Growth Accounting

Growth accounting divides the growth in output of a firm or a country into two parts. The first part is the growth in output that can be attributed to growth in all factor inputs, holding technology constant. The second part is the growth that is solely due to an increase or decrease in technology.

Growth accounting does not explain why factor inputs or technology changes. Instead, we are just trying to divide the credit for observed output growth into proximate sources, given the observed growth rates of inputs.

$$Y_t = A_t F(K_t, L_t)$$

$$\dot{Y}_t = \dot{A}_t F(K_t, L_t) + A_t F_K(K_t, L_t)\dot{K}_t + A_t F_L(K_t, L_t)\dot{L}_t$$

$$\frac{\dot{Y}_t}{Y_t} = \frac{\dot{A}_t F(K_t, L_t)}{Y_t} + \frac{A_t F_K(K_t, L_t)\dot{K}_t}{Y_t} + \frac{A_t F_L(K_t, L_t)\dot{L}_t}{Y_t}$$

Solow Growth Accounting Equation:

$$\frac{\dot{Y}_t}{Y_t} = \frac{\dot{A}_t}{A_t} + \beta\frac{\dot{K}_t}{K_t} + (1-\beta)\frac{\dot{L}_t}{L_t}$$

In practice, we approximate the instantaneous growth rates in the theory with growth rates based upon neighboring time periods.

Example: $\frac{\dot{Y}_t}{Y_t} \doteq \frac{\Delta Y_t}{Y_t} = \frac{Y_{t+1}-Y_t}{Y_t}$

$$\frac{\Delta Y_t}{Y_t} = \frac{\Delta A_t}{A_t} + \beta\frac{\Delta K_t}{K_t} + (1-\beta)\frac{\Delta L_t}{L_t}$$

$$\frac{\Delta Y_t}{Y_t} = \frac{\Delta A_t}{A_t} + \beta \frac{\Delta K_t}{K_t} + (1 - \beta) \frac{\Delta L_t}{L_t}$$

Question: Which variables in the equation can we measure directly in data?

Answer: We can measure (with some error) (Y, K, L) and β.

How can we measure technology or the growth in technology?

Solow:

He proposed to measure the growth rate of technology $\frac{\Delta A_t}{A_t}$ between neighboring periods as a residual.

Implications:

If the theory is correct, then the measured growth rate in technology $\frac{\Delta A_t}{A_t}$ is true technological change plus any resulting errors that occur in measuring all the other variables that enter the Solow growth accounting equation.

Solow Findings: US 1909- 1949

1. Output per unit of labor input grows by about 100 percent over the period.

2. The capital-labor ratio grows by about 30 percent over the period. So there is "capital deepening".

3. Technology grows by about 80 percent over the period. Thus, about 80 percent of the growth in output per unit of labor input over the period is accounted for by growth in the technology and the remaining 20 by increases in the capital-labor ratio.

4. The measure of the technology level falls in a number of recession and depression years and tends to increase in expansions. Thus, measured technology growth rates are "pro cyclical".

