional population information into the maximum likelihood estimates.[72]

3.1.3 Measuring Factor Shares Both countries have data on aggregate compensation of employees as a percentage of GDP for a few select years.[73] To derive the aggregate share of labor, I multiply this estimate by the ratio of the total working population (including working proprietors and unpaid family labor) to paid employees. Under perfect competition and constant returns to scale, the aggregate share of capital is simply one minus this figure.

69. Given their longer half-life, one needs a longer time series on residential and nonresidential investment.
70. Singapore did not produce cement in the early postwar era.
71. A two-dimensional matrix B is biproportional to matrix A if $b_{ij} = r_i s_j a_{ij}$.
72. For example, I have data on the working population by age and education, jointly, for a subsample of the 1961 Hong Kong working population. I also have data on the entire working population, by age and education, separately. I use the biproportional matrix model to estimate the entire working population by sex and education. The implicit assumption is that the subsample reporting rate for each cell can be approximated by the product of row and column factors r_i, s_j.
73. Where necessary, I interpolate linearly between the years provided to derive an estimate for years of interest to me. When I must go out of the sample range, I assume that the ratio remains constant at that of the last available year.

With geometric depreciation, and perfect foresight, the rental price of capital good k_i is given by:[74]

$$P_{k_i}(T) = P_{I_i}(T - 1)r(T) + \delta_i P_{I_i}(T) - [P_{I_i}(T) - P_{I_i}(T - 1)], \tag{3.5}$$

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 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.

To estimate the payments share of each subcategory of differentiated labor, I use census and survey data on reported income to construct estimates of the mean return to each type of labor. In many instances I do not have detailed income data by a complete three- or four-way classification. In those cases I assume that the unknown relative returns across finer categories are equal to the relative returns across known categories. For example, say I wish to estimate wages by three attributes (ijk), but only know w_{ij} and w_{jk}. I assume that:

$$\frac{w_{\hat{i}\hat{j}\hat{k}}}{w_{\hat{i}\hat{j}k}} = \frac{w_{\hat{j}\hat{k}}}{w_{\hat{j}k}} \quad \text{and} \quad \frac{w_{\hat{i}\hat{j}\hat{k}}}{w_{i\hat{j}\hat{k}}} = \frac{w_{\hat{i}\hat{j}}}{w_{i\hat{j}}}$$

Using the obvious restrictions,[75] this allows me to estimate w_{ijk} for all ijk categories.

3.2 RESULTS[76]

As a benchmark, I first present a simple analysis (Table 5), with no differentiation of capital or labor input, using easily available govern-

74. This equation can be modified to take into account taxes and depreciation allowances. Given the variety of tax shields available in Singapore, I doubt that it is in any way meaningful to use published data on tax rates, or, even taxes assessed, because these must fall disproportionately on unshielded groups. In Hong Kong, the flat tax on profits was 12.5% until 1966, when it was raised to 15%. As late as 1988, the tax rate was still only 16.5% for unincorporated enterprises and 18% for corporations. Because effective capital taxation rates in both countries are really quite low, I have chosen not to make any adjustment for taxes and depreciation allowances (American Chamber of Commerce Hong Kong 1988, p. 57; Riedel 1974, p. 144).

75. E.g., $\sum_k w_{\hat{i}\hat{j}k} L_{\hat{i}\hat{j}k} = w_{\hat{i}\hat{j}} L_{\hat{i}\hat{j}}$.

76. All results reported in this section are based upon the translog method of analysis. Thus, reported output and factor growth rates are actually the value of natural log differences. Where factors are differentiated into subinputs, the reported growth rate

Table 5 CRUDE ESTIMATE OF TOTAL FACTOR PRODUCTIVITY GROWTH

Time period	*Growth of* Output	*Growth of* Labor	*Growth of* Capital	*Average capital share*	*Percentage contribution of* Labor	*Percentage contribution of* Capital	*Percentage contribution of* TFP Δ
Hong Kong							
71–76	0.406	0.165	0.447	0.330	0.27	0.36	0.36
76–81	0.512	0.253	0.527	0.386	0.30	0.40	0.30
81–86	0.294	0.095	0.388	0.421	0.19	0.55	0.26
86–90	0.260	0.036	0.237	0.414	0.08	0.38	0.54
71–90	1.472	0.549	1.599	0.384	0.23	0.42	0.35
Singapore							
70–75	0.454	0.247	1.005	0.553	0.24	1.22	−0.47
75–80	0.408	0.256	0.503	0.548	0.28	0.68	0.04
80–85	0.300	0.069	0.620	0.491	0.12	1.01	−0.13
85–90	0.383	0.252	0.273	0.468	0.35	0.33	0.31
70–90	1.545	0.825	2.402	0.533	0.25	0.83	−0.08

ment data.[77] As can be seen from Table 5, growth in total factor productivity has contributed to a substantial 30–50% of output growth in Hong Kong in each of the four subperiods, with an overall contribution of 35% between 1971 and 1990. Fully 56% of the increase in output per worker in Hong Kong between 1971 and 1990 is attributable to TFP growth. In the case of Singapore, TFP growth is massively negative during some subperiods and strongly positive during others. These pe-

is that of the translog index of aggregate factor input. The estimates for Singapore reported below differ somewhat from those presented in earlier drafts of this paper. I have eliminated some computational errors in the original and have also benefited from additional data provided by the Singaporean government. The net effect is to make the rate of total factor productivity growth lower, and the rate of return on capital higher, than I had originally estimated.

77. Labor input is simply the number of working persons. The benchmark capital stock of each economy (1971 and 1970) is estimated by cumulating 10 previous years of government data on gross domestic fixed capital formation using a depreciation rate of 10%. Thus, for this benchmark analysis, I do not make use of inventory data nor of my pre-1960/61 capital formation estimates. Hong Kong data for 1961–1965 do not include a real estate developer's margin, while those for post-1966 do. I take the average real estate developer's margin for 1966–1970 and add that proportion to private investment in buildings and works in 1961–1965. Hong Kong government revisions of their GDP estimates indicate that early estimates were considerably under the mark. I use the average underestimate during the 1966–1970 period to adjust upwards the value of GDP in 1961 (for which the Hong Kong government has not published revised numbers). Hong Kong Census and Statistics Department, *Estimates of Gross Domestic Product 1961 to 1975; Estimates of Gross Domestic Product 1966 to 1990.*

Table 6 TOTAL FACTOR PRODUCTIVITY GROWTH

Time period	Growth of			Average capital share	Percentage contribution of		
	Output	Labor	Capital		Labor	Capital	TFP Δ
Hong Kong							
61–66	0.577	0.130	0.694	0.393	0.14	0.47	0.39
66–71	0.322	0.126	0.377	0.355	0.25	0.42	0.33
71–76	0.406	0.098	0.361	0.330	0.16	0.29	0.54
76–81	0.512	0.350	0.527	0.386	0.42	0.40	0.18
81–86	0.294	0.108	0.374	0.421	0.21	0.54	0.25
Singapore							
66–70	0.507	0.157	0.576	0.562	0.14	0.64	0.23
70–75	0.454	0.317	0.860	0.553	0.31	1.05	−0.36
75–80	0.408	0.289	0.466	0.548	0.32	0.63	0.05
80–85	0.300	0.249	0.474	0.491	0.42	0.78	−0.20

culiar results are at least partly attributable to business cycle fluctuations.[78] Overall, between 1970 and 1990, total factor productivity growth contributed to −8% of output growth in Singapore. Capital accumulation explains 117% of the increase in output per worker in the Singaporean economy during this period.

