The Sources of Long-Term Economic Growth

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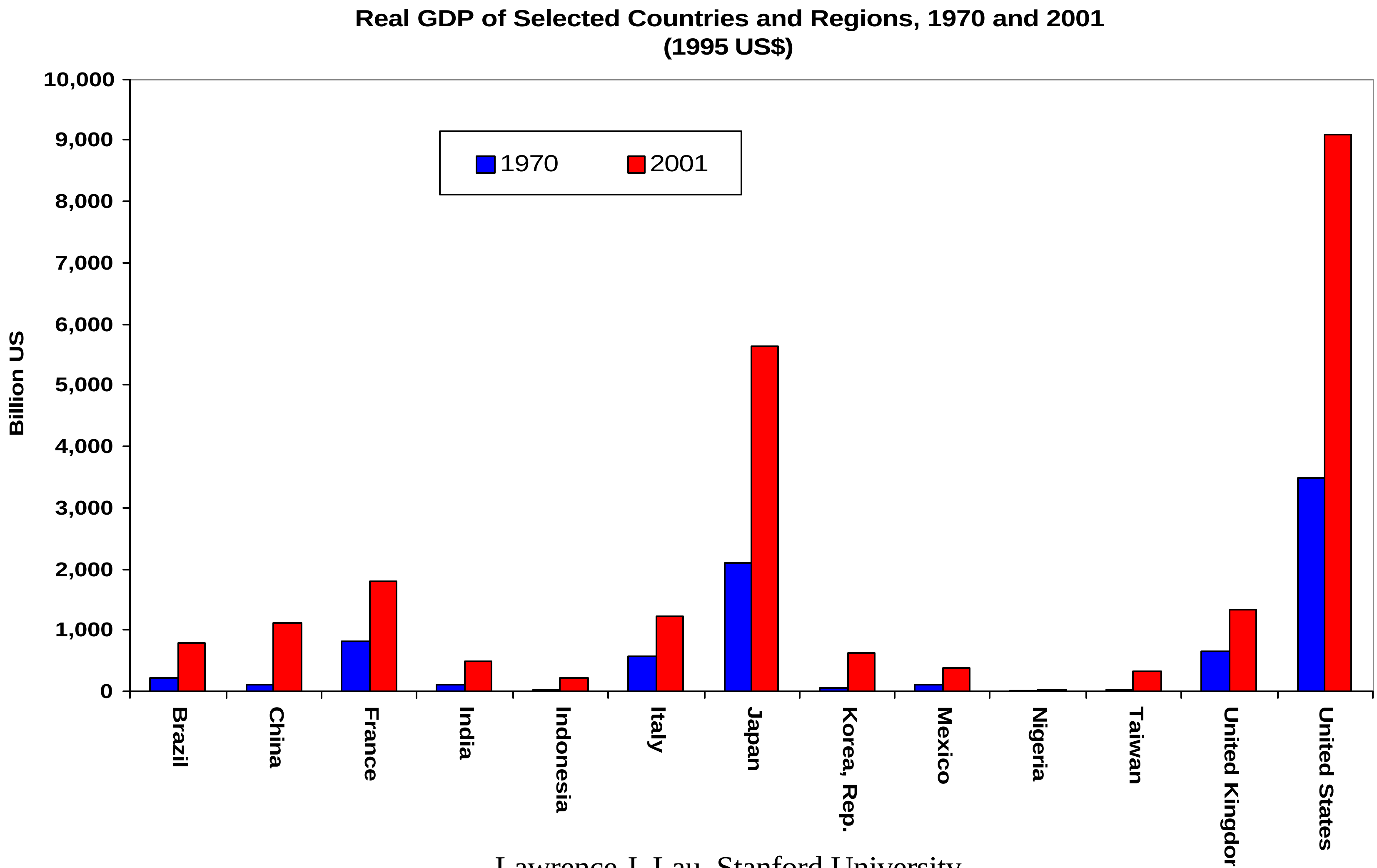
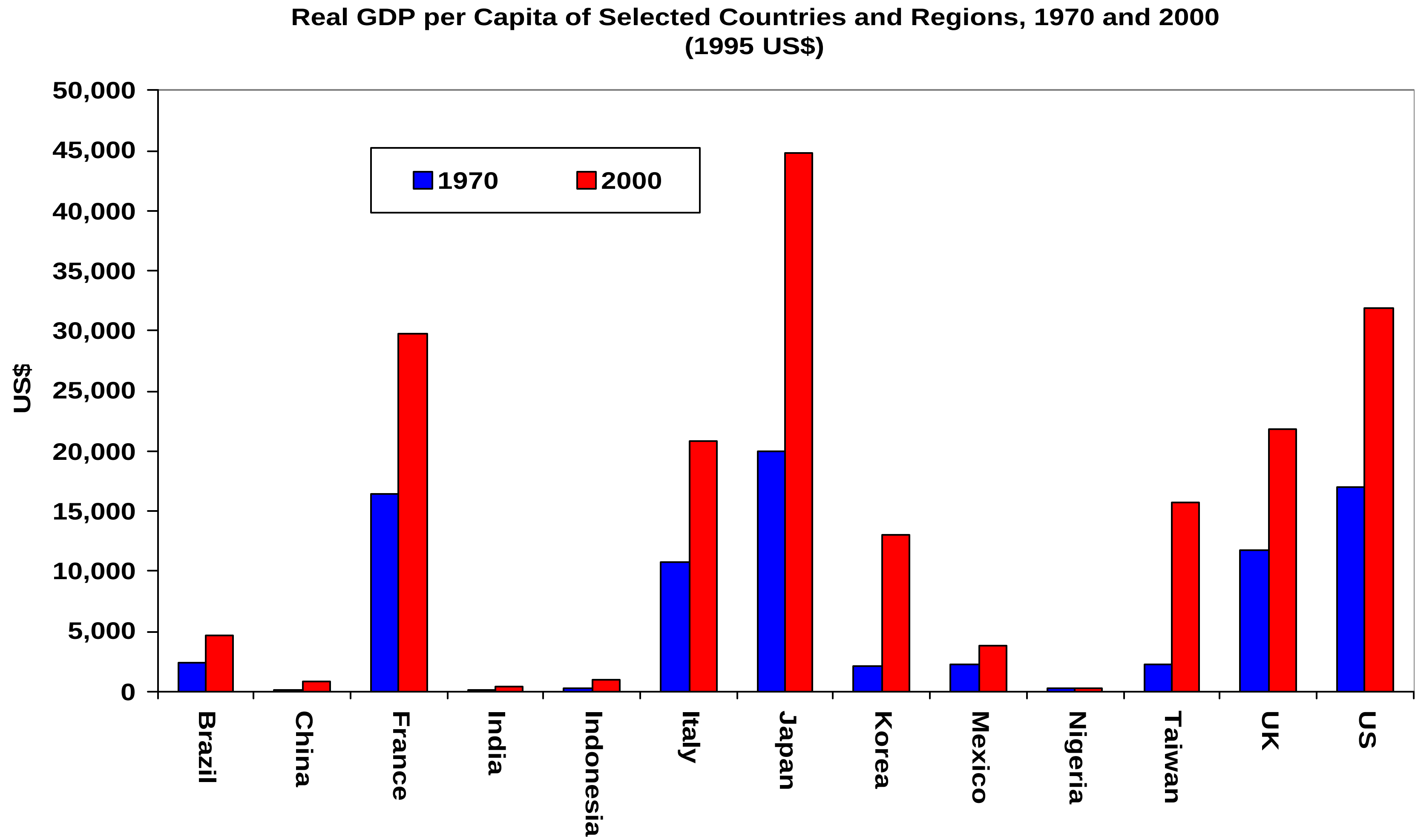
Preview

- Accounting for Growth in the Real Output of an Economy
- The Methodology
- The Empirical Experience of Developed and Developing Economies
  - Tangible Input (in particular tangible capital) -Driven Growth in the Early Stage of Economic Development
  - Intangible Input- or Technical Progress-Driven Growth in the Mature Stage of Economic Development
- Prospects of Future Economic Growth for East Asian Developing Economies

Real GDP of Selected Countries and Regions, 1970 and 2001



Real GDP per Capita of Selected Countries and Regions, 1970 and 2001



What Are the Sources of Long-Term Economic Growth?

- Great dispersion in the levels and rates of growth of real GDP across economies
- What are the causes of these differences? Can the differences be explained by the differences in the levels and rates of growth in measured inputs such as tangible or physical capital (structure and equipment), labor hours, and land
- How important is technical progress, or equivalently improvements in productive efficiency, or growth in total factor productivity in explaining these differences?
- **TECHNICAL PROGRESS (GROWTH IN TOTAL FACTOR PRODUCTIVITY)**
  = GROWTH IN OUTPUT HOLDING ALL <u>MEASURED</u> INPUTS CONSTANT

Accounting for Economic Growth

- Decomposing the growth of output by its proximate sources:
  - How much of the growth of output can be attributed to the growth of <u>measured</u> inputs, tangible capital and labor (and land—the land input is not normally included as a source of growth of output because it is fixed in quantity)? and
  - How much of the growth of output can be attributed to technical progress (also known as growth in total factor productivity), i.e. improvements in productive efficiency over time?

Accounting for Economic Growth

- Simon Kuznets (1966), Nobel Laureate in Economics, observed that "the direct contribution of man-hours and capital accumulation would hardly account for more than a tenth of the rate of growth in per capita product--and probably less." (p. 81)
- Moses Abramovitz (1956) and Robert Solow (1957), another Nobel Laureate in Economics, similarly found that the growth of output cannot be adequately explained by the growth of inputs
- Edward Denison (1962), under the assumption that the degree of returns to scale is 1.1, found less technical progress
- Griliches and Jorgenson (1966), Jorgenson, Gollop and Fraumeni (1987) and Jorgenson and his associates found even less technical progress by adjusting capital and labor inputs for quality improvements

Accounting for Economic Growth

- Boskin and Lau (1990), applying the meta-production function approach to data on constant-price capital stocks and labor hours, found that technical progress has been the most important source of growth for the developed countries (the Group-of-Five (G-5) Countries—France, West Germany, Japan, United Kingdom and the United States) in the postwar period

The Concept of a Production Function

- Definition:
  - A production function is a rule which gives the quantity of output, Y , for a given quantity of input, X , denoted:

$$Y = F(X)$$

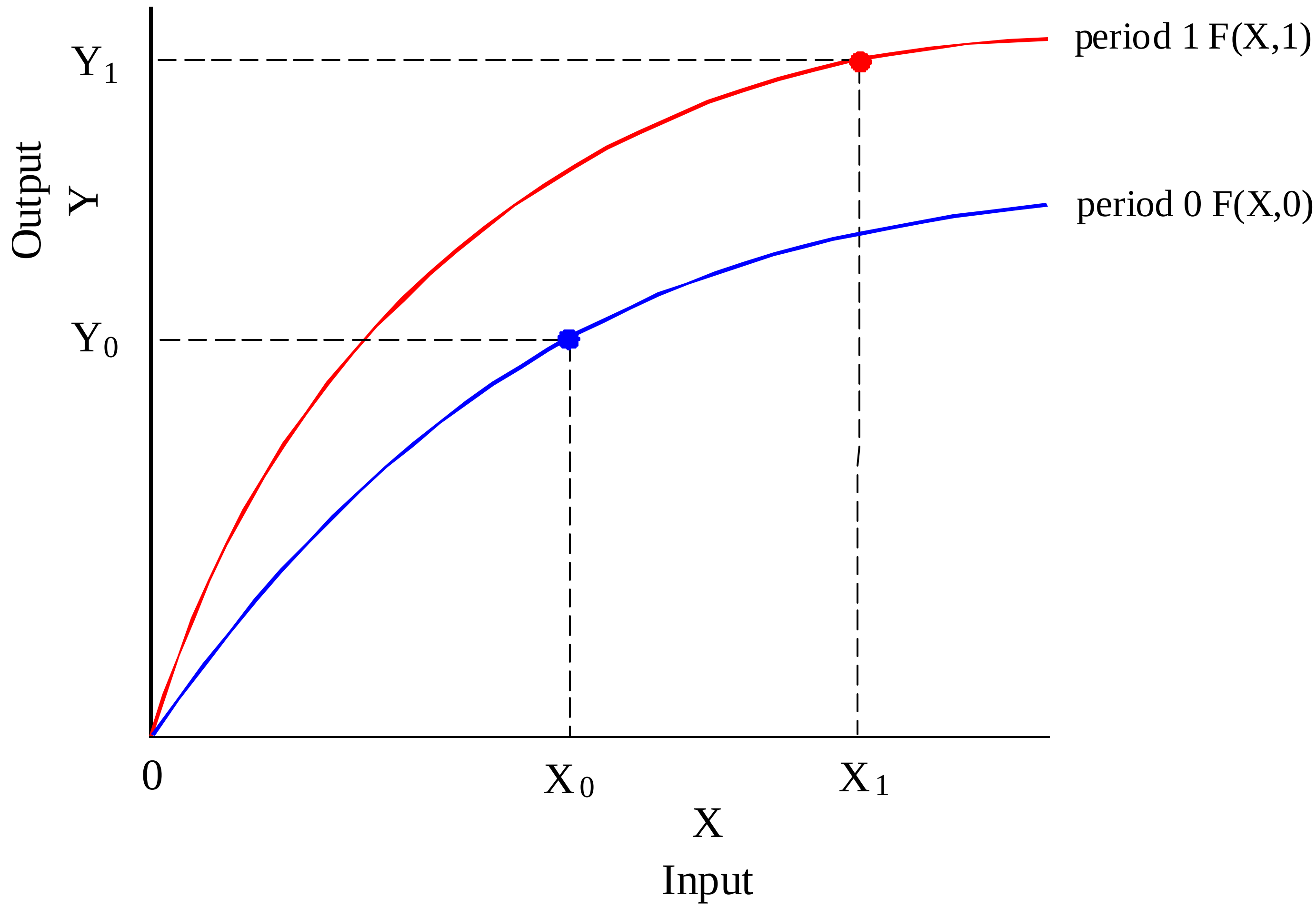
The Economist's Concept of Technical Progress