5. The aggregate production function displays a positive and diminishing marginal product of capital.

CHART 2

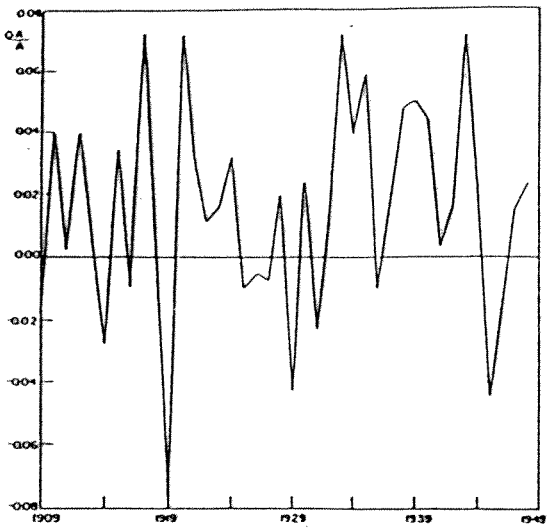


CHART 3

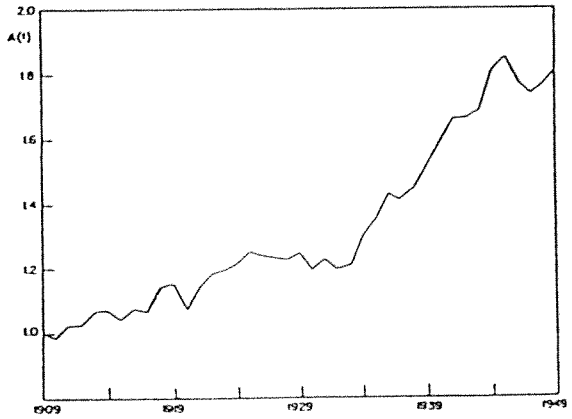
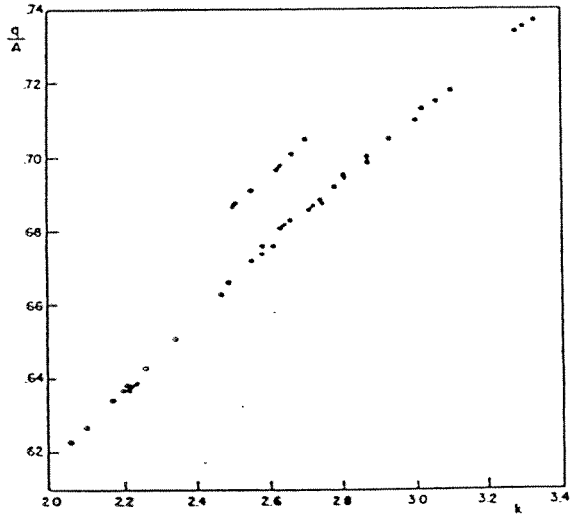


CHART 4



Homework 3: Repeat Using US 1948 -2005 data

Advantage:

1. Superior quality data

2. No World Wars and No Great Depression

3. Can Examine Robustness across different periods

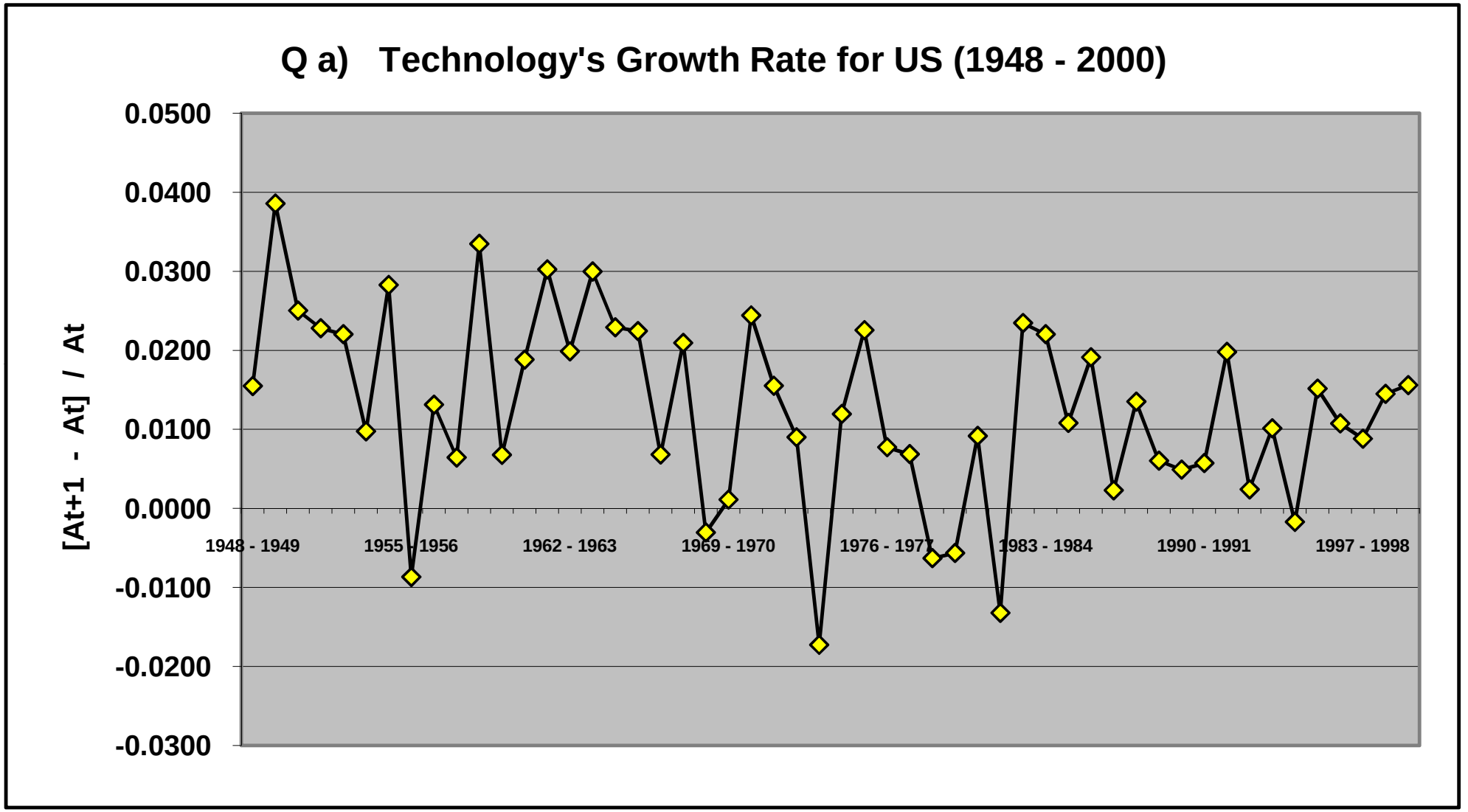
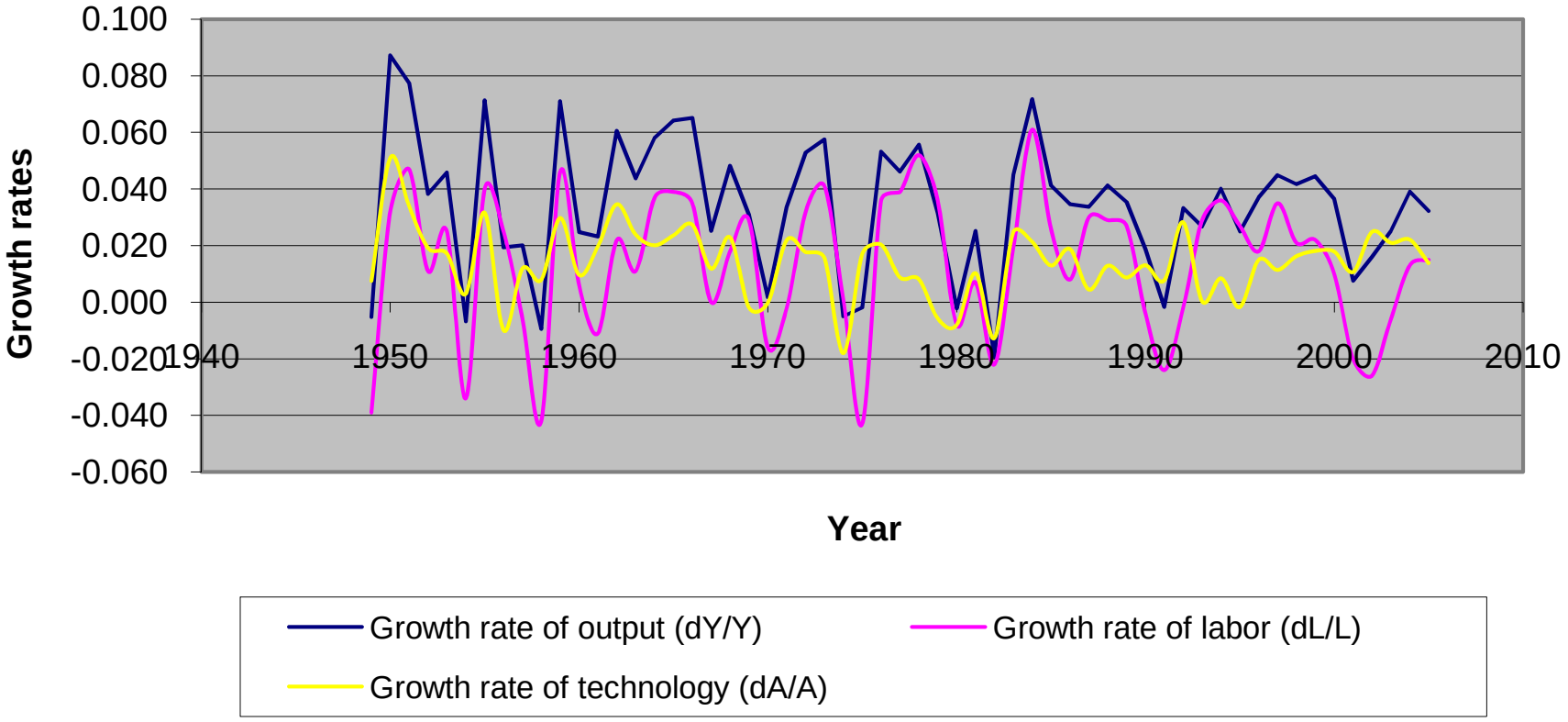