Table 6 presents my detailed analysis, using differentiated inputs, of TFP growth in the two economies. Once again, the analysis indicates that TFP growth has accounted for a substantial portion of output growth in Hong Kong. The net effect of the more careful analysis, aside from extending the sample period to the early 1960s, is to increase substantially the contribution of productivity growth in the 1971–1976 period, when hours of work fell dramatically, and substantially lower its contribution during the 1976–1981 period, when the educational quality of the labor force rapidly improved. In the case of Singapore, the alternating pattern of positive and negative contributions of productivity growth induced by business cycle fluctuations is once again apparent. The differentiation of capital goods results in a slower rate of growth of capital input, but the adjustment for the educational quality of labor increases the rate of growth of effective labor input. The net effect is to lower somewhat the negative contribution of productivity growth in the 1970–1975 period and increase its negative contribution in the 1980–1985

78. 1975/1985 were recession years, and 1970/1980/1990 were boom years. For both countries, end-points are dictated by the years in which census data are collected, which are essential for the more detailed analysis further below.

Table 7 ANNUAL TFP GROWTH—SINGAPORE

Time period	Growth of Output	Growth of Labor	Growth of Capital	Absolute contribution of Labor	Absolute contribution of Capital	Absolute contribution of TFP Δ
74–75	0.039	0.066	0.166	0.029	0.093	−0.083
75–76	0.069	0.059	0.099	0.027	0.054	−0.011
76–77	0.075	0.092	0.085	0.042	0.046	−0.013
77–78	0.082	−0.011	0.080	−0.005	0.044	0.044
78–79	0.089	0.119	0.092	0.055	0.050	−0.016
79–80	0.093	0.062	0.107	0.028	0.058	0.006
80–81	0.092	0.069	0.112	0.032	0.061	−0.001
81–82	0.066	0.072	0.100	0.035	0.051	−0.020
82–83	0.079	0.072	0.110	0.038	0.052	−0.011
83–84	0.080	0.049	0.099	0.027	0.045	0.008
84–85	−0.017	−0.030	0.088	−0.017	0.039	−0.038
85–86	0.018	0.016	0.061	0.009	0.028	−0.018
86–87	0.090	0.062	0.049	0.032	0.024	0.035
87–88	0.106	0.074	0.062	0.036	0.032	0.038
88–89	0.088	0.064	0.077	0.031	0.039	0.018
Average	0.070	0.056	0.092	0.027	0.048	−0.004

period. Table 7 presents an annual analysis of total factor productivity growth in Singapore that shows that, after averaging out all business cycle effects, the average annual contribution of total factor productivity to output growth in Singapore between 1974 and 1989 was approximately −.004, or −6% of output growth. Overall, despite all of the detailed differentiation of labor and capital input, the results are fairly close to the crude back-of-the-envelope estimates presented in Table 5. Hong Kong has experienced rapid total factor productivity growth, while Singapore has, on average, experienced *slightly negative growth* in total factor productivity.[79]

I conclude this section by presenting the real rates of return on capital implied by my analysis.[80] As shown in Table 8, the real return to capital

79. I have performed sensitivity tests in which I (a) adjusted labor input by citizenship/residency status in Singapore (which lowers the growth of labor input by a miniscule amount) or (b) used Hong Kong's aggregate share of labor (which is larger) to compute the Singaporean TFP estimates (which raises the estimate of Singaporean TFP to an average of .000 between 1974 and 1989). These results, as well as greater detail on the measures of labor and capital input that underlie the computations reported above, are available upon request from the author.

80. Recall the capital rental pricing equation in the earlier section on measuring factor shares. I subtract the rate of inflation implied by the GDP deflator to arrive at the real return.

Table 8 IMPLIED REAL RATES OF RETURN ON CAPITAL

Hong Kong		*Singapore*			
Year	*Real Return*	*Year*	*Real Return*	*Year*	*Real Return*
1960–61	0.287	1965–66	0.368	1980–81	0.169
1965–66	0.142	1969–70	0.401	1981–82	0.073
1970–71	0.241	1973–74	0.337	1982–83	0.087
1975–76	0.085	1974–75	0.140	1983–84	0.094
1980–81	0.240	1975–76	0.173	1984–85	0.070
1985–86	0.222	1976–77	0.152	1985–86	0.089
		1977–78	0.162	1986–87	0.106
		1978–79	0.153	1987–88	0.110
		1979–80	0.214	1988–89	0.128

in Hong Kong has fluctuated through time, but remains over 20%.[81] In Singapore the real return to capital, initially at about 40%, has fallen rapidly through time, and is now, during boom years such as the late 1980s, just over 10%. Because I have not measured land input, and because the analysis is performed using the residual share of national income not accruing to labor, the true rate of return on all assets in each economy is probably somewhat lower than that shown in Table 8. Crude cross-national estimates of capital stocks (discussed later) suggest that by the mid-1980s, Singapore had one of the lowest returns to physical capital in the world. The days in which Singapore can continue to sustain accumulation driven growth are clearly numbered.

4. *Theoretical Explanations*

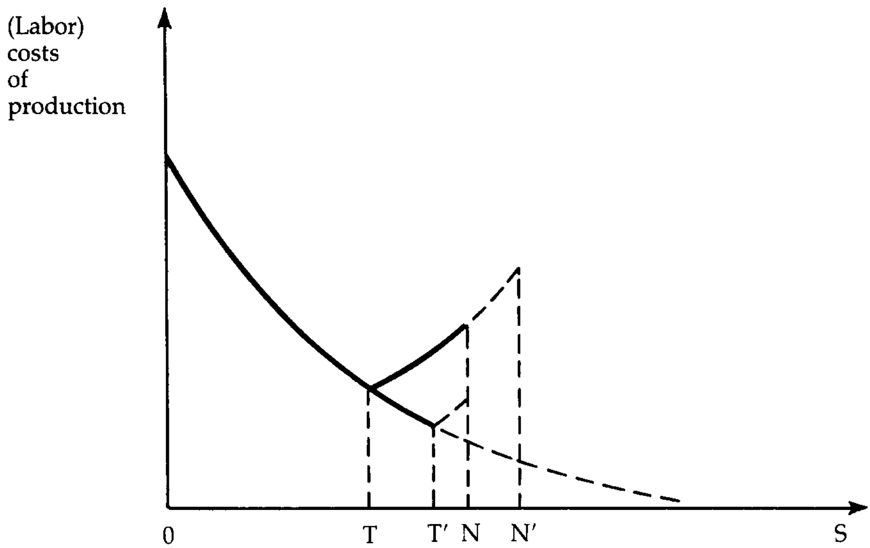
This section explores possible theoretical explanations for the results presented earlier. I begin by suggesting an argument derived from my model (1991a) of invention and bounded learning by doing, which links the productivity of new technologies to a society's learning maturity, before turning to a consideration of the possible bias induced by high endogenous rates of depreciation.

