ECON 310 - MACROECONOMIC THEORY

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Disclaimer

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This version compiled October 19, 2016.

Chapter 7: Economic Growth (Exogenous)

The consequences for human welfare [growth] are simply staggering. Once one starts thinking about them, it is hard to think of anything else.

-Robert E. Lucas Jr.
1995 Bank of Sweden Prize for Economic Sciences

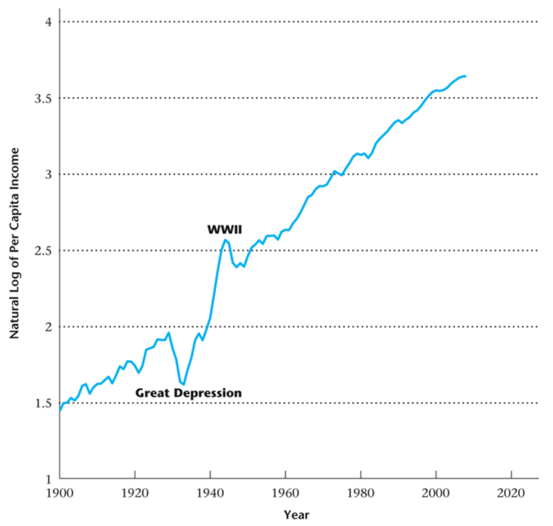
Topics

- Look at some facts on economic growth
- Build some models
- Exogenous Growth (Malthus and Solow)
- Endogenous Growth
- Check what our models have to say

Some Notes

- Lucas potential social gains from understanding business cycles $<$ growth
- Avoid 5% reduction (temporary) due to business cycle
- Affect growth rate by 1% in 100 years GDP will be 2.7 more
- ... that is 270%!

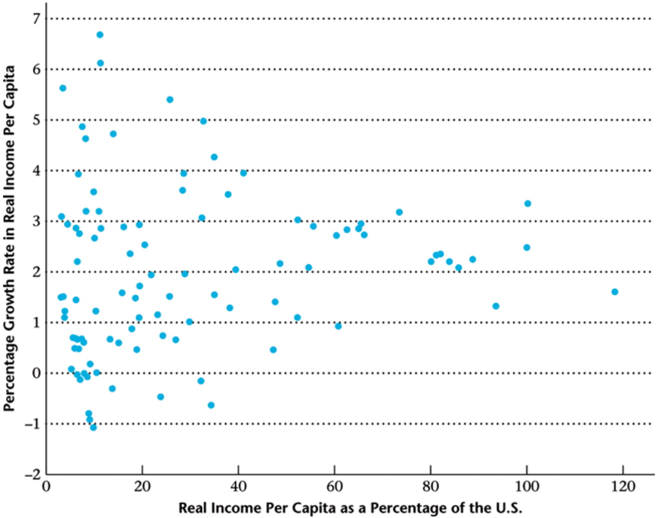
Figure 1: Natural Logarithm of Per Capita Real GDP



Growth Facts across Countries

- Note: Except for the Great Depression and World War II, growth in U.S. per capita real income has not strayed far from 2% per year since 1900.
- Before Industrial Revolution (1800) standards of living differed little over time and across countries
- Since IR per capita income growth has been sustained by the richest countries (US 2% since 1869)
- $\rho(\text{investment, output/worker}) > 0$
- $\rho(\text{population growth rate, output/worker}) < 0$
- $\rho(Y/N_{1960}, E[\Delta Y/N]_{1960-1995}) \approx 0$
- $\rho(Y/N_{1960}, E[\Delta Y/N]_{1960-1995}|poor) \approx 0$
- Differences in per capita income increased between 1800-1950 (Industrialized vs non-industrialized)

