Intermediate Macroeconomic Theory

Costas Azariadis

Lecture 5: Economic Growth

1. THE ISSUES

a. Facts of growth: successes, failures
b. Sources of growth: where does success come from?
c. The dynamics of growth. Does every country get rich in the long run?
d. The Solow growth model

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2.THE SOURCES OF GROWTH

a) **The aggregate production function**

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

$$Y_t = GDP;\ A_t = TFP;\ K_t = capital\ stock\ or\ services;\ N_t = employment$$

$$F(K, N) \approx K^{.36} N^{.64}$$

b) **Measuring of the APF**

K_t = economy wide capital
N_t = economy wide labor
A_t = TFP = measures
-state of technology
-how well aggregate (K,N) are deployed among different uses

Walmart Example

K_t = million square feet of floor space
N_t = thousand employees

Q: Where to place retail stores & dist'n centers?
How many employees to put in each location?

A: Walmart is not perfect.
Does not equate MPN, MPK across stores.
If it did, Walmart 's TFP would go up! Profits, too!

c) Sources of growth & growth accounting

The production function says:
growth in Y = growth in A + capital share times growth in K + labor share times growth in N

"growth" in K: more capital; better capital
"growth" in N: more workers; higher level of skills

Example:
1) PC or phones in 1988 vs. now
2) educational achievement in 1908 vs. now

Economic Growth

Growth Accounting from APF

$$\frac{\Delta Y}{Y} = \frac{\Delta A}{A} + .36\frac{\Delta K}{K} + .64\frac{\Delta N}{N}$$

$\frac{\Delta Y}{Y}$: % GDP growth

$\frac{\Delta A}{A}$: % TFP growth

$\frac{\Delta K}{K}$: % capital growth

$\frac{\Delta N}{N}$: % employment growth

Economic Growth

Table 6.3

Sources of Economic Growth in the United States (Percent per Year)

	(1) 1929–1948	(2) 1948–1973	(3) 1973–1982	(4) 1929–1982	(5) 1982–2008
Source of Growth					
Labor growth	1.42	1.40	1.13	1.34	0.89
Capital growth	0.11	0.77	0.69	0.56	0.84
Total input growth	1.53	2.17	1.82	1.90	1.73
Productivity growth	1.01	1.53	–0.27	1.02	1.01
Total output growth	**2.54**	**3.70**	**1.55**	**2.92**	**2.76**

Sources: Columns (1)–(4) from Edward F. Denison, *Trends in American Economic Growth, 1929–1982*, Washington, D.C.: The Brookings Institution, 1985, Table 8.1, p. 111. Column (5) from Bureau of Labor Statistics Web site, Multifactor Productivity Trends news release, Table 1, accessed through *www.bls.gov/news.release/prod3.t01.htm.*

* TFP doubles from 1940 to 2008
* Labor productivity doubles from 1975 to 2005
* TFP growth equals 1/3 of income growth, ½ of per capita growth

Economic Growth

d) Why did TFP fall in the 1970's? Rise in the 1990's?

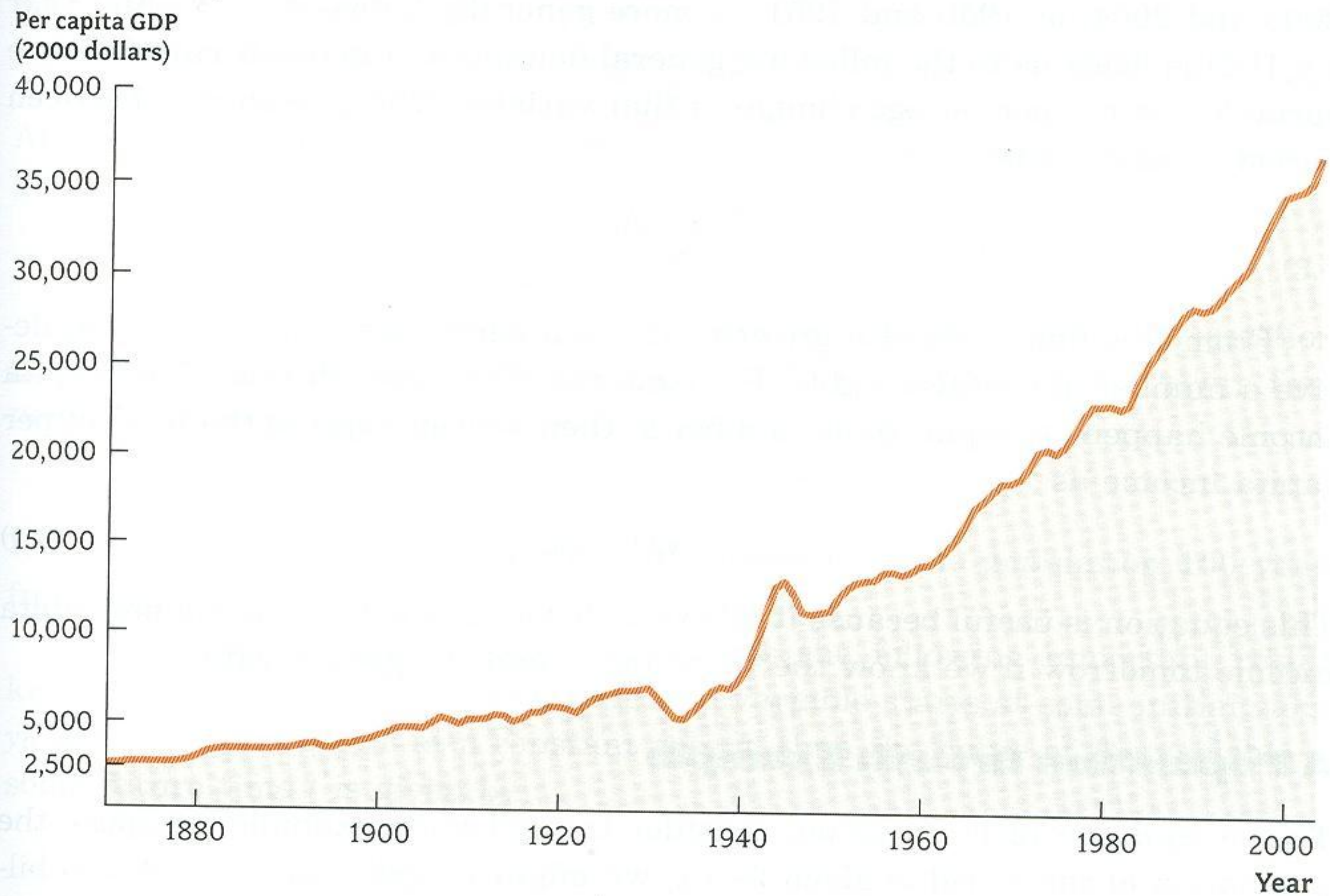
- oil shock vs
- IT revolution

Industrial revolutions involve initial falls in TFP because
-much capital becomes obsolete
-people slow to learn new technologies

Industrial revolutions also involve initial stock market declines (obsolete firms)
Eventually TFP & stock market both recover.

Economic Growth

Per Capita GDP in the United States, 1870–2004



Source: Data from 1870 to 1928, Maddison, *The World Economy* (see Figure 3.1). Data from 1929 to 2004, U.S. Department of Commerce, Bureau of Economic Analysis.