- A production function may change over time. Thus:
  - $Y = F(X, t)$
- Definition:
  - There is technical progress between period 0 and period 1 if given the same quantity of input, X_0 , the quantity of output in period 1, Y_1 , is greater than the quantity of output in period 0, Y_0 , i.e.,

$$F(X_0,1) \geq F(X_0,0)$$

- TECHNICAL PROGRESS = THE GROWTH OF OUTPUT HOLDING MEASURED INPUTS CONSTANT

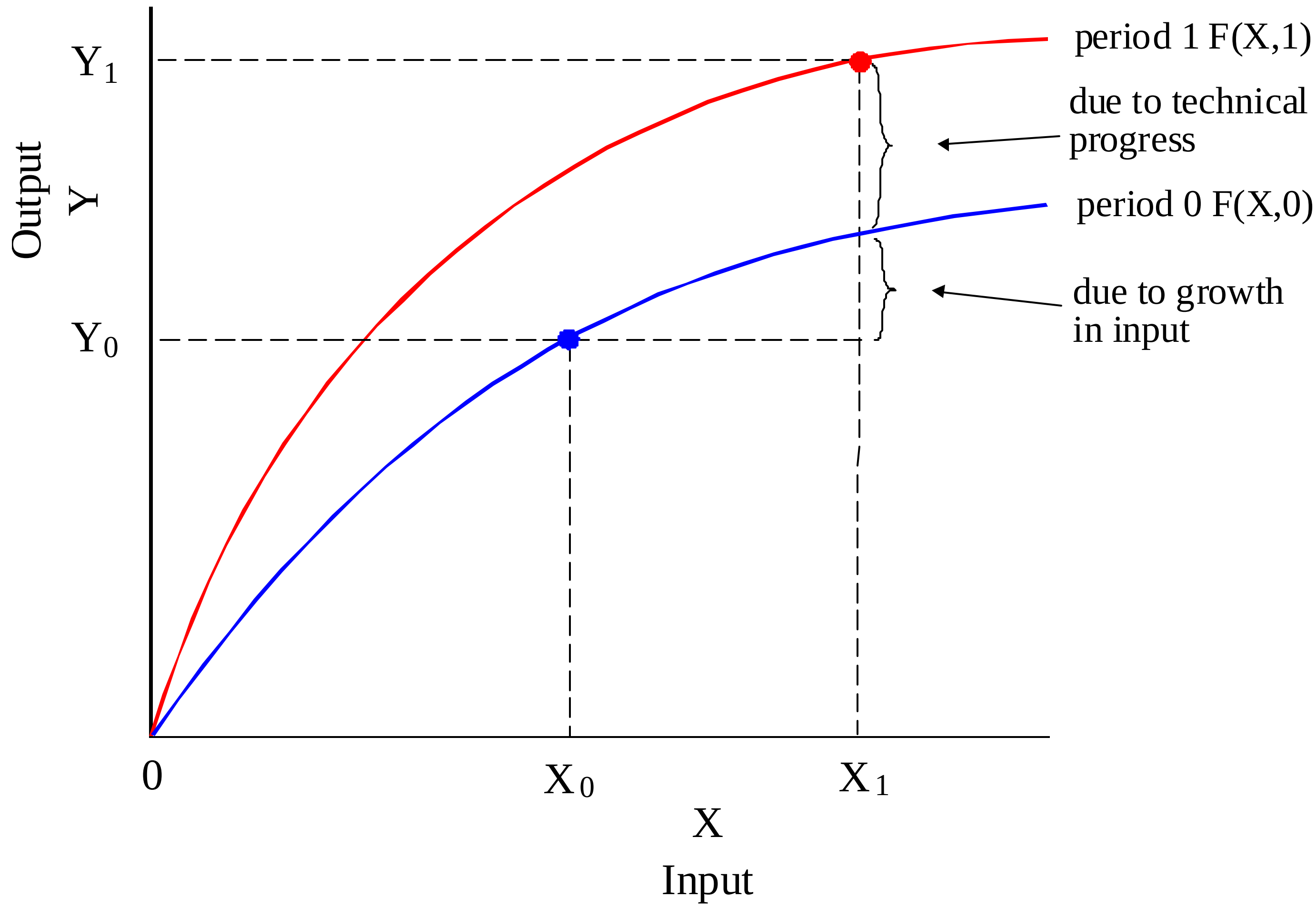
Technical Progress: The Single-Output, Single-Input Case



Decomposition of the Growth of Output

- If the production function is known, the growth of output can be decomposed into:
  - (1) The growth of output due to the growth of measured inputs (movement along a production function) and
  - (2) Technical progress (shift in the production function)
- The growth of output due to the growth of inputs can be further decomposed into the growth of output due to tangible capital, labor (and any other measured inputs)

Decomposition of the Growth of Output



Interpretation of Technical Progress (Growth of Total Factor Productivity)

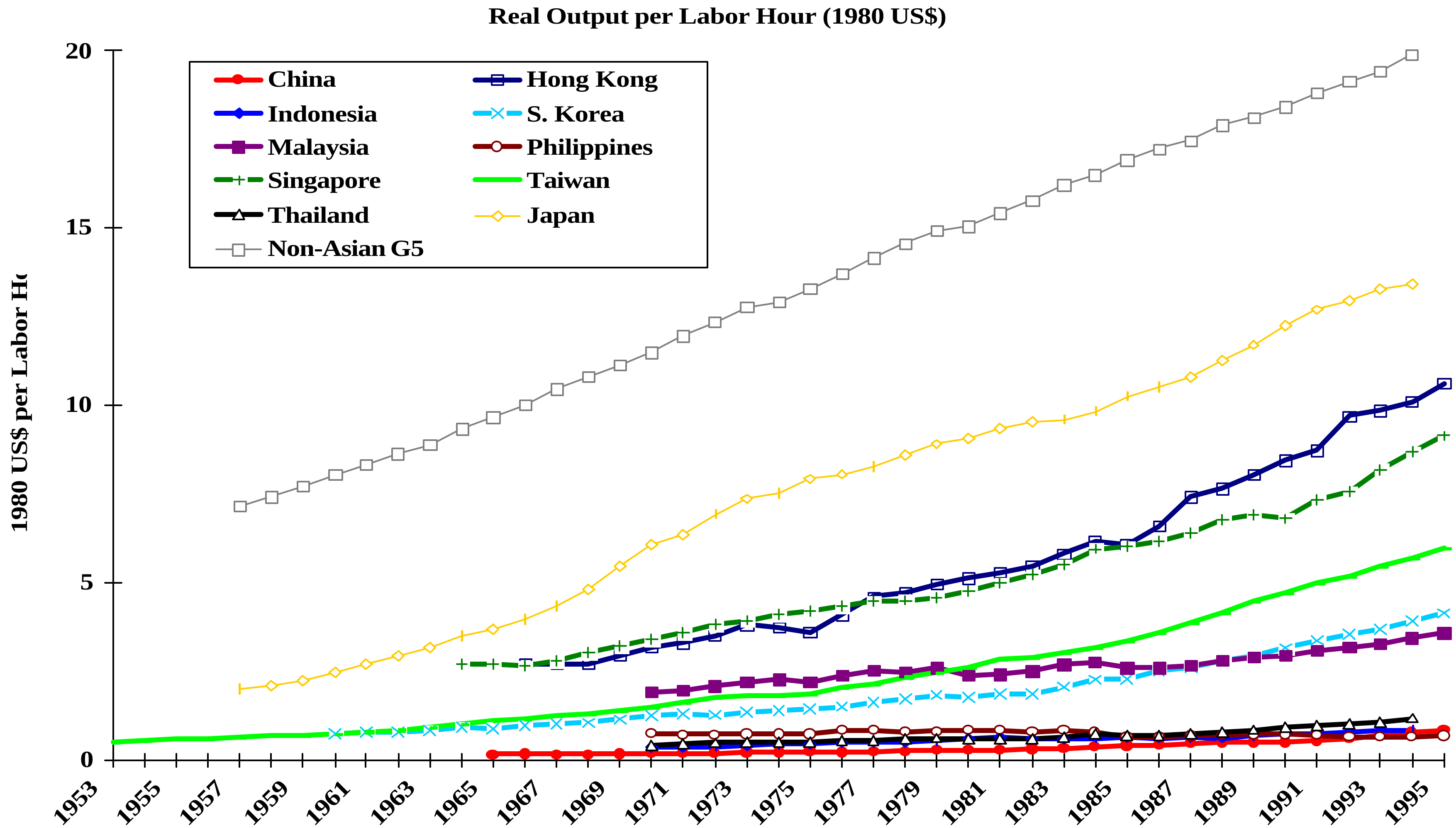
- Not "Manna from Heaven"
- The effects of growth in unmeasured "Intangible Capital" (Human Capital, R&D Capital, Goodwill and Reputational Capital (Advertising, Branding and Market Development), Information System, Software, etc.)
- The effects of growth or degradation and depletion in other omitted and unmeasured inputs (Land, Natural Resources, Water Resources, Environment, etc.)
- The effects of improvements in technical and allocative efficiency over time, e.g., learning-by-doing
- "Residual" or "Measure of Our Ignorance"

Rates of Growth of Inputs & Outputs of the East Asian Developing & the G-7 Countries

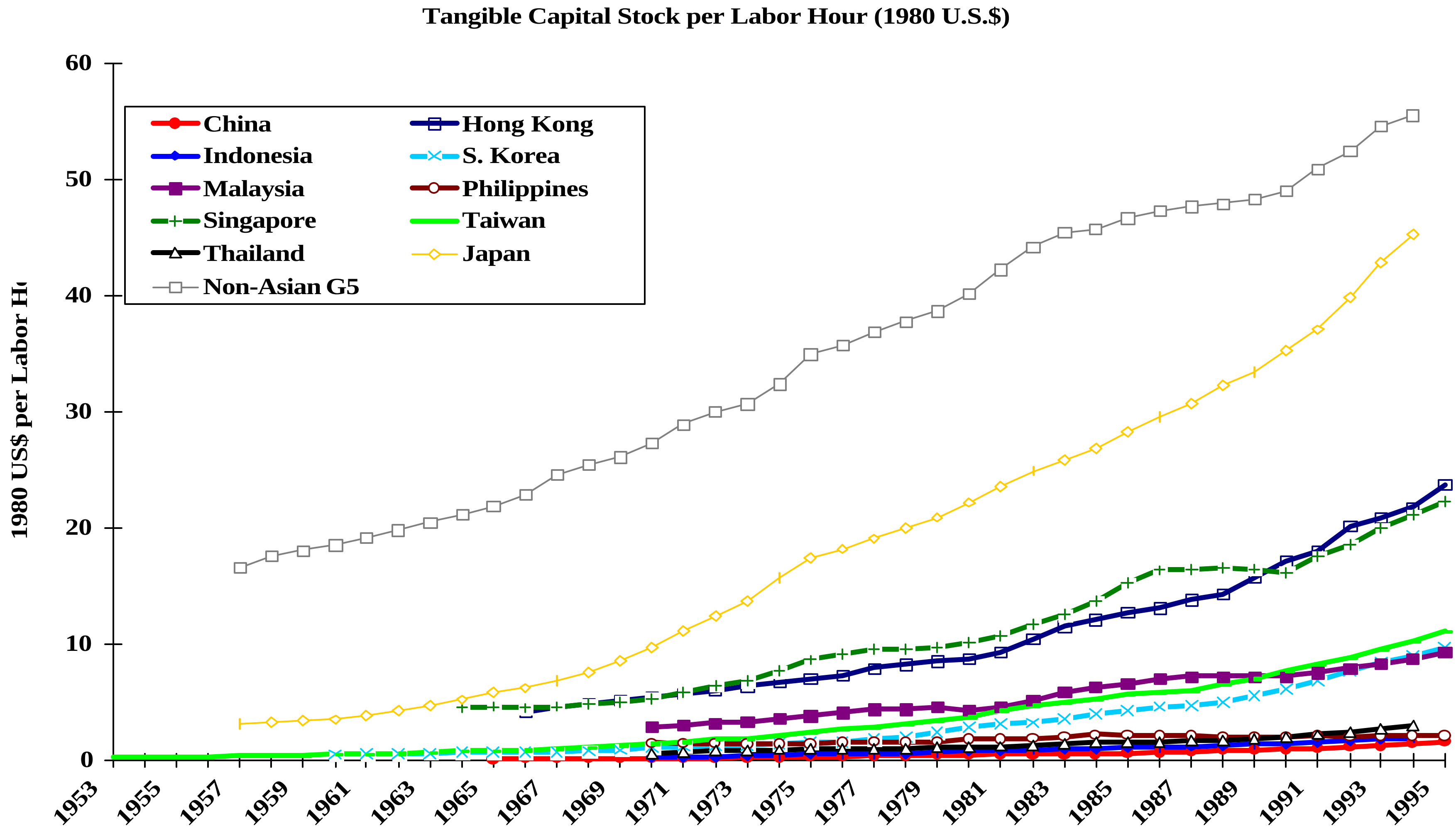
Table 3.1: Average Annual Rates of Growth of Real GDP, Capital, Labor and Human Capital (percent)
(Extended sample period)

Country	Period	GDP	Capital Stock	Utilized Capital	Employmen	Labor Hours	Human Capital	Average Human Capital
Hong Kong	66-95	7.4	8.8	8.6	2.6	2.4	4.8	2.1
S. Korea	60-95	8.5	12.3	12.3	3.1	3.3	6.2	4.0
Singapore	64-95	8.8	10.3	10.3	4.3	4.7	5.9	3.5
Taiwan	53-95	8.4	11.8	11.8	2.7	2.3	5.3	2.8
Indonesia	70-94	6.7	8.9	9.8	3.1	3.1	9.6	7.7
Malaysia	70-95	7.3	11.8	11.8	3.7	3.7	7.7	4.9
Philippines	66-95	4.0	5.8	5.9	3.2	3.2	10.8	8.5
Thailand	66-94	7.6	9.1	9.4	2.8	2.8	8.5	5.8
China	65-95	8.4	10.3	10.3	3.0	3.0	5.9	3.3
Japan	57-94	5.9	8.1	8.0	1.1	0.6	2.1	0.9
Canada	57-94	3.8	4.8	4.7	2.3	1.9	3.0	1.1
France	57-94	3.3	3.9	3.9	0.4	-0.2	2.0	1.1
W. Germany	57-94	3.2	3.3	3.1	0.1	-0.3	1.5	1.0
Italy	59-94	3.5	5.2	5.3	0.0	-0.3	1.8	1.3
UK	57-94	2.4	3.9	3.8	0.2	-0.1	1.2	0.8
US	49-94	3.1	3.0	3.3	1.7	1.3	2.1	0.8