Figure 2: Growth rate of output per worker vs. US



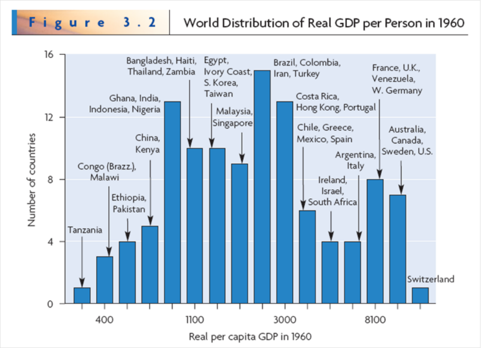


Figure 3.2
World Distribution of Real GDP per Person in 1960
Number of countries
Real per capita GDP in 1960
Tanzania
Congo (Brazz.), Malawi
Ethiopia, Pakistan
China, Kenya
Ghana, India, Indonesia, Nigeria
Bangladesh, Haiti, Thailand, Zambia
Egypt, Ivory Coast, S. Korea, Taiwan
Malaysia, Singapore
Brazil, Colombia, Iran, Turkey
Costa Rica, Hong Kong, Portugal
Chile, Greece, Mexico, Spain
Ireland, Israel, South Africa
Argentina, Italy
France, U.K., Venezuela, W. Germany
Australia, Canada, Sweden, U.S.
Switzerland

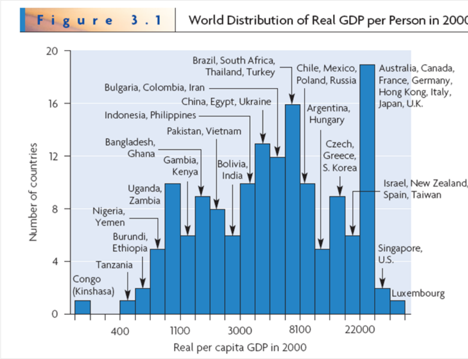


Figure 3.1
World Distribution of Real GDP per Person in 2000
Number of countries
Real per capita GDP in 2000
Congo (Kinshasa)
Tanzania
Burundi, Ethiopia
Nigeria, Yemen
Uganda, Zambia
Bangladesh, Ghana
Gambia, Kenya
Pakistan, Vietnam
Indonesia, Philippines
Bolivia, India
China, Egypt, Ukraine
Bulgaria, Colombia, Iran
Brazil, South Africa, Thailand, Turkey
Chile, Mexico, Poland, Russia
Argentina, Hungary
Czech, Greece, S. Korea
Israel, New Zealand, Spain, Taiwan
Australia, Canada, France, Germany, Hong Kong, Italy, Japan, U.K.
Singapore, U.S.
Luxembourg

