Macroeconomics

Growth: Facts in the Long Run

Guess which country?

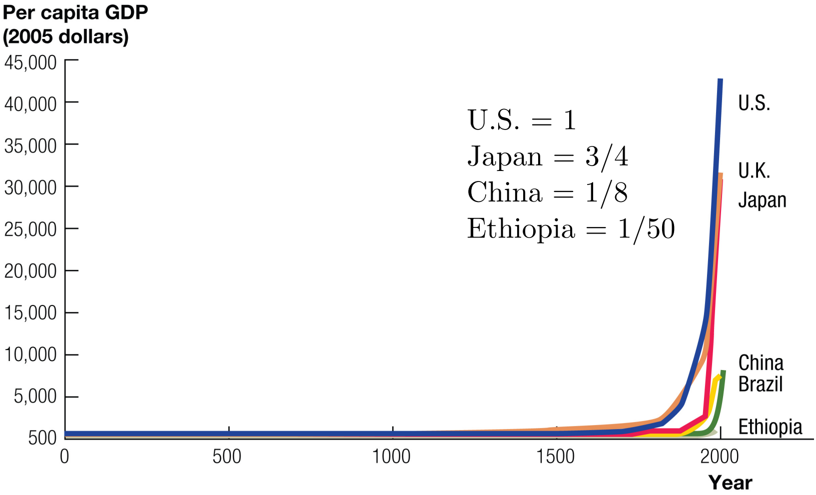
- Life expectancy is less than 50 years
- 1 out every 10 infants dies before the age of one
- More than 90% of households have no electricity, refrigerator, telephone, or car
- Fewer than 10% of adults have completed high school.

- Answer : Kenya or United States around 1890!

The Power of Economic Growth

- In just a century, the U.S. economy has been completely transformed
  - Almost all households have electricity, refrigerators, cellphones, and cars
  - Overwhelming majority graduates from high school, many college
  - New goods: air-conditioning, dishwashers, jet planes, skyscrapers, home movie theaters, iPads
- Health: Life expectancy in 1900 = 50 years, today 78 years
  - The richest man in the world in the mid 1800s – the great European financier Nathan Rothschild – died from an infection that $10 of antibiotics would cure today.
- A typical college student today will earn a lifetime income about twice his or her parents.

GDP per capita



U.S. = 1
Japan = 3/4
China = 1/8
Ethiopia = 1/50

Source: Jones (2002)

Growth over the very long run

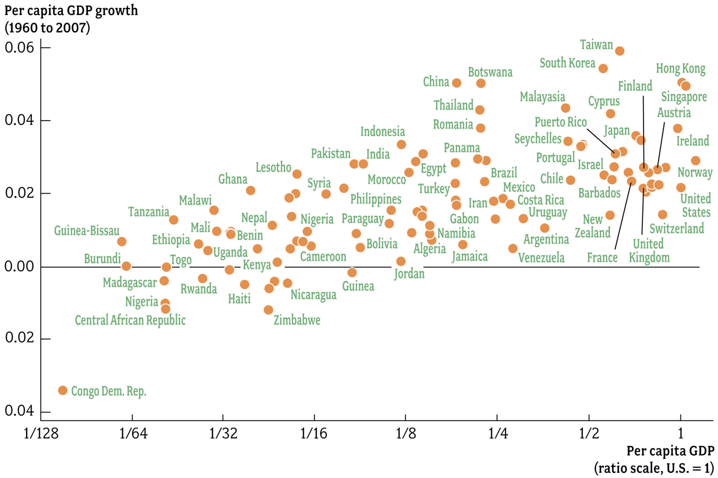
- Sustained increases in standards of living are a recent phenomenon.
- It emerges in different places at different times.
  - Thus, per capita GDP differs remarkably around the world.
  - A video: http://tinyurl.com/3y3tpn6
- The Great Divergence: The recent era of increased difference in standards of living across countries.
- Before 1700: Per capita GDP in nations differed only by a factor of two or three.
- Today: Per capita GDP differs by a factor of 50 for several countries.

Growth: Facts from the Long-Run
Why do we care About Growth? About RGDP Growth?

A Broad Sample of Countries

- Over the period 1960 - 2007
  - Some countries have exhibited a negative growth rate.
  - Other countries have sustained nearly 6 percent growth.
  - Most countries have sustained about 2 percent growth.
- Small differences in growth rates result in large differences in standards of living.