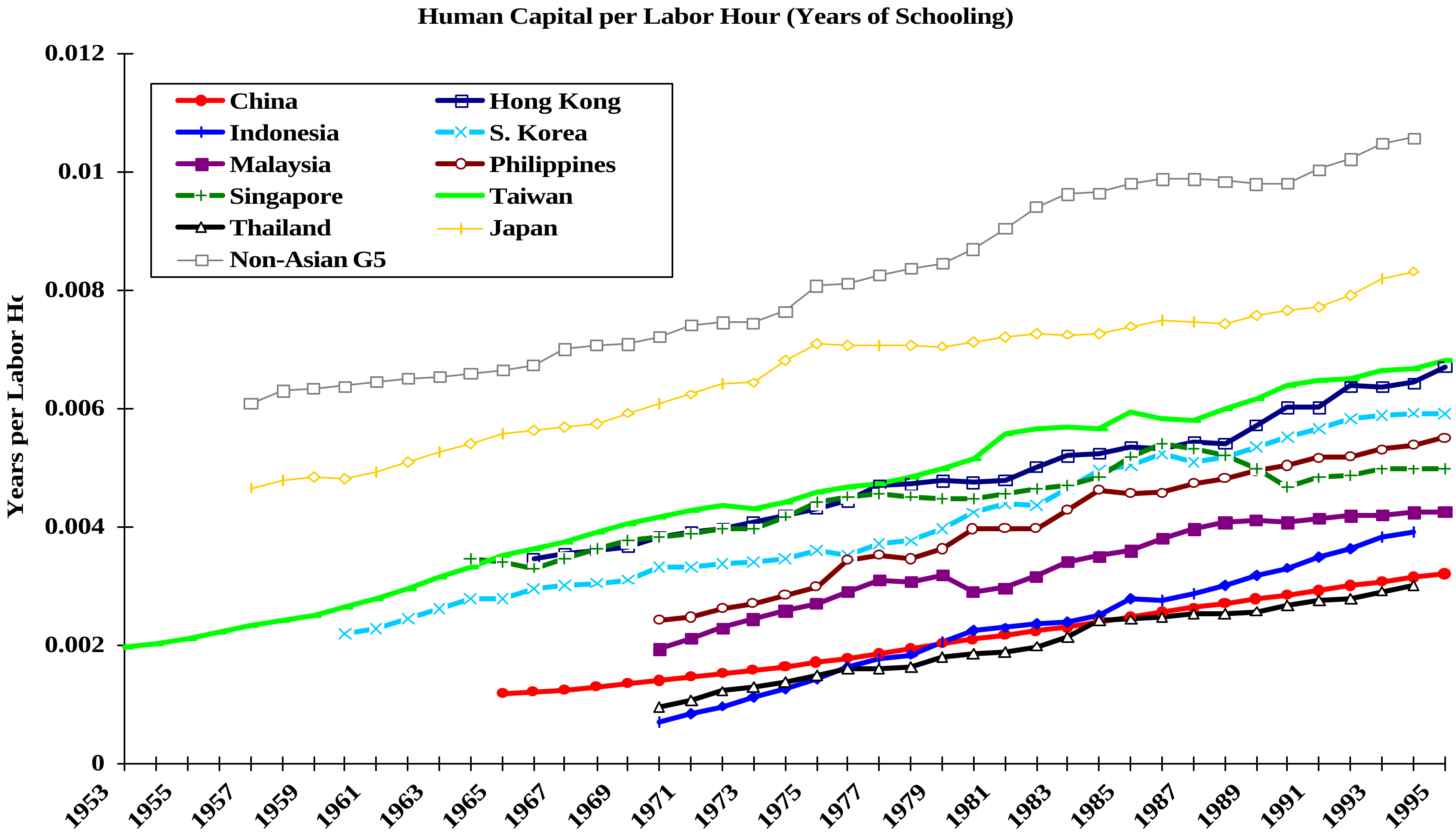
Real Output per Labor Hour (1980 US$)



Tangible Capital Stock per Labor Hour (1980 US$): Selected Economies



Human Capital per Labor Hour (Years of Schooling): Selected Economies



Difficulties in the Measurement of Technical Progress (Total Factor Productivity)

- (1) The confounding of economies of scale and technical progress
  - Solution: pooling time-series data across different countries--at any given time there are different scales in operation; the same scale can be observed at different times
- (2) The under-identification of the biases of scale effects and technical progress
  - Bias in scale effects--as output is expanded under conditions of constant prices of inputs, the demands for different inputs are increased at differential rates
  - Bias in technical progress--over time, again under constant prices, the demands of different inputs per unit output decreases at different rates
  - Solution: econometric estimation with flexible functional forms

Two Leading Alternative Approaches to Growth Accounting

- (1) Econometric Estimation of the Aggregate Production Function, E.g., the Cobb-Douglas production function

$$Y_t = A_0 e^{\gamma t} K_t^{\alpha} L_t^{\beta}$$

or, taking natural logarithms

$$\ln Y_t = \ln A_0 + \alpha \ln K_t + \beta \ln L_t + \gamma t$$

- (2) Traditional Growth-Accounting Formula
  - **Are Differences in Empirical Results Due to Differences in Methodologies or Assumptions or Both?**

The Meta-Production Function Approach as an Alternative

- Introduced by Hayami (1969) and Hayami & Ruttan (1970, 1985)
- Haymai & Ruttan assume that $F_i(.) = F(.)$:
  - $Y_{it} = F(K_{it}, L_{it}, t)$, $i = 1, \ldots, n$; $t = 0, \ldots, T$
- Which implies that all countries have identical production functions in terms of <u>measured</u> inputs
- Thus pooling of data across multiple countries is justified

Extension by Boskin, Lau & Yotopoulos

- Extended by Lau & Yotopoulos (1989) and Boskin & Lau (1990) to allow time-varying, country- and commodity-specific differences in efficiency
- Applied by Boskin, Kim, Lau, & Park to the G-5 countries, G-7 countries, the East Asian Newly Industrialized Economies (NIEs) and developing economies in the Asia/Pacific region

The Extended Meta-Production Function Approach: The Basic Assumptions (1)

(1) All countries have the same underlying aggregate production function F(.) in terms of standardized, or “**efficiency-equivalent**”, quantities of outputs and inputs, i.e.

(1) $$Y^*_{it} = F(K^*_{it}, L^*_{it}) \ , \ i = 1,\ldots,n.$$

The Extended Meta-Production Function Approach: The Basic Assumptions (2)

(2) The measured quantities of outputs and inputs of the different countries may be converted into the unobservable standardized, or "efficiency-equivalent", units of outputs and inputs by multiplicative country- and output- and input-specific time-varying **augmentation factors**, $A_{ij}(t)$'s, i = 1,...,n; j = output (0), capital (K), and labor (L):

(2) $$Y^*_{it} = A_{i0}(t)Y_{it} \;;$$

(3) $$K^*_{it} = A_{iK}(t)K_{it} \;;$$

(4) $$L^*_{it} = A_{iL}(t)L_{it} \;; i = 1, ..., n.$$

The Extended Meta-Production Function Approach: The Basic Assumptions (2)

- In the empirical implementation, the commodity augmentation factors are assumed to have the constant geometric form with respect to time. Thus:

(5) $Y^*_{it} = A_{i0}\,(1+c_{i0})^t Y_{it}$;

(6) $K^*_{it} = A_{iK}\,(1+c_{iK})^t K_{it}$;

(7) $L^*_{it} = A_{iL}\,(1+c_{iL})^t L_{it}$; $i = 1,\ldots,n$.

A_{i0}'s, A_{ij}'s = augmentation level parameters

c_{i0}'s, c_{ij}'s = augmentation rate parameters

The Extended Meta-Production Function Approach: The Basic Assumptions (2)

- For at least one country, say the ith, the constants A_{i0} and A_{ij}'s can be set identically at unity, reflecting the fact that "efficiency-equivalent" outputs and inputs can be measured only relative to some standard.
- The A_{i0} and A_{ij}'s for the U.S. are taken to be identically unity.
- Subject to such a normalization, the commodity augmentation level and rate parameters can be estimated simultaneously with the parameters of the aggregate production function.

The Commodity-Augmenting Representation of Technical Progress

One specialization of

$Y = F(K, L, t)$ is

$Y^* = F(K^*, L^*)$, where

Y^*, K^*, and L^* are efficiency-equivalent quantities. Thus, in terms of measured quantities,

$$Y = A_0(t)\,F(A_K(t)K,\, A_L(t)L).$$

The Meta-Production Function Approach

- It is important to understand that the meta-production function approach assumes that the production function is identical for all countries only in terms of the <u>efficiency-equivalent</u> quantities of outputs and inputs; it is not identical in terms of measured quantities of outputs and inputs
- A useful way to think about what is the same across countries is the following—the isoquants remain the same for all countries and over time with a suitable renumbering of the isoquants and a suitable re-scaling of the axes

The Extended Meta-Production Function Approach: The Basic Assumptions (3)

(3) The aggregate meta-production function is assumed to have a flexible functional form, e.g. the transcendental logarithmic functional form of Christensen, Jorgenson & Lau (1973).

The Extended Meta-Production Function Approach: The Basic Assumptions (3)

- The translog production function, in terms of "efficiency-equivalent" output and inputs, takes the form:

  $$(8) \quad \ln Y^*_{it} = \ln Y_0 + a_K \ln K^*_{it} + a_L \ln L^*_{it} + B_{KK}(\ln K^*_{it})^2/2 + B_{LL}(\ln L^*_{it})^2/2 + B_{KL}(\ln K^*_{it})(\ln L^*_{it}), \; i = 1,\ldots,n.$$

- By substituting equations (5) through (7) into equation (8), and simplifying, we obtain equation (9), which is written entirely in terms of **observable** variables:

The Estimating Equation

(9) $$\ln Y_{it} = \ln Y_0 + \ln A^*_{i0} + a^*_{Ki} \ln K_{it} + a^*_{Li} \ln L_{it} + c^*_{i0} t + B_{KK}(\ln K_{it})^2/2 + B_{LL}(\ln L_{it})^2/2 + B_{KL}(\ln K_{it})(\ln L_{it}) + (B_{KK}\ln(1+c_{iK}) + B_{KL}\ln(1+c_{iL}))(\ln K_{it})t + (B_{KL}\ln(1+c_{iK}) + B_{LL}\ln(1+c_{iL}))(\ln L_{it})t + (B_{KK}(\ln(1+c_{iK}))^2 + B_{LL}(\ln(1+c_{iL}))^2 + 2B_{KL}\ln(1+c_{iK})\ln(1+c_{iL}))t^2/2,$$

$i = 1,\ldots,n$, where A^*_{i0}, a^*_{Ki}, a^*_{Li}, c^*_{i0} and c_{ij}'s, $j = K, L$ are country-specific constants.

Tests of the Maintained Hypotheses of the Meta-Production Function Approach

- The parameters B_{KK}, B_{KL}, and B_{LL} are independent of i, i.e., of the particular individual country. This provides a basis for testing the maintained hypothesis that there is a single aggregate meta-production function for all the countries.
- The parameter corresponding to the $t^2/2$ term for each country is not independent but is completely determined given B_{KK}, B_{KL}, B_{LL}, c_{iK}, and c_{iL}. This provides a basis for testing the hypothesis that technical progress may be represented in the constant geometric commodity-augmentation form.

The Labor Share Equation

- In addition, we also consider the behavior of the share of labor costs in the value of output:

  $$(10)\ w_{it}L_{it}/p_{it}Y_{it} = a^*_{Lii} + B_{KLi}(\ln K_{it}) + B_{LLi}(\ln L_{it}) + B_{Lti}t,\ i = 1,\ldots,n.$$

Instantaneous Profit Maximization under Competitive Output and Input Markets

- The share of labor costs in the value of output should be equal to the elasticity of output with respect to labor: (11) $w_{it}L_{it} / p_{it}Y_{it} = a^*_{Li} + B_{KL}(\ln K_{it}) + B_{LL}(\ln L_{it}) + (B_{KL}\ln(1+c_{iK}) + B_{LL}\ln(1+c_{iL}))t$, $i = 1,...,n$.
- This provides a basis for testing the hypothesis of profit maximization with respect to labor.

Test of Hypotheses: The Meta-Production Function Approach

- The maintained hypotheses of the meta-production function approach
  - "Identical Meta-Production Functions" and
  - "Factor-Augmentation Representation of Technical Progress"
- The different kinds of purely commodity-augmenting technical progress
- The hypothesis of no technical progress

The Different Kinds of Purely Commodity-Augmenting Technical Progress

$Y = A_0(t) F(A_K(t)K, A_L(t)L)$

$= A_0(t)F(A_K K, A_L L)$, purely output-augmenting (Hicks-neutral)

$= A_0 F(A_K(t)K, A_L L)$, purely capital-augmenting (Solow-neutral)

$= A_0 F(A_K K, A_L(t)L)$, purely labor-augmenting (Harrod-neutral)

The Hypothesis of No Technical Progress

- $c_{i0} = 0; c_{iK} = 0; c_{iL} = 0$
- This hypothesis is rejected for the Group-of-Five Countries.
- This hypothesis cannot be rejected for the East Asian NIEs.

The Sources of Economic Growth: Findings of Kim & Lau As Reported by Krugman (1994)

- Using data from the early 1950s to the late 1980s, Kim and Lau (1992, 1994a, 1994b) find, by estimating a meta-production function for the G-5 and the 4 Newly Industrialized Economies (NIEs—Hong Kong, South Korea, Singapore and Taiwan) that:
- (1) No technical progress in the East Asian NIEs but significant technical progress in the industrialized economies (IEs)
- (2) East Asian economic growth has been tangible input-driven, with tangible capital accumulation as the most important source of economic growth (the latter applying also to Japan)
  - Working harder as opposed to working smarter
- (3) Technical progress is the most important source of economic growth for the IEs, followed by tangible capital, accounting for over 50% and 30% respectively, with the exception of Japan
  - NOTE THE UNIQUE POSITION OF JAPAN!
- (4) Technical progress is purely tangible capital-augmenting and hence complementary to tangible capital, confirming the earlier findings of Boskin and Lau for the Group-of-Five (G-5) Countries

The Findings of Kim & Lau (1992, 1994a, 1994b)

- (5) Despite their high rates of economic growth and rapid capital accumulation, the East Asian Newly Industrialized Economies actually experienced a significant decline in productive efficiency relative to the industrialized countries as a group
- (6) Technical progress being purely tangible capital-augmenting implies that it is less likely to cause technological unemployment than if it were purely labor-augmenting

Accounts of Growth (Early 1950s-Late 1980s): Kim & Lau (1992, 1994a, 1994b)