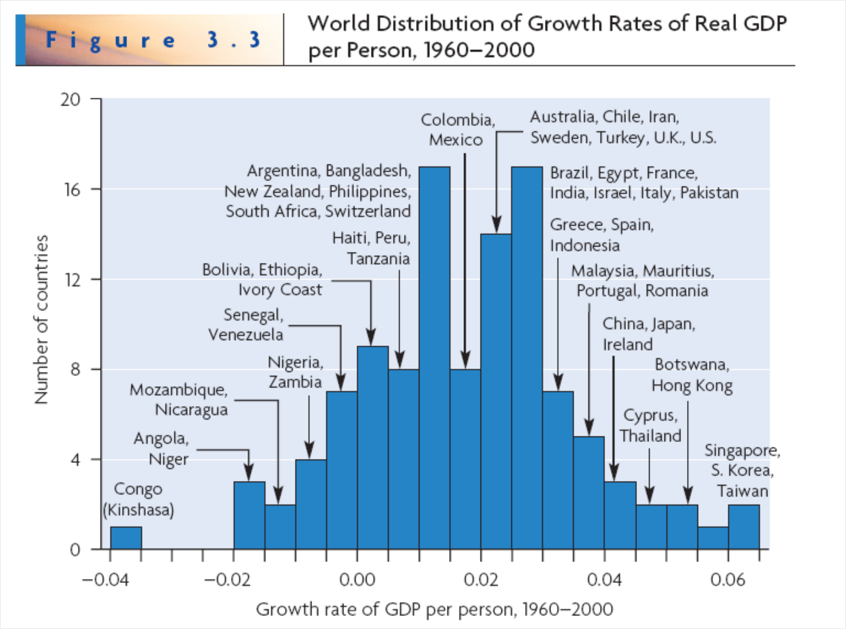


Figure 3.3
World Distribution of Growth Rates of Real GDP per Person, 1960–2000
20
16
12
8
4
0
Number of countries
Congo (Kinshasa)
Angola, Niger
Mozambique, Nicaragua
Nigeria, Zambia
Senegal, Venezuela
Bolivia, Ethiopia, Ivory Coast
Haiti, Peru, Tanzania
Argentina, Bangladesh, New Zealand, Philippines, South Africa, Switzerland
Colombia, Mexico
Australia, Chile, Iran, Sweden, Turkey, U.K., U.S.
Brazil, Egypt, France, India, Israel, Italy, Pakistan
Greece, Spain, Indonesia
Malaysia, Mauritius, Portugal, Romania
China, Japan, Ireland
Botswana, Hong Kong
Cyprus, Thailand
Singapore, S. Korea, Taiwan
−0.04
−0.02
0.00
0.02
0.04
0.06
Growth rate of GDP per person, 1960–2000

Figure 3: Output per worker vs. Investment rate

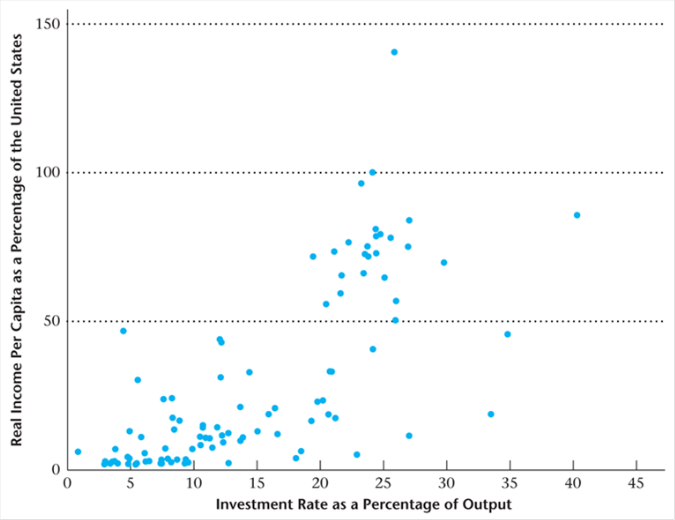
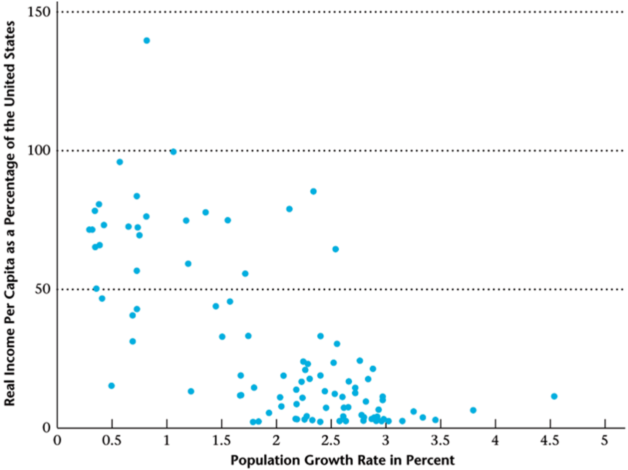


Figure 4: Output per worker vs. Population growth



Source: A. Heston, R. Summers, and B. Aten, *Penn World Table Version 6.1*, Center for International Comparisons at the University of Pennsylvania (CICUP), October 18, 2002, available at pwt.econ.upenn.edu.

Malthusian Model: Dismal Science

- Thomas Malthus: *Essay on the Principle of Population* (1798)
- Model was stated in words but translated into formal model
- Advance in food technology would increase population growth
- With higher pop. growth the average consumption/capita falls
- Population and consumption will grow over time
- No increase in standards of living unless limits to growth
- Pessimistic about $\uparrow$ Std of living without intervention

Reverend Thomas R. Malthus (1766-1834)

Utility of Malthusian Model

- For 1798 good approximation, before Industrial Revolution
- Fact was that standards of living were stagnant
- Mostly agricultural production, population grew but so did production
- Malthus too pessimistic
  - After 1800 sustained growth in some countries esp. w/o population control
  - drop in birth rates (endogenous) (causation)
  - increase in life expectancy - population is falling even w/ immigration
- Why was Malthus wrong?
  - Increase in K (K is reproducible)
  - higher standard of living $\downarrow$ mortality but $\downarrow$ birth rates