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Economic Growth

Next 50 year growth=80%

170%

75%

U.S. Real Per Capita GDP in 2005 Dollars

Year	Per Capita Real GDP
1790	1,025
1791	1,054
1792	1,098
1793	1,151
1794	1,265
1795	1,305
1796	1,307
1797	1,294
1798	1,310
1799	1,362
1800	1,397
1801	1,421
1802	1,421
1803	1,401
1804	1,411
1805	1,441
1806	1,462
1807	1,417
1808	1,376
1809	1,437
1810	1,471
1811	1,494
1812	1,510
1813	1,552
1814	1,573
1815	1,543
1816	1,501
1817	1,493
1818	1,501
1819	1,485
1820	1,499
1821	1,534
1822	1,546
1823	1,557
1824	1,602
1825	1,626
1826	1,634
1827	1,635
1828	1,608
1829	1,620
1830	1,718
1831	1,807
1832	1,873
1833	1,874
1834	1,851
1835	1,895
1836	1,897
1837	1,860
1838	1,885
1839	1,884
1840	1,838
1841	1,826
1842	1,831
1843	1,869
1844	1,922
1845	1,986
1846	2,084
1847	2,154
1848	2,153
1849	2,109
1850	2,132
1851	2,224
1852	2,391
1853	2,495
1854	2,490
1855	2,513
1856	2,543
1857	2,486
1858	2,521
1859	2,641
1860	2,606
1861	2,594
1862	2,857
1863	3,011
1864	2,977
1865	2,992
1866	2,786
1867	2,763
1868	2,801
1869	2,805
1870	2,814
1871	2,868
1872	3,030
1873	3,200
1874	3,170
1875	3,091
1876	3,152
1877	3,243
1878	3,283
1879	3,596
1880	3,816
1881	4,193
1882	4,296
1883	4,290
1884	4,114
1885	4,034
1886	4,278
1887	4,504
1888	4,664
1889	4,699
1890	5,060
1891	5,011
1892	5,147
1893	4,737
1894	4,418
1895	4,841
1896	4,687
1897	4,804
1898	5,246
1899	5,515
1900	5,557
1901	5,739
1902	5,914
1903	5,976
1904	5,656
1905	6,170
1906	6,300
1907	6,346
1908	5,552
1909	5,836
1910	5,776
1911	5,871
1912	6,051
1913	6,168
1914	5,587
1915	5,657

Economic Growth

Next 50 year growth=300%

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1916	6,353
1917	6,108
1918	6,587
1919	6,607
1920	6,460
1921	6,191
1922	6,445
1923	7,170
1924	7,251
1925	7,311
1926	7,684
1927	7,652
1928	7,645
1929	8,016
1930	7,247
1931	6,725
1932	5,809
1933	5,700
1934	6,281
1935	6,792
1936	7,629
1937	7,971
1938	7,637
1939	8,188
1940	8,832
1941	10,240
1942	11,999
1943	13,771
1944	14,706
1945	14,382
1946	12,676
1947	12,323
1948	12,645
1949	12,365
1950	13,225
1951	14,007
1952	14,297
1953	14,710
1954	14,363
1955	15,128
1956	15,157
1957	15,187
1958	14,802

1959	15,596
1960	15,661
1961	15,766
1962	16,466
1963	16,940
1964	17,675
1965	18,576
1966	19,559
1967	19,836
1968	20,590
1969	21,021
1970	20,820
1971	21,249
1972	22,140
1973	23,200
1974	22,861
1975	22,592
1976	23,575
1977	24,412
1978	25,503
1979	26,010
1980	25,640
1981	26,030
1982	25,282
1983	26,186
1984	27,823
1985	28,718
1986	29,443
1987	30,115
1988	31,069
1989	31,877
1990	32,112
1991	31,614
1992	32,255
1993	32,747
1994	33,671
1995	34,111
1996	34,977
1997	36,102
1998	37,238
1999	38,592
2000	39,750
2001	39,774

2002	40,107
2003	40,728
2004	41,806
2005	42,697
2006	43,425
2007	43,926
2008	43,714

Economic Growth

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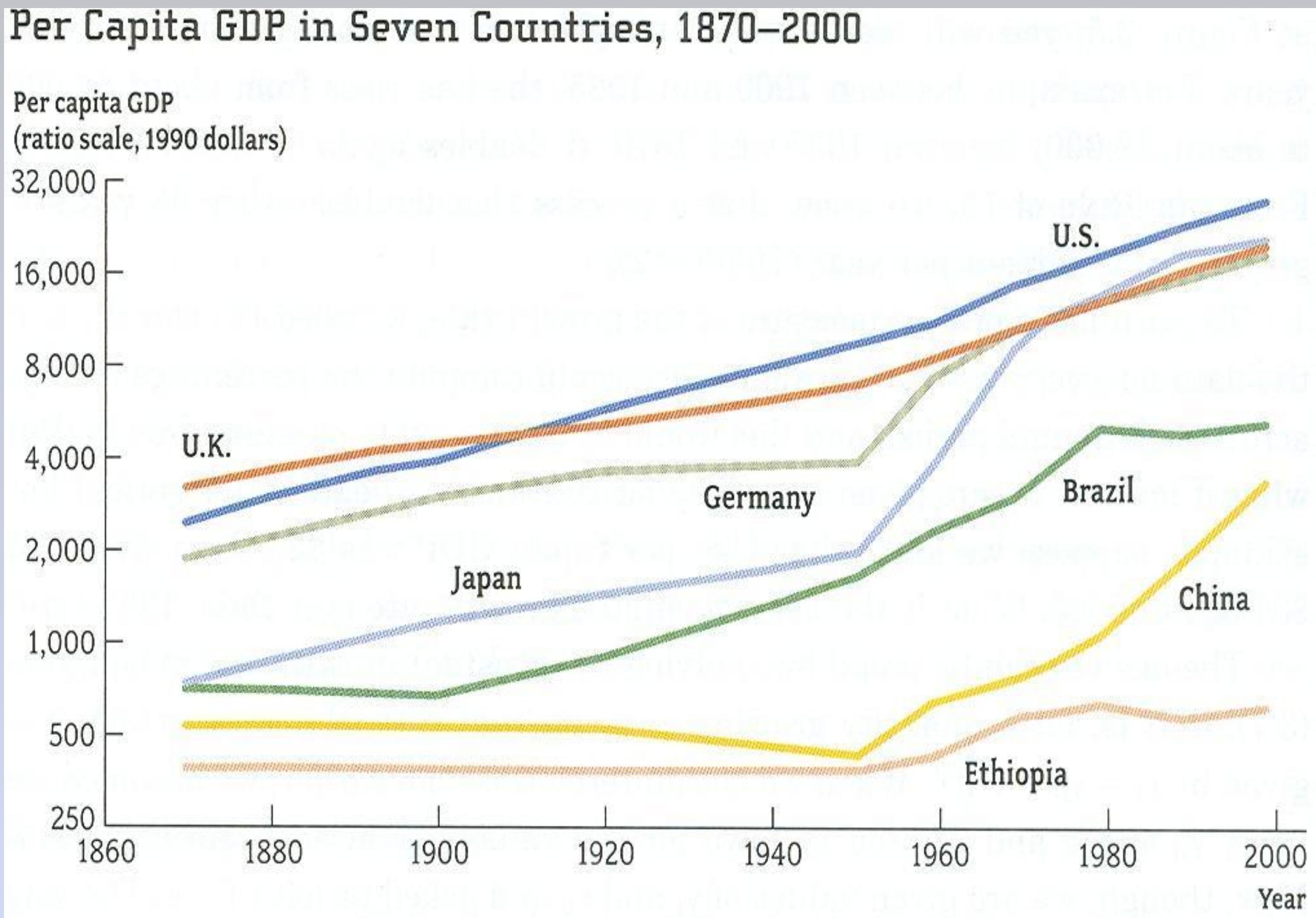

Source: Maddison, *The World Economy* (see Figure 3.1). Observations are presented every decade after 1950 and less frequently before that as a way of smoothing the series.