4.1 INVENTION AND BOUNDED LEARNING BY DOING

Economic history and empirical studies of technical change strongly suggest that new technologies do not achieve their full productive po-

81. The unusually low real return in 1965–1966 is due to an 8.5% deflation in capital goods prices, which (according to the data) was not matched by the 1% fall in the GDP deflator. Incidentally, in casual questioning of Hong Kong entrepreneurs over the past 10 years, I have consistently received an estimate of a real return in excess of 20%.

Figure 2 INVENTION AND BOUNDED LEARNING BY DOING



tential at their moment of invention. Experience gained in the use of new techniques seems to allow large gains in productivity by introducing a series of small improvements on otherwise unchanged technologies.[82] At the same time, it must be recognized that the factory floor is not the only source of technical change and that large technical breakthroughs emanate from the research lab, where individuals engage in purposeful attempts at developing new technologies.[83] Consideration of the interaction between learning on the factory floor and research and development in the laboratory should allow for a richer understanding of the growth process.

Figure 2 summarizes my crude attempt at modeling this interaction. At any point in time, a society only knows how to produce a finite set of goods, [0,N], which are ordered by increasing technical sophistication along the real line. The cost of producing one unit of each of these goods in, say, units of labor is given by the curve drawn in Figure 2. Experience in production (learning by doing) leads to cost reductions. I assume, however, that learning is bounded, that is, that each tech-

82. For examples, see Mak and Walton's (1972) historical study of the introduction of steamboats to western inland rivers, and Head's (1991) econometric analysis of learning by doing and productivity growth in the U.S. steel rail industry.

83. It is interesting to note that the early scientific breakthroughs that led to the development of Watt's steam engine were not the result of production experience or random tinkering, but rather the outcome of commissioned research and development efforts designed to address specific problems like improving the efficiency of distilling operations and mine pumps (Burke, 1985).

nology has associated with it some level below which unit labor requirements cannot fall. This lower bound is denoted by the dashed exponentially declining line drawn in Figure 2. As a society accumulates production experience, more and more goods attain this lower bound. If one assumes that there are symmetrical spillovers of learned knowledge across all industries, a single parameter can summarize the cumulated learning experience of the economy. This is denoted by T in Figure 2, which is also the most recent industry to exhaust learning possibilities. As production experience accumulates, T moves to the right, as learning is exhausted sequentially along the real line and the costs of production of all goods to the right of T decline. This is illustrated by the movement from T to T' in Figure 2.

Research and development leads to the development of new products, denoted by an increase of N to N' in Figure 2. How much it costs to produce a new good depends upon a society's familiarity with the production of existing goods. I assume that costs of production are higher the further beyond the economy's cumulated learning experience one tries to move. Thus, the cost curve is assumed to be upward sloping to the right of T. In general equilibrium, sustained invention depends crucially upon sustained learning, because, in the absence of learning, new products are increasingly costly and unprofitable to produce. Because learning in each good is bounded, sustained learning by doing in turn depends upon a sustained flow of new inventions. Along the steady state balanced growth path both learning ($\dot{T}$) and invention ($\dot{N}$) proceed at the same rate.[84]

To apply the closed economy model outlined earlier to the Hong Kong and Singaporean experience, some additional thought is necessary. Presumably some of the knowledge gained from production experience is embodied in explicit modifications of capital goods or production processes and, hence, is easily transferable internationally. This would imply that the upward slope of the cost curve should be much smaller for lesser developed countries, learning how to produce well-established goods, than for developed economies exploring the frontiers of knowledge. In principle, this blueprinted and embodied knowledge should be available (at a cost) to entrepreneurs throughout the world. Some evidence exists, however, that much of the knowledge acquired by learning is not embodied in capital, but, rather, in the labor force,[85]

84. The reader more comfortable with formalism will wish to consult my 1991 (a,b) papers. The extension of these one-factor models to a multifactor setting is straightforward.

85. Epple, Argote, and Devadas (1991) found that the transfer of learned knowledge (i.e., productivity) in a truck plant from the first shift to a newly opened and otherwise identical second shift was largely incomplete, strongly suggesting that this knowledge was not embodied in capital goods.

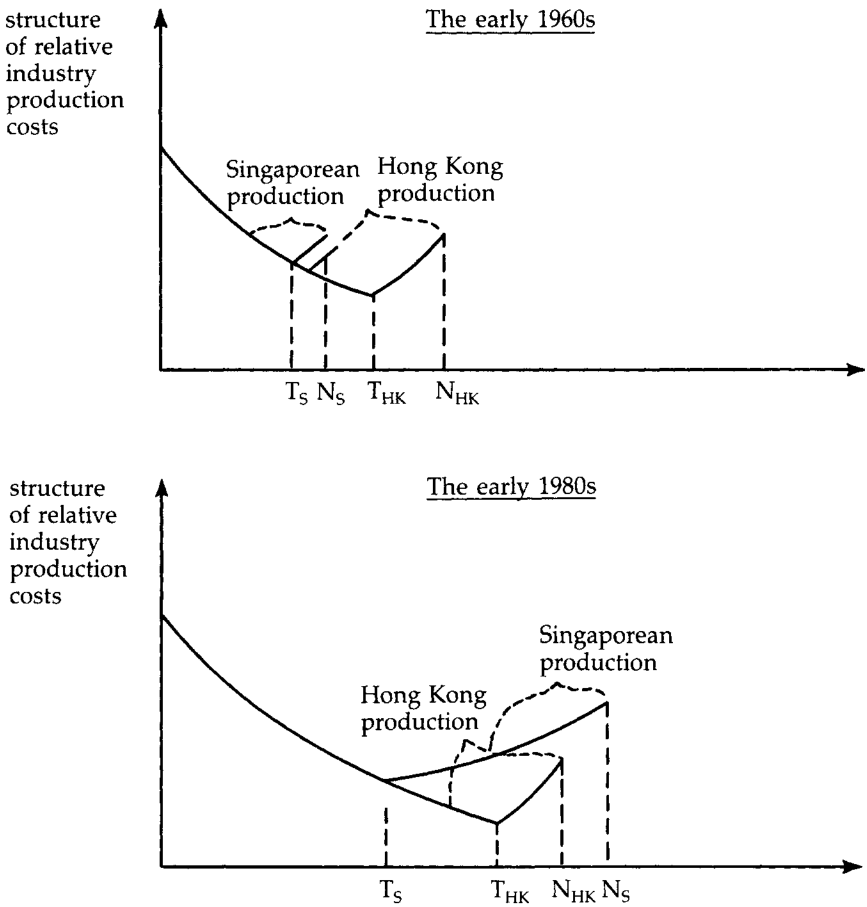
which makes it considerably less mobile internationally. In this sense, I believe that the early postwar migration of the Chinese urban population to Hong Kong dramatically and instantaneously improved the "learned" maturity of the Hong Kong economy,[86] providing it with an early comparative advantage in light industrial manufacturing over most other LDCs.[87] Since the late 1960s, Singapore has benefited from an inflow of foreign investment and foreign managers. It seems reasonable to conclude, therefore, that whereas since the late 1940s, Hong Kong has had to learn how to use each technology on its own, much labor-embodied technical know-how has been transferred by foreign corporations to Singapore. For the purposes of my argument, however, I will need to assume that this transferral is imperfect or incomplete.