    Better opportunities (women enter labor force)

    Large families (opportunity costs of raising large family is large since wages increase)x

Solow Model

- simple model makes sharp predictions
- savings rate and population growth rate drives model
- optimistic than Malthus
- sustained increase in standard living can occur w/ $\uparrow$ in technology
- build an aggregate model:
  - consumers
  - production
  - competitive equilibrium
  - dynamic model but look at SS

Robert Solow

Consumer Behavior

- We'll simplify the problem:
- Workers work full time, i.e. inelastic supply of labor
- Proportion of income saved and consumed is exogenous and constant
- Population grows at rate n: $N' = (1 + n)N$
- N is population and labor force since everyone supplies 1 unit
- $n > -1$ possibility of $n < 0$ shrinking population
- Consumer behavior: Consume (C) or Save (S) ergo $C + S = Y$
- Constant savings rate (s) so that $S = sY$
- Consumption is $C = (1 - s)Y$
- For now s is exogenous discuss how it can be endogenized later...

Representative Firm

- Production function: $y = zF(k, 1) = zf(k)$
- lower case $y = Y/N$ output per worker, $k = K/N$ capital per worker (See Fig 6.14)

Investment and Depreciation

- Assume capital depreciates at constant rate d.
- $K' = (1 - d)K + I$

Figure 5: Per-worker production function

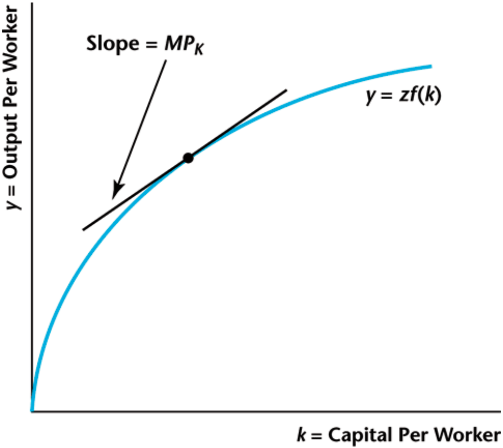


Figure 6: SS Quantity of K/N

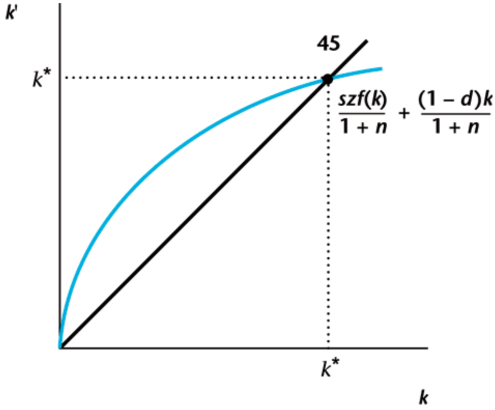


Figure 7: SS K/N

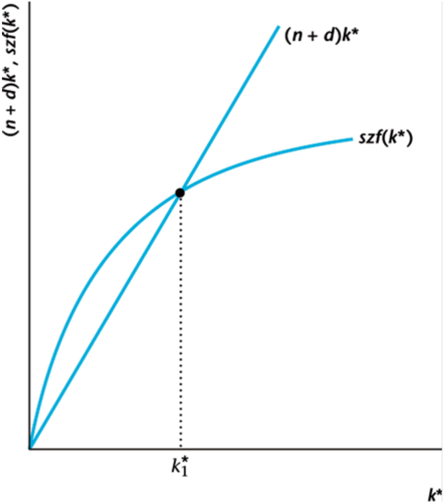


Figure 8: Increase in savings rate

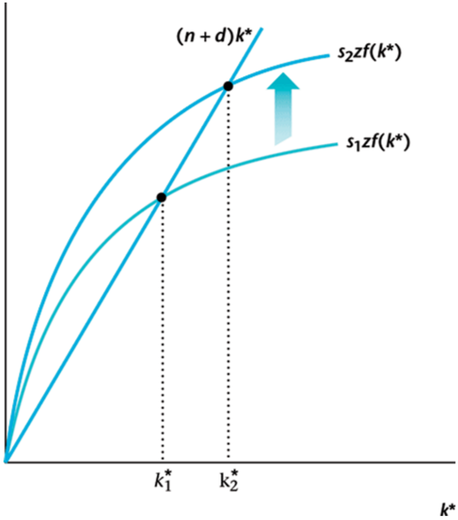


Figure 9: Transitional dynamics

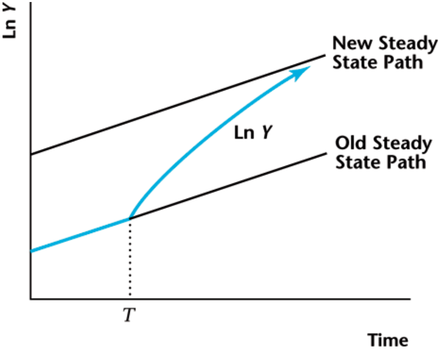
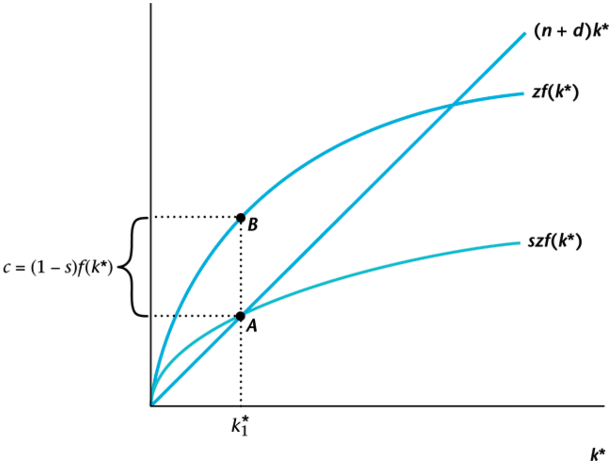


Figure 10: Steady State C/N



Golden Rule

- The level of k* that maximizes steady state consumption is called the Golden Rule steady state capital per worker
- At this magical level, the slope of the production function is equal to the slope of the $(n+d)k$ line.

$$\begin{aligned} \frac{\partial c*}{\partial k} &= zf'(k*) - (n+d) = 0 \\ zf'(k*) &= n+d \end{aligned}$$

- Therefore, at the golden rule $MP_K = (n+d)$
- This optimal k is known as golden rule (See Fig. 7.33)
- Golden rule savings rate s_{gr} coincides where $k*_{max} = k_{gr}$
- Biblical interpretation treat everyone the same
- c* remains same across periods

