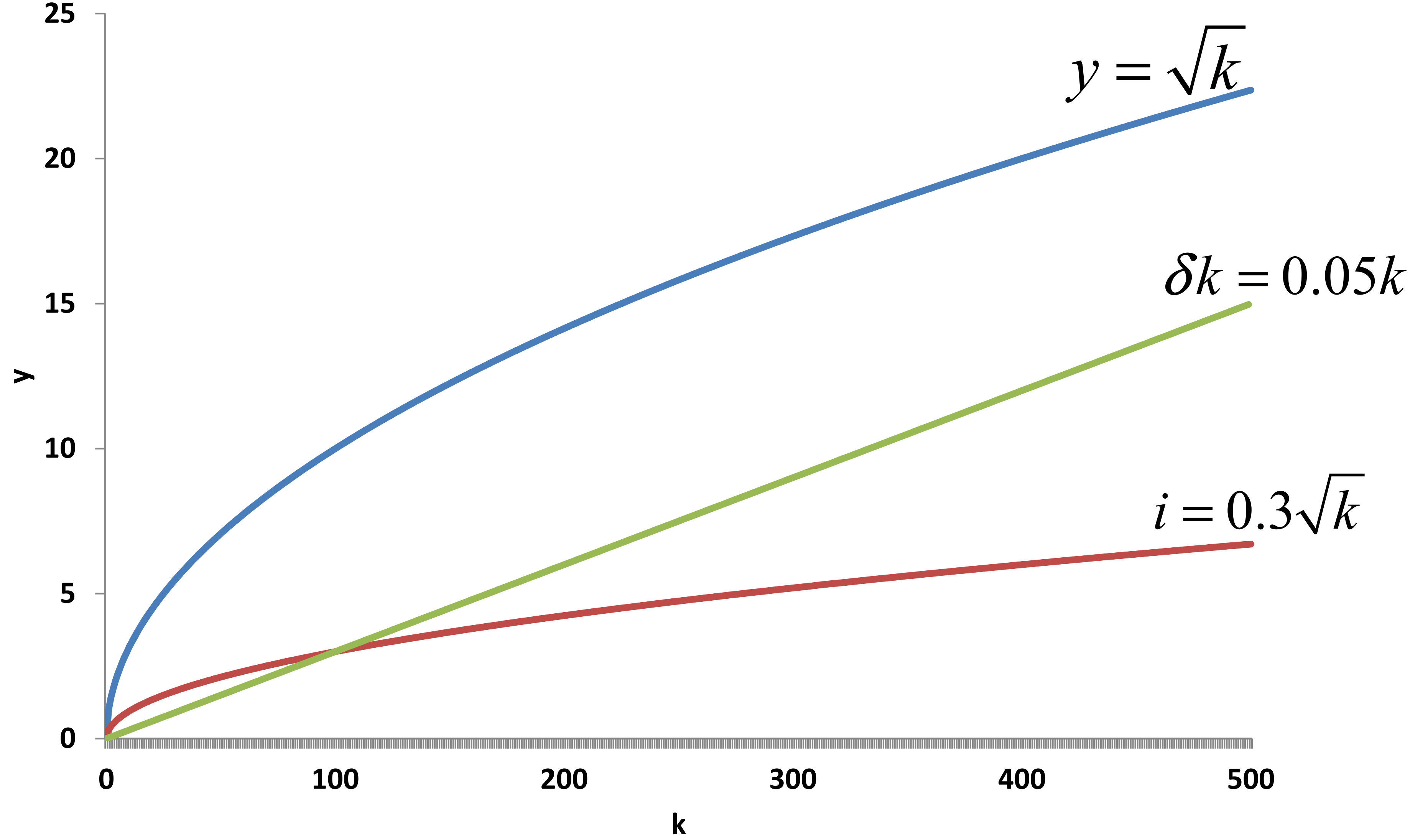
MACROECONOMICS I

Class 4. The Solow-Swan Model (Cont.)

March 14th, 2014



25
20
15
10
5
0
y
0
100
200
300
400
500
k
$y = \sqrt{k}$
$\delta k = 0.05k$
$i = 0.3\sqrt{k}$

The Solow-Swan Model: Population Growth

- Labor force is growing at a constant rate **n**:

$$\mathbf{L_{t+1}=(1+n)L_t}$$

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

What happens to Capital/Labor ratio (k)?

It is affect by *investment (+)*, *depreciation (-)*, and *population growth (-)*