How Did We Get Here: Variation in Current Real GDP



Source: Jones (2002)

The Power of Growth

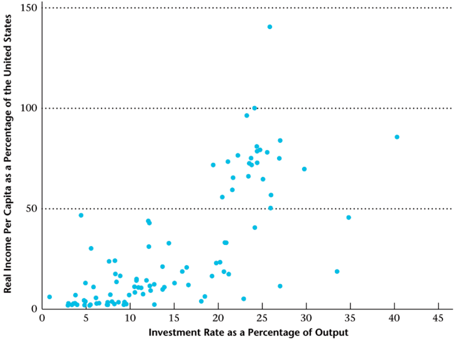
- South Korea: Sustained growth of 6% since 1960
  - Doubles every 12 years
  - In 50 years – about two generations – doubles 4 times $\Rightarrow 2^4 = 16$ times richer than grandparents!!
- Contrast with Venezuela or Nigeria
  - Negative growth for 40 years
  - Grandchildren are poorer than grandparents

Growth is like compound interest: small differences in growth rates compound over time to generate enormous differences in incomes

Growth: Facts from the Long-Run Determinants of Growth in the Data

What Determines Growth?

We need a model, but what matters? what should we model?



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.

Investment is positively correlated with GDP levels.

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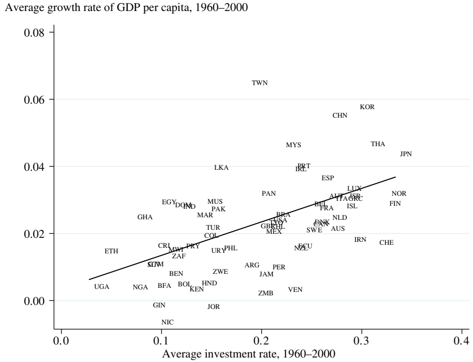
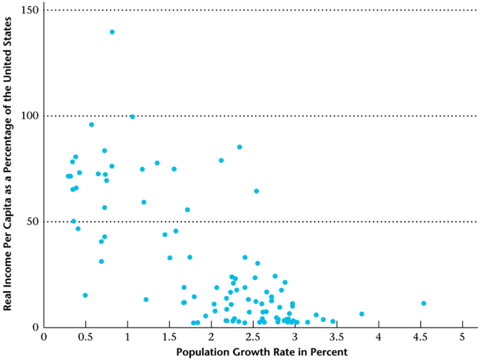


FIGURE 1.15 The relationship between average growth of GDP per capita and average growth of investments to GDP ratio, 1960–2000.

Investment is correlated with GDP growth (Source: Acemoglu (2008))

What Determines Growth?

Great resource for data is: pwt.econ.upenn.edu



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.

Population growth is negatively correlated with GDP levels.

What Determines Growth?

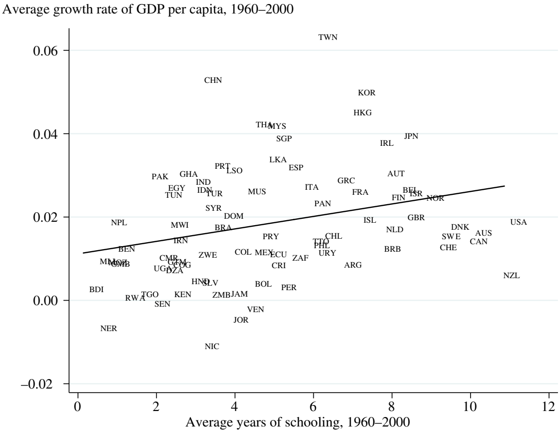
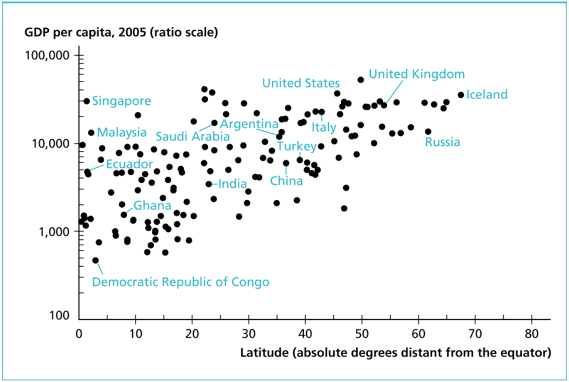


FIGURE 1.16 The relationship between average growth of GDP per capita and average years of schooling, 1960–2000.

Schooling levels are positively correlated with GDP growth rates.

What Determines Growth?

This is why we need a model!!!



Sources: Heston, Summers, and Aten (2006); World Bank (2007a).

Latitude is positively correlated with GDP levels and growth rates!

Growth Accounting

Growth Accounting

- Output produced with aggregate production function

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

- How much have changes in each of A_t, K_t, and N_t contributed to output growth?

- Output growth varies
  - across countries
  - within countries over time

- This can provide clues about where to look for causes

Constant Returns to Scale

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

Assumption: F has constant returns to scale in capital and labor

- double capital *and* labor

$\Rightarrow$ double Y

- Formally, this means:

$$\text{for any } x,\ F(xK, xN) = xF(K, N)$$

A_t is total factor productivity:

- double A_t

$\Rightarrow$ with same inputs (K, L), produce twice as much output

What Accounts for Output Growth?