Q a) Technology's Growth Rate for US (1948 - 2000)
[At+1 - At] / At
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
-0.0100
-0.0200
-0.0300
1948 - 1949
1955 - 1956
1962 - 1963
1969 - 1970
1976 - 1977
1983 - 1984
1990 - 1991
1997 - 1998

Figure 1: Growth rates of output (dY/Y), labor (dL/L) and technology (dA/A)



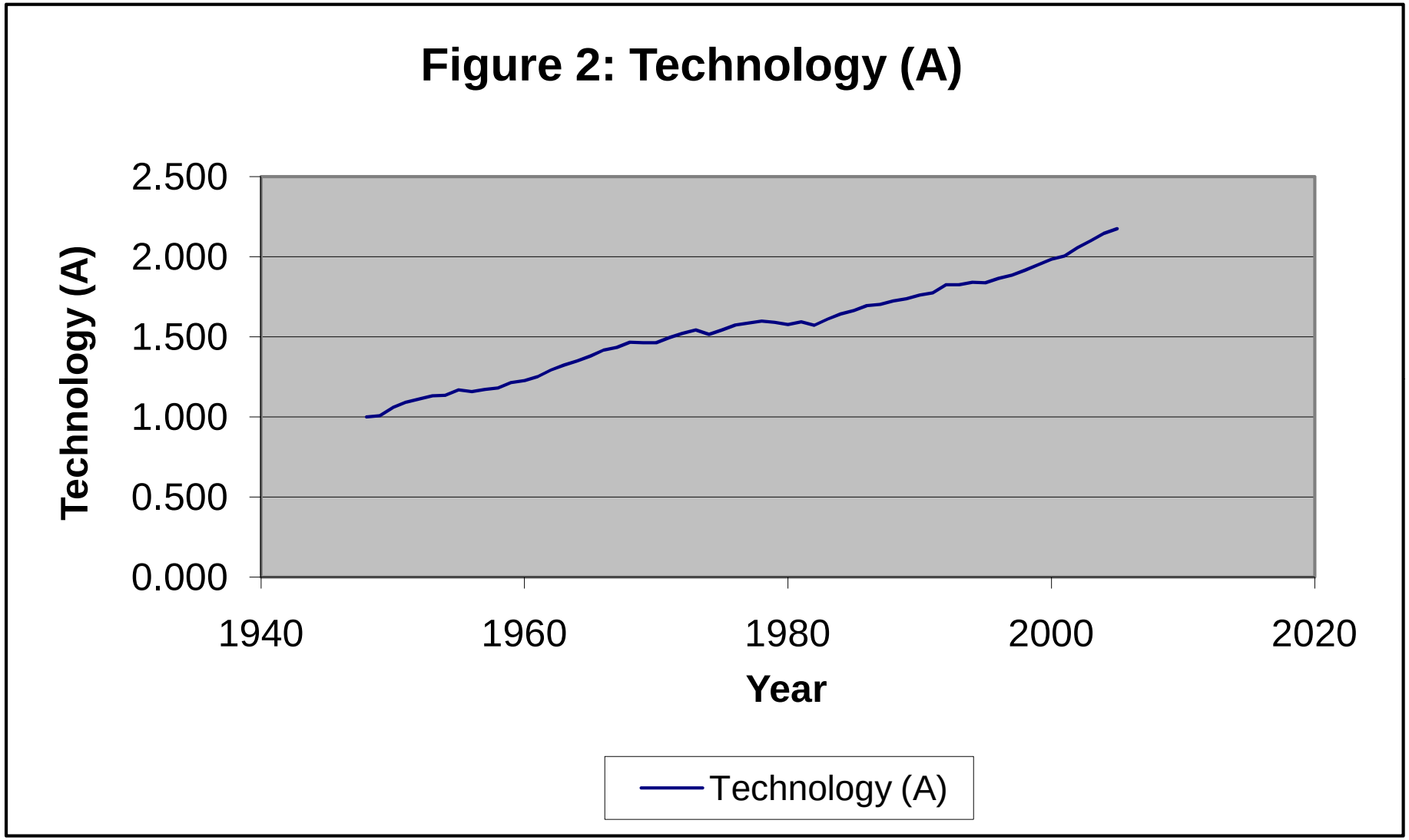
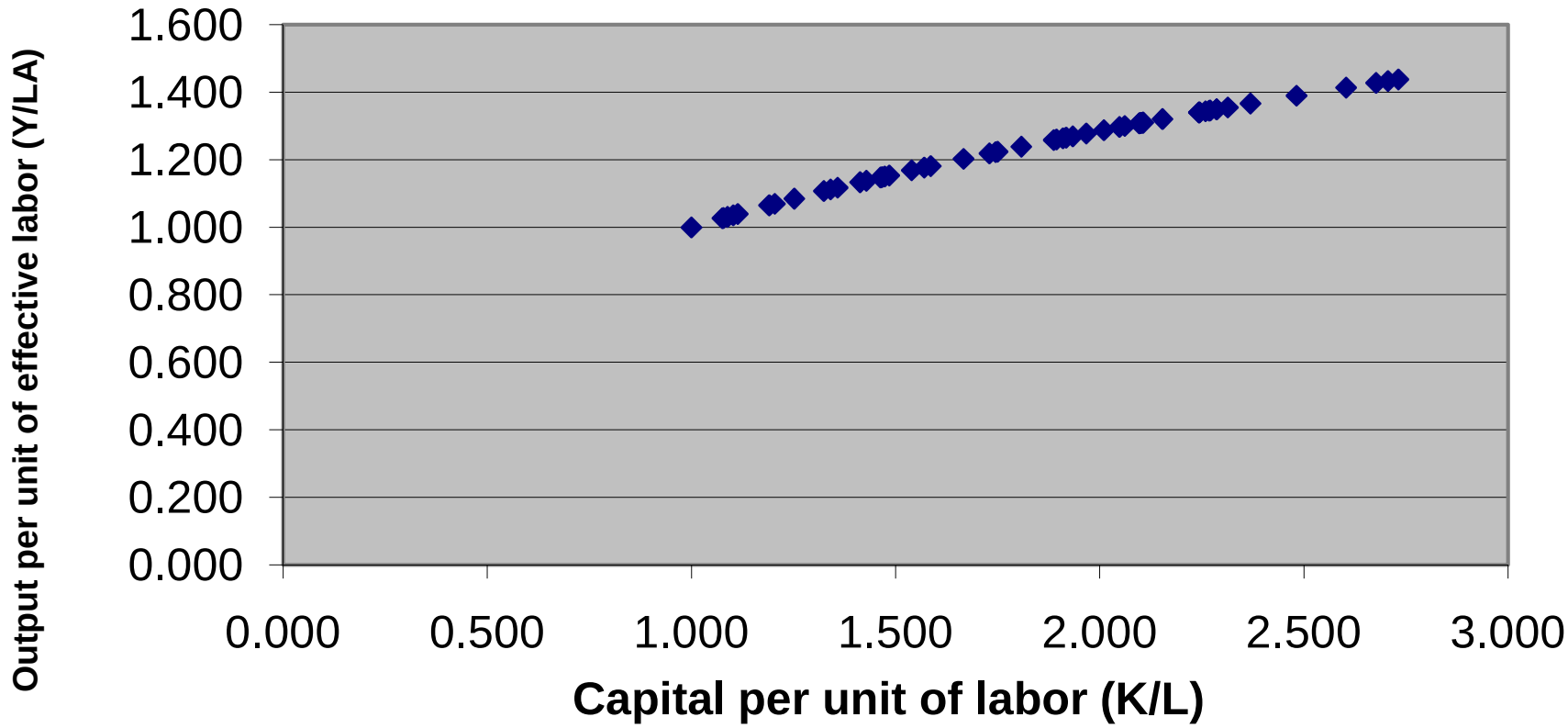