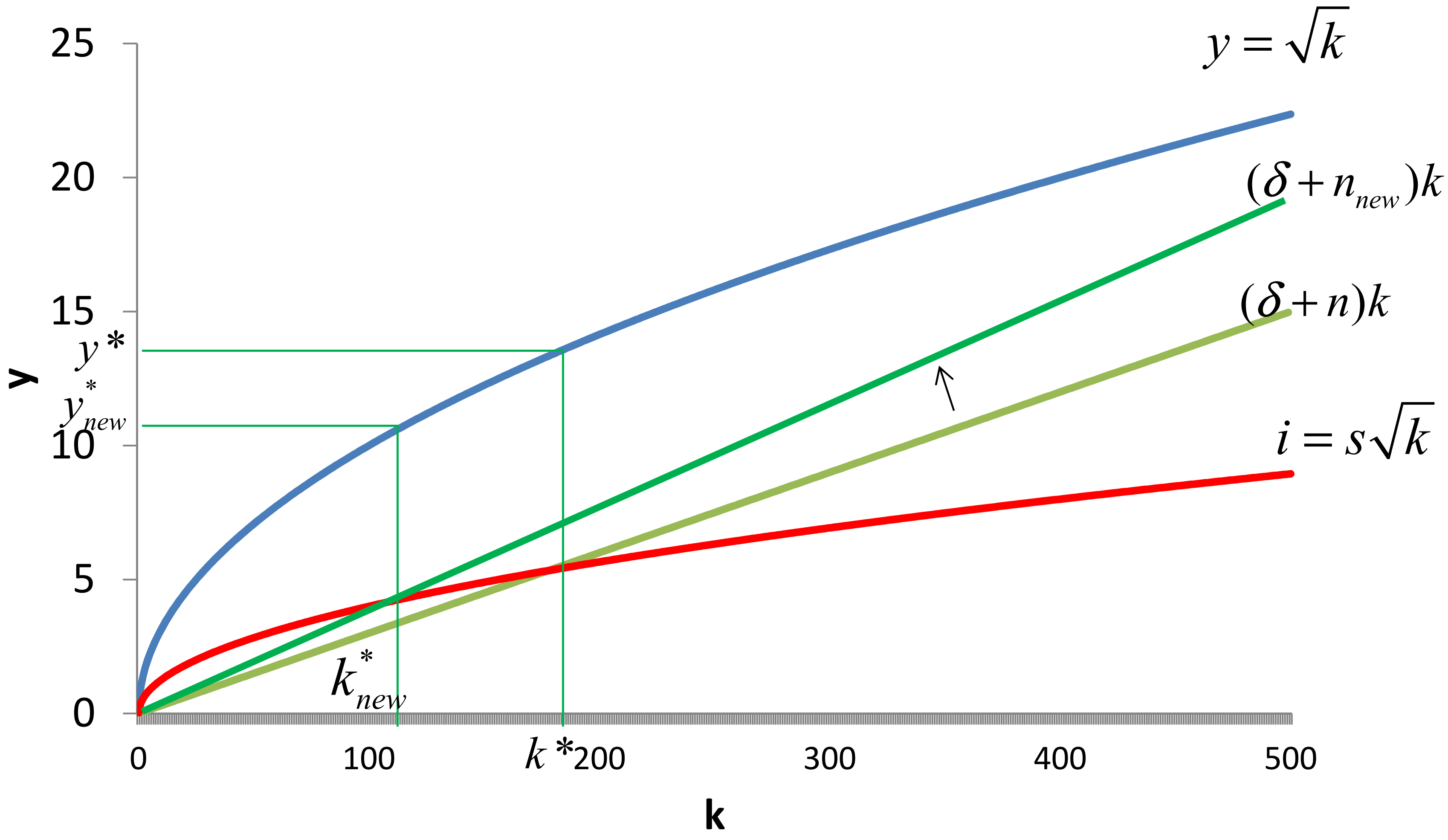
Law of motion for k?

$$k_{t+1}= sf(k_t)+(1- \square - n)k_t$$

$$\Delta k = sy - (\delta + n)k$$

Solow-Swan Model: Population Growth (Cont.)

Economies with high rates of population growth will have **lower** GDP per capita



Government policy response?

Population Growth: Summary

Steady state: $$s\sqrt{k} = (\delta + n)k \rightarrow k^* = \frac{s^2}{(\delta + n)^2}$$

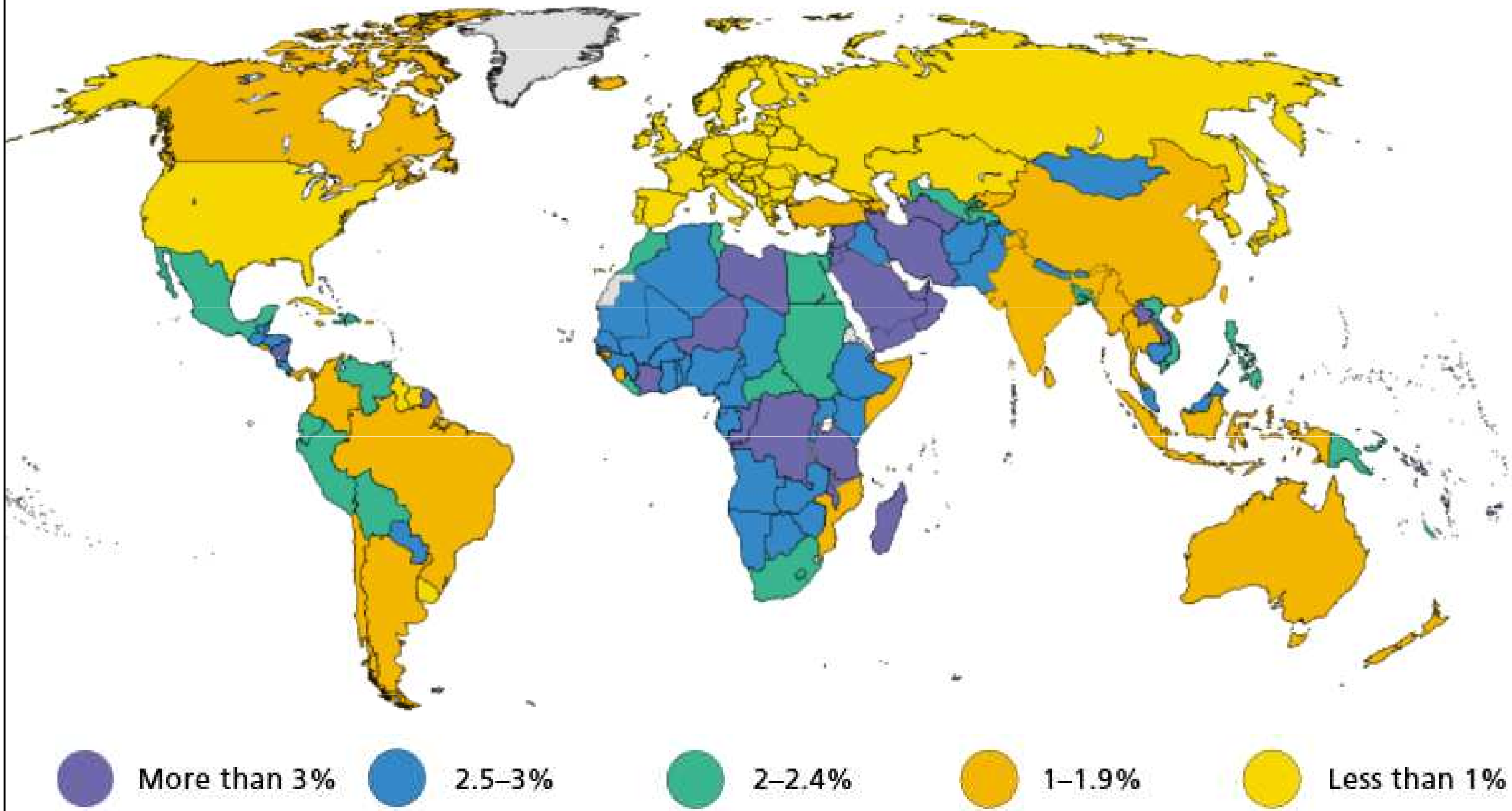
• Population growth **increases** Y and K (level effects)