Figure 3 illustrates the development of the Hong Kong and Singaporean economies in terms of the model discussed earlier. In the early 1960s, Hong Kong's learned industrial maturity was far greater than that of Singapore, as reflected by $T_{HK} > T_S$ in the diagram. Hong Kong, endowed with greater quantities of human capital and aided slightly by foreign investment, was also finding it easier to copy foreign technologies and enter new sectors (e.g., plastics and electronics). This is reflected in the greater length of $[T_{HK}, N_{HK}]$ relative to $[T_S, N_S]$. Overall, Hong Kong produced a more advanced bundle of goods. By the early 1980s, Singapore had caught up and, if anything, begun to surpass Hong Kong in the technical sophistication of manufacturing output, as shown in the early-1980s diagram. In the intervening two decades, both economies experienced substantial learning by doing, shown by the rightward movement of T_{HK} and T_S between the two periods. Nevertheless, because of the aggressive targeting policies of the Singaporean government, by the early 1980s, Singapore was mostly producing goods on the upward-sloping portion of its cost curve. The upward slope of this curve was, however, considerably less than that faced by Hong Kong, because Singapore has benefited from the learned knowledge and experience transferred by its many foreign investors and managers.

Can this scenario explain the TFP results reported earlier? The answer is that it depends upon the structure of the constant relative prices at which Singaporean real GDP growth is measured. Provided the relative increase in prices as one moves beyond T_S on the technological ladder is less than the increasing factor cost, measured real output would fall as a result of the reallocation induced by Singaporean targeting policies. The relative prices faced by the Singaporean economy are, of course,

86. If you will, an instantaneous increase of T to T' in Figure 2.
87. The long-run dynamic consequences of this preemption effect are highlighted in Young (1991b).

Figure 3 THE DEVELOPMENT OF HONG KONG AND SINGAPORE



the international prices at which it trades.[88] A multicountry version of the model would, in all probability, lead to nonmonotonic world prices, which, when contrasted with the increasing Singaporean costs of production, would imply that a premature movement up the technological ladder results in a fall in measured productivity.[89] Thus, fundamentally,

88. By the early 1980s, most tariff barriers had been removed.

89. Consider a model with N economies, with $T_1 < T_2 < \ldots < T_S < \ldots < T_N$. With more advanced economies having higher wages, the world cost curve would take the form of overlapping V's (as in my 1991b model of learning and trade). Consequently, even with imperfect competition, prices would not be monotonically increasing beyond T_S. The reader will note that in the earlier text and diagrams, I assume that even

I am arguing that Singapore is a victim of its own targeting policies. In individual sectors, Singapore probably has experienced total factor productivity growth. This improvement in productivity, however, is masked by the further and further movement beyond the society's level of industrial maturity; that is, a growing output-reducing distortion.

As evidence against this argument, I should note that Tsao (1982) found that Singapore was not experiencing any productivity growth *within* most ISIC 3 digit manufacturing sectors (e.g., electronics, etc.) either. I would maintain, however, that, given the rapid transformation in the composition of output within these broad sectors, my argument could just as easily apply to these results. Evidence of a lack of any appreciable learning or productivity improvement in the production of narrowly defined products (i.e., at the factory level), would, however, clearly refute my hypothesis.

Although I have presented evidence earlier, on the remarkable rate of structural transformation of the Singaporean economy, I feel that the words of Goh Keng Swee, Singapore's Minister of Finance, in March 1970 are equally compelling: ". . . the electronics components we make in Singapore require less skill than that required by barbers or cooks, involving mostly repetitive manual operations."[90] By 1983 Singapore was the world's largest exporter of disk drives.[91] By the late 1980s, Singapore was one of Asia's leading financial centers. As of today, the Singaporean government is targeting biotechnology and, no doubt, with its deep pockets, will achieve "success" in this sector. One cannot help but sense that this is industrial targeting taken to excess.[92]

4.2 ENDOGENOUS DEPRECIATION

In the presence of capital embodied technical progress the effective depreciation rate is endogenous, as capital is scrapped not because it wears out but because the appearance of new technologies eliminates quasi-rents on older assests.[93] Consideration of the possible effect of endogenous depreciation would seem to be particularly relevant for economies

after benefiting from the transfer of foreign know-how, the Singaporean cost curve is still monotonically increasing beyond T_S. Were it to be monotonically decreasing then it is likely that, with the nonmonotonically declining world price distribution implied by the overlapping V's, measured productivity would not fall as the Singaporean economy moved further and further beyond T_S.

90. Goh (1972, p. 275).
91. Lim and Fong (1986, p. 89).
92. I should emphasize that I am not arguing that transformation per se is detrimental to long-run productivity growth. Clearly, bounded learning by doing implies that continued transformation is necessary for sustained growth.
93. For formal examples, see Solow (1962 & 1959).

Table 9 SENSITIVITY OF THE RESULTS TO THE DEPRECIATION RATE

	Hong Kong (1971–1990)			Singapore (1970–1990)		
		Contribution of TFP Growth			Contribution of TFP Growth	
Depreciation rate (%)	*Growth of capital*	*Absolute*	*Percentage*	*Growth of capital*	*Absolute*	*Percentage*
0	1.93	.39	.27	2.78	−.32	−.21
10	1.60	.52	.35	2.40	−.12	−.08
20	1.49	.56	.38	2.19	−.01	−.01
30	1.47	.57	.39	2.07	.06	.04
40	1.49	.56	.38	1.99	.10	.06
50	1.50	.56	.38	1.93	.13	.08
60	1.51	.55	.38	1.90	.15	.10
70	1.51	.55	.38	1.87	.16	.11
80	1.51	.55	.38	1.85	.17	.11
90	1.50	.56	.38	1.84	.18	.12
100	1.49	.56	.38	1.83	.19	.12

Notes: The analysis for Singapore makes use of figures for output growth of 1.545, labor input growth of 0.825, and an average capital share of 0.533 presented earlier in Table 5. The analysis for Hong Kong makes use of output growth of 1.472, labor input growth of 0.549, and an average capital share of 0.384.

such as Hong Kong and Singapore, which have experienced a rapid transformation of their industrial structure. In particular, as noted in Section 2, Singapore has experienced one of the most rapid rates of structural change in manufacturing in the world, which is precisely what has allowed it to eliminate Hong Kong's initial lead in industrialization. The depreciation rates used earlier in the growth accounting exercise come from studies of the United States and, hence, are arguably inappropriate for an economy experiencing rapid structural change. Depending upon the time path of investment, higher depreciation rates might imply a smaller cumulative increase in the capital stock and, hence, higher total factor productivity growth.