Figure 2: Technology (A)
Technology (A)
2.500
2.000
1.500
1.000
0.500
0.000
1940
1960
1980
2000
2020
Year
Technology (A)

Figure 3: Output per unit of effective labor (Y/LA) v.s. Capital per unit of labor (K/L)



Krugman: The Myth of Asia's Miracle

Krugman makes three main points that involve using Solow growth accounting and Solow growth theory:

1. Growth in the Soviet Union - "A History Lesson"

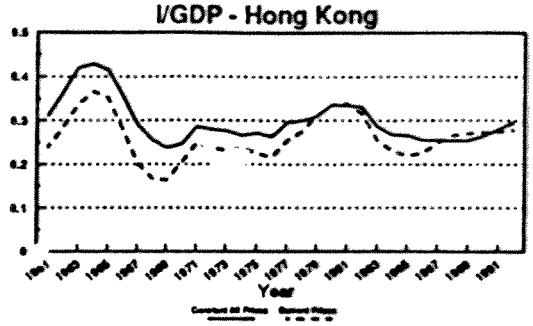
2. Growth in the Asian Tigers - Same Story

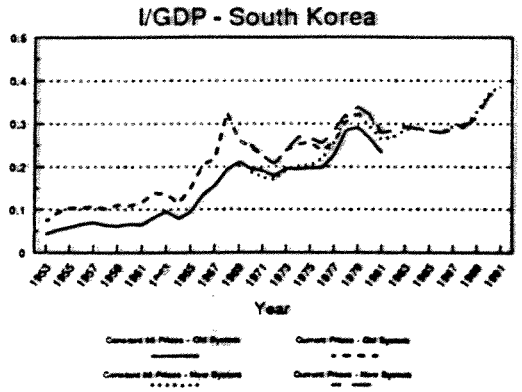
3. Projection: Asian Tigers future growth will look more like US future growth

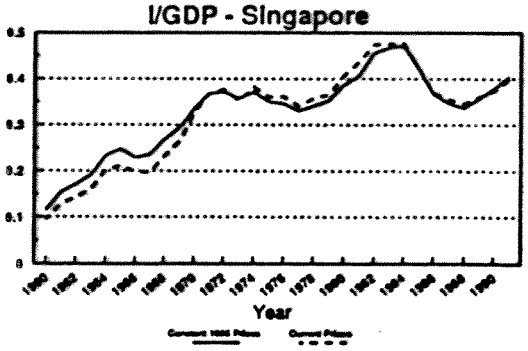
Table 1-2: Educational Attainment of the Working Population (%)								
	Hong Kong		Singapore		South Korea		Taiwan	
	1966	1991	1966	1990	1966	1990	1966	1990
None	19.2	5.6	55.1	⇓	31.1	6.4	17.0	4.5
Primary	53.6	22.9	28.2	33.7	42.4	18.5	57.2	28.0
Secondary+	27.2	71.4	15.8	66.3	26.5	75.0	25.8	67.6

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

Figure 1: I/GDP Ratios







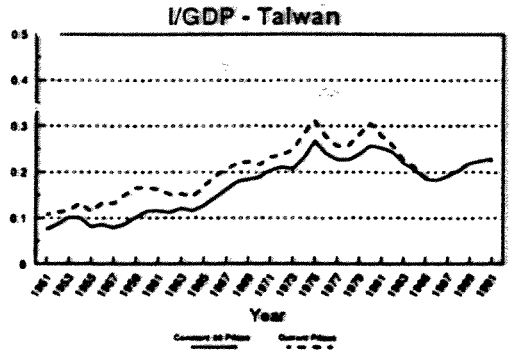


Table: Asian Growth "Miracle"

Variable	Hong Kong	South Korea	Singapore	Taiwan
Labor's Share	.628	.68	.47	.71
GDP Growth	7.3	10.4	8.5	9.6
Capital Growth	8.0	13.7	11.5	12.3
Labor Growth	3.2	6.4	5.7	5.1
TFP Growth	2.3	1.6	-0.3	2.4

Source: Young (1994)

Schmitz: Competitive Pressure and Labor Productivity

Q1. What influences labor productivity and total factor productivity?

Note: Our theories say that productivity is very important. Theory says it grows if technology grows ... but the theory does not explain why technology grows!

Q2. Does competitive pressure influence productivity?

Facts about the Iron Ore Market:

1. Large fall in world Steel production in 1980s.

2. Expected to be long lasting by industry experts.

3. Iron Ore is key input into producing steel.

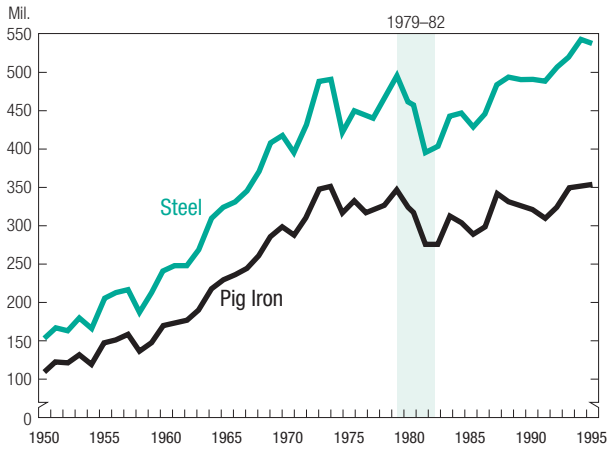
4. Expectation: Some Iron Ore Producers would exit who were servicing Atlantic basin steel producers.