N!B! Both Y and K <u>grow</u> in the steady state at the rate **n,** but **k*** and **y*** are constant

• Population growth **reduces** k* and y*

Population growth consists of *natural* population increases + *migration*

Population Growth Rates, 1985-1995



Source: The World Bank

Income per person in 2003 (logarithmic scale)
100,000
10,000
1,000
100
0
1
2
3
4
5
Population growth (percent per year; average 1960–2003)
Luxembourg
United States
Denmark
Norway
Canada
Australia
Hong Kong
Israel
United Kingdom
Portugal
South Korea
Brazil
Costa Rica
Uruguay
China
Jamaica
Guatemala
Jordan
India
Lesotho
Cote d'Ivoire
Pakistan
Gambia
Burundi
Guinea-Bissau
Ethiopia
Niger

The Role of Technological Progress

- Technological change, increase in factor productivity
  - ✓ Larger output for given quantities of capital and labor

$$Y = F(K, L, A)$$

- **State of technology (A)**

How does technological progress translates into larger output?

Labor-augmenting technological progress

$$Y = F(K, \boxed{A \cdot L})$$ **Effective labor**

- **A** as **labor efficiency**
- TP reduced number of workers needed to produce the same output
- TP increases output using the same number of workers

The Solow-Swan Model with Technological Progr

$$Y = F(K_{(+)}, L_{(+)}, A_{(+)})$$

- Technology is improving every year at the **exogenous rate (*g*)**

$$\frac{A_{t+1} - A_t}{A_t} = g$$

Production function: **GDP per effective labor**

$$Y = F(K, A \cdot L)$$

$$\frac{Y_t}{A_t L_t} = F\left(\frac{K_t}{A_t L_t}\right)$$

The Solow-Swan Model with Technological Progre

- From **GDP per effective labor** to the **GDP per capita**?

$$Y = F(K, A \cdot L)$$

$$\frac{Y_t}{A_t L_t} = F\left(\frac{K_t}{A_t L_t}\right)$$

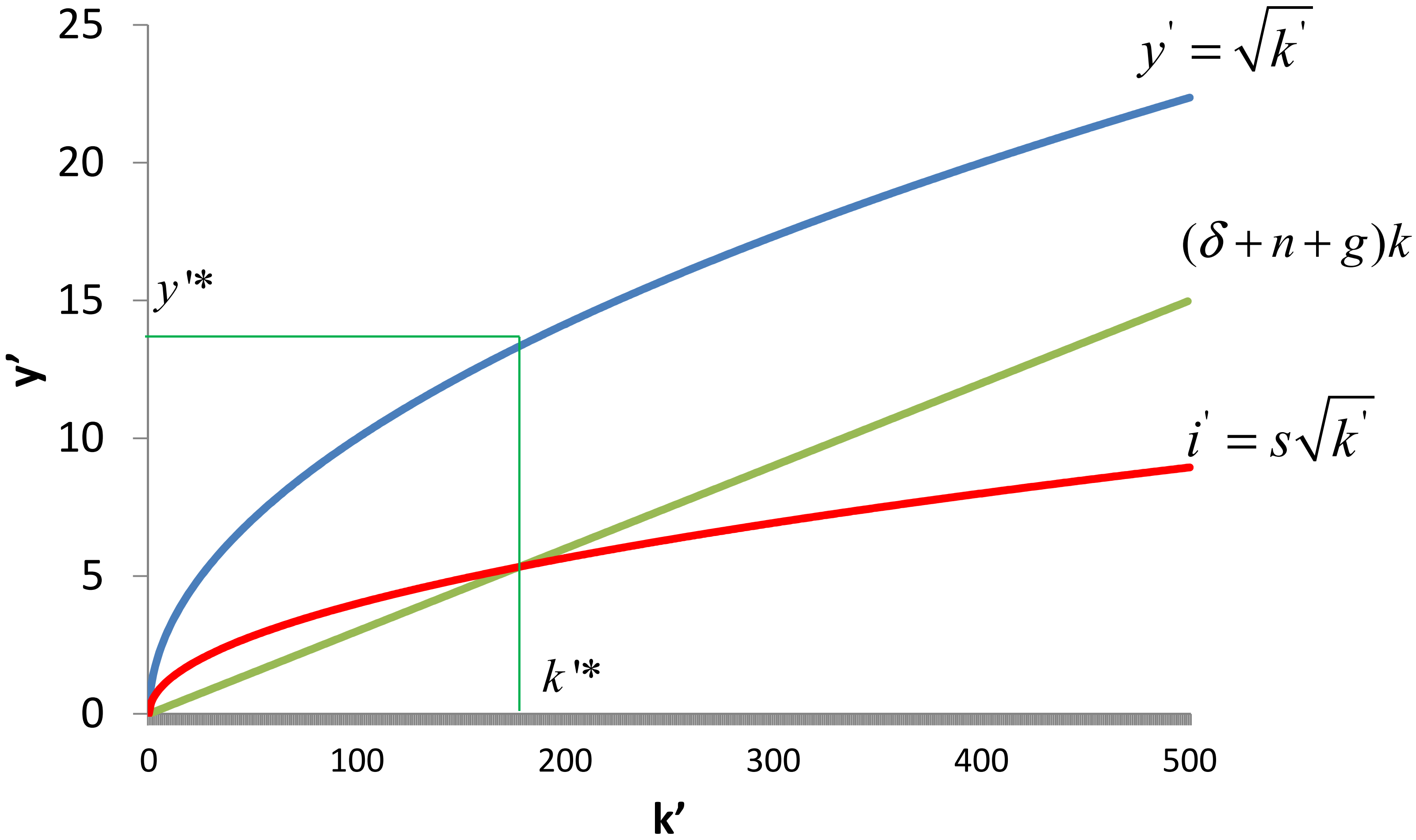
GDP per effective labor → $$y_t^{'} = f(k_t^{'})$$ ↑