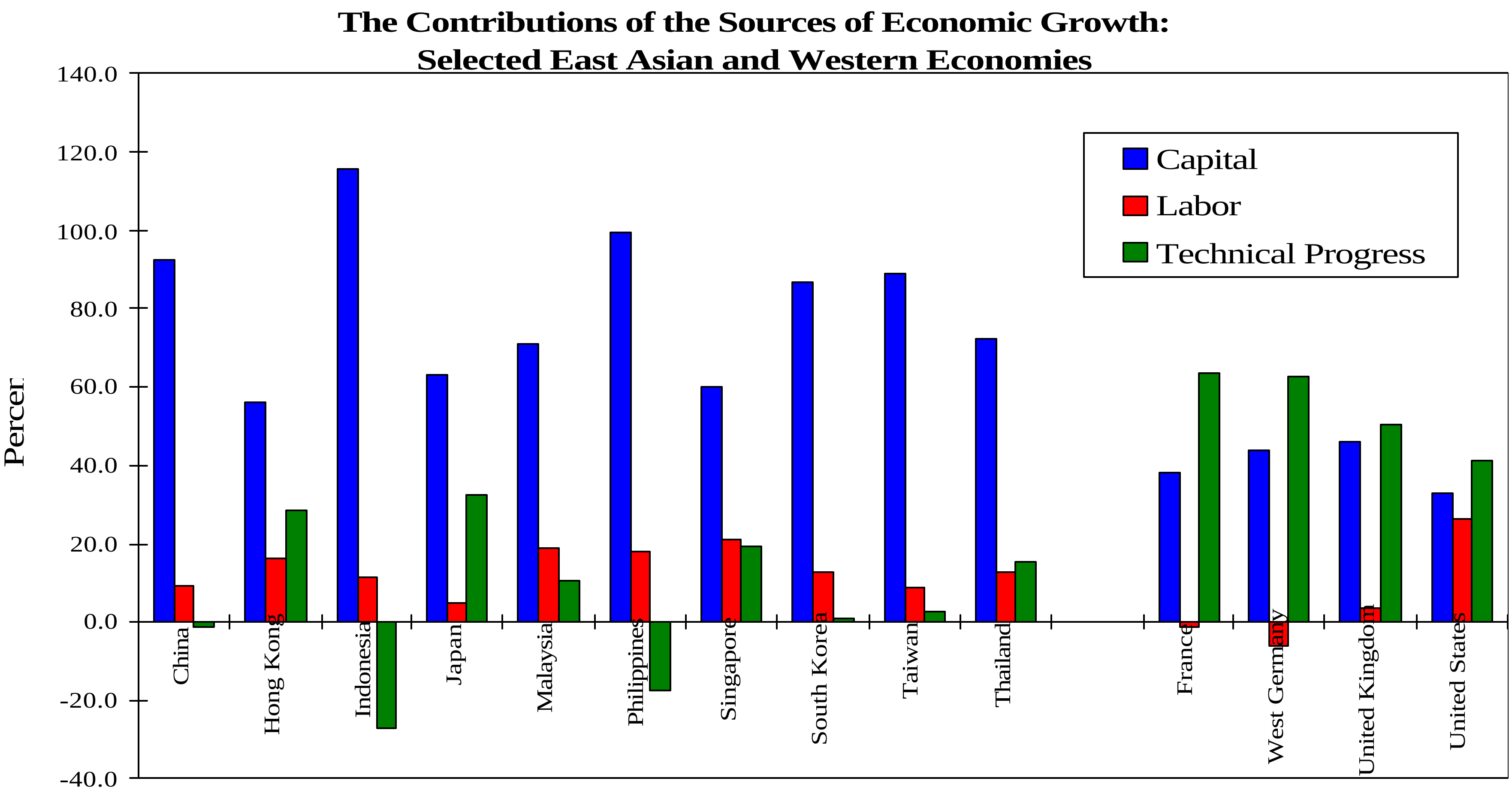
Table 2.2: Relative Contributions of the Sources of Economic Growth (percent)				
Economy	**Tangible Capital**	**Labor**	**Technical Progress**	
Hong Kong	**74**	**26**	**0**	
Singapore	**68**	**32**	**0**	
S. Korea	**80**	**20**	**0**	
Taiwan	**85**	**15**	**0**	
Japan	**56**	**5**	**39**	
Non-Asian G-5	**36**	**6**	**59**	

The Sources of Economic Growth: Selected East Asian and Western Economies

The Contributions of the Sources of Growth (percent)

	Capital	Labor	Technical Progress
East Asian Economies			
China	92.2	9.2	-1.4
Hong Kong	55.8	16.0	28.2
Indonesia	115.7	11.5	-27.2
Japan	62.9	4.7	32.4
Malaysia	70.9	18.7	10.4
Philippines	99.5	18.0	-17.5
Singapore	60.0	20.9	19.1
South Korea	86.3	12.7	1.0
Taiwan	88.9	8.6	2.5
Thailand	71.9	12.7	15.4
Western Industrialized Economies			
France	37.8	-1.3	63.5
West Germany	43.7	-6.3	62.6
United Kingdom	46.0	3.7	50.3
United States	32.9	26.2	40.9

The Sources of Economic Growth: Selected East Asian and Western Economies



Empirical Evidence for the Hypothesis of No Technical Progress in East Asian NIEs

- Tsao (1985) and Young (1992) for Singapore
- Kim & Lau (1992, 1994a, 1994b) and Young (1995) for the four East Asian NIEs
- Paul Krugman (1994)
- Kim & Lau (1996) extend the same finding to other East Asian economies--China, Indonesia, Malaysia, Philippines, and Thailand

Empirical Evidence Against the Hypothesis of No Technical Progress

- Young (1992) for Hong Kong
- The World Bank (1993)
- Credibility of such studies undermined by restrictive maintained hypotheses such as
  - CONSTANT RETURNS TO SCALE
  - NEUTRALITY OF TECHNICAL PROGRESS &
  - INSTANTANEOUS COMPETITIVE PROFIT MAXIMIZATION

Purely Capital-Augmenting Technical Progress

$$Y = A_0(t)\ F(A_K(t)K,\ A_L(t)L)$$

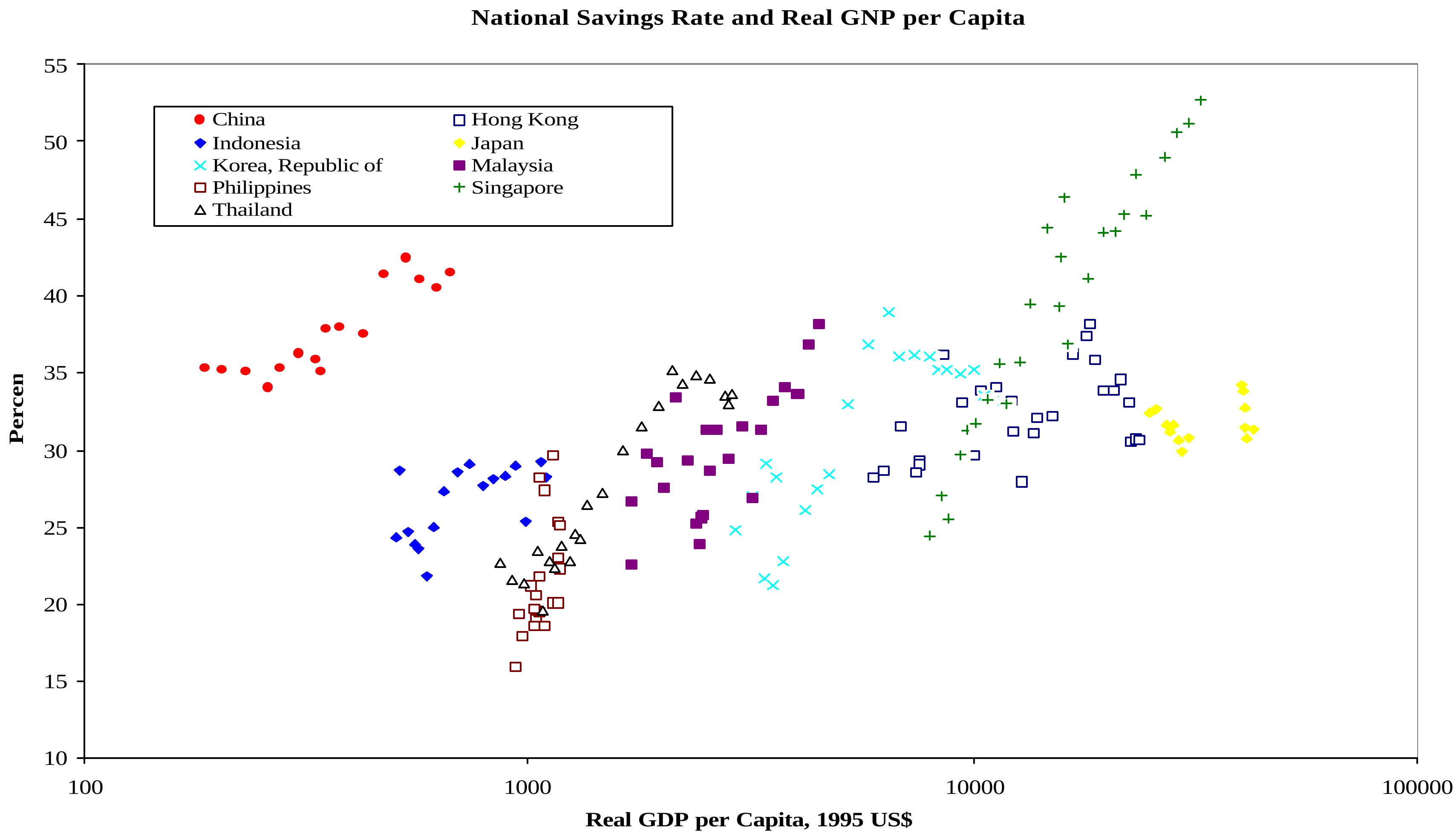
$$= A_0 F(A_K(t)K,\ A_L L)$$

$$= A_0 F(A_K(1+c_{iK})^t K,\ A_L L)$$

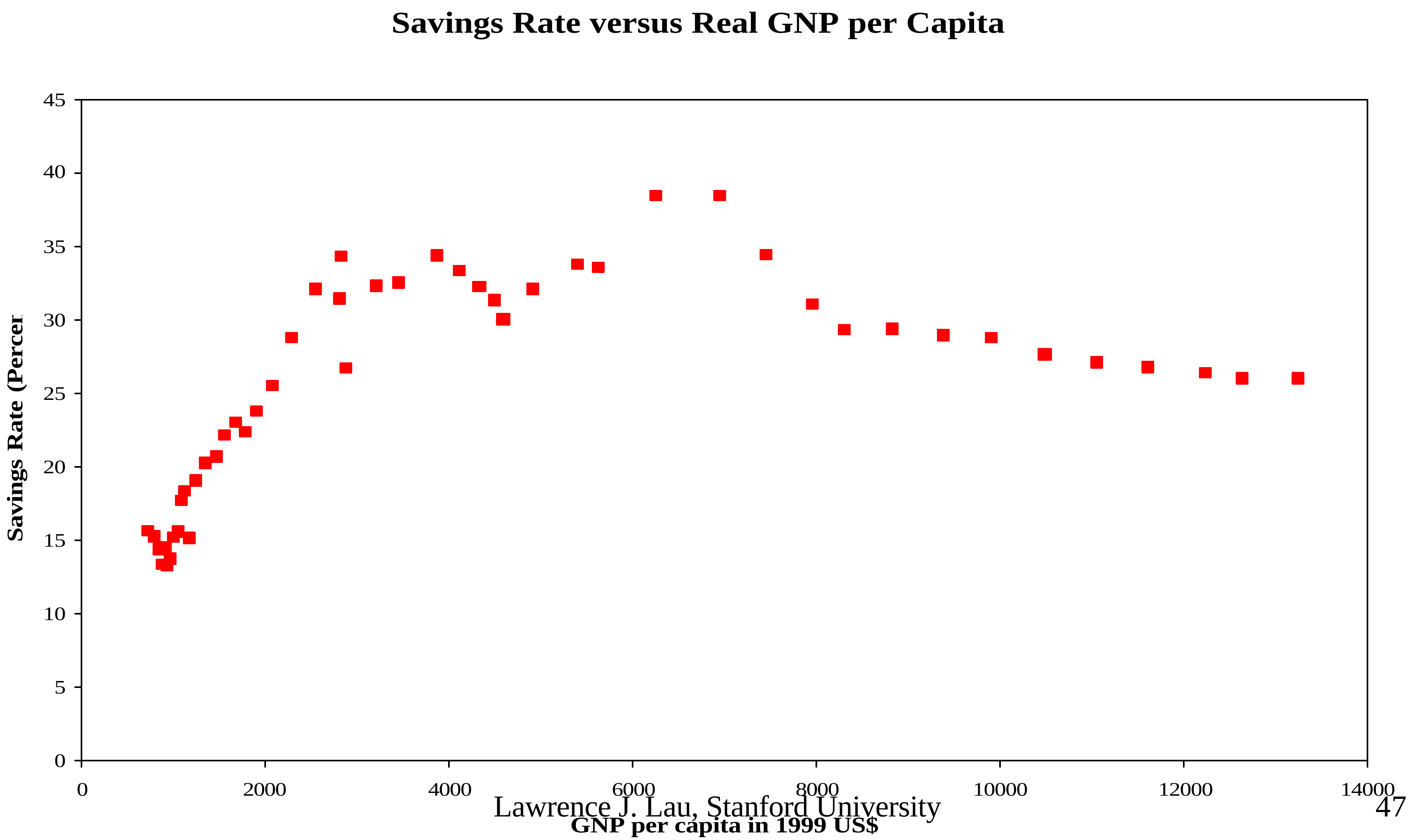
The production function can also be written as:

$$= A_0 F(A_K\, e^{c_{iK}.t} K,\ A_L L)$$

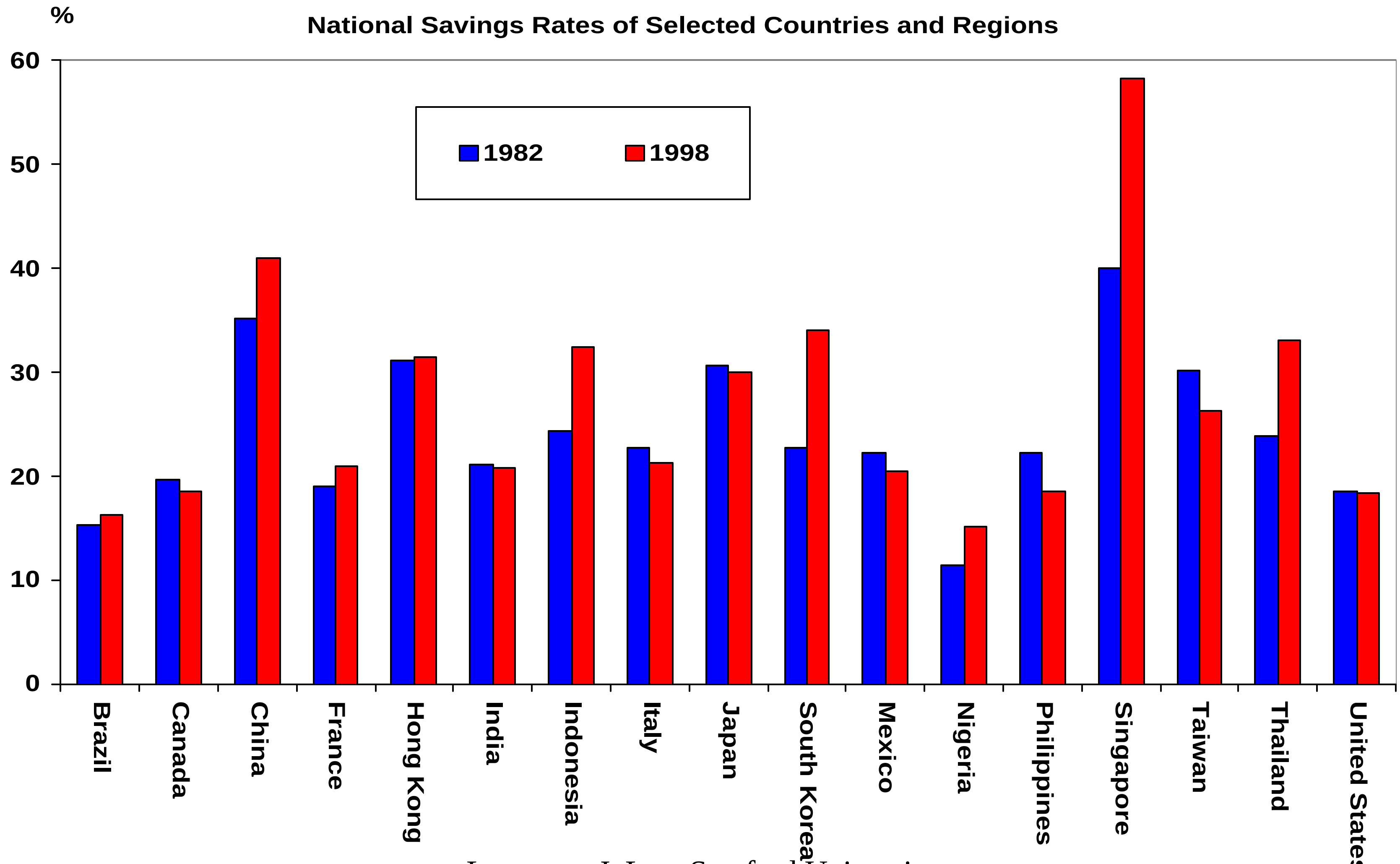
The Savings Rate and Real Output per Capita: East Asian Economies