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

- The above equation, if log-differentiate implies:

$$\underbrace{\frac{\Delta Y_t}{Y_t}}_{\substack{\text{output} \\ \text{growth}}} = \underbrace{\frac{\Delta A_t}{A_t}}_{\substack{\text{contribution of} \\ \text{tech. progress}}} + \underbrace{\alpha_{Kt}\frac{\Delta K_t}{K_t}}_{\substack{\text{contribution of} \\ \text{capital accumulation}}} + \underbrace{\alpha_{Nt}\frac{\Delta N_t}{N_t}}_{\substack{\text{contribution of} \\ \text{labor growth}}}$$

where

- α_{Kt} is capital's share of income
- α_{Nt} is labor's share of income

Contributions to US Output Growth (% annual)

Source	1929-48	1948-73	1973-82	1982-2008
labor	1.42	1.40	1.13	0.89
capital	0.11	0.77	0.69	0.84
productivity	1.01	1.53	-0.27	1.01
total	2.54	3.70	1.55	2.76

Contributions change over time

- 30s-40s: low growth in capital
- 50s-60s: high productivity growth, high output growth
- 70s: productivity slowdown, low output growth
- 80s-90s-00s: productivity rebound, slower labor growth

Standards of Living

- We just looked at contributions to change in output growth
- What about standards of living?
  - Better measured by output per worker
- What accounts for changes in output per worker?

Standards of Living

From above, we have

$$\frac{\Delta Y_t}{Y_t} = \frac{\Delta A_t}{A_t} + \alpha_{Kt}\frac{\Delta K_t}{K_t} + \alpha_{Nt}\frac{\Delta N_t}{N_t}$$

Growth in output/worker is

$$\underbrace{\frac{\Delta Y}{Y} - \frac{\Delta N}{N}}_{\text{growth in } Y/N} = \underbrace{\frac{\Delta A}{A}}_{\substack{\text{technological}\\ \text{progress}}} + \underbrace{\alpha_{Kt}\left(\frac{\Delta K}{K} - \frac{\Delta N}{N}\right)}_{\substack{\text{capital deepening}\\ \text{growth in } K/N}}$$

Two ways to raise standards of living

1. Increase Total Factor Productivity
2. Increase capital per worker

The Solow Growth model

The Solow model

- Due to Robert Solow, who won Nobel Prize for contributions to the study of economic growth
- A major paradigm:
  - widely used in policy making
  - benchmark against which most recent growth theories are compared
- What are the determinants of economic growth and the standard of living in the long run?

Questions

- Why do economies grow?
- Why do growth rates differ across countries?
- Why do growth rates differ over time within a country?
- How much can an economy grow by accumulating capital?

Key Ingredients

Households

- Consume, save, supply labor
- Population grows over time at rate n

$$N_{t+1} = (1+n)N_t$$

Firms

- Produce with capital and labor, constant returns to scale

$$Y_t = AF(K_t, N_t)$$

- Accumulate Capital

$$K_{t+1} = (1-d)K_t + I_t$$

Households

Simplifying Assumptions:

1. Households live forever
2. Each household supplies a fixed amount of labor
3. "Rule of Thumb" savings
   - Budget constraint:

$$C_t + \underbrace{S_t}_{\text{Savings}} = \underbrace{Y_t}_{\text{Income}}$$

   - Households save a constant fraction s of their income

$$S_t = sY_t \qquad \text{or} \qquad C_t = (1-s)Y_t$$

Rule of Thumb Savings

$$S_t = sY_t$$

- **Note 1**: s is the savings *rate*
  - In previous lectures we sometimes used s to denote optimal quantity of national savings. Here it is the *fraction* of income that is saved.
- **Note 2**: This is a behavioral rule
  - May not be optimal
  - We are asking: if households behave this way, what will happen?

What is different from what we did so far?

In previous lectures, we studied

- Tradeoff between leisure and consumption
  - One period Model
- Tradeoff between present output and future output
  - Two period model

Economic Growth:

- What determines standards of living in the long run?
  - Infinite period model (Sometimes called "infinite horizon")
  - Focus on how the economy changes over time

Production

- Aggregate production function *in each period*:

$$Y_t = AF(K_t, N_t)$$

  - Assume constant returns to scale

- Capital Accumulation

$$K_{t+1} = (1-d)K_t + I_t$$

  - I_t is investment, d is the depreciation rate

- Population/Work force grows exogenously at rate n

$$N_{t+1} = (1+n)N_t$$

Our Goal

- Given exogenous parameters: $\{d, s, n, A\}$
  - depreciation rate, savings rate, population growth rate, TFP
- Study endogenous variables of interest:

$$\{C, S, Y, I, K\}$$

  - What happens in short run?
  - What happens in the long run?
- Ultimately interested in what factors affect growth and standards of living