Capital per effective labor

- We are interested in **GDP per capita** $y = \frac{Y_t}{L_t} = A_t \cdot F\left(\frac{K_t}{A_t L_t}\right) = A_t \cdot f(k_t^{'})$

The Solow-Swan Model with Technological Progre

Steady state: Constant levels of capital and output **per effective worker**



The Solow-Swan Model: Technological Progress (

- Capital and output per effective worker are constant in steady state
- **What about per capita variables?**

$$y^* = A_t \cdot \boxed{f(k'_*)}$$

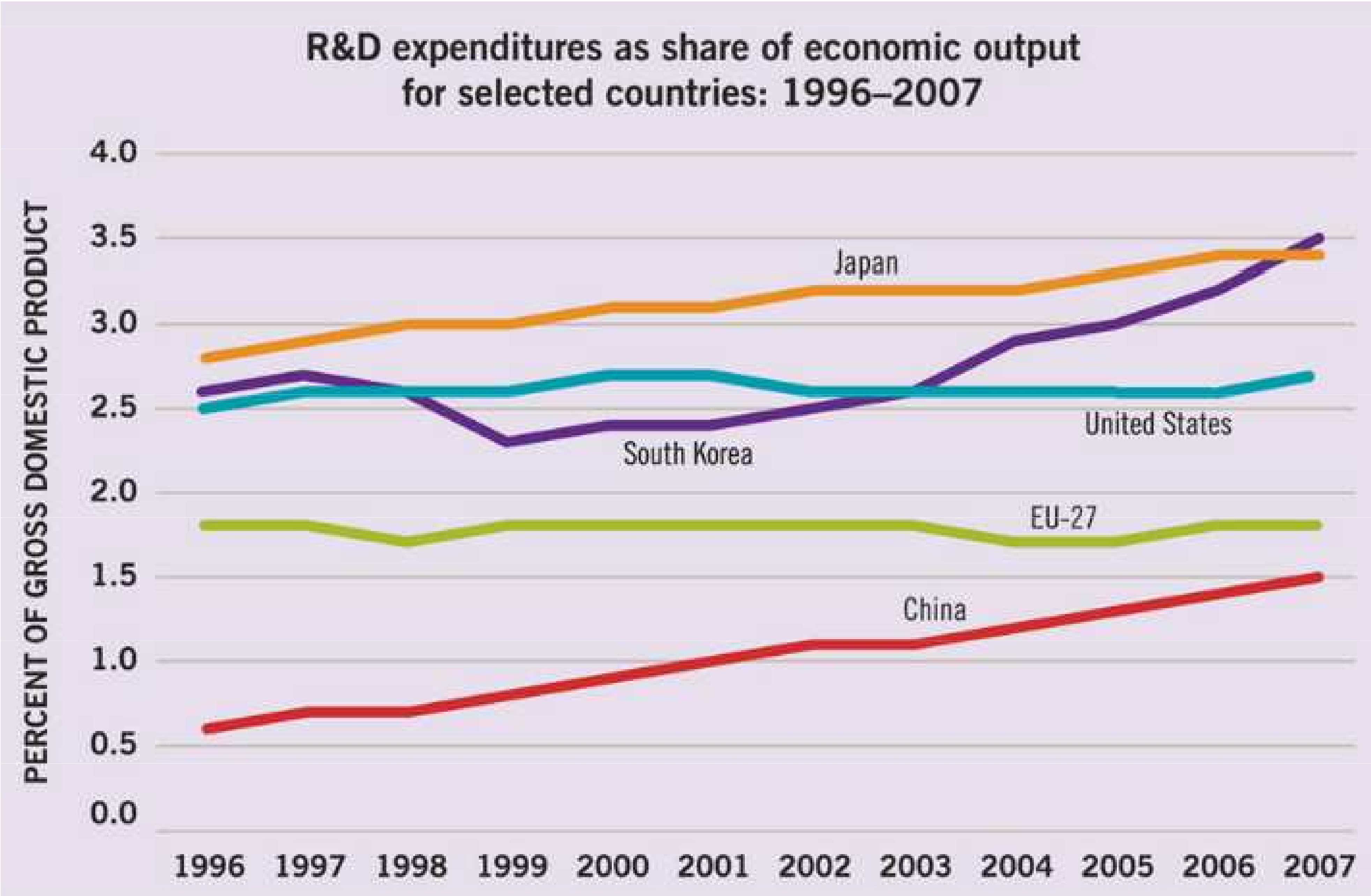
GDP per capita grows at the rate **of technological progress (sustainable growth)**

Balanced growth path: growth of variables at the same rate

•Per **capita variables** (capital, output and consumption) grow at a constant rate **g**

- **Per effective labor** variables are **not growing** in the steady state

N!B! Solow model explains 60 % of cross-country variation of the GDP per capita by differences in savings rate and population growth



R&D expenditures as share of economic output
for selected countries: 1996–2007
PERCENT OF GROSS DOMESTIC PRODUCT
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
Japan
United States
South Korea
EU-27
China

Growth Accounting

- Real GDP per capita growth rate for **Czech Republic** in 2011 was **1.7 %**
- Real GDP per capita growth rate for the **USA** in 2012 was **2.2 %**

How much of this growth is due to the factors' accumulation and/or technology?

Growth accounting: breakdown of observed growth of GDP into changes in inputs and technology

$$Y = F(A, K, L)$$

$$\Delta Y = \Delta A + \Delta K + \Delta L$$

Contribution of technology as a residual

$$\Delta A = \Delta Y - \Delta K - \Delta L$$

Growth Accounting (Cont.)