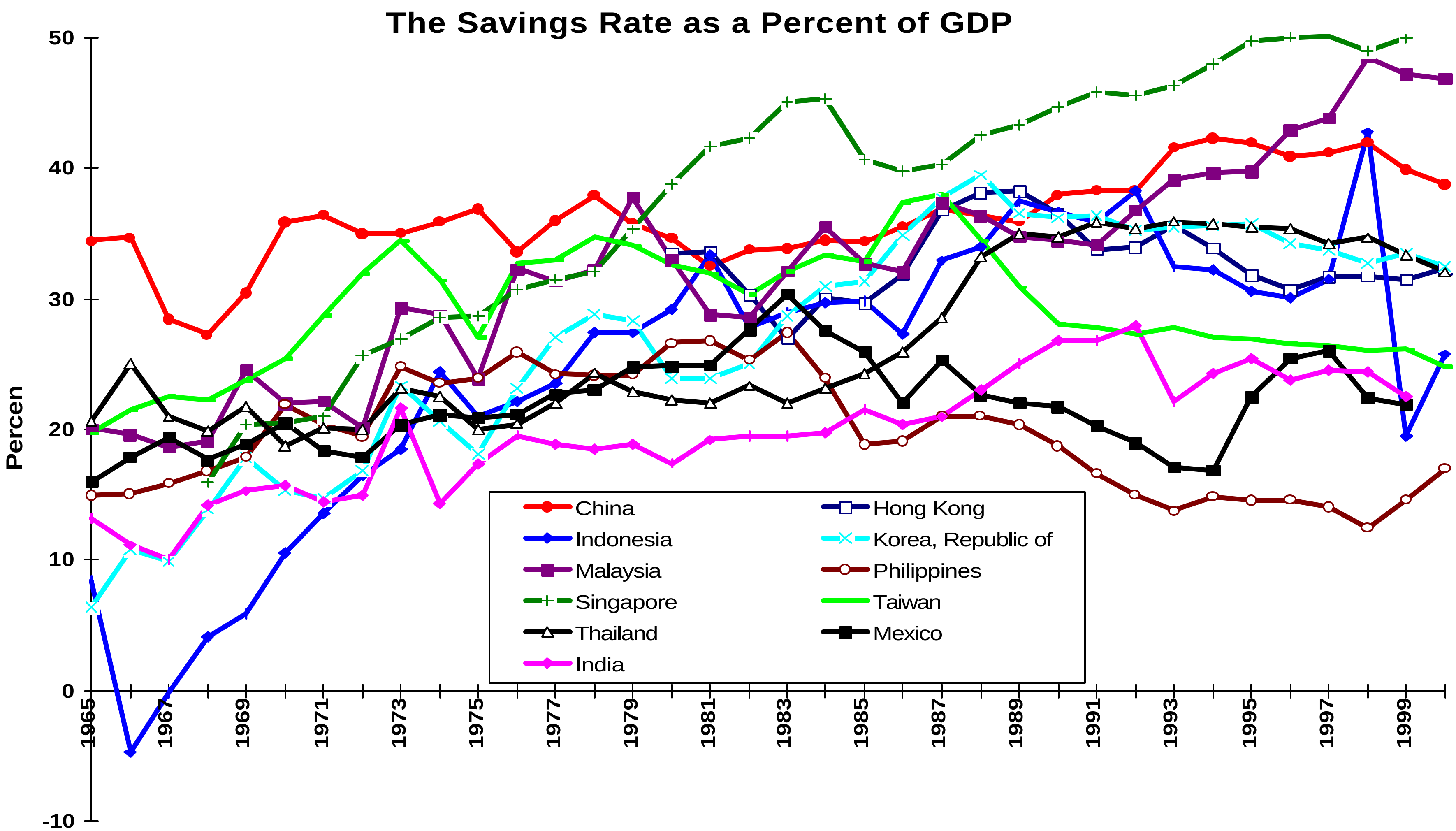
The Savings Rate and Real Output per Capita: Taiwan



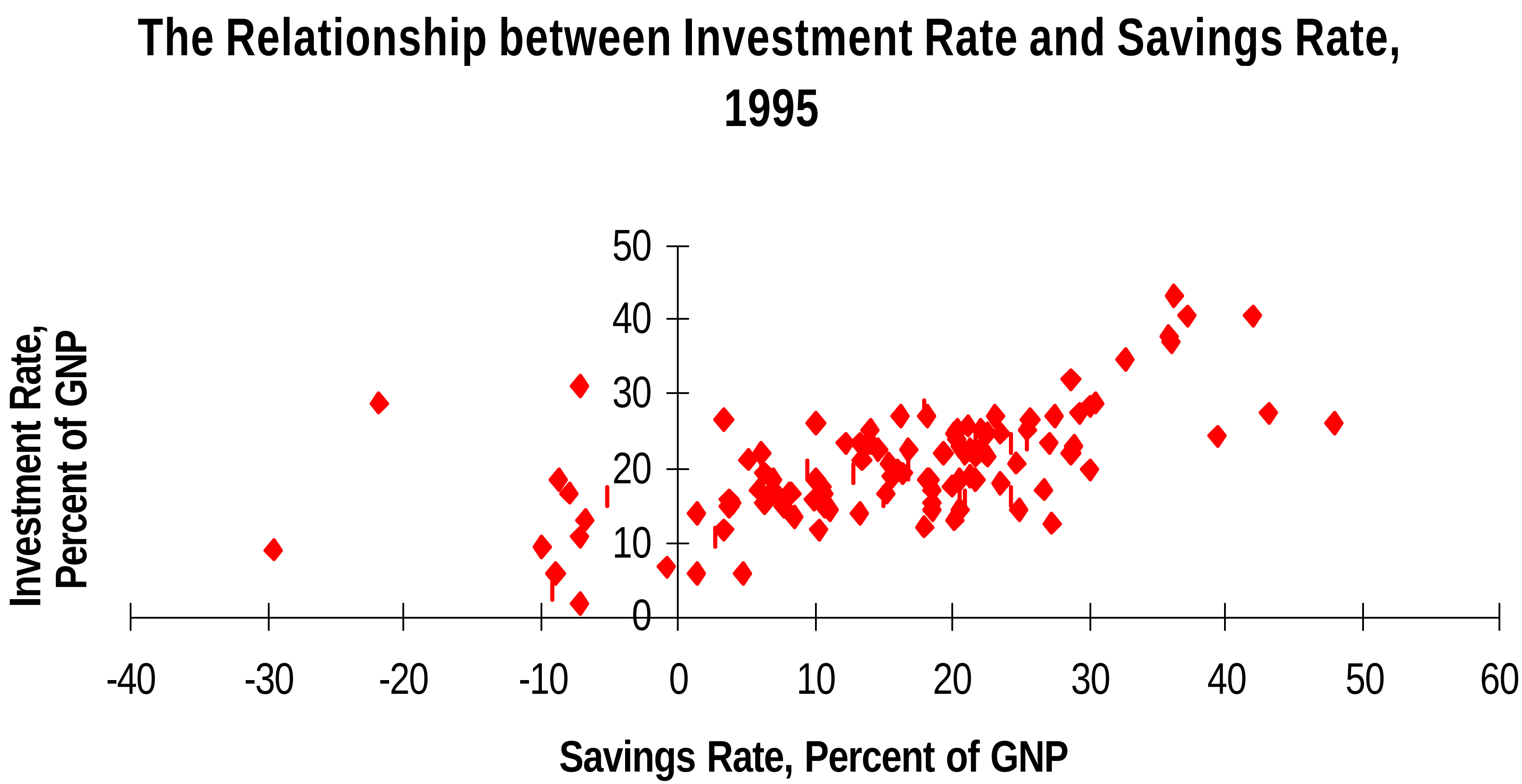
National Savings Rate as a Percent of GDP: Selected Countries and Regions



The Savings Rate as a Percent of GDP: Selected East Asian Countries and Regions



The Relationship between Investment Rates and Savings Rates



Why is There No Measured Technical Progress in East Asian NIEs? (1)

- (1) Low level of investment in intangible capital (human capital, R&D capital, knowledge capital and other forms of intangible capital)
  - The effects of technical progress in these production function studies are essentially captured by the estimated parameters of the time trend, which is supposed to reflect the influence of the changes in the omitted or unmeasured inputs, such as human capital, R&D capital, R&D capital, knowledge capital, land or more generally the natural endowment of resources, and other intangible "investments" such as software and market development.
  - However, since the developing East Asian economies, until very recently, have invested relatively little in intangible capital (e.g., R&D, especially in basic research), such omitted or unmeasured variables are actually unlikely to be important in them.

Why is There No Measured Technical Progress in East Asian NIEs? (1)

- Thus the indigenously generated improvements in technology have been quite scarce in developing East Asian economies other than Japan.
- By contrast, the industrialized economies invest a significant percentage of their GDP in R&D and even greater amounts in innovation and other productivity-enhancing activities.
- Thus, it should not be surprising that technical progress, or the "residual", is much larger in the industrialized economies than in the developing East Asian economies.
- Moreover, utilization of other countries' intangible capital is not costless--royalties, license fees, maintenance and service contracts, cross-licensing, full pricing of capital goods
- Complementary indigenous investment is required, e.g., the new rice varieties of the Green Revolution

Why is There No Measured Technical Progress in East Asian NIEs? (2)

- (2) The distribution of "Innovation Rents" (quite properly) favors the innovators and investors
  - The industries in the developing East Asian economies typically employ mature technologies with limited innovation possibilities but the capital goods and technology for which, mostly imported, have been fully priced (i.e., the acquisition as well as royalty costs fully reflect the possible efficiency gains and the amortization of R&D and other developmental costs) in the international market, so that there may be little or no net increase in value added, over and above the normal returns to the factor inputs. In other words, the "innovation rents" have been largely captured by the inventors, manufacturers and distributors of the new equipment or intermediate inputs in the industrialized economies in markets that are only very imperfectly competitive.

Why is There No Measured Technical Progress in East Asian NIEs? (2)

- The "rents" can also take the form of royalties and licensing fees paid to the foreign technology licensors by the developing East Asian economies, or through transfer pricing by foreign direct investors, reducing correspondingly the domestic part of the real value-added.
- Monopolistic pricing of capital equipment, technology licenses and critical components (e.g., systems integration capability for aircraft manufacturers; plastic lens for cameras), and the control over marketing through the establishment of brand names limit the value added by manufacturers/assemblers in developing East Asian economies, e.g., notebook computers
- Monopsonistic pricing for OEM manufacturers--the benefits of learning-by-doing on the part of the OEM manufacturers accrue mostly to the owners of brand names, designs, and marketing organizations
- Consequently, even if a new technology were adopted, its effect might not be reflected in the form of a higher real value-added, holding measured factor inputs constant.

Why is There No Measured Technical Progress in East Asian NIEs? (3)

- (3) Problems of Measurement of Capital
  - Fixed investment in equipment in industrialized economies are typically measured, at factor costs, net of the intangible inputs required, whereas fixed investment in equipment in developing economies, being mostly imported from developing economies, are measured inclusive of intangible inputs, returns to intellectual capital, monopoly rents, and turnkey installation costs
    - E.g., the fixed investment in equipment of the same semiconductor fabrication plant may well be higher in a developing economy as compared to an industrialized economy
    - A simple way to understand this point is that capital equipment in industrialized economies may be sold unbundled with the "soft" costs (including software), whereas capital equipment in developing economies are typically sold bundled with the "soft" costs

Why is There No Measured Technical Progress in East Asian NIEs? (4)

- (4) Aggregation
  - It is possible, in fact likely, that there may have been positive technical progress in certain efficient (tradable) sectors and industries in the developing East Asian economies.
  - However, this may be largely offset by rising inefficiency in certain other industries, especially those in the nontradable sectors.
  - The economy as a whole may exhibit no measured technical progress.
  - Rising inefficiency can persist only in protected markets under monopolistic or oligopolistic conditions. Thus, technical progress at the microeconomic or industrial level may be nullified by the inefficiency caused by the lack of competition in the domestic market.

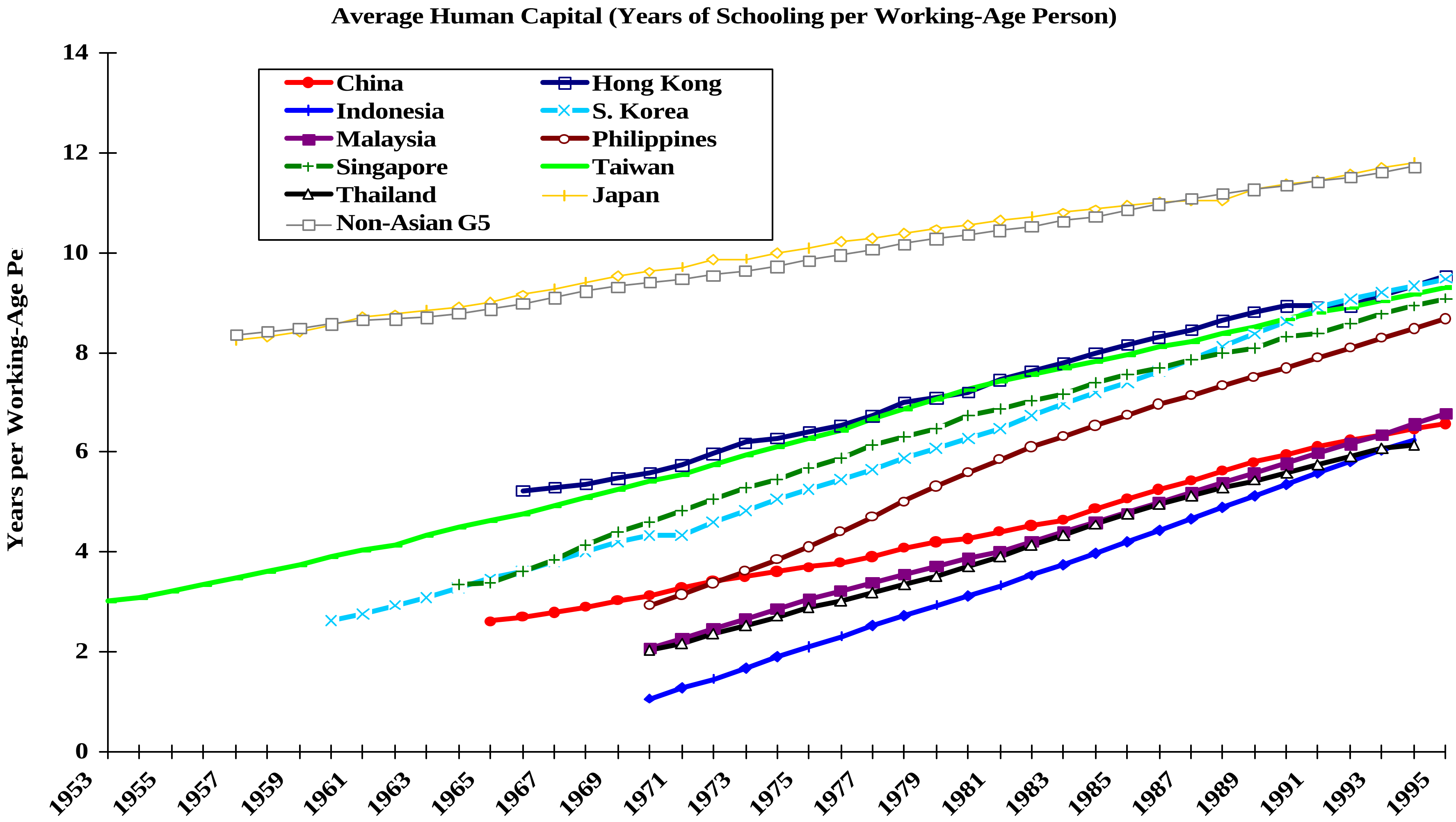
Why is There No Measured Technical Progress in East Asian NIEs? (5)

- (5) Economies of Scale
  - There are significant measured economies of scale, in all inputs taken together, for the developing East Asian economies. For economies in which both output and inputs have been growing, economies of scale and technical progress provide alternative explanations for the ability of producing more than doubled the output by merely doubling the inputs.
  - We have found is that as far as the developing East Asian economies are concerned, it is economies of scale, rather than technical progress, that have contributed to the outstanding economic performance.