Figure 11: Golden Rule K/N

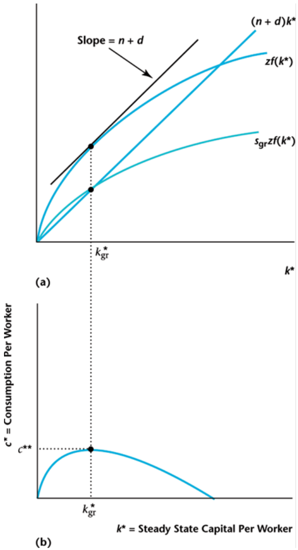


Figure 12: Steady State Increase in Labor Force Growth

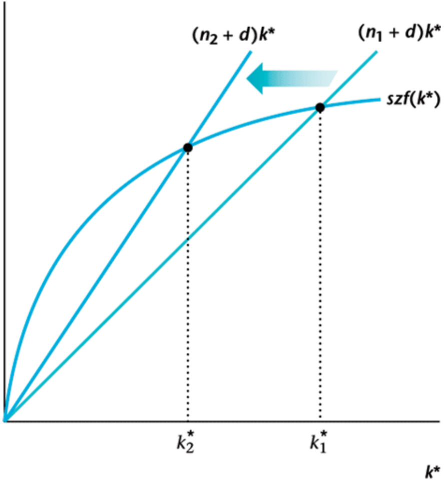


Figure 13: Output per worker vs. Investment rate

$\rho(\text{investment, output/worker}) > 0$

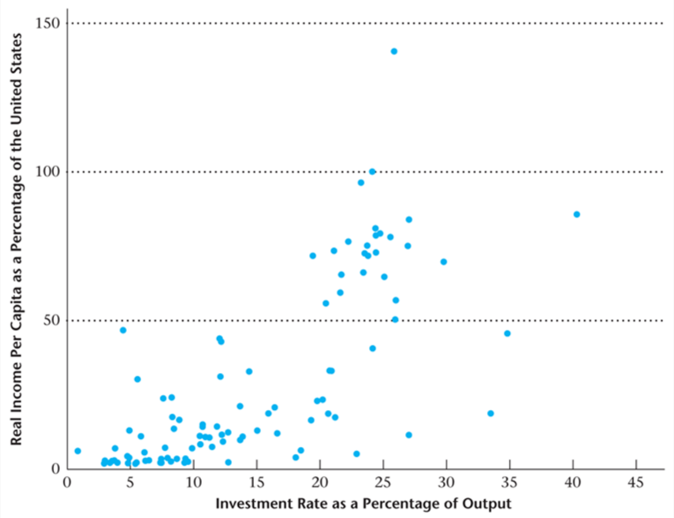
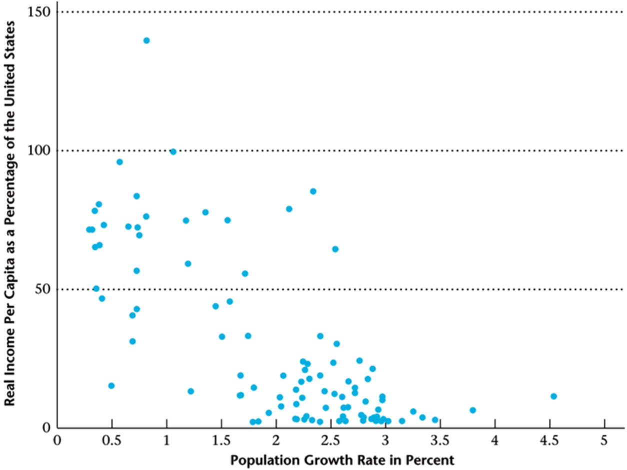


Figure 14: Output per worker vs. Population growth

ρ(population growth rate, output/worker) < 0

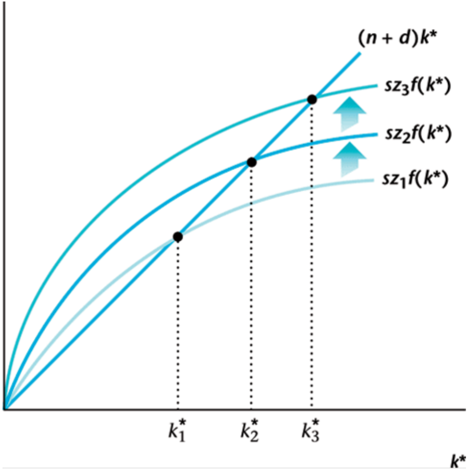


Source: A. Heston, R. Summers, and B. Aten, *Penn World Table Version 6.1*, Center for International Comparisons at the University of Pennsylvania (CICUP), October 18, 2002, available at pwt.econ.upenn.edu.

Increase in TFP

- savings is bounded from $0 < s < 1$
- Increase in z from z_1 to z_2
- Causes increase in k from k_1^* to k_2^* (Fig. 7.22)
- savings is one-time shot but TFP can lead to unbounded growth
- Malthus told TFP no long run effects
- Hopefully as long as TFP increases

Figure 15: ↑ in z in Solow Model



Solow Residual

- Production function specification - Cobb-Douglas

$$Y = zK^{\alpha}N^{1-\alpha}, 0 < \alpha < 1$$

- CRS - homogeneity properties
- capital receives α share of Y and labor $1-\alpha$ [US post-WWII $\alpha = 0.34$]

$$\begin{aligned} z &= \frac{Y}{K^{\alpha}N^{1-\alpha}} \\ \textit{or} & \\ \log z &= \log Y - \alpha \log K - (1-\alpha)\log N. \end{aligned}$$

- f(inventions, weather, mgmt techniques, G regulations, price of energy, etc)