- **Capital** (**K**) increases by 1 unit

  What is the effect on output Y?

$$Y = F(A, K, L)$$

$$F(A, K+1, L) - F(A, K, L)$$

Marginal product of capita (MP_K)

TE Capital stock increased by 10 units and MP_K =0.1. What is the impact on GDP?

$$\Delta Y = 0.1 \cdot 10 = 1 \text{ unit}$$

Growth Accounting (Cont.)

- **Labor** (**L**) increases by 1 unit

What is the effect on output Y?

$$Y = F(A, K, L)$$

$$F(A, K, L+1) - F(A, K, L)$$

Marginal product of labor (MP_L)

TE Labor force increases by 10 units and MP_K =0.3.

$$\Delta Y = 0.3 \cdot 10 = 3 \text{ units}$$

Solow Residual

- Accounting for the increase in all components

$$Y = F(A, K, L)$$

$$\Delta Y = \boxed{MP_A \cdot \Delta A} + MP_K \cdot \Delta K + MP_L \cdot \Delta L$$

How to account for the technological change?

Calculate it as a **residual**

$$MP_A \cdot \Delta A = \Delta Y - MP_K \cdot \Delta K - MP_L \cdot \Delta L$$

Solow Residual: the left-over growth of output when growth attributed to the changes in labor and capital is subtracted

Solow Residual (Cont.)

- Where do we get marginal products of capital and labor?

$$\Delta Y = MP_A \cdot \Delta A + MP_K \cdot \Delta K + MP_L \cdot \Delta L$$

Mathematical manipulations

- Transforming changes to growth rates

GDP growth rate

$$\frac{\Delta Y}{Y} = MP_A \cdot \frac{\Delta A}{Y} + MP_K \cdot \frac{\Delta K}{Y} + MP_L \cdot \frac{\Delta L}{Y}$$

Unobservable technological change (g)

$$\frac{\Delta Y}{Y} = g + \frac{F_k K}{Y} \frac{\Delta K}{K} + \frac{F_L L}{Y} \frac{\Delta L}{L}$$

Solow Residual (Cont.)

$$\frac{\Delta Y}{Y} = g + MP_K \cdot \frac{\Delta K}{Y} + MP_L \cdot \frac{\Delta L}{Y}$$

$$\frac{\Delta Y}{Y} = g + \frac{MP_K \cdot K}{Y} \cdot \frac{\Delta K}{K} + \frac{MP_L \cdot L}{Y} \cdot \frac{\Delta L}{L}$$

Share of capital in output

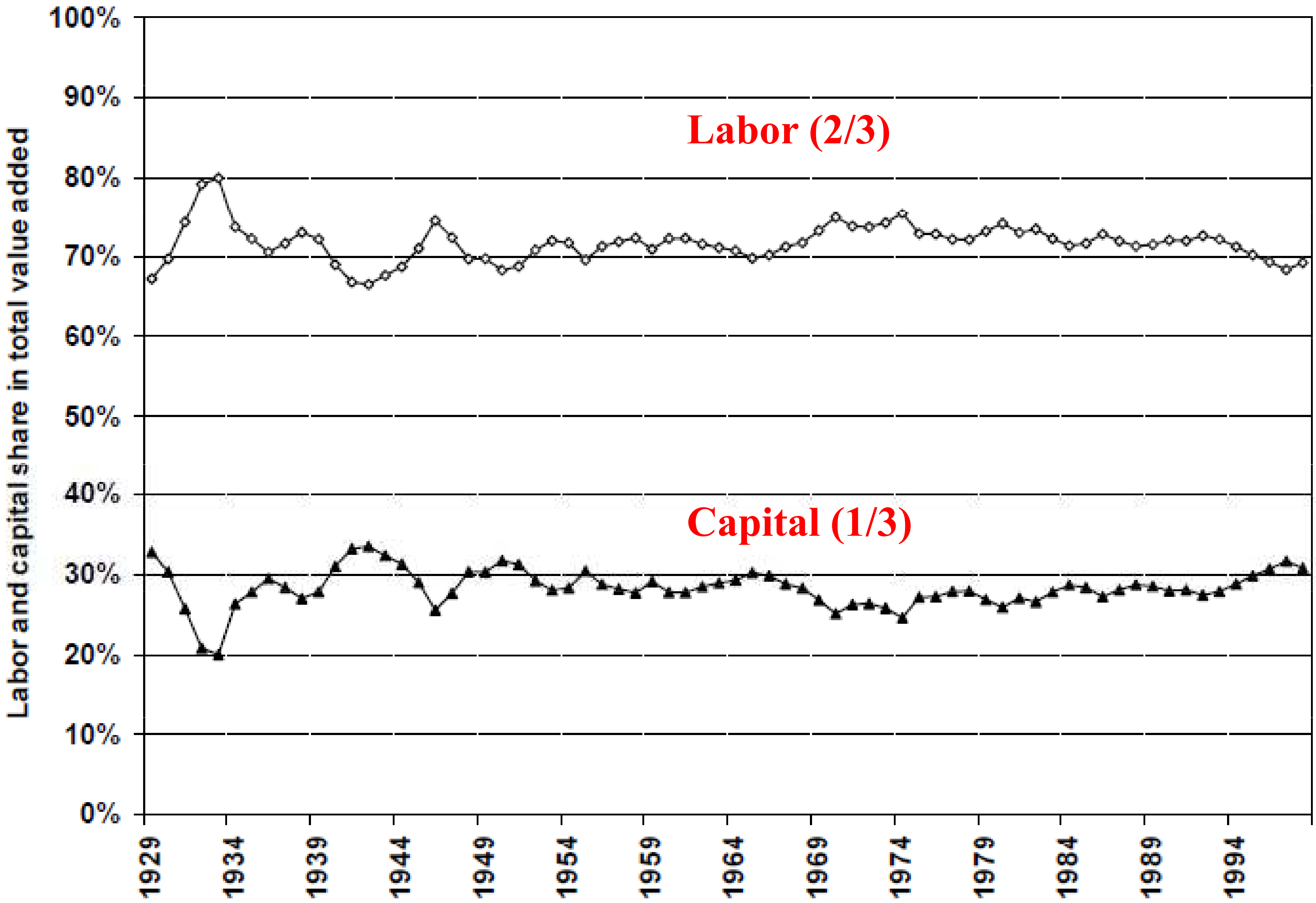
Share of labor in output

N!B! Key assumption: Factors of production are **paid their marginal product**

- **Wages** and **rental rate** of capital reflect productivity of factors

$$\frac{\Delta Y}{Y} = g + \alpha \cdot \frac{\Delta K}{K} + \beta \cdot \frac{\Delta L}{L}$$