Why is There No Measured Technical Progress in East Asian NIEs? (6)

- (6) Omission of the value of the quality of life
  - It is also possible that in some East Asian economies, such as Singapore, some public infrastructural investments have been made to improve the quality of life, e.g., cleaner air and water, less traffic congestion, etc., rather than to increase real GNP directly. Since the measurement of the real output (real GDP) does not reflect these non-pecuniary benefits but the inputs used are included in the measurement of inputs (tangible capital), it may appear, from a consideration of the growth of measured real output alone, that tangible capital has not been employed efficiently, and that the efficiency of its use has not improved over time.

Average Human Capital (Years/Working-Age Person: Selected Economies)



Sources of East Asian Economic Growth with 3 Inputs and Technical Progress—No Breaks

	Tangible Capital	Labor	Human Capital	Technical Progress
Hong Kong	69.37	29.08	1.55	0.00
South Korea	75.44	22.33	2.23	0.00
Singapore	59.36	38.82	1.82	0.00
Taiwan	80.83	17.37	1.80	0.00
Indonesia	77.49	17.36	5.15	0.00
Malaysia	59.48	37.68	2.83	0.00
Philippines	54.60	41.24	4.16	0.00
Thailand	73.91	22.66	3.44	0.00
China	83.75	14.12	2.13	0.00
Japan	50.44	5.70	0.56	43.30
Non-Asian G-5 Countries	37.79	3.54	0.86	57.81

Sources of East Asian Economic Growth with 3 Inputs and Technical Progress—With Breaks in 1985

		Tangible Capital	Labor	Human Capital	Technical Progress
Hong Kong	66-95	56.89 (8.79)	23.65 (2.44)	2.51 (4.80)	16.94
South Korea	60-95	65.45 (12.28)	18.62 (3.35)	3.84 (6.31)	12.08
Singapore	64-95	53.10 (10.23)	33.94 (4.70)	3.23 (5.92)	9.73
Taiwan	53-95	71.26 (11.76)	15.61 (2.33)	3.15 (5.40)	9.99
Indonesia	70-94	71.20 (10.88)	14.59 (2.72)	9.38 (10.34)	4.83
Malaysia	70-95	54.22 (9.65)	32.47 (4.68)	5.12 (8.02)	8.19
Philippines	70-95	54.05 (5.40)	37.81 (3.94)	8.15 (7.41)	-0.01
Thailand	70-94	60.84 (9.68)	18.06 (2.93)	5.65 (8.00)	15.44
China	65-95	83.87 (11.63)	11.92 (2.55)	4.21 (5.99)	0.00
Japan	57-94	49.04 (7.98)	5.23 (0.56)	1.08 (2.15)	44.65
Non-Asian G-5 Countries	57-94	37.44 (3.52)	3.36 (0.17)	1.70 (1.68)	57.49

Simultaneous Capital- and Human Capital-Augmenting Technical Progress

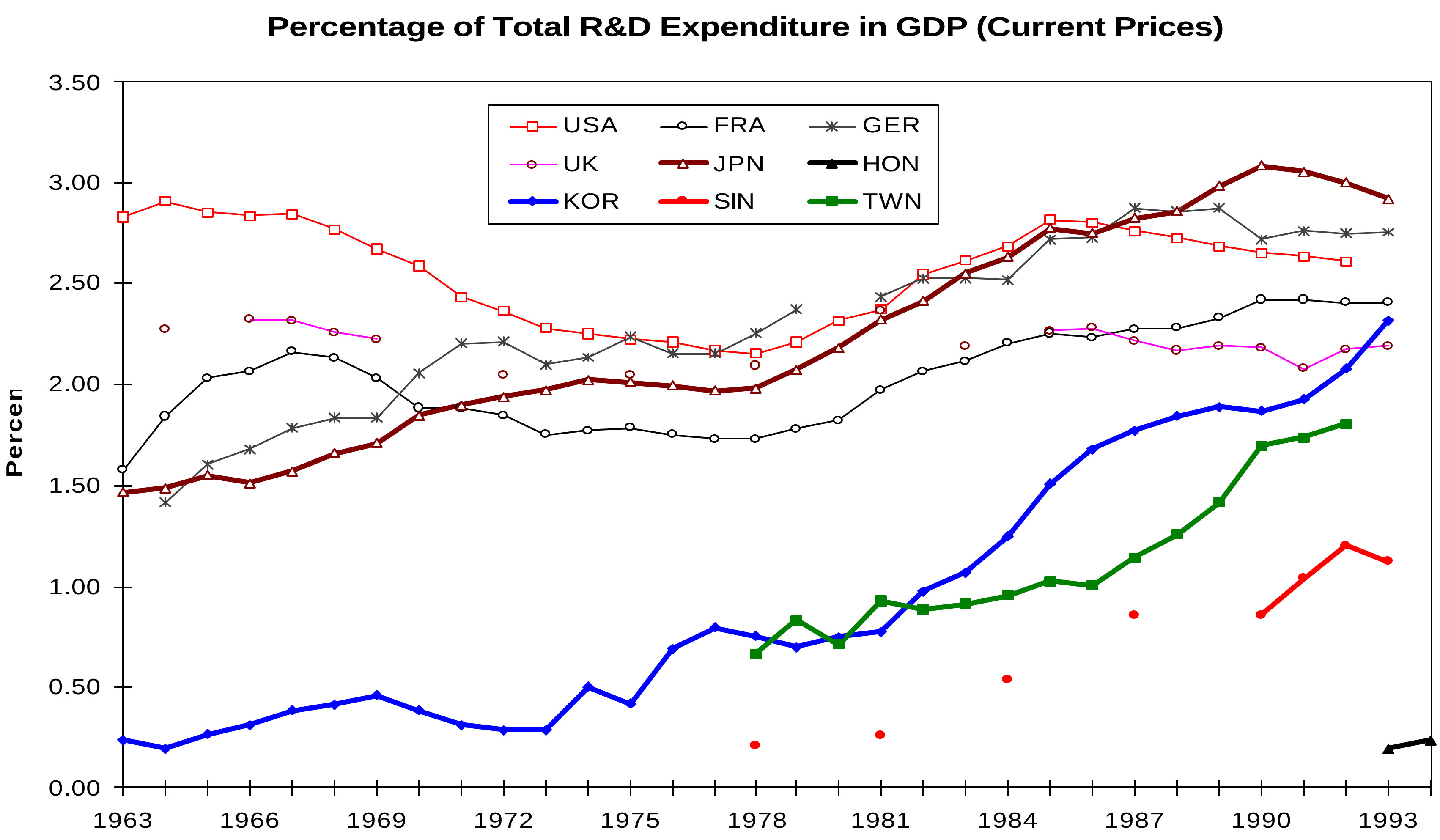
$$Y = A_0(t)\,F(A_K(t)K,\ A_H(t)H,\ A_L(t)L)$$