To test for the effect of endogenous depreciation, I rerun my crude growth accounting exercise (which did not differentiate capital or labor inputs) with varying depreciation rates.[94] As shown in Table 9, cranking

94. I should note that the validity of this procedure does not actually require that elements of the capital stock be physically scrapped. As noted by Solow (1959), given some factor substitutability, embodied technical change does not actually lead to scrapping of capital assets. Older assets do, however, suffer a capital loss as less and less of the economy's other factors of production are allocated to work with them. In essence, the older assets are asymptotically scrapped. Solow elegantly shows that if past investment streams are depreciated at a rate equal to the rate of physical depreciation plus the rate of embodied technical progress (which equals the rate of capital loss due to

up the depreciation rate does not do much to the contribution of total factor productivity growth in Hong Kong but does improve its contribution in Singapore. At no level of depreciation, however, does the contribution of TFP in Singapore even begin to approach that experienced in Hong Kong. Structural change is likely to have had its strongest impact on the depreciation of machinery and, perhaps, transport equipment, which, according to my estimates, make up about 30% of the Singaporean capital stock. Structural change is unlikely, however, to have significantly increased the rate of depreciation of residential and nonresidential structures.[95] Consequently, it is hard to believe that the annual depreciation rate of the Singaporean capital stock exceeds 30%. Thus, as an absolute upper bound, Table 9 suggests that total factor productivity may have contributed to about 4% of output growth in Singapore between 1970 and 1990, which is well below the 35% recorded by Hong Kong (with 10% depreciation) during the same period. High endogenous depreciation rates provide, at best, only a partial explanation of the low total factor productivity growth recorded by the Singaporean economy.

5. *Implications for Other Models of Endogenous Growth*

Clearly, the early educational superiority of the Hong Kong labor force, when combined with the economy's higher rate of TFP growth, provides further evidence, in addition to that garnered in numerous cross-national regressions, in favor of models of endogenous technical change that emphasize the supply of human capital as determining the ability of an economy to absorb new technologies (e.g., Romer, 1990).[96] The results of the case study are less favorable, however, toward linear endogenous growth models that emphasize the accumulation of basic factors of production. Those models (e.g., Lucas, 1988; Romer, 1986) that emphasize externalities in the accumulation of human and physical capital would predict that conventional growth accounting, which does not include these externalities in the factor shares, would find that

obsolescence), the resulting estimate of the capital stock allows for a correct estimate of the rate of TFP growth. In the above I am essentially following his approach.

95. Disposal of obsolete inventories should, presumably, be captured in the survey data I use to estimate the level of inventories.

96. However, as pointed out to me by Gary Becker, one wonders why Singapore's productivity growth has not improved as its population has become better educated. Clearly, the positive coefficient on human capital in the Barro (1991) regressions implies that most countries should be growing faster over time, because their populations have become better educated, although this effect would be somewhat counterbalanced by the slowdown implied by the negative coefficient on initial income (convergence).

Table 10 SHARE OF UNSKILLED LABOR

Hong Kong			Singapore		
Year	*In payments to labor*	*In total factor payments*	Year	*In payments to labor*	*In total factor payments*
1961	.78	.46			
1966	.79	.49	1966	.69	.30
1971	.79	.52	1970	.72	.32
1976	.77	.52	1975	.66	.30
1981	.70	.39	1980	.61	.27
1986	.60	.36	1985	.53	.30

Note: Because of a lack of early wage data, Hong Kong 1961–1971 and Singapore 1966–1970 computed using relative factor returns from later years. Share of unskilled labor in total payments to labor calculated by imputing the average return to a completely uneducated male or female to all workers in that sex category, and then dividing by the actual reported income of all workers. Share in total factor payments calculated by multiplying the preceding number by my estimates of the aggregate share of labor.

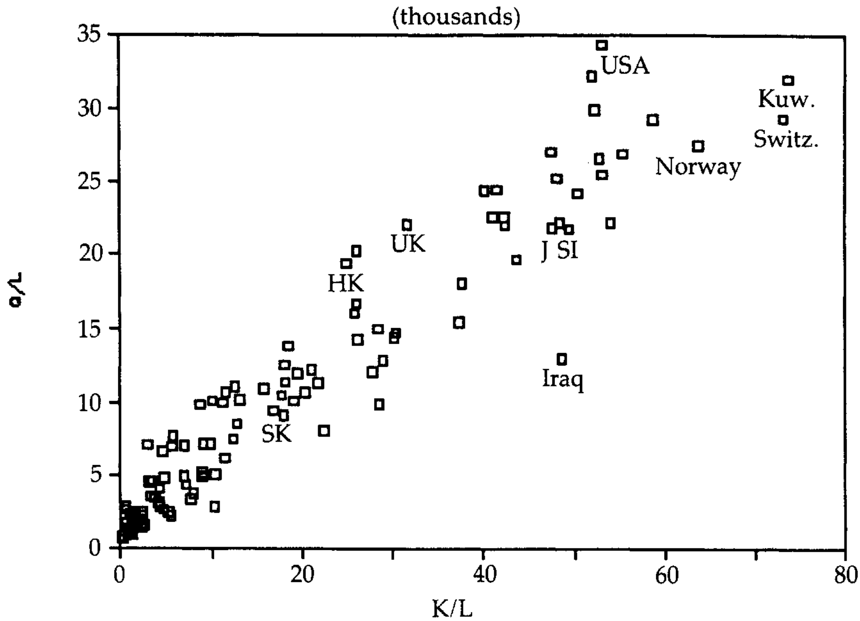
the economy that experienced greater accumulation also experienced greater TFP growth. Clearly, I find exactly the opposite result. Those models that emphasize a marginal product of accumulable factors bounded substantially away from zero (e.g., Jones and Manuelli, 1990) would predict that any economy experiencing rapid factor accumulation should show a rapid decline in the share of national income accruing to the principal nonaccumulable factor, i.e., raw labor. As Table 10 shows, Singapore, which experienced the greater factor accumulation, shows an almost constant share of unskilled labor in total factor payments. The share of unskilled labor in total payments to labor in Singapore has, however, fallen over time, while in Hong Kong the share of unskilled labor in total payments to labor fell rapidly in the early 1980s.[97] Thus, one might argue that the evidence on this score is somewhat mixed. Overall, however, with a share of unskilled labor of at least a third, the production functions for both economies show considerable concavity in accumulable factors.

Figure 4 presents a scatter diagram of output per worker and capital per worker in 1985 for 120 economies.[98] It is striking how well these

97. The decline between 1976 and 1981 may have been due to the inflow of 400,000 persons from Mainland China during 1978–1980. The decline from 1981 to 1986, however, cannot be attributed to immigration (which was restricted during this period) (Sit, 1981, pp. 5, 8).