Historical Factor Shares



Source: Acemoglu, 2009

Accounting for Economic Growth in the United States

				SOURCE OF GROWTH			
Years	Output Growth $\Delta Y/Y$	=	Capital $\alpha \Delta K/K$	+	Labor $(1-\alpha)\Delta L/L$	+	Total Factor Productivity $\Delta A/A$
			(average percentage increase per year)				
1948–2007	3.6		1.2		1.2		1.2
1948–1972	4.0		1.2		0.9		1.9
1972–1995	3.4		1.3		1.5		0.6
1995–2007	3.5		1.3		1.0		1.3

Source: Mankiw, 2009

Growth Accounting for a Sample of Countries

Country	(1) Growth Rate of GDP	(2) Contribution from Capital	(3) Contribution from Labor	(4) TFP Growth Rate
		Panel A: OECD Countries, 1947–73		
Canada	0.0517	0.0254	0.0088	0.0175
($\alpha = 0.44$)		(49%)	(17%)	(34%)
France[a]	0.0542	0.0225	0.0021	0.0296
($\alpha = 0.40$)		(42%)	(4%)	(54%)
Germany[b]	0.0661	0.0269	0.0018	0.0374
($\alpha = 0.39$)		(41%)	(3%)	(56%)
Italy[b]	0.0527	0.0180	0.0011	0.0337
($\alpha = 0.39$)		(34%)	(2%)	(64%)
Japan[b]	0.0951	0.0328	0.0221	0.0402
($\alpha = 0.39$)		(35%)	(23%)	(42%)
Netherlands[c]	0.0536	0.0247	0.0042	0.0248
($\alpha = 0.45$)		(46%)	(8%)	(46%)
U.K.[d]	0.0373	0.0176	0.0003	0.0193
($\alpha = 0.38$)		(47%)	(1%)	(52%)
U.S.	0.0402	0.0171	0.0095	0.0135
($\alpha = 0.40$)		(43%)	(24%)	(34%)
		Panel B: OECD Countries, 1960–95		
Canada	0.0369	0.0186	0.0123	0.0057
($\alpha = 0.42$)		(51%)	(33%)	(16%)
France	0.0358	0.0180	0.0033	0.0130
($\alpha = 0.41$)		(53%)	(10%)	(38%)
Germany	0.0312	0.0177	0.0014	0.0132
($\alpha = 0.39$)		(56%)	(4%)	(42%)
Italy	0.0357	0.0182	0.0035	0.0153
($\alpha = 0.34$)		(51%)	(9%)	(42%)
Japan	0.0566	0.0178	0.0125	0.0265
($\alpha = 0.43$)		(31%)	(22%)	(47%)
U.K.	0.0221	0.0124	0.0017	0.0080
($\alpha = 0.37$)		(56%)	(8%)	(36%)
U.S.	0.0318	0.0117	0.0127	0.0076
($\alpha = 0.39$)		(37%)	(40%)	(24%)

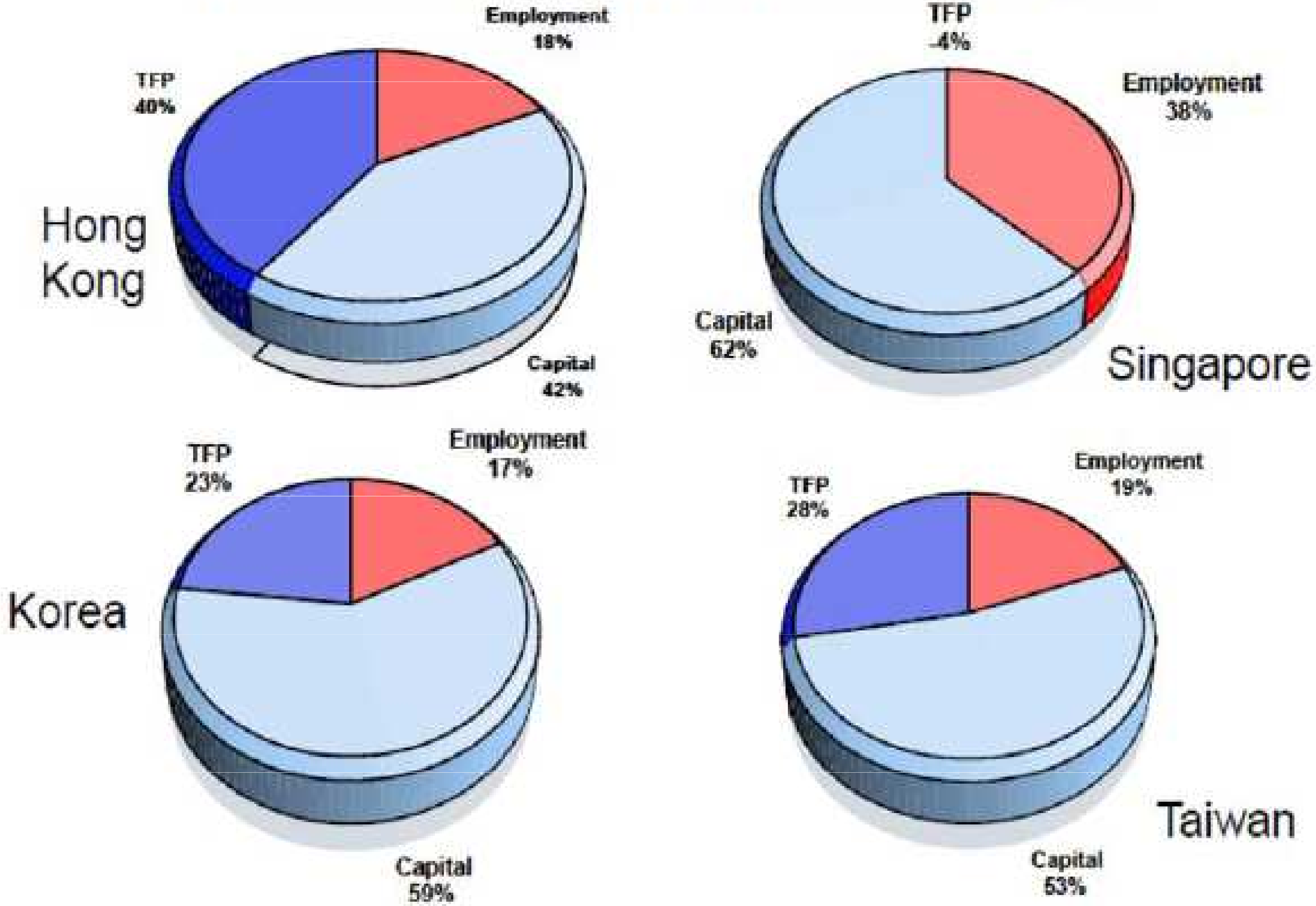
The Asian Growth Miracle?