$$= A_0F(A_K(t)K,\ A_HH,\ A_LL)$$

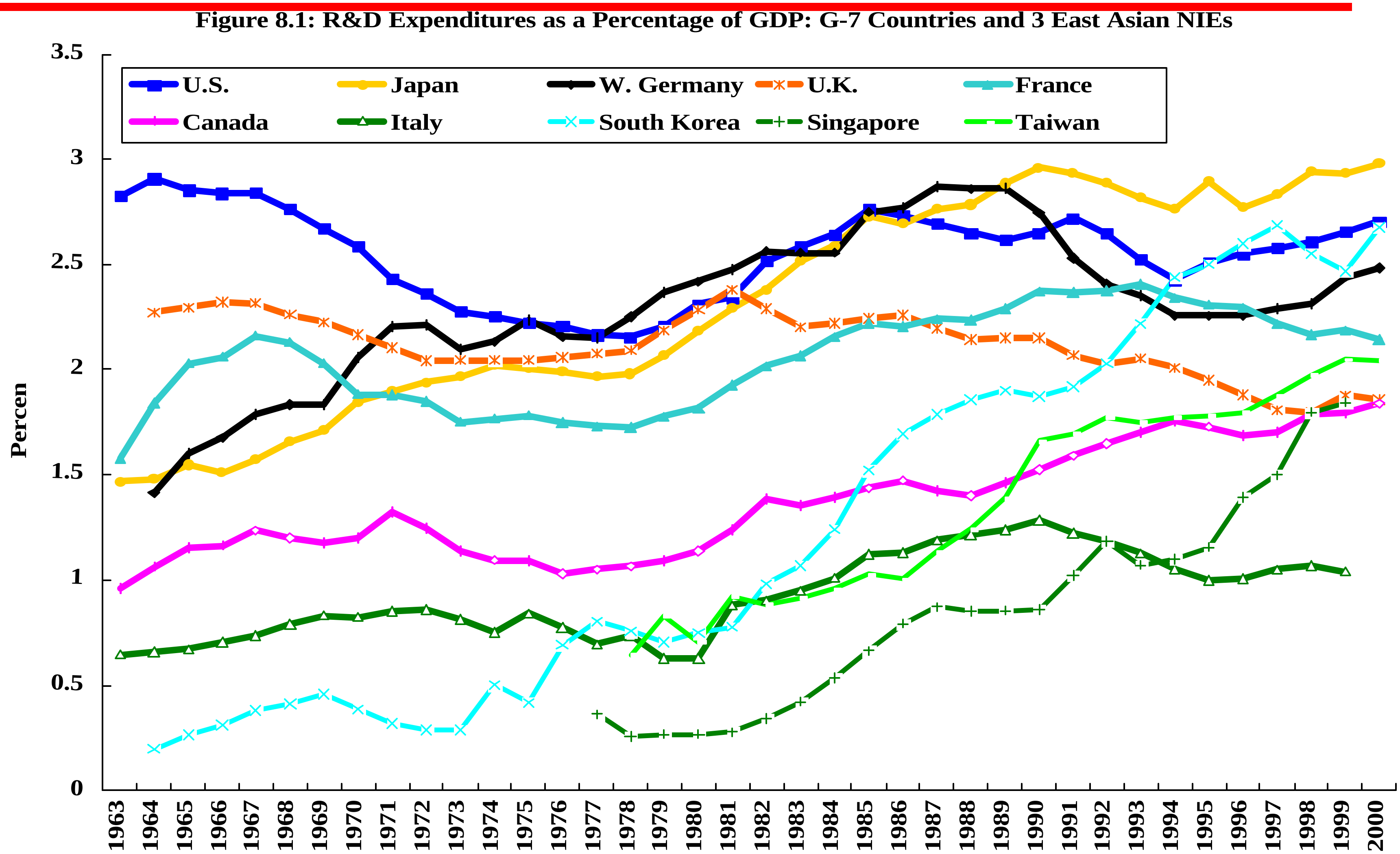
$$= A_0F(A_KK,\ A_H(t)H,\ A_LL)$$

$$= A_0F(A(t)K^{\alpha}H^{\beta},\ A_LL)$$

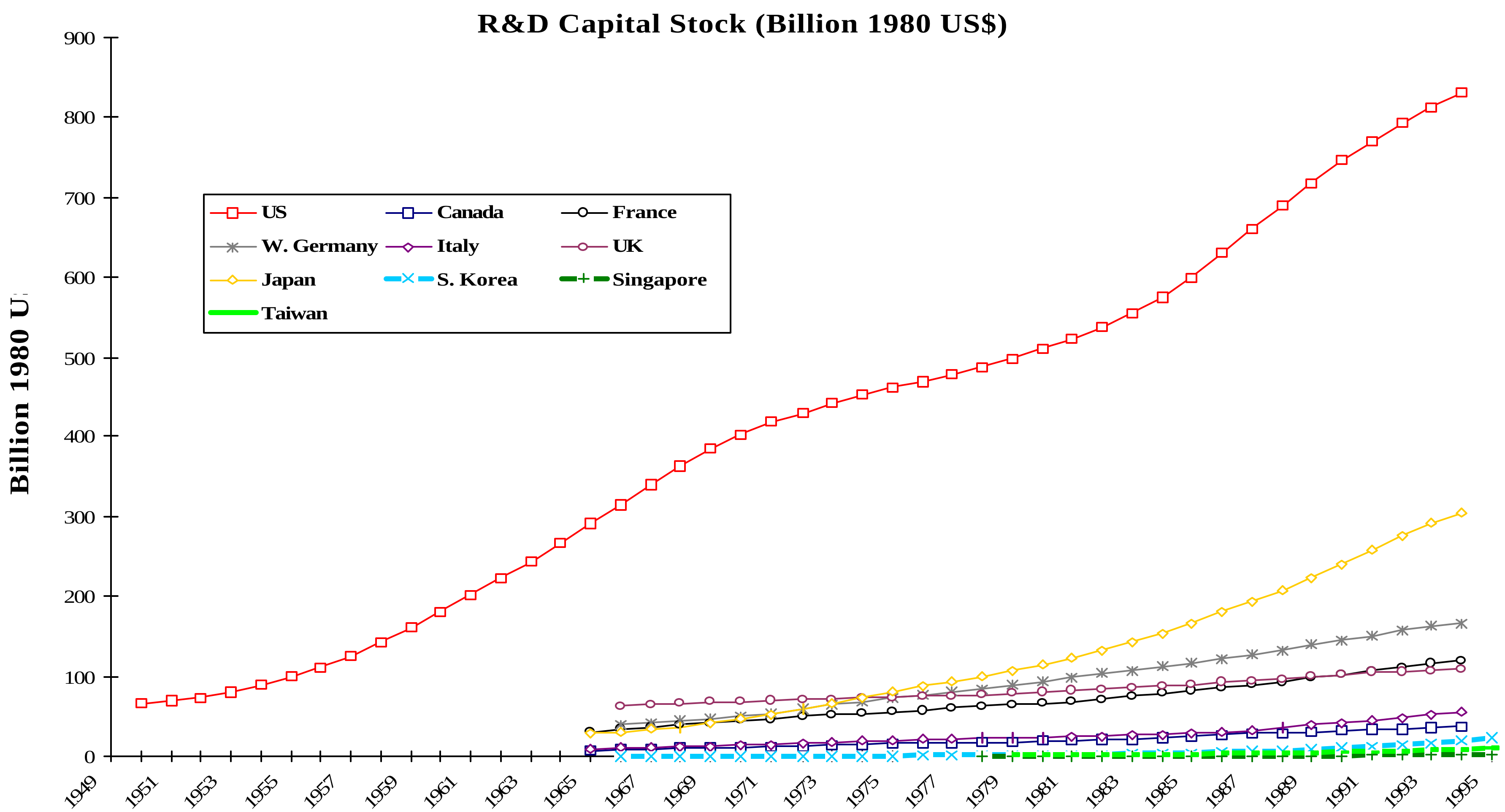
R&D Expenditure as a Percentage of GDP



R&D Expenditures as a Ratio of GDP: G-7 Countries and 3 East Asian NIES

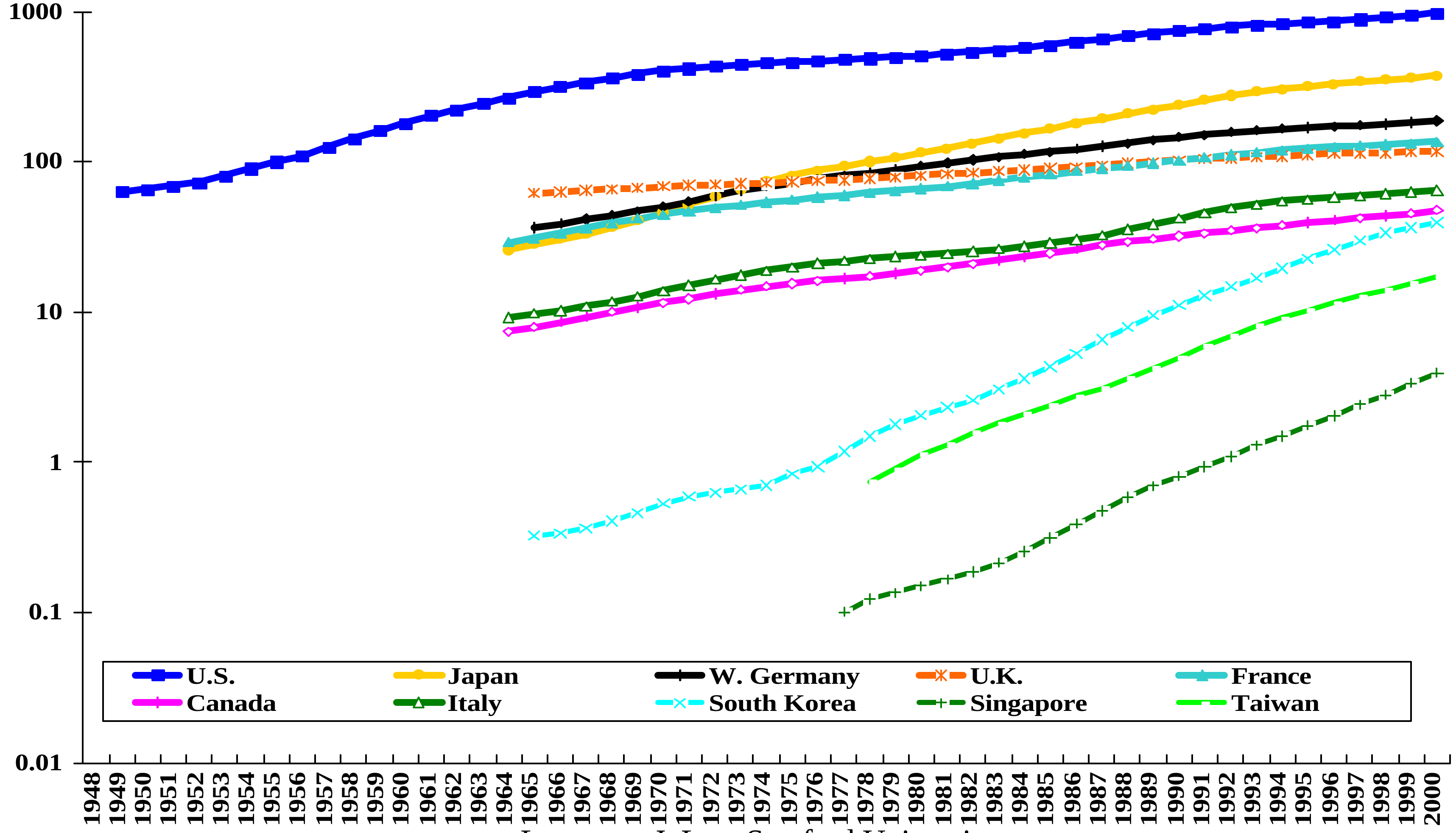


R&D Capital Stock

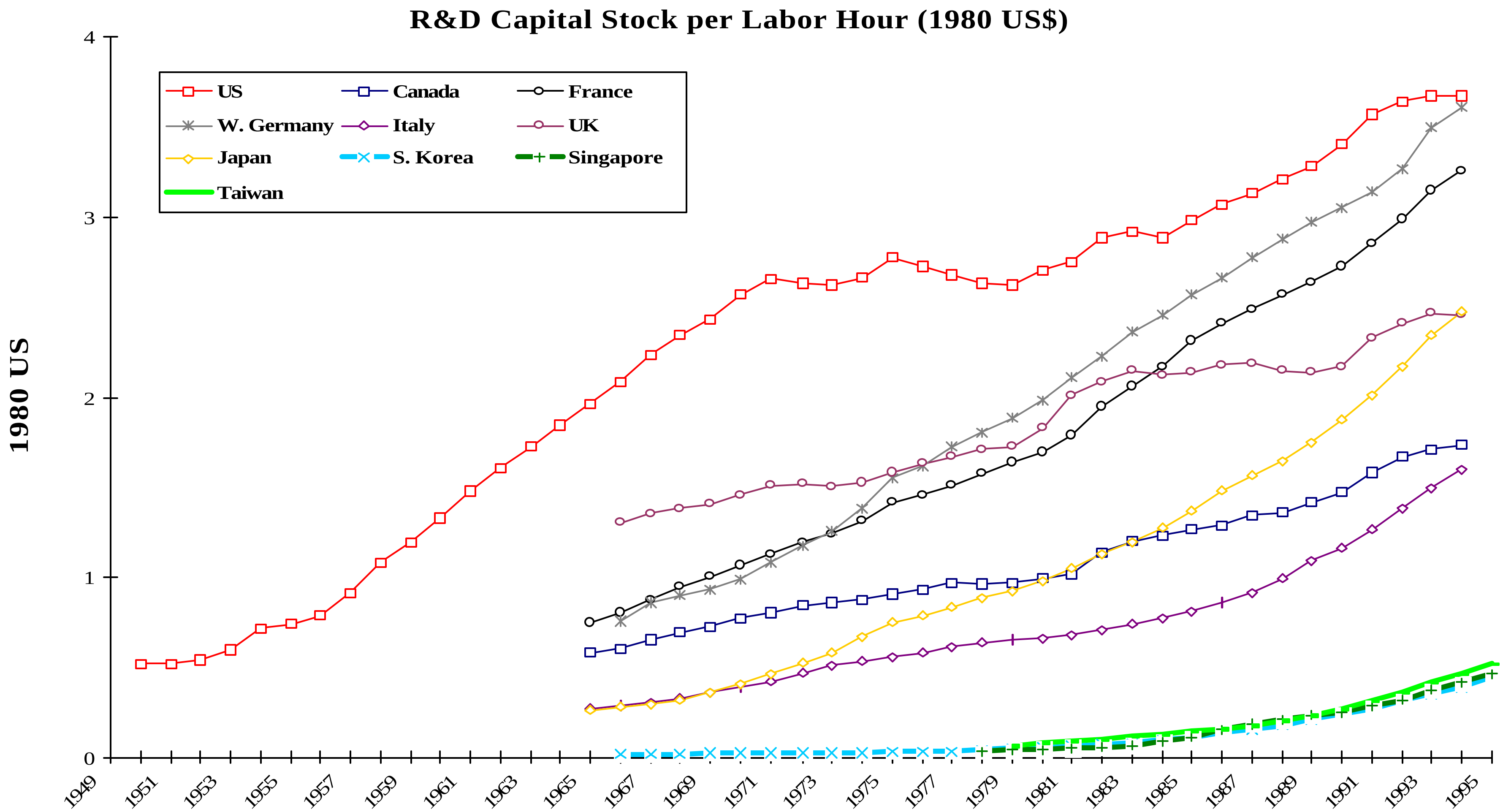


R&D Capital Stocks: G-7 Countries and 3 East Asian NIEs

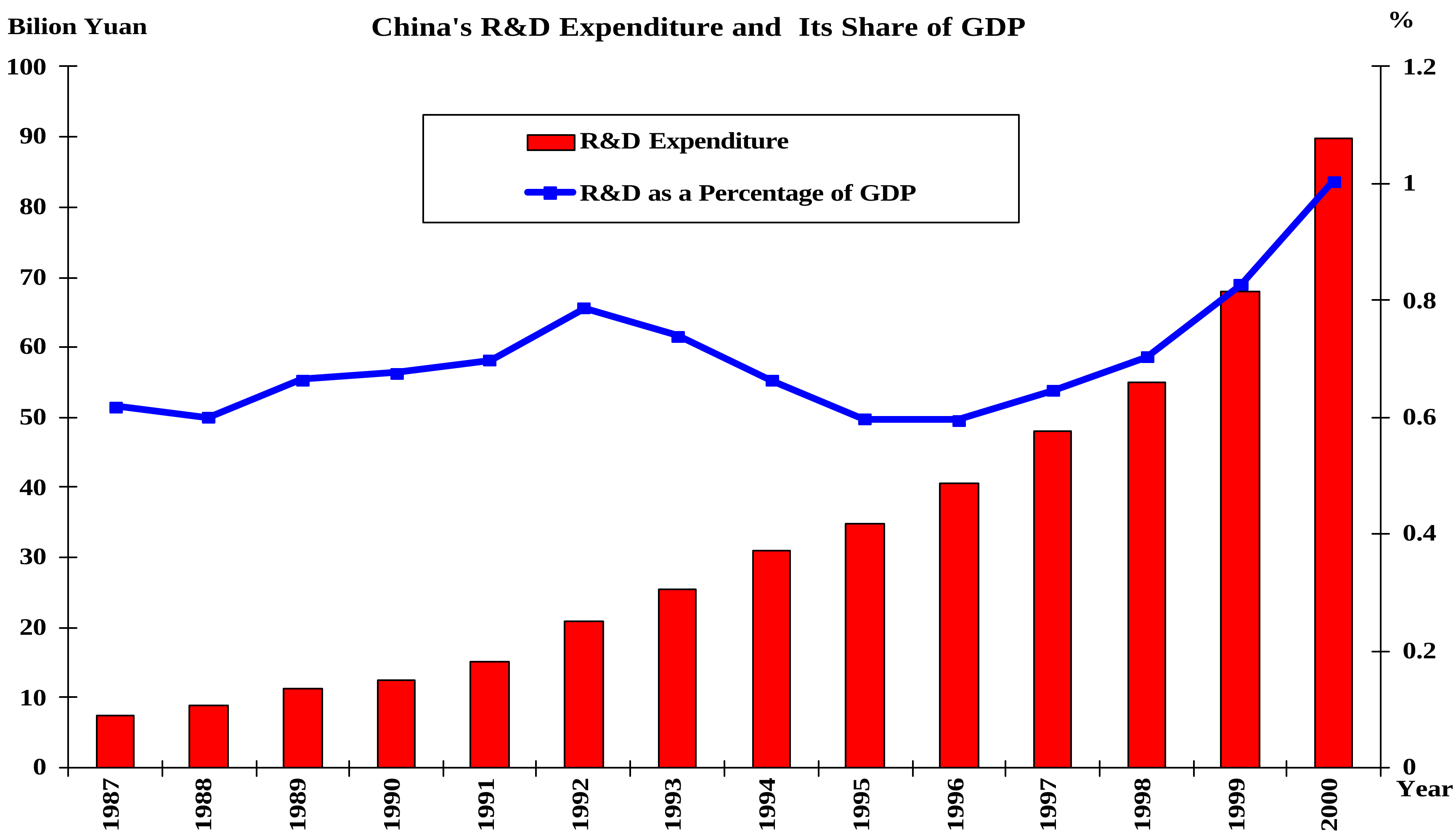
Figure 8.2: R&D Capital Stocks in Billions of 1980 U.S. Dollars