98. The data are drawn from Summers & Heston Mark V. I estimate capital per worker by cumulating the S&H investment data (at constant prices) forward (starting with the earliest data available) using a 10% depreciation rate. The sample is the same as that presented in Table 11. Alan Heston has informed me that the Mark V investment figures for the United States (only) do not include public investment. Following his advice, I have added 2% to the reported investment/GDP ratio for the United States.

Figure 4 CONSTANCY OF THE CAPITAL OUTPUT RATIO



disparate economies, with enormous variation in the quality of data and level of income, manage to cluster around a constant capital–output ratio. With evidence like this, it is easy to become a strong believer in the most elementary (physical capital only) form of the linear model. The problem is that the constancy of the capital–output ratio is precisely one of the stylized facts which the neoclassical model, with its concavity in accumulable factors, originally sought to explain. As is well known, with labor augmenting technical change, endogenous capital accumulation, in an otherwise concave production function, will lead to a constant capital–output ratio.

Table 11 presents 120 country-specific time series regressions of the natural log of output per worker on a constant and the natural log of capital per worker.[99] Once again, the large coefficient on capital, well in excess of capital's share, found in many economies can be seen as strong evidence in favor of the linear model.[100] However, if one believes

99. The regressions are run using the Summers & Heston Mark V data set. Ten years of investment data are used to establish the initial capital–worker ratio. The regression is then run on the remaining annual data. Countries with less than 25 years of total data, or without data on output per worker, are excluded from the sample.

100. A similar interpretation is usually given to the significance of the investment to GDP ratio in cross-national growth regressions.

Table 11 REGRESSION OF $ln(Q/L)$ ON $ln(K/L)$

Country	*Coeff.*	*SE*	*Grade*	*Country*	*Coeff.*	*SE*	*Grade*
Luxembourg	1.13	0.061	a	Zimbabwe	1.27	0.177	c
Italy	0.77	0.026	a	Kenya	1.19	0.322	c
Norway	0.76	0.023	a	Cyprus	1.14	0.078	c
Finland	0.73	0.033	a	Colombia	1.11	0.045	c
Germany	0.66	0.020	a	Malta	0.97	0.068	c
Netherlands	0.63	0.018	a	Tunisia	0.80	0.073	c
Australia	0.62	0.023	a	Jamaica	0.78	0.083	c
Portugal	0.60	0.017	a	Brazil	0.76	0.046	c
Spain	0.60	0.018	a	Ecuador	0.72	0.040	c
Greece	0.59	0.009	a	Cameroon	0.61	0.028	c
Belgium	0.58	0.013	a	Tanzania	0.56	0.081	c
Japan	0.58	0.010	a	Botswana	0.56	0.046	c
Austria	0.55	0.008	a	Guatemala	0.56	0.030	c
Canada	0.54	0.027	a	Turkey	0.55	0.020	c
France	0.53	0.007	a	Honduras	0.54	0.034	c
Sweden	0.53	0.032	a	Bolivia	0.54	0.035	c
Ireland	0.47	0.018	a	Thailand	0.52	0.024	c
UK	0.45	0.024	a	Panama	0.51	0.022	c
USA	0.45	0.029	a	Philippines	0.49	0.029	c
Denmark	0.43	0.033	a	Malaysia	0.49	0.033	c
New Zealand	0.18	0.039	a	Mexico	0.47	0.038	c
				Venezuela	0.47	0.099	c
Hong Kong	**0.81**	0.035	b	Iran	0.47	0.132	c
Israel	0.75	0.054	b	T&T	0.47	0.103	c
Iceland	0.72	0.060	b	Syria	0.46	0.086	c
Korea	0.52	0.017	b	South Africa	0.44	0.027	c
Yugoslavia	0.50	0.044	b	Peru	0.42	0.093	c
Switzerland	0.40	0.023	b	Paraguay	0.42	0.019	c
				Morocco	0.41	0.037	c
				Indonesia	0.41	0.026	c
				Singapore	**0.39**	0.035	c
				Dom. Rep.	0.39	0.039	c
				Costa Rica	0.36	0.040	c
				Chile	0.36	0.087	c
				Argentina	0.34	0.031	c
				India	0.31	0.032	c
				Pakistan	0.31	0.114	c
				Uruguay	0.29	0.072	c
				Sri Lanka	0.25	0.036	c
				Ivory Coast	0.23	0.056	c
				El Salvador	0.20	0.075	c
				Senegal	−0.07	0.075	c
				Barbados	−0.23	0.080	c
				Bangladesh	−0.34	0.330	c

Table 11 REGRESSION OF *ln*(*Q*/*L*) ON *ln*(*K*/*L*) (*Continued*)

Country	*Coeff.*	*SE*	*Grade*	*Country*	*Coeff.*	*SE*	*Grade*
Mozambique	1.12	0.284	d	Burundi	0.25	0.021	d
Guyana	1.04	0.179	d	Rwanda	0.24	0.038	d
Liberia	0.89	0.178	d	Cen Afr Rep	0.24	0.123	d
Angola	0.81	0.669	d	Uganda	0.24	0.181	d
Egypt	0.77	0.038	d	Nepal	0.22	0.026	d
Guinea	0.76	0.094	d	Swaziland	0.22	0.052	d
Burma	0.71	0.046	d	Fiji	0.20	0.107	d
Zambia	0.69	0.082	d	Iraq	0.19	0.103	d
Congo	0.67	0.084	d	Sudan	0.17	0.093	d
Burkina Faso	0.59	0.110	d	Afghanistan	0.17	0.077	d
Mauritius	0.58	0.044	d	Togo	0.16	0.040	d
Taiwan	0.57	0.012	d	Nicaragua	0.16	0.121	d
China	0.53	0.050	d	Gambia	0.15	0.023	d
Cape Verde	0.51	0.172	d	Nigeria	0.12	0.057	d
Lesotho	0.50	0.038	d	Haiti	0.12	0.026	d
Mali	0.50	0.082	d	Somalia	0.09	0.068	d
Ghana	0.48	0.076	d	Benin	0.09	0.034	d
Gabon	0.42	0.072	d	Zaire	−0.00	0.061	d
Madagasgar	0.40	0.373	d	Niger	−0.02	0.128	d
Suriname	0.38	0.101	d	Mauritania	−0.07	0.050	d
Ethiopia	0.38	0.028	d	Saudi Arabia	−0.08	0.534	d
Malawi	0.35	0.031	d	PNG	−0.37	0.074	d
Algeria	0.32	0.031	d	Sierra Leone	−1.09	0.438	d
Jordan	0.28	0.028	d	Kuwait	−3.89	0.667	d
Chad	0.26	0.463	d				

Notes: Coeff. refers to B in the regression: $ln(Q/L) = C + B\, ln(K/L)$. Grade refers to the Summers & Heston quality rating.

in a concave neoclassical production function, one would argue that the capital stock is endogenous and that its large coefficient in the regression reflects its correlation with the error term, that is, technical change. We can make use of our case study to help resolve this debate. As Table 11 shows, Hong Kong, the economy that experienced endogenous capital accumulation, has one of the highest coefficients in the world. Singapore, the one economy where we can confidently assert that the capital stock increased exogenously, has one of the smallest coefficients among countries with similar quality data. At .39, the coefficient on capital in Singapore is roughly equal to its share of national income at the end of the sample period (mid-1980s). Thus, our paired case study strongly suggests that the constancy of the capital–output ratio and the large coefficient on capital in cross-national and country specific regressions are due to the endogenous response of capital accumulation to technical change, within the context of an otherwise concave production function.