Economic Growth

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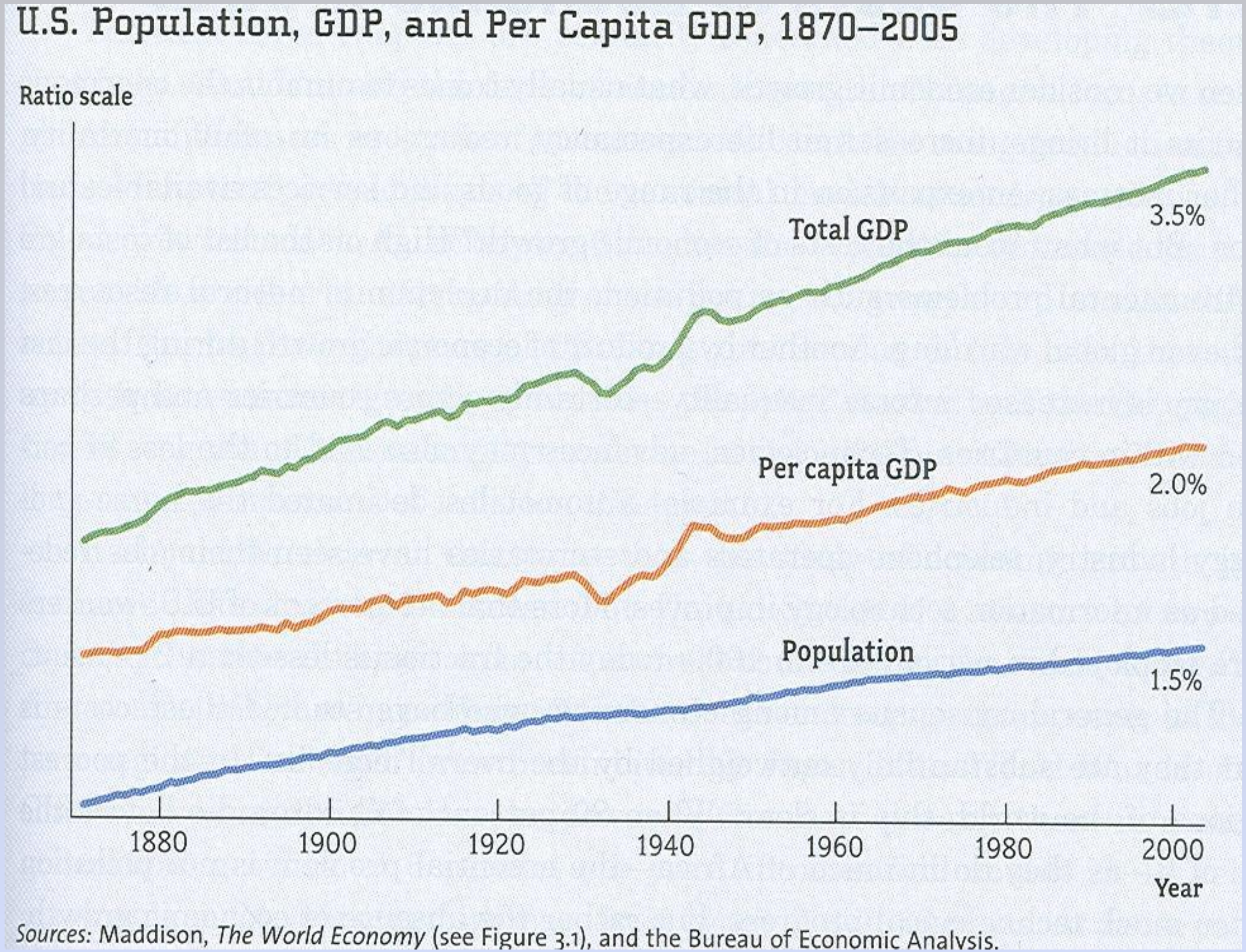

3. GROWTH DYNAMICS: THE SOLOW MODEL

a)**Issues**

-Growth miracles:

- Europe: U.K., Finland, Ireland, Spain
- Asia: Japan, Korea; Taiwan, H-K, Singapore; China, India
- Africa: Kenya (1970's), Lesotho, Namibia
- L.America: Chile, Brazil(slowly)

"Miracle" means convergence to U.S. living standards

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Growth disasters:

Argentina (since 1940)

Uruguay

Japan (since 1990)

Italy (since 1990)

Russia (1910-2000)

China (1910-1980)

Pakistan (up to 2000)

Afghanistan (forever)

Egypt (since 1920)

Most of Central America

Subsaharan Africa

"Disaster"= falling forever behind relative to U.S.

What is the recipe for a ”miracle”? For a ”disaster”?

b)<u>The Solow Model</u> (1956)

-Associates growth with
”Capital deepening”= piling up more & more capital per worker

-Ignores growth from:
1) improvement in quality of capital & labor
2) investment in R&D
3) improvement in markets & institutions
4) expansion in international trade

Economic Growth

-Following in the footsteps of classical economics from 19th century→ {Ricardo, Marx}

-Key contributions from
Robert Solow (1956)
Trevor Swan (1956)

-Basic Idea
Closed economy without gov't or taxes

$$Y_t = C_t + S_t + T_t = C_t + I_t + G_t$$

ignore T_t, G_t

→ In equilibrium Saving= Investment: $S_t = I_t$

c)**Mathematics of the Model**

- Building Blocks: Capital K_t , Employment N_t
- Employment grows at constant rate: n

$$N_t = (1+n)N_{t-1} = \ \dots = (1+n)^t N_0$$

Gross investment I_t equals net investment $K_{t+1} - K_t$ + depreciation dK_t

$$I_t = K_{t+1} - K_t + dK_t$$

d = depreciation rate ≈ .08 per year

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-Saving is proportional to GDP

$$S_t = sY_t = sAK_t^{\alpha} N_t^{1-\alpha}$$

a) The data

s= saving rate ≈ .18 for rich nations
≈ .25-.30 for middle income nations
≈ .02-.05 for really poor nations
≈ .45 for China

A= TFP

α = capital share ≈.36

-Equate saving with investment

$$sAK_t^{\alpha} N_t^{1-\alpha} = K_{t+1} - (1-\delta)K_t \qquad (1)$$

-Divide eq.(1) by N_t on both sides. Express everything in terms of the capital/labor ratio: $k_t = \dfrac{K_t}{N_t}$