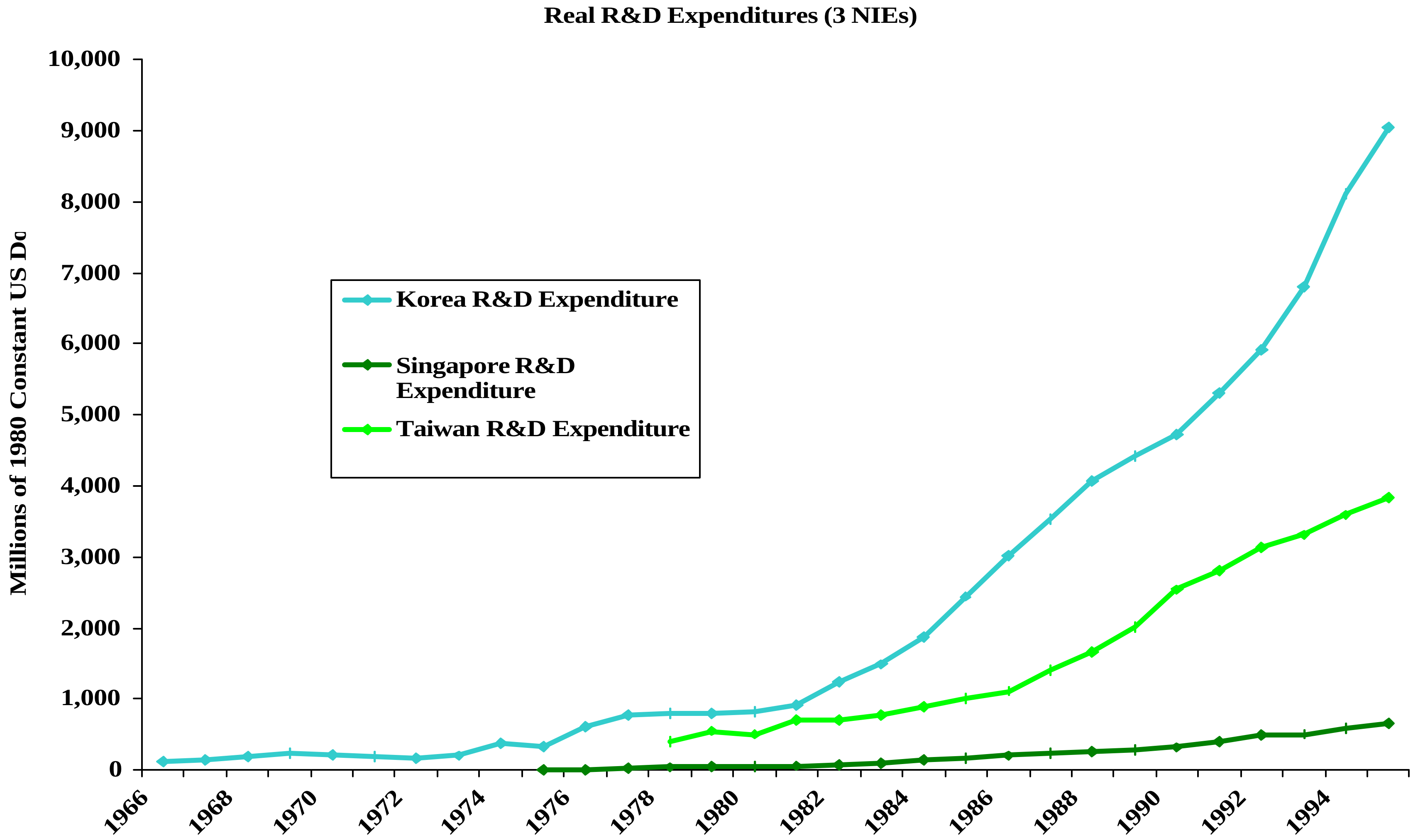
R&D Capital Stock per Unit Labor



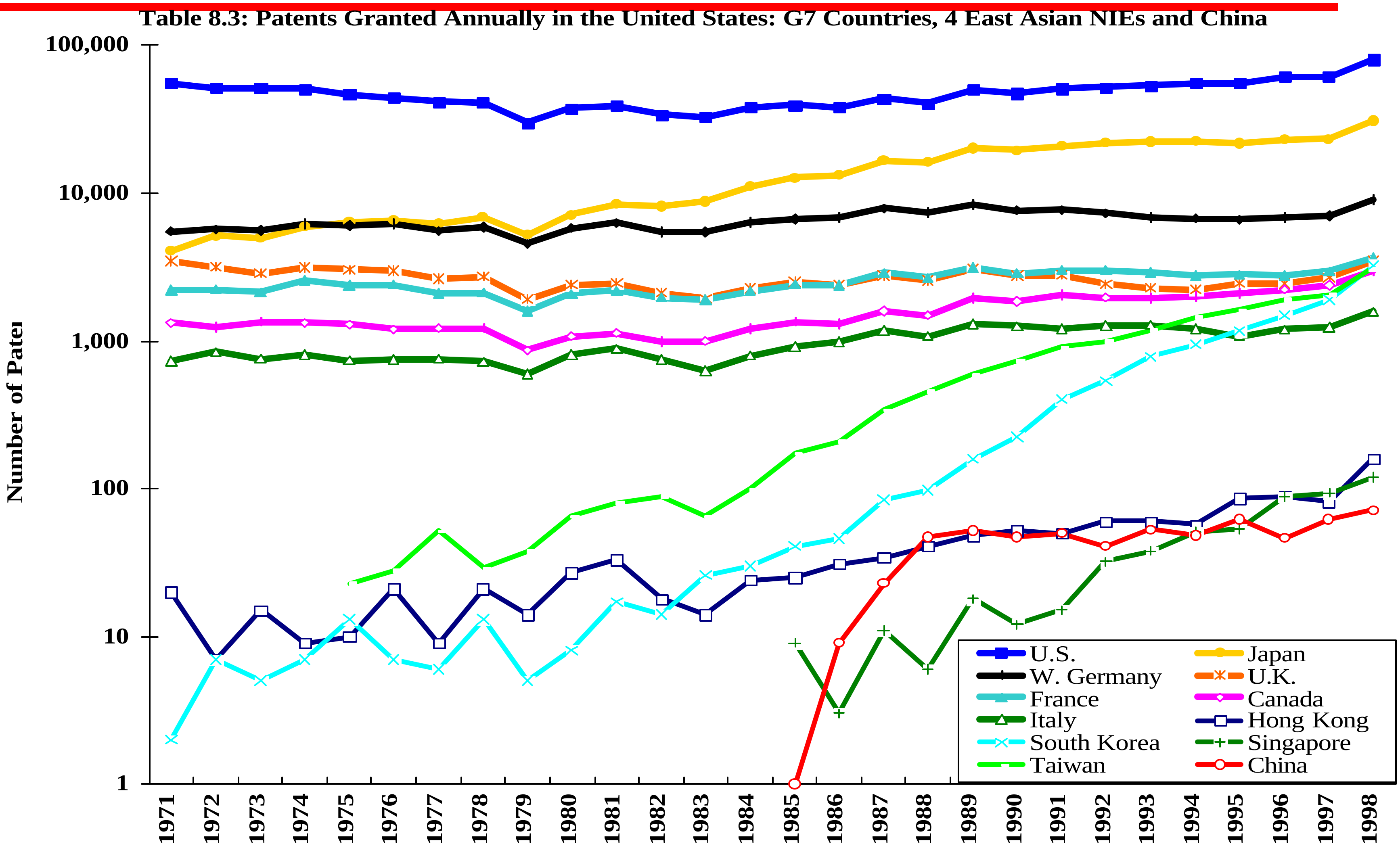
R&D Expenditures: China



R&D Expenditures: 3 East Asian Newly Industrialized Economies

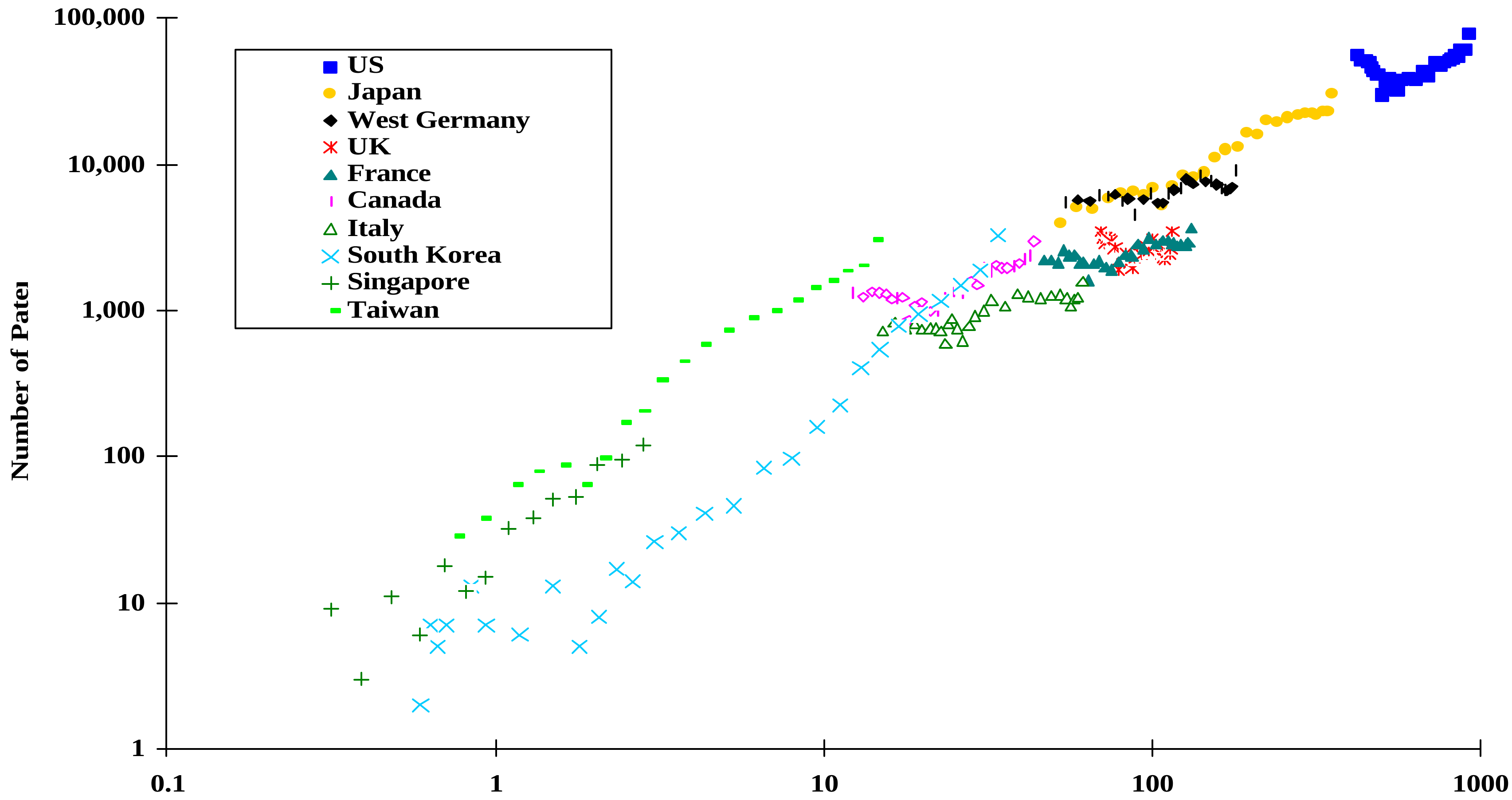


Patents Granted in the United States: G-7 Countries and East Asian Developing Countries



Patents Granted in the United States and R&D Capital Stock

Figure 8.4: The Number of U.S. Patents Granted Annually vs. R&D Capital Stocks



Sources of East Asian Economic Growth with 4 Inputs and Technical Progress—With Breaks in 1985

	Sample Period	Tangible Capital	Labor	Human Capital	R&D Capital	Technical Progress
South Korea	65-95	63.35	13.61	2.10	20.94	0.00
Singapore	77-95	47.33	21.55	1.37	29.75	0.00
Taiwan	78-95	58.73	11.42	1.32	28.54	0.00
Japan	64-94	44.83	5.20	0.82	14.63	34.52
Non-Asian G-7 Countries	65-94	33.71	3.71	1.32	12.53	48.72

The Non-Uniqueness of the Postwar East Asian Experience

- Abramovitz and David (1973): U. S. economic growth in the 19th Century can be largely attributed to the growth of tangible inputs
- Tostlebee (1956): The growth in U.S. agriculture in the 19th Century can be attributed to the growth of tangible inputs, with a negative rate of growth of total factor productivity
- Hayami and Ogasawara (1999): Japanese economic growth between the Meiji Restoration and the World War I can be largely attributed to the growth of tangible inputs, principally capital
- Godo and Hayami (1999): Confirms the lack of technical progress in prewar Japan (with human capital included)

The Sources of Economic Growth--Developing Economies

- Different types of measured inputs play different roles at different stages of economic growth
- Tangible capital accumulation is the most important source of growth in the early stage of economic development
- But simply accumulating tangible capital is not enough--it must also be efficiently allocated
- Efficient tangible capital accumulation is the major accomplishment of the East Asian NIEs in the postwar period
  - Market-directed allocation of new investment, aided by export orientation, promotes efficiency
  - Private enterprises have the incentives for prompt self-correction
- Intangible capital accumulation becomes important only after a certain level of tangible capital per worker is achieved but has begun to be important for some East Asian NIEs such as South Korea and Taiwan

The Sources of Economic Growth--Industrialized Countries

- The most important source of economic growth for industrialized countries is technical progress, accounting for more than half of the growth of output
- Tangible capital is the next important source of economic growth, accounting for almost a third
- Technical progress reflects the effects of intangible capital--R&D capital, knowledge capital, goodwill, etc.
- The United States is the world leader in human capital and R&D capital

Is Economic Growth Sustainable? Krugman's Worry about East Asia

- If the major source of economic growth is the growth of tangible capital, then given the diminishing marginal productivity of tangible capital, as more and more tangible capital is accumulated, each additional unit of tangible capital will be less productive than the unit before it. Eventually economic growth must slow down and then stop altogether.
- The former Soviet Union was used as an example where a great deal of tangible capital was accumulated but failed to be productive, as was Mainland China before the economic reforms of 1979
- Boskin and Lau (1990) found that tangible capital and technical progress (intangible capital) are complementary—at the microeconomic level, this phenomenon is manifested in the form of capital-skill complementarity
- Investment in intangible capital can enhance the productivity of tangible capital because of its complementarity with tangible capital and retard the decline in the marginal productivity of tangible capital and hence counteract the "Krugman effect"

Is Economic Growth Sustainable? Was East Asian Economic Growth a Bubble?

- Past economic growth neither a miracle nor a mere bubble
  - Economic growth experience replicated in different East Asian economies
  - Sustained economic growth over decades
  - Recent crisis due to many factors, of which "irrational exuberance" is only one
  - Economic fundamentals remain sound--high savings rates, investment in human capital, and more recently in R&D capital, entrepreneurship, market orientation
- Past economic growth tangible input-driven rather than intangible input or technical progress-driven--it is attributable to growth in tangible inputs, particularly the efficient and rapid accumulation of tangible capital
- However, East Asian economies lag far behind in both tangible and intangible capital
- Considerable room for continuation of rapid tangible input-driven economic growth in the future--tangible capital per unit labor in East Asian economies, with the exception of Japan, still lags significantly behind the developed economies
- Intangible capital per unit labor, e.g., R&D capital, lags even further behind, offering additional opportunities for investment

Is East Asian Economic Growth Sustainable?

- The attractiveness of investment in intangible capital depends on the protection of intellectual property rights, which in turn depends on whether a country is a producer of intellectual property--some of the East Asian economies, e.g., Hong Kong, South Korea, Singapore and Taiwan are ahead of other East Asian economies with the possible exception of Japan on this score
- Intangible capital is different from tangible capital in three important aspects:
  - Intangible capital is freely mobile across countries
  - Intangible capital is simultaneously deployable in different locations without diminution of its effectiveness (increasing returns in the utilization of intangible capital)
  - Intangible capital enhances the productivity of existing tangible capital whereas additional tangible capital diminishes the productivity of existing tangible capital
- Investment in intangible capital, e.g., R&D investments, has begun to increase in the East Asian NIEs
- There is also evidence of positive technical progress in the more recent period in South Korea, Singapore and Taiwan, reflecting their increased investment in intangible capital

Prospects for Future Economic Growth Remain Good

- Prospects for continued economic growth in East Asia remain good—room for continuation of tangible-input-driven growth
- Fundamentals are sound—high savings rates, priority for education, private-enterprise market economy
- The experience of developed economies, especially that of Japan, suggests that investment in R&D capital and other forms of intangible capital has high returns once a level of tangible capital per unit labor has been achieved
- A shift towards the service sector (education and recreation) and self-employment
- The people of East Asia are entrepreneurial, hard-working, and thrifty--all they need is a good, market-friendly, predictable and stable environment
- A vision of the future and a realistic strategy for getting there