Overall, the results of this paired case study indicate that the linear model is not a useful means of thinking about the growth process. In this context, it is somewhat unfortunate that the linear model, known, in its crudest form, as the AK model, has become the standard workhorse for modeling endogenous growth. Anything that changes the savings rate in this model automatically translates into a permanent change in the growth rate. This allows one to quickly and easily model the "permanent" effects of political bargaining, social conflict, infrastructure development, distortionary taxation, etc. In a model of endogenous technical change, however, most, although not all, of these factors would result in only level effects on income, without changing the long-run rate of growth.[101] As the case of Singapore shows, level effects can be of enormous magnitude and, consequently, of great policy interest. The concave neoclassical production function, however, provides a perfectly adequate means of examining and quantifying level effects, without implying permanent differences in growth rates.

The early linear models appear to have liberated the profession from the intellectual straitjacket of the neoclassical growth model that, with the exception of some work on learning by doing (e.g., Arrow, 1962; Sheshinski, 1967), had relegated technical change and long-run growth to the realm of the unexplainable. The observation that sustained growth requires linearity (or more) in something, be it factors of production or factors of production plus knowledge, is a valuable insight. The important question now is whether a reduction of all of the elements that underlie the growth process to AK still allows one to consider issues of sufficient complexity to be of practical use. By the mid-1980s, Singapore's capital–output ratio was double that of Hong Kong, and its aggregate return to capital was possibly one of the lowest in the world.[102] With an investment to GDP ratio already exceeding 40% and, by the early 1990s, a reasonably educated labor force, it is clear that Singapore will only be able to sustain further growth by reorienting its policies from factor accumulation toward the considerably more subtle issue of technological change. I do not believe that AK provides many insights into how this might be accomplished.

101. For example, Romer (1990) shows how a subsidy to capital accumulation does not change the long-run rate of endogenous innovation and growth.

102. See Figure 4. A rough estimate of the nominal return to capital (ignoring asset value appreciation) is provided by: $r = sQ/K - \delta$, where s is the share of capital in output. If one is willing to make the heroic assumption that the share of capital is approximately the same in all economies, one can use the data in Figure 4 to rank order the return to capital in the different economies. Singapore is ranked 12th from the bottom in this sample of 120 economies.

6. *Conclusion*

This paper has used a paired case study of Hong Kong and Singapore to develop some insights into the growth process and evaluate the empirical validity of existing models of endogenous growth. To this end, I have highlighted some of the significant differences between the two economies, focusing, in particular, on differences in the initial quality of their labor forces and subsequent rates of factor accumulation and industrial transformation. Because of space limitations, I have had to ignore other fascinating details of their growth experience that could also serve to inform models of endogenous growth. For example, most entrepreneurs in Hong Kong are former production workers who used personal savings to open up their own firms. Conventional financial intermediation (banks and equity markets) has played almost no role in the development of Hong Kong's manufacturing sector, although there exists some evidence of the use of informal traditional credit markets.[103] A further study of these phenomena, when compared to contrasting or similar behavior and institutions in other economies, could deepen our understanding of the role of entrepreneurship and financial intermediation in the development and diffusion of knowledge. Carefully selected case studies, with the right combination of similarity and dissimilarity, can usefully complement abstract theoretical reasoning and cross-national econometric tests.

REFERENCES

American Chamber of Commerce Hong Kong. (1988). *Doing Business in Today's Hong Kong*. Hong Kong: Oxford University Press.

Arrow, Kenneth J. (1962). The economic implications of learning by doing. *Review of Economic Studies* 29:155–173.

Bacharach, Michael (1965). Estimating non-negative matrices from marginal data. *International Economic Review* 6:294–310.

Barro, Robert J. (1991). Economic growth in a cross section of countries. *Quarterly Journal of Economics* May:407–444.

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

Buchanan, Iain. (1972). *Singapore in Southeast Asia: An Economic and Political Appraisal*. London: G. Bell and Sons Ltd.

Burke, James. (1985). *The Day the Universe Changed*. Boston: Little, Brown and Company.

Chen, Edward K. Y. (1979). *Hyper-Growth in Asian Economies*. London: Macmillan Press Ltd.

Davis, S. G. (1977). *Hong Kong in its Geographical Setting*. New York: AMS Press, Inc.

103. For details, see Young (1989).

Deyo, Frederic C. (1981). *Dependent Development and Industrial Order.* New York: Praeger Publishers.

Epple, Dennis, Linda Argote, and Rukmini Devadas. (1991). Organizational learning curves: A method for investigating intra-plant transfer of knowledge acquired through learning by doing. *Organization Science* 2:58–70.

Fan, Shuh Ching. (1974). *The Population of Hong Kong.* Hong Kong: Swindon Book Co., Ltd.

Fischer, Stanley. (1991). Growth, macroeconomics and development. In *Macroeconomics Annual 1991.* Olivier J. Blanchard and Stanley Fischer (eds.). Cambridge: MIT Press.

Goh, Keng Swee. (1972). *The Economics of Modernization and Other Essays.* Singapore: Asia Pacific Press.

Gollop, Frank M., and Dale W. Jorgenson. (1980). U.S. productivity growth by industry 1947–73. In *New Developments in Productivity Measurement and Analysis.* John W. Kendrick and Beatrice N. Vaccara (eds.). Chicago: University of Chicago Press.

Grossman, Gene, and Elhanan Helpman. (1991a). Quality ladders in the theory of growth. *Review of Economic Studies* LVIII:43–61.

———. (1991b). *Innovation and Growth in the Global Economy.* Cambridge: MIT Press.

Government pushes Singapore into wafer fabrication. (1988). *Far Eastern Economic Review* 18:85–86.

Hambro, Dr. Edvard. (1955). *The Problem of Chinese Refugees in Hong Kong* (report submitted to the United Nations High Commissioner for Refugees). Holland: A.W. Sijthoff-Leyden.

Head, C. Keith. (1991). Learning by doing and infant industries. Ph.D. Thesis. Cambridge, MA: MIT.

Hi-tech vision of a low-growth future. (1985). *Far Eastern Economic Review.* 14 March:68–71.

Hong Kong Census and Statistics Department. (1977). *Estimates of Gross Domestic Product 1961 to 1975.* Hong Kong: Government Printer.

———. (1991). *Estimates of Gross Domestic Product 1966 to 1990.* Hong Kong: Government Printer.

———. (August 1991). *Hong Kong Monthly Digest of Statistics.*

———. (1987). *Hong Kong 1986 By-Census.* Hong Kong: Government Printer.