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$$\frac{sAK_t^{\alpha} N_t^{1-\alpha}}{N_t} = \frac{K_{t+1}}{N_{t+1}} \frac{N_{t+1}}{N_t} - (1-\delta)\frac{K_t}{N_t}$$

$$sA\left(\frac{K_t}{N_t}\right)^{\alpha} = (1+n)\frac{K_{t+1}}{N_{t+1}} - (1-\delta)\frac{K_t}{N_t}$$

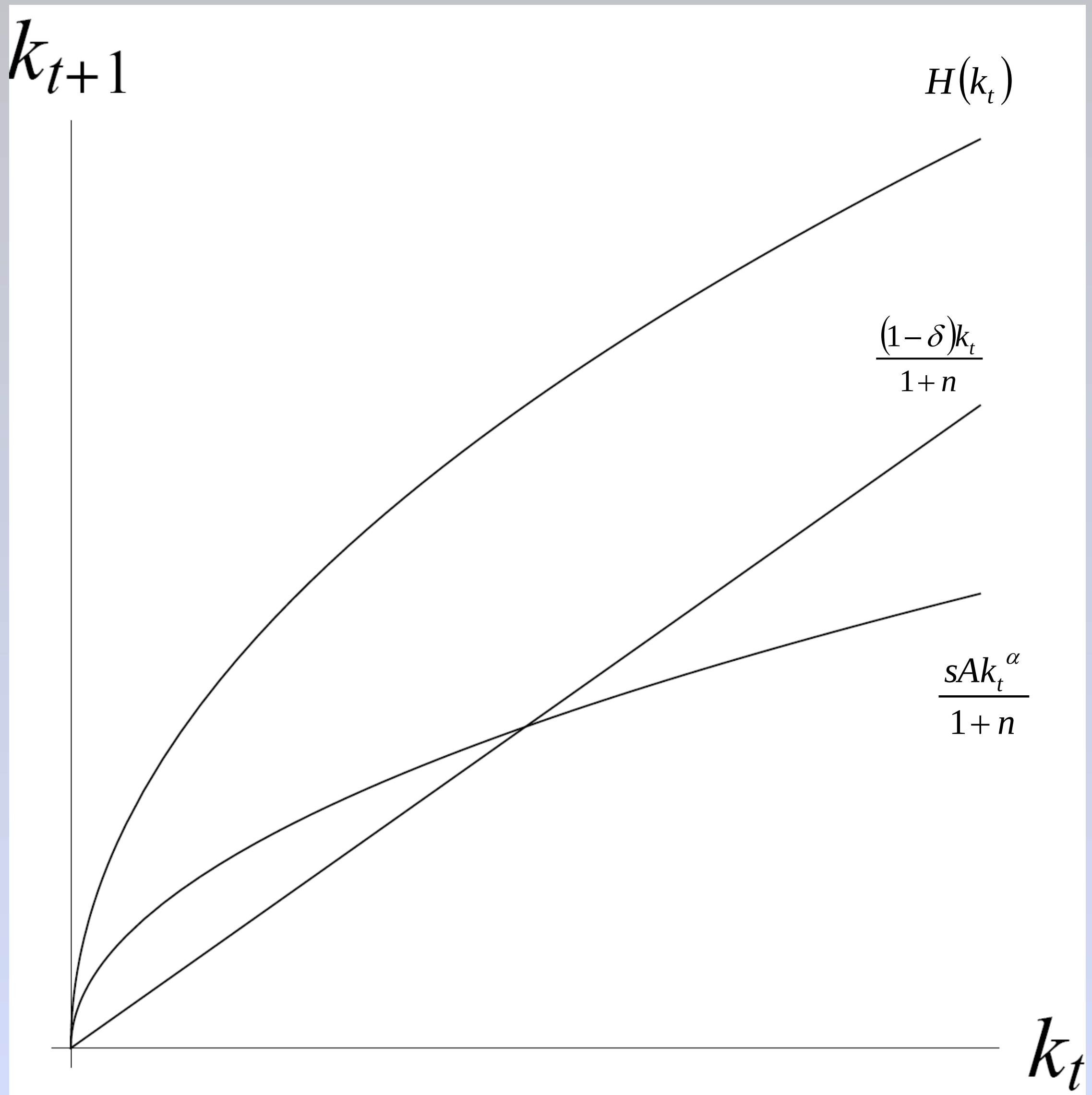
$$(1+n)k_{t+1} = (1-\delta)k_t + sAk_t^{\alpha}$$

$$k_{t+1} = H(k_t) \qquad (2a)$$

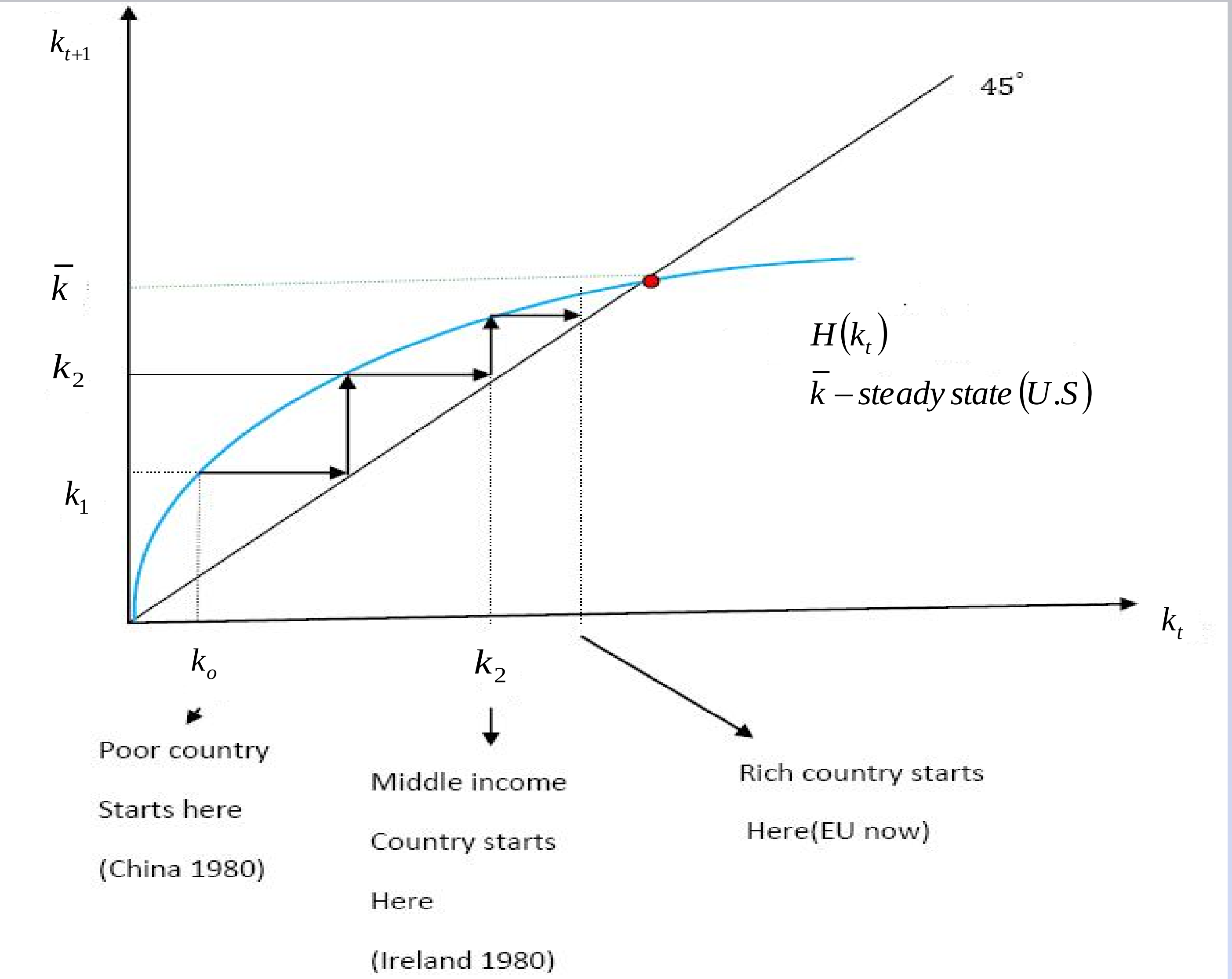
$$H(k_t) = \frac{(1-\delta)k_t + sAk_t^{\alpha}}{1+n} \qquad (2b)$$