A. Young (1995) QJE

Country	Period	Avg growth in per capita income (%)
Honk-Kong	1966-1991	5.7
Singapore	1966-1990	6.8
South Korea	1966-1990	6.8
Taiwan	1966-1990	6.7

Exceptional growth due to changes in TFP or factor accumulation?

Growth Breakdown 1966-90 for Asian Dragons



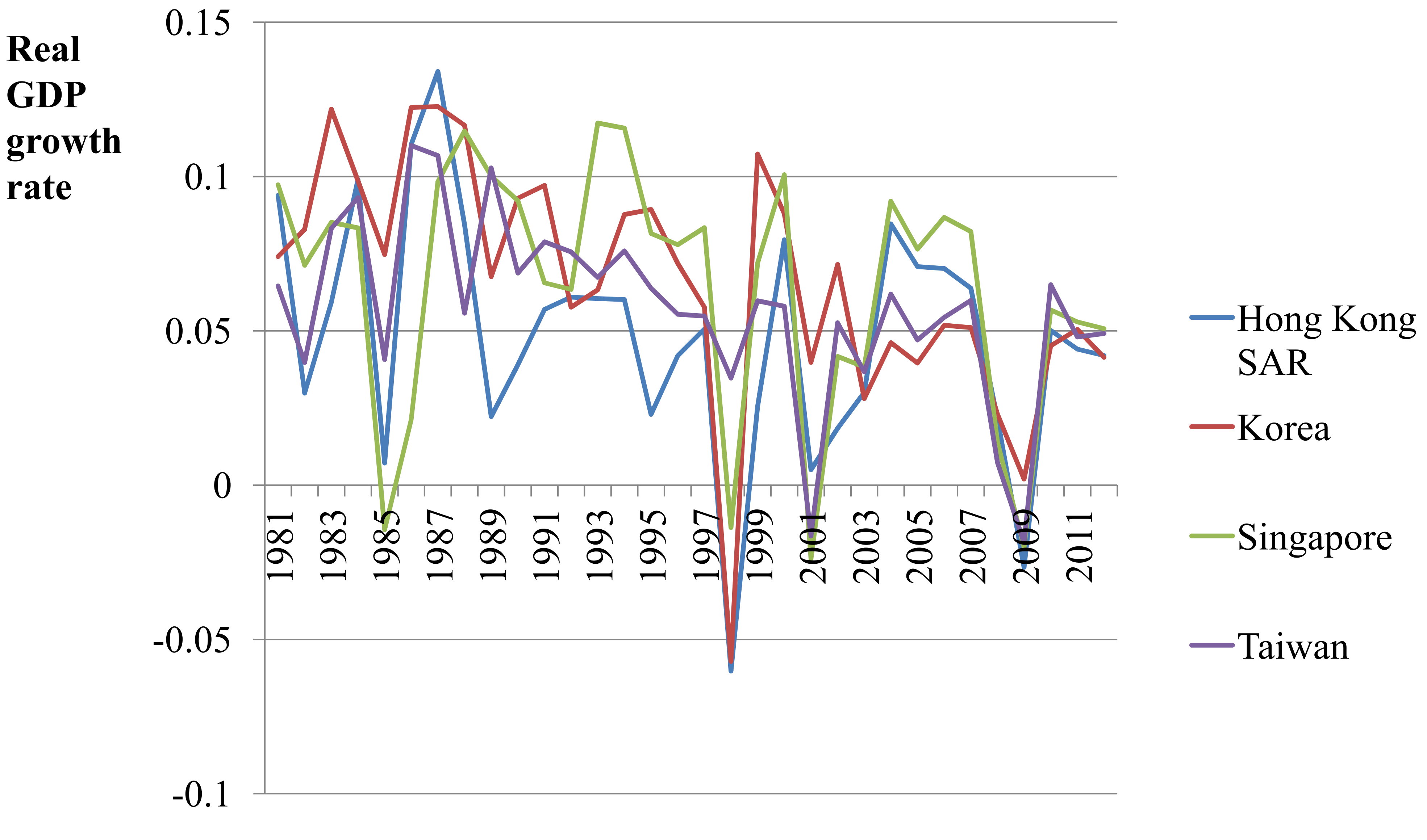
The Asian Growth Miracle?