———. *Survey of Industrial Production.* Various issues.

Hong Kong Census Commissioner. (n.d.). *Hong Kong: Report on the 1961 Census.* Hong Kong: Government Printer.

Hong Kong Commissioner for Census Statistics. (n.d.). *Report on the 1966 By-Census.* Hong Kong: Government Printer.

Hong Kong Government Information Services. (1972). *Hong Kong Population and Housing Census 1971.* Hong Kong: Government Printer.

———. (1983). *Hong Kong 1983: A Review of 1982.* Hong Kong: Government Printer.

———. (1972). *1971 Census of Manufacturing Establishments.* Hong Kong: Government Printer.

How MAS directs Singapore Inc. (1984). *Euromoney.* September:103–107.

Jones, Larry E., and Rodolfo Manuelli. (1990). A convex model of equilibrium growth. *Journal of Political Economy* 98:1008–1038.

Jorgenson, Dale W., Frank M. Gollop, and Barbara M. Fraumeni. (1987). *Productivity and U.S. Economic Growth.* Cambridge: Harvard University Press.

King, Ambrose Y. C., and Rance P. L. Lee (eds.). (1981). *Social Life and Development in Hong Kong*. Hong Kong: Chinese University Press.
Lee, Soo Ann. (1973). *Industrialization in Singapore*. Australia: Longman Australia.
Leeming, Frank. (1977). *Street Studies in Hong Kong: Localities in a Chinese City*. Hong Kong: Oxford University Press.
Lethbridge, David (ed.). (1980). *The Business Environment in Hong Kong*. Hong Kong: Oxford University Press.
Levine, R., and D. Renelt. (1991). A sensitivity analysis of cross-country growth regressions. Manuscript. World Bank, March.
Lim, Chong Yah, et al. (1988). *Policy Options for the Singapore Economy*. Singapore: McGraw-Hill Book Company.
Lim, Linda, and Pang-Eng Fong. (1986). *Trade, Employment and Industrialization in Singapore*. Geneva: International Labour Organization.
Lin, Tzong-biau, Rance P. L. Lee, and Udo-Ernst Simones. (1979). *Hong Kong: Economic, Social and Political Studies in Development*. New York: M. E. Sharpe, Inc.
Lucas, Robert E., Jr. (1988). On the mechanics of economic development. *Journal of Monetary Economics* 22:3–42.
Mak, James, and Gary M. Walton. (1972). Steamboats and the great productivity surge in river transportation. *Journal of Economic History* XXXII:619–640.
Miners, N. J. (1981). *The Government and Politics of Hong Kong*. 3rd ed. Hong Kong: Oxford University Press.
Mirza, Hafiz. (1986). *Multinationals and the Growth of the Singapore Economy*. New York: St. Martin's Press.
Nyaw, Mee-Kau, and Chan-Leong Chan. (1982). Structure and development strategies of the manufacturing industries in Singapore and Hong Kong. *Asian Survey* 22:442–469.
Pryor, E. G. (1983). *Housing in Hong Kong*. 2nd ed. Hong Kong: Oxford University Press.
Rebelo, Sergio. (1991). Long run policy analysis and long run growth. *Journal of Political Economy* 99:500–521.
Riedel, James. (1974). *The Industrialization of Hong Kong*. Tübingen, Germany: J. C. B. Mohr (Paul Siebeck).
Romer, Paul M. (1986). Increasing returns and long-run growth. *Journal of Political Economy* 94:1002–1037.
———. (1990). Endogenous technical change. *Journal of Political Economy* 98:S71–S102.
Sheshinski, Eytan. (1967). Optimal accumulation with learning by doing. In *Essays on the Theory of Optimal Economic Growth*. K. Shell (ed.). Cambridge: MIT Press.
Singapore, Chief Statistician. (n.d.). *Monthly Digest of Statistics*, June 1962. Singapore: Government Printer.
Singapore Department of Social Welfare. *Social Survey of Singapore 1947*. Singapore: G.H.Hiat & Co.
Singapore Department of Statistics. (1983). *Economic & Social Statistics Singapore 1960–1982*. Singapore: National Printers.
———. (n.d.). *Report on the Census of Population 1970 Singapore*. Singapore: National Printers.
———. (n.d.). *Yearbook of Statistics Singapore 1967*. Singapore: National Printers.
———. (n.d.). *Yearbook of Statistics Singapore 1990*. Singapore: National Printers.

Singapore Ministry of Labour. (n.d.). *Annual Report 1989*. Singapore: Mentor Printers Ltd.
Singapore Ministry of National Development. (n.d.). *Singapore Sample Household Survey 1966*. Singapore: National Printers.
Sit, Victor Fung-shuen (ed.). (1981). *Urban Hong Kong*. Hong Kong: Summerson Eastern Publishers Ltd.
———. (1983). *Made in Hong Kong*. Hong Kong: Summerson Eastern Publishers.
Solow, Robert M. (1962). Substitution and fixed proportions in the theory of capital. *Review of Economic Studies* XXIV:207–218.
———. (1959). "Investment and Technical Progress." In *Mathematical Methods in the Social Sciences 1959*, ed. by Kenneth J. Arrow, Samuel Karbin and Patrick Suppes. Stanford: Stanford University Press, 1960.
Stokey, Nancy L. (1988). Learning by doing and the introduction of new goods. *Journal of Political Economy* 96:701–717.
Szczepanik, Edward. (1958). *The Economic Growth of Hong Kong*. London: Oxford University Press.
"Time to go it alone." *Far Eastern Economic Review* 21 July 1983:61–65.
Tsao, Yuan. (1982). Growth and productivity in Singapore: A supply side analysis. Ph.D. thesis. Cambridge, MA: Harvard University.
Wan, Henry Y. Jr. (1975). Trade, development and inventions—the Evolutionary path. Manuscript. Ithaca, NY: Cornell University.
Wong, Siu-lun. (1988). *Emigrant Entrepreneurs: Shanghai Industrialists in Hong Kong*. Hong Kong: Oxford University Press.
Woronoff, Jon (1980). *Hong Kong: Capitalist Paradise*. Hong Kong: Heinemann Asia.
You, Poh Seng, and Chong Yah Lim (eds.). (1984). *Singapore: Twenty-five Years of Development*. Singapore: Nan Yang Xing Zhou Lianhe Zaobao.
Young, Alwyn. (1989). Hong Kong and the art of landing on one's feet. Ph.D. dissertation. Medford, MA: Fletcher School of Law and Diplomacy.
———. (1991a). Invention and Bounded Learning by Doing. NBER Working Paper No. 3712.
———. (1991b). Learning by doing and the dynamic effects of international trade. *Quarterly Journal of Economics* CVI, pp. 369–405.

Comment

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This is an important paper: it suggests that much of the "new growth theory" has been barking up the wrong tree.

Let me present Alwyn Young's stylized facts in a slightly different order from the way he does. As he points out, there is a remarkable constancy of the capital–output ratio across countries; there is also a