→ The Solow model in eq. (2) describes how k evolves over time: k_{t+1} depends on k_t, k_t depends on k_{t-1}, etc.

Economic Growth



Economic Growth



Steady state in the real world: income per worker, capital per worker grow at constant rate(not zero as in Solow model)

e)A numerical example

Think of emerging economy, 1 pd=1 generation let (1+n)=2 → (population doubles every 30 years)

$$\delta = 1$$
$$1 + n = 2$$
$$s = .2, \alpha = .5$$
$$A = 10, sA = 2$$

Then the Solow equation

$$k_{t+1} = \sqrt{k_t}$$

steady state $\bar{k}$=1(capital)

$\bar{y} = 10\sqrt{1}$=10(income per capita)

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Suppose initial values:

$$k_o = \frac{1}{100}, y_o = 10\sqrt{k_o} = 1 \Rightarrow$$

$$(k_1, y_1) = \left(\frac{1}{10}, \sqrt{10}\right) = (.10, 3.2)$$

$$(k_2, y_2) = (.32, 5.5)$$

$$(k_3, y_3) = (.55, 7.5)$$

$$(k_4, y_4) = (.75, 8.5)$$

Very high growth rate ($k_0 \to k_1$)

High growth rate ($k_1 \to k_2$)

Moderate growth rate ($k_2 \to k_3$)

Slow growth rate ($k_3 \to k_4$)

* Growth miracles should be expected.
In 4 generations this economy improves from 10% of steady-state income to 85% of steady-state income

4. MIRACLES & DISASTERS

a) **Making a Miracle**

Low initial income due to shortage of capital.

Capital shortage means high MPK → high return on capital

High RoR attracts lots of saving from domestic & foreign sources

→ high investment

→ high growth

b) **Comparing growth rates**

Growth rate inversely related to p.c. income

China grows at 10% Korea at 4%, Japan 2%

c)**Disasters**

Q: How do we explain persistent poverty? Where does the Solow model fail?

Note: Capital shortage does not always result in high RoR on physical capital.

Exceptions include:

-war or uncertainty about property rights

-corruption or high taxes on capital

-poorly functioning economic institutions incl. frequent changes in legal environment

-lack of saving due to subsistence consumption (Africa saves little)

d) **Subsistence consumption**

Suppose $\hat{y}$ = subsistence income per capita= $A\left(\hat{k}\right)^{\alpha} \approx \$500$

$\hat{k}$ = subsistence level of capital $\approx \$1,000$

Then aggregate saving

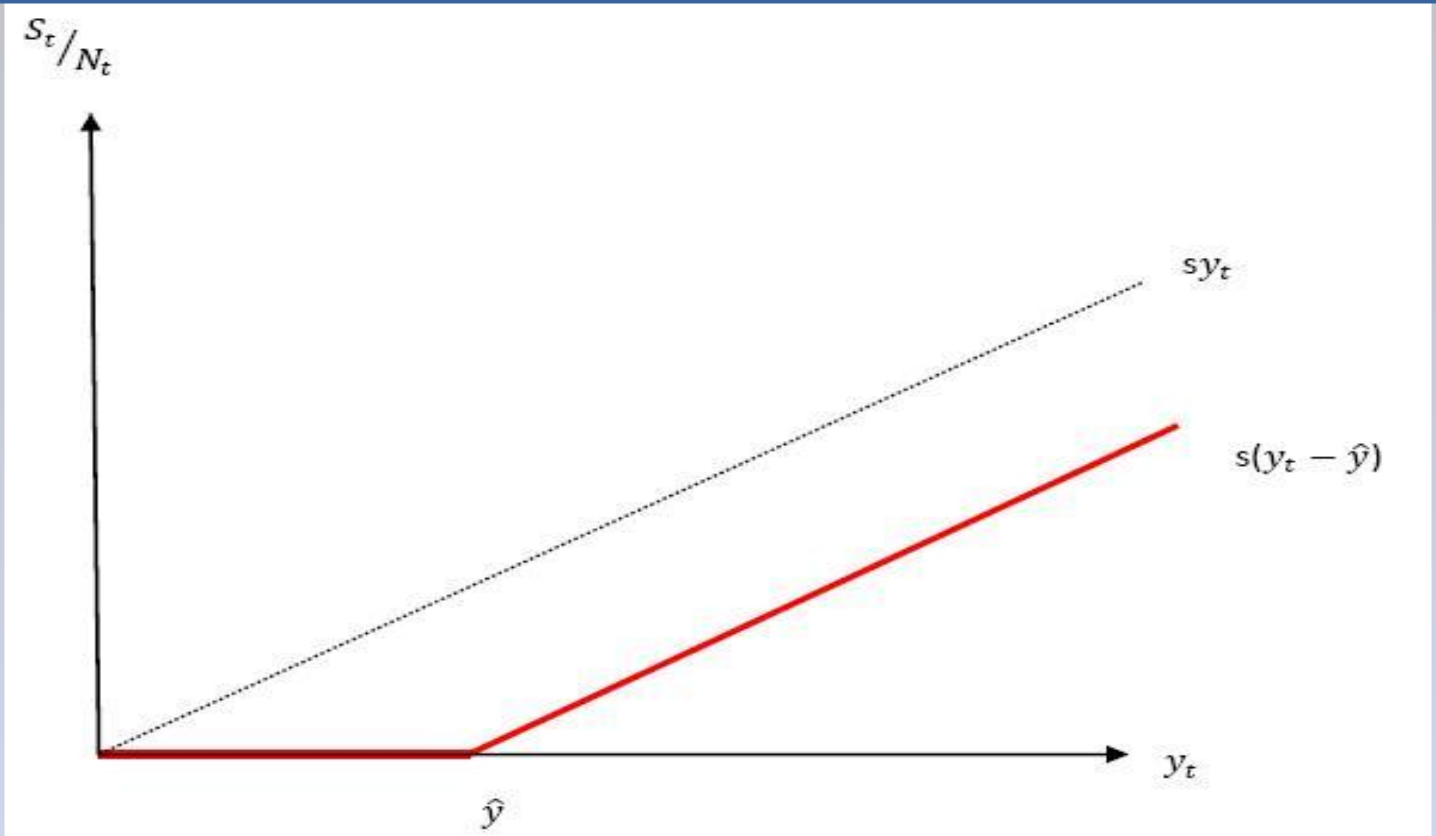
$$S_t = 0 \text{ if } y_t \leq \hat{y}$$