5. Large increases in labor productivity after the crisis among some surviving Atlantic basin producers.

Chart 1

World Steel and Pig Iron Production

In Noncommunist Countries, Annually, 1950–96, Millions of Metric Tons



Source: U.S., various years

Charts 2 and 3

Regional Pig Iron Production

Annually, 1950–96, Millions of Metric Tons

Chart 2 In the Atlantic and Pacific Basins

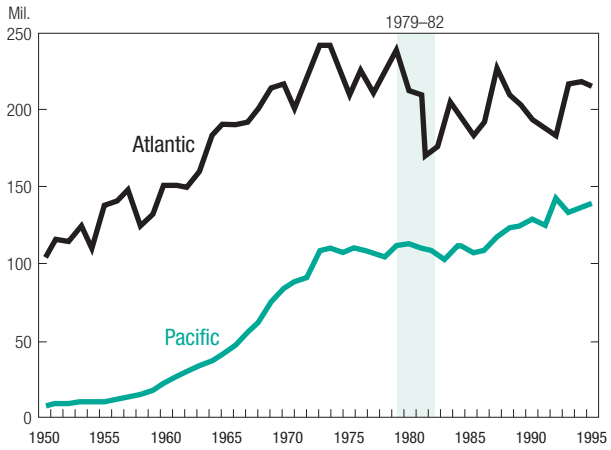
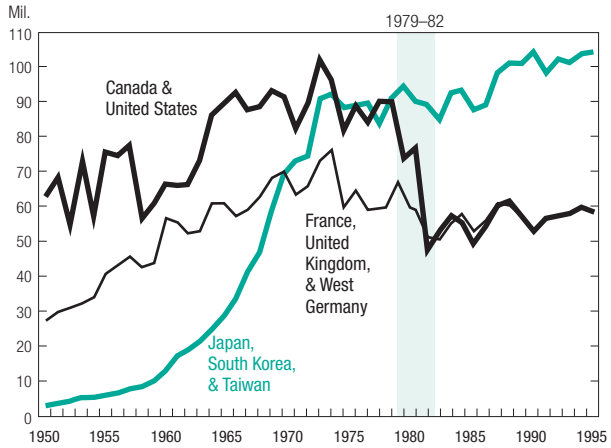


Chart 3 In Other Groups of Countries



Source: U.S., various years

Table 1

World Iron Ore Production in 1980

Area	1980 Production (Million Metric Tons) Reported by USGS	1980 Production (Million Metric Tons) Reported by Country	1980 Metal Content Reported by USGS (% Iron)
Top Noncommunist Producers			
Atlantic Basin			
Brazil	114.7	113.0	65.0
Canada	48.7	49.1	63.2
France	28.9	28.9	31.4
South Africa	26.3	26.3	63.9
Sweden	27.2	27.0	64.7
United States	70.7	70.7	63.1
Pacific Basin			
Australia	95.5	97.0*	63.2
India	41.9	41.6	62.5
Total	453.9	453.6	61.7
Other Totals			
Noncommunist Countries	558.8	—	60.8
Communist Countries	332.4	—	52.2
World	891.2	—	57.6

*Australia reported production for the financial year ended June 1980.
Sources: U.S., various years; Appendix

Facts about Atlantic Basin Iron Ore Producers:

1. Low cost producer: Brazil.

2. Higher cost producers: US, Canada, France, Sweden, South Africa

Table 3

Costs of Producing and Transporting Iron Ore in 1984 . . .

Costs Estimated by the U.S. Bureau of Mines for Selected Iron Ore Mines

Country	Number of Mines Studied	Production Costs (U.S. $ Per Ton)				Transportation Costs						
						By Rail (From Mine to Port)			*By Ocean* (From Port to Destination)			
		Mining		Beneficiation		U.S. $ Per Ton Km.		Distance (Km.)	U.S. $ Per Ton		Destination	Ship Size (Thou. Dead-weight Tons)
		Low	High	Low	High	Low	High		Low	High		
Atlantic Basin												
Brazil	13	.70	2.00	.50	1.70	.005	.007	640–730	7.00	9.00	Japan	130–150
									5.25	6.00	Japan	220
									5.75	6.50	W. Europe	50–65
									4.50	6.00	W. Europe	80–155
Canada	3	2.00	2.50	3.00	3.50	.008	.009	410–450	n.a.	n.a.	Japan	130–150
									3.00	4.25	W. Europe	100–160
Europe*	5	2.60	7.20	1.50	4.50	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
United States	9	2.00	4.50	3.25	5.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Pacific Basin												
Australia	5	1.60	2.60	.30	1.60	.003	.004	50–430	5.00	6.00	S. Korea	100–150
									6.50	8.75	W. Europe	100–150
India	5	1.00	5.00	.50	1.50	.020**	n.a.	60–470	n.a.	n.a.	n.a.	n.a.

n.a. = not available

* The European countries included in the study are Norway, Spain, and Sweden.