Country	Period	TFP growth
Asian Tigers		
Honk-Kong	1966-1991	2.3
Singapore	1966-1990	0.2
South Korea	1966-1990	1.7
Taiwan	1966-1990	2.1
Other Countries		
Canada	1960-1989	0.5
France	1960-1989	1.5
Germany	1960-1989	1.6
Italy	1960-1989	2.0
Japan	1960-1989	2.0
UK	1960-1989	1.3
US	1960-1989	0.4
Brazil	1960-1985	1.6
Chile	1960-1985	0.8
Mexico	1960-1985	1.2

The miracle was bound to stop

Exceptional growth due to the factors accumulation? Conclusion?

Asian Tigers: Performance After 1990s



Source: IMF World Economic Outlook Database

Asian Tigers: Performance After 1990s

Country	Period	Avg growth in per capita income (%)
Honk-Kong	1966-1991	5.7
Singapore	1966-1990	6.8
South Korea	1966-1990	6.8
Taiwan	1966-1990	6.7

Country	Average growth rate 1990-2012 (%)
Hong Kong	3.9
Singapore	5.9
South Korea	5
Taiwan	4.8

Global Slowdown in Economic Growth

GDP per capita growth rate (% per year)

Country	1948-1972	1972-1995	1995-2010
Canada	2.9	1.8	1.6
France	4.3	1.6	1.1
Germany	5.7	2	1.3
Italy	4.9	2.3	0.6
Japan	8.2	2.6	0.6
UK	2.4	1.8	1.7
USA	2.2	1.5	1.5

Source: Mankiw (2013)

What are the reasons?

Theories Explaining Disparities in Development

Fundamental causes

- ✓ Geography: geographical concentration of poverty and prosperity

Tropical climate: lazy people, diseases, and poor agricultural lands

Counter examples: Botswana, Nogales

- ✓ Culture: beliefs, values, ethics, trust, cooperation

Counter examples: North and South Korea

- ✓ Ignorance of policy makers: poor policies

Transfer of resources to a small powerful group

The Institutional Hypothesis

• Countries differ in economic success because of **different institutions (rules)**

Laws, regulations, enforcement of property rights and social norms

Extractive institutions: concentration of power in the hands of elite

Inclusive institutions: inclusive markets and opportunities

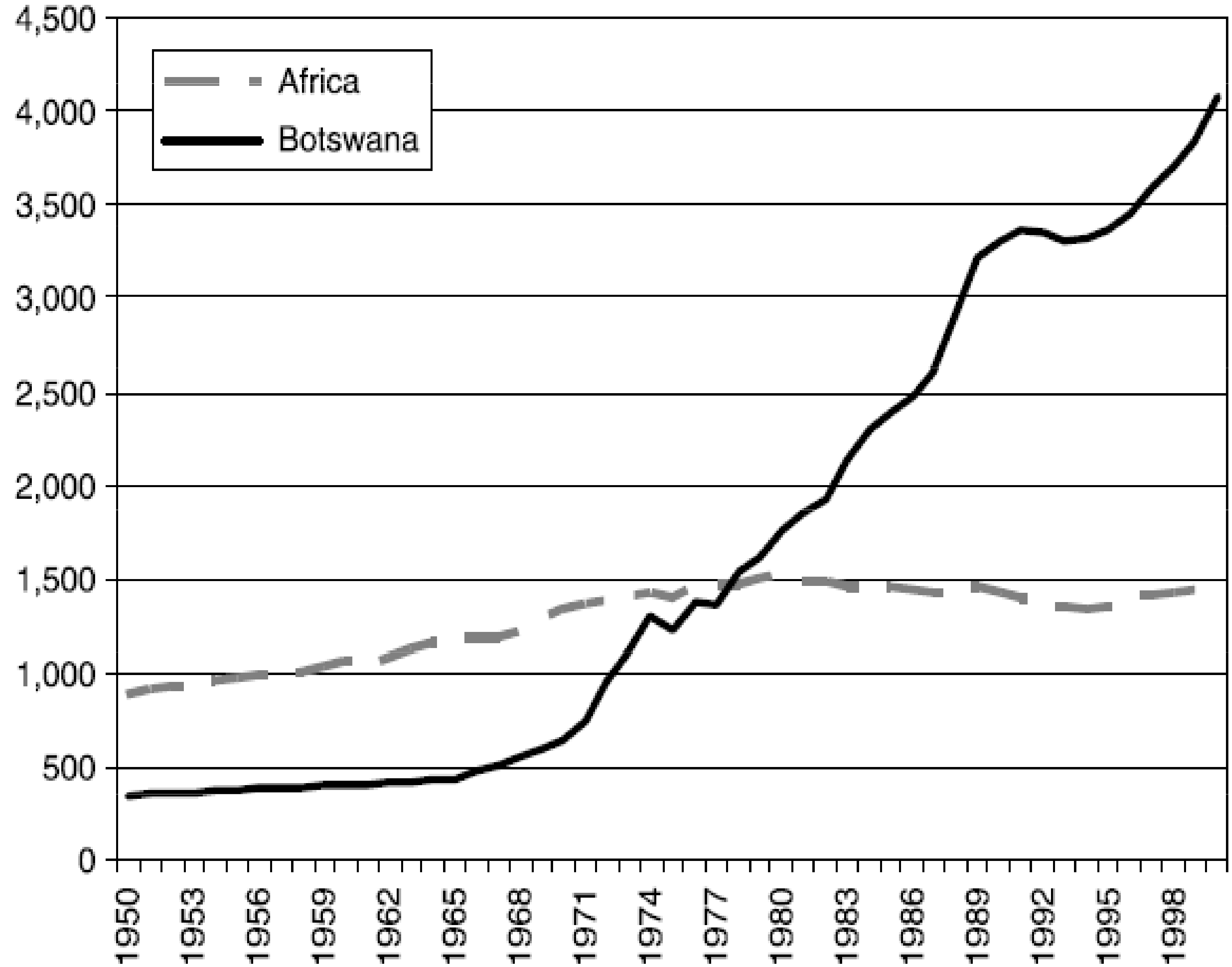
Free choice of occupation, education, constrained and broadly distributed power

Institutions => **Incentives** to acquire education, start a business and innovate

Nogales

African Growth Miracle

GDP per capita



Next class: Business cycles

N!B! Homework is due next week before the class