$$S_t = s(y_t - \hat{y})N_t \text{ if } y_t > \hat{y}$$

Saving is a constant fraction of

<u>non-subsistence income, not of total income</u>

Economic Growth

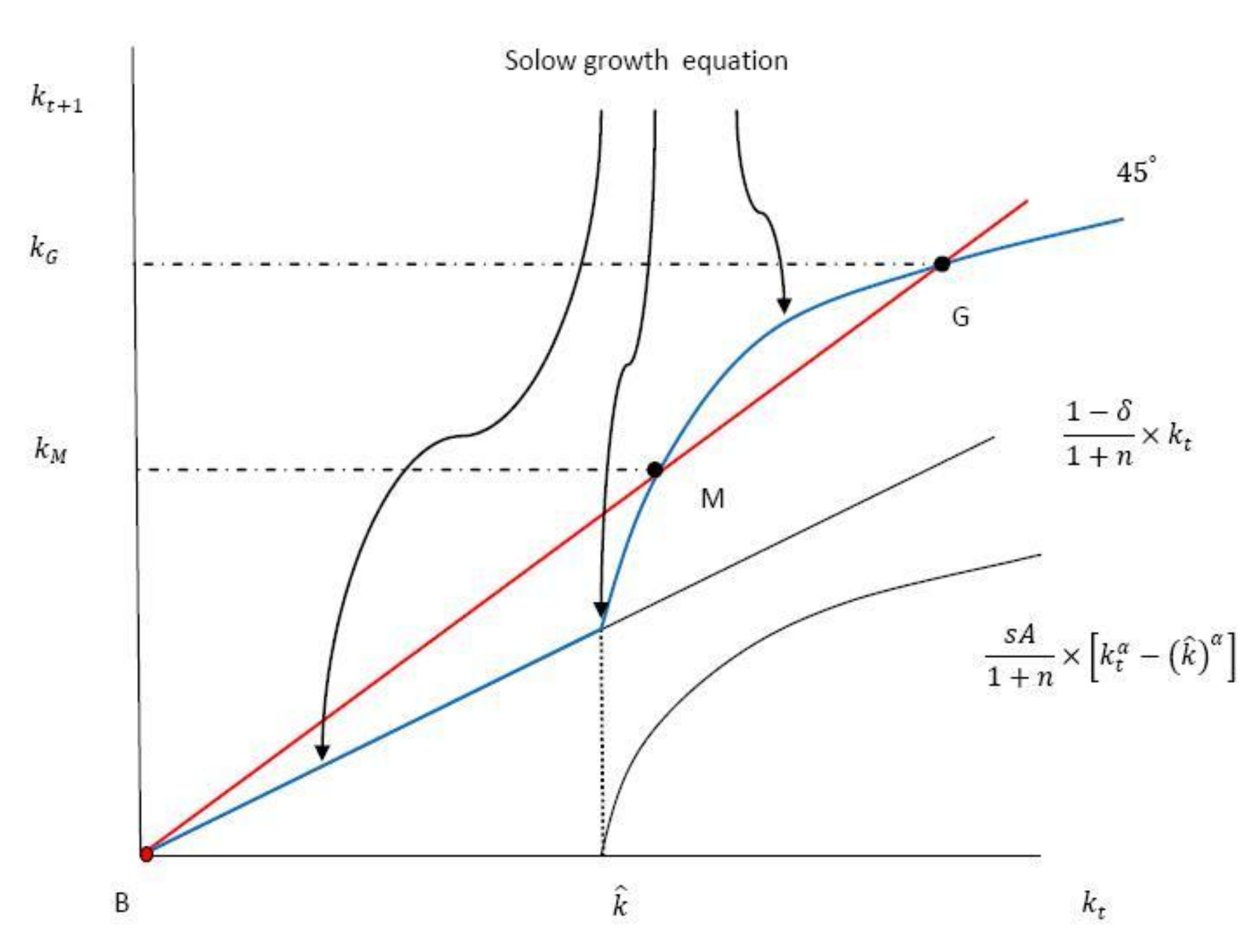


The Solow model with subsistence consumption

$$k_{t+1} = \frac{1-\delta}{1+n} k_t \quad if\ k_t < \hat{k}$$

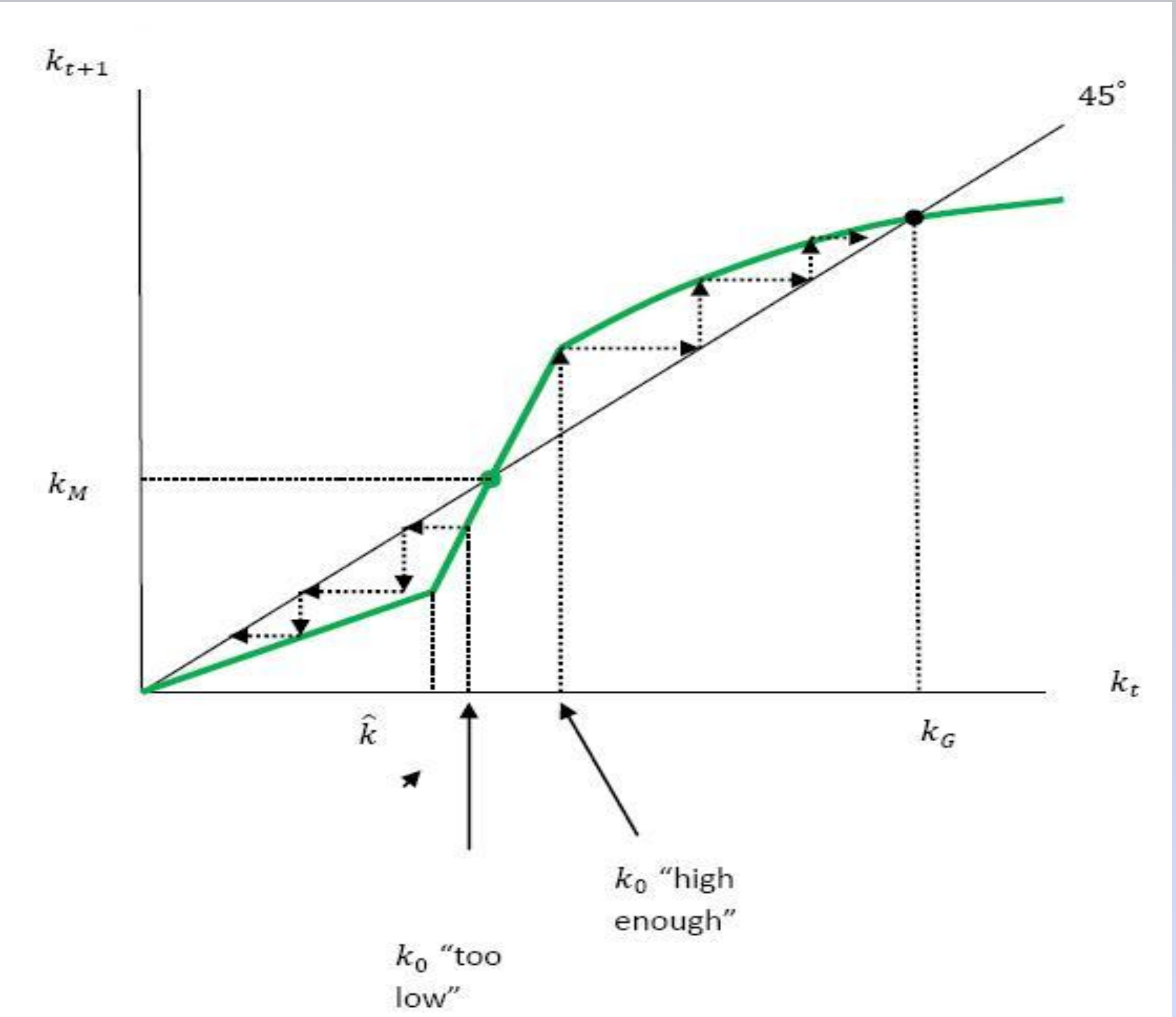
$$k_{t+1} = \frac{1-\delta}{1+n} k_t + \frac{sA\left[k_t^{\alpha} - \hat{k}^{\alpha}\right]}{1+n} \quad if\ k_t > \hat{k}$$