**India's rail transport costs from mines to ports are reported as an average rather than a range.

Source: Bolis and Bekkala 1987

Table 4

. . . And in 1994

Costs Estimated by Natural Resources Canada for Selected Iron Ore Mines

		U.S. $ Per Ton		
			Transportation Costs	
Country	Producer (Company)	Production Costs* (Concentrates Only)	*By Rail* From Mine to Port	*By Ocean* From Port to N. Europe
Atlantic Basin				
Brazil	CVRD, Carajás	2.15	4.10	6.30
	CVRD, Minas Gerais	3.15	3.50	6.50
	MBR	2.50	7.00	6.50
	Samitri	2.95	7.50	6.50
Canada	QCM	9.20	2.00	6.30
	IOC	10.85	2.50	6.30
	Wabush	9.05	5.70	6.30
South Africa	Sishen	8.80	7.50	8.00
Sweden	LKAB	10.50	7.00	3.35
Pacific Basin				
Australia	BHP	7.95	2.25	9.05
	Hamersley	4.15	2.50	9.05
	Robe River	3.50	1.75	9.05
India	Kudremukh	6.35	1.50	8.50

*Production costs here may include more than the mining and beneficiation costs on Table 3, such as the costs of agglomeration.

Source: Boyd and Perron 1997

Charts 4–11

A Striking Relationship

Iron Ore Production and Productivity in Countries With Different Amounts of Competitive Pressure on Mines in the 1980s
Annually, 1960–96 (as available), Compared to Levels in 1980
(Index, 1980=1)

Charts 4–6 Little or No Increase in Competitive Pressure

Chart 4 **Australia**

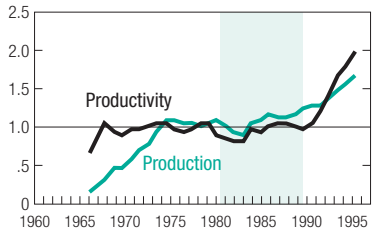


Chart 5 **Brazil**

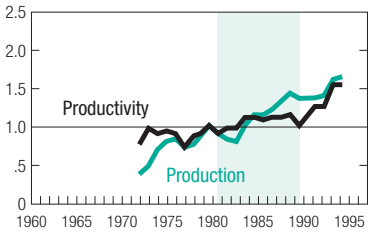
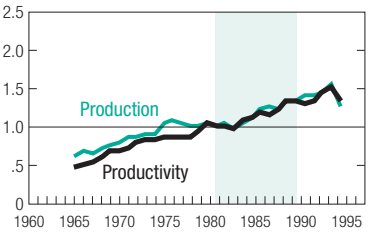


Chart 6 **India**



Charts 7–11 Significant Increase in Competitive Pressure

Chart 7 **Canada**

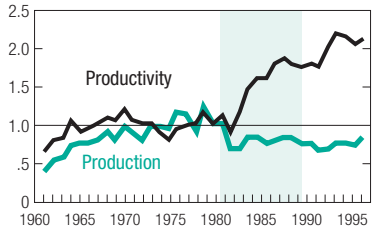


Chart 8 **France**

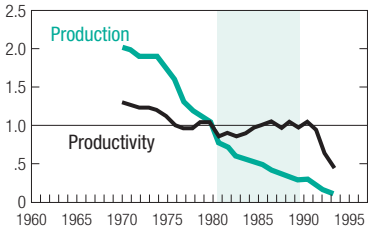


Chart 9 **South Africa**

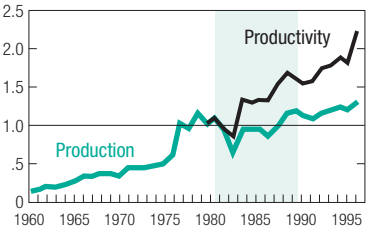


Chart 10 **Sweden**

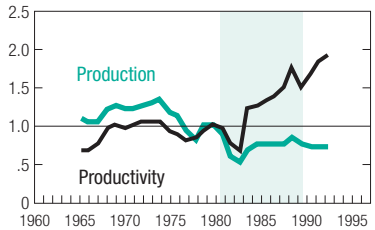
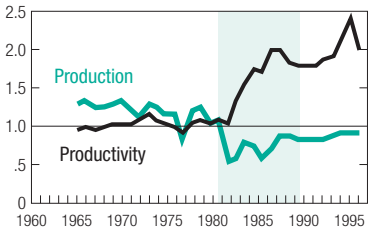


Chart 11 **United States**



Sources: See Appendix.