Figure 16: Solow Residual 1948-2001

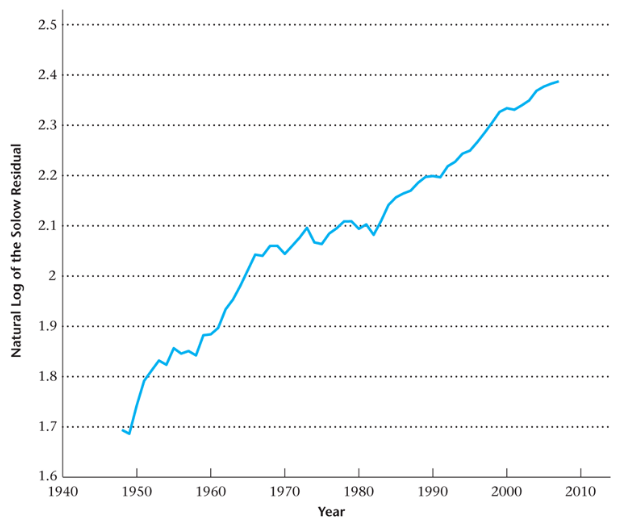


Figure 17: GDP deviations and Solow Residual

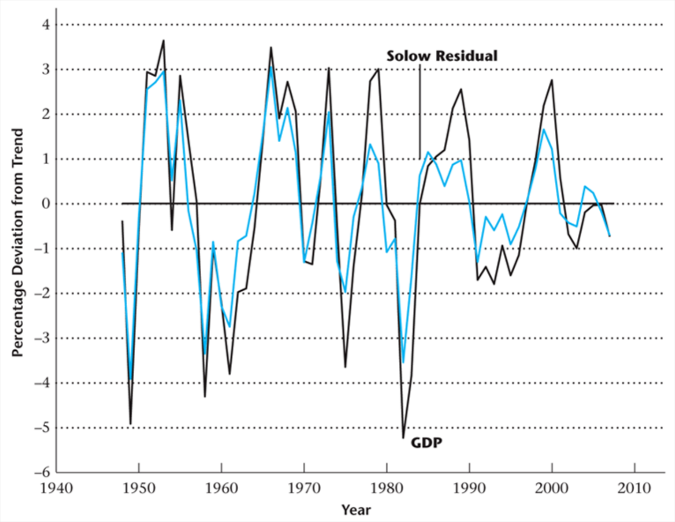


Table 6.1 Average Annual Growth Rates in the Solow Residual

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Years	Average Annual Growth Rate
1950–1960	1.42
1960–1970	1.61
1970–1980	0.50
1980–1990	1.05
1990–2000	1.36
2000–2007	0.76

Table 6.2 Measured GDP, Capital Stock, Employment, and Solow Residual

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Year	$\hat{Y}$ (billions of 2000 dollars)	$\hat{K}$ (billions of 2000 dollars)	$\hat{N}$ (millions)	$\hat{z}$
1950	1777.3	5991.8	58.89	5.715
1960	2501.8	8602.1	65.78	6.580
1970	3771.9	12557.1	78.69	7.721
1980	5161.7	17273.8	99.30	8.115
1990	7112.5	22877.9	118.80	9.011
2000	9817.0	29917.1	136.90	10.312
2007	11523.9	35910.4	146.05	10.875

Table 6.3 Average Annual Growth Rates

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Years	$\hat{Y}$	$\hat{K}$	$\hat{N}$	$\hat{z}$
1950–1960	3.48	3.68	1.11	1.42
1960–1970	4.19	3.86	1.80	1.61
1970–1980	3.19	3.24	2.36	0.50
1980–1990	3.26	2.85	1.81	1.05
1990–2000	3.28	2.72	1.43	1.36
2000–2007	2.32	2.64	0.93	0.76

Table 6.4 East Asian Growth Miracles

	Output	Capital	Labor	Total Factor Productivity
Hong Kong (1966–1991)	7.3%	7.7%	2.6%	2.3%
Singapore (1966–1990)	8.7%	10.8%	4.5%	0.2%
South Korea (1966–1990)	10.3%	12.9%	5.4%	1.7%
Taiwan (1966–1990)	9.4%	11.8%	4.6%	2.6%
United States (1966–1990)	3.0%	3.2%	2.0%	0.6%