Economic Growth



Three steady states: k_G (good) @ G; k_M (middle)@ M; 0(bad)@ B.

Economic Growth



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Disaster: $k_O < k_M$: too low because saving not enough to pay for depreciation and population growth. Per capita (k,y) go to zero slowly.

Miracle: $k_O > k_M$: high enough initial capital.

Enough saving to replace depreciation, provide for pop. growth and leave a surplus to raise per capita K.

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e)<u>Policies that Make Miracles or Produce Disasters</u>

Make a miracle: If $k_O < k_M$, how do we jump the hurdle value k_M ?

Produce a disaster: If $k_O > k_M$, what polices lower K/N below k_M ?

<u>Ideas to Consider</u>

Key: Temporary shocks to the economy may have permanent effects

1)Marshall plan for Europe: a gift of capital

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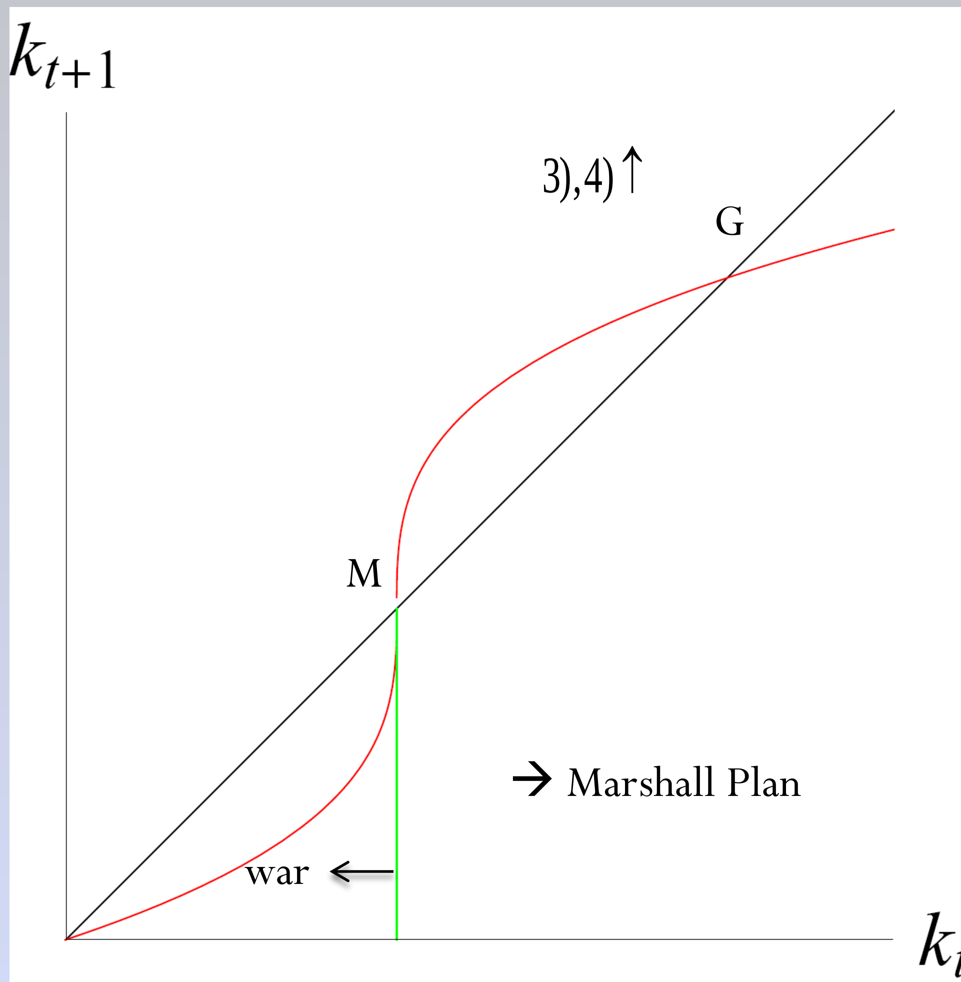
2) Wars in the Horn of Africa (Ethiopia, Somalia) → Capital destroyed



(1, 2) are changes in initial capital, k_o

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3)Temporary restrictions on childbearing (China). Value of n goes down temporarily.

4)Improvements in capital markets and institutions (financial liberalization in Asia, 198O's). Value of A goes up permanently.

3)&4) are shifts in the Solow equation. Both decrease the hurdle value k_M .

5. WHAT THE SOLOW MODEL PREDICTS ABOUT GROWTH

a. Expect growth miracles in countries that
- are not too poor to start with
- follow policies that are not too stupid
- are not too unlucky

b. Expect growth disasters in countries that
- are too poor
- follow bad policies even for a short spell
- are unlucky in peace/war

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c. Growth in living standards is initially rapid, then falls off.

d. In the long run there is no growth in per capita income Predictions a,b,c are factual, d is not. What explains the advancement of living standards in even the richest countries?

6. GROWTH IN THE VERY LONG RUN

a) Why does growth peter out in the Solow model?
-As k up, MPK decreases, rate of return on K decreases, output growth decreases, saving not enough to pay for *d*K plus net investment.

→ Pool of saving cannot keep up with growth in K.
-Even if we can increase K/N, labor supply is limited.
Growth in Y/N requires increases in K/N and L^S /N

Economic Growth

-To grow Y/N forever we need at least one of these things:

1) Profit per unit capital not to fall as we grow (Marx's "falling rate of profit" should not be true)

2) Workers to build up their skill, or human capital, as economy grows

3)Technical progress in ideas, products, methods of production (steam engine, electricity, internet, PDA, solar energy, …)

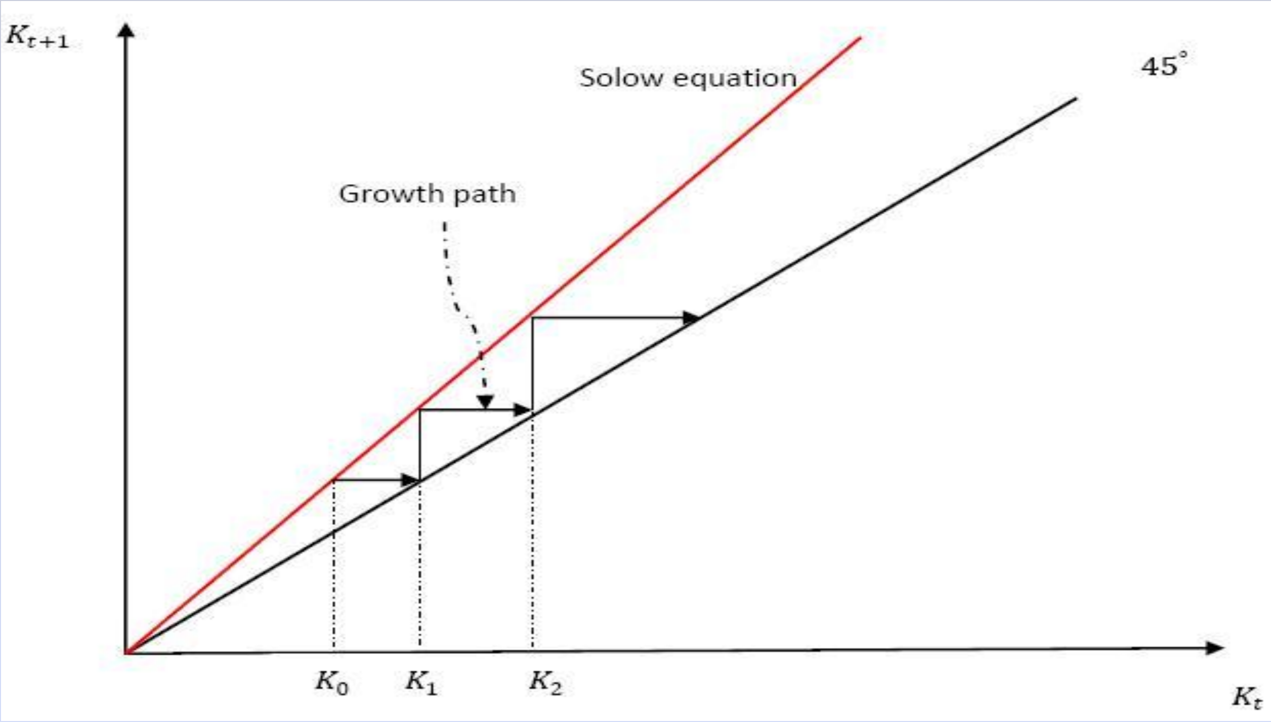
b) An example: The AK model
Solow model w/o labor and with constant MPK=A
Output $Y_t = AK_t$ assumes skills grow as fast as physical capital.

Economic Growth

Solow equation $$K_{t+1} = (1-\delta)K_t + sAK_t \Rightarrow$$

$$\frac{K_{t+1}}{K_t} = \frac{Y_{t+1}}{Y_t} = 1 - \delta + sA$$

Growth rate is constant $g = sA - \delta$



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c) Another example: pure technical progress

Suppose TFP in the Solow model increases at a constant rate, g, i.e.

$$A_{t+1}=(1+g)A_t$$

To keep things simple, set population growth and depreciation to one. Then we have

$$k_{t+1} = sA_t k_t^{\alpha}$$

$$y_t = per-capita\, income = A_t k_t^{\alpha}$$

From these two, we eliminate (k_t,k_{t+1}) and express everything in terms of output. Then,

$$\left(\frac{y_{t+1}}{A_{t+1}}\right)^{\frac{1}{\alpha}} = sy_t$$

or

$$y_{t+1} = A_{t+1}(sy_t)^{\alpha} \qquad (*)$$

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Divide (*) by it's predecessor $y_t = A_t\left(sy_{t-1}\right)^{\alpha}$
To obtain an equation in growth rates

$$\frac{y_{t+1}}{y_t} = \left(\frac{A_{t+1}}{A_t}\right)\left(\frac{y_t}{y_{t-1}}\right)^{\alpha} \qquad (**)$$

let

$$\gamma_{t+1} \equiv \frac{y_{t+1}}{y_t}$$

Then (**) *becomes*

$$\gamma_{t+1} = (1+g)\gamma_t^{\;\alpha}$$

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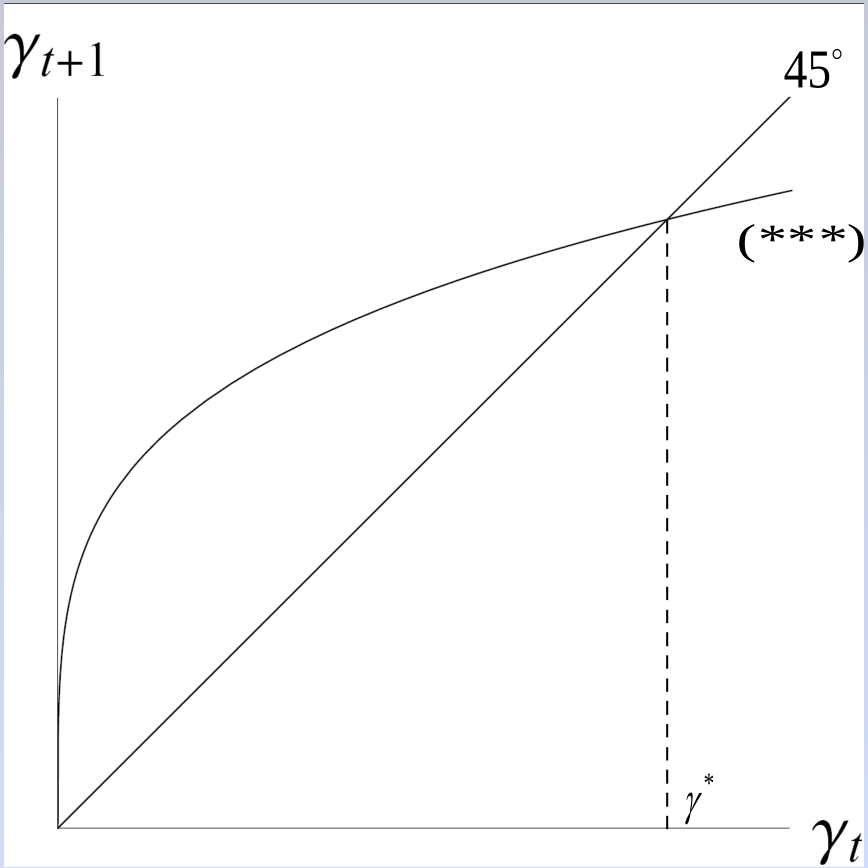
The steady state growth rate is

$$\gamma^* = (1+g)^{\frac{1}{1-\alpha}} \approx 1 + \frac{g}{1-\alpha} \approx \frac{3}{2} g$$

For small values of g.



Thus if g ≈ 1% as in U.S. growth accounting, the Solow model says that *per capita income should increase by 1.5% per year in the steady state*

Q: Actual per-capita income in the U.S. has been increasing on average by 1.9% per year. Where does the difference between 1.9% and 1.5% come from?

Economic Growth

Q: How does human capital grow?

Investing in education and skills
Investing in health:
- longevity boosts saving;
- contagious diseases reduce labor supply