ECON 206
MACROECONOMIC ANALYSIS

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Chapter # 3

A sketch of the U.S. around 1900

- Life expectancy at birth, the average length of life starting from birth, was about 50 [today: 77]
- One out of every 10 infants died before his or her first birthday [today: 7 out of every 1,000]
- 90 percent of households did not have electricity, refrigerator, telephone, or a car [today most do]
- Fewer than 10 percent of adults had graduated from high school [today: 85 percent]

An Overview of Long-Run Economic Growth

(Chapter 3)

A sobering comparison

	USA 1900	USA today	Kenya today
Life expectancy at birth	50	77	50
Infant mortality	0.1	0.007	0.06
Real GDP per capita (1990 $)	$4,100	$28,000	$1,000

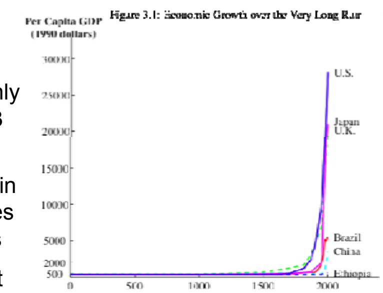
Our objectives today

- Cover the key facts about economic growth that we wish to understand later with models
- Examine the global extent of economic growth
- Understand how growth is a *recent* phenomenon
- Learn some tools: calculating growth rates and using ratio scales
- Talk a little about the *costs* of economic growth

If growth has been uneven across geographic boundaries, what about across **time**?

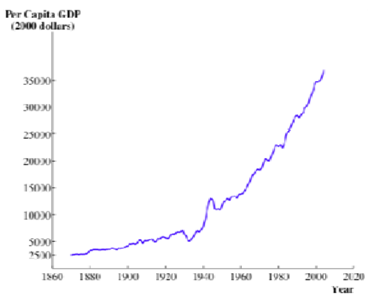
- Growth is a relatively recent phenomenon, only in the past 2 or 3 centuries
- Growth arrived in different countries at different times
- Today, a “Great Divergence”

Figure 3.1: Economic Growth over the Very Long Run



Note: Data from Angus Maddison, *The World Economy: Historical Statistics* (Paris: OECD Development Center, 2003).

Figure 3.2: Per Capita GDP in the United States



Note: Data from 1870 to 1928 from Maddison, cited in Figure 3.1. Data from 1929 to 2004 from the Bureau of Economic Analysis.

- Since 1870, GDP per person in the U.S. has risen 15-fold: from about $2,500 to about $37,000
- Another way to think about this is to compare **your** lifetime income with your parents'
- You'll be about **twice** as rich, because incomes have been doubling every 30 years, or roughly once every generation

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With a constant growth rate *n*, population after one year is $L_1 = L_0(1+\bar{n})$.

After two years, it is $L_2 = L_1(1+\bar{n})$.

Combining these, we find that

$$L_2 = L_0(1+\bar{n})(1+\bar{n}) = L_0(1+\bar{n})^2.$$

So for some year *t*, $L_t = L_0(1+n)^t$.

When L_0 = 6 billion and n = 0.02, L_{100} = 43.5 billion

The math of growth

- In Figure 3.2, GDP per capita is increasing by an *increasing* amount
- The increases are roughly proportional to the level at any point, say by some proportion *g*

$$y_{2005} - y_{2004} = \bar{g} \times y_{2004}$$

$$\frac{y_{2005} - y_{2004}}{y_{2004}} = \bar{g}.$$

- The left-hand side of the second equation, *g*, is the percentage change in GDP per capita, the *growth rate*. A little more math shows us:

$$y_{t+1} = y_t(1+g).$$

Simplifying: The Rule of 70

- The growth rate equation isn't very user-friendly
- For example: compound 3% interest over 10 years = $(1.03)^{10} \approx 1.34$, not 1.30
- Can we find a simple relationship about constant growth?
- "Time it takes to **double**" is cleaner

$$y_t = 2y_0 = y_0(1+\bar{g})^t$$

$$\Longrightarrow 2 = (1+\bar{g})^t.$$

So then: $t = 0.7/\bar{g}$.

In words: if growth is 2 percent, it takes **70**÷2=35 years to double

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- With a constant *growth rate*, level increases are larger and larger over time
- Calculating levels using growth rates over a period of time is mathematically a little complicated
- Example: With 6 billion people in the world today and a constant annual growth rate of 2%, how large will world population be in 100 years?
- Hint: It's **not**
  - 6 billion + 2% x 6 billion x 100 years
  - (which equals 6 + 12 billion extra)

Some observations

- Small differences in growth rates ultimately produce big differences in levels!
  - At 1% growth, income takes about 70 years to double
  - At 5% growth, it takes only 14 years!!
  - Doubling time depends only on the growth rate, and *not* on the level
- If growth rates are so important, is there an easier way to see them?

Plotting on a ratio scale

(a.k.a. log scale)

- If the y-axis is scaled in terms of ratios or multiples of an amount rather than its levels,
- Then a series growing at a constant rate appears as a straight line on a ratio scale

We will also need to compute annual growth rates — but how?

- Rule of 70: if something is doubling every *t* years, you know that the growth rate is 70 ÷ *t*
  - (With GDP, it's 70÷35 years = 2%)
- Using the raw data: be a little careful!

$$y_t = y_0(1+\bar{g})^t \longrightarrow \boxed{\bar{g} = \left(\frac{y_t}{y_0}\right)^{1/t} - 1}$$

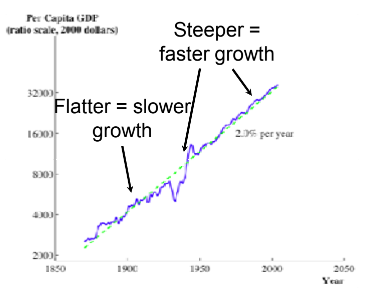
- You have to use a calculator or spreadsheet for this
- Note: this will give you 0.02 for 2% growth

On a ratio scale, equal spacings are constant ratios (here, 2:1 or doubling)

GDP per person has grown at a fairly constant rate of 2%

The slopes reveal faster or slower growth

Figure 3.5: Per Capita GDP in the United States: Ratio Scale



Note: This is the same data shown in Figure 3.2 but plotted using a *ratio scale*. Notice that the ratios of the equally-spaced labels on the vertical axis are all the same, in this case equal to 2. The dashed line exhibits constant growth at a rate of 2.0 percent per year.

Growth rate notation

- These are all the same:
- The annual growth rate of x
- $(x_{t+1} - x_t) / x_t = x_{t+1}/x_t - 1$, or if the data are spaced further apart in time,
- g_x or g(x) $\quad g_x = \left(\frac{x_t}{x_0}\right)^{1/t} - 1$
- All are numbers like 0.02 (which is 2%) per year

Ratio scales allow us to see and tell stories about shifting growth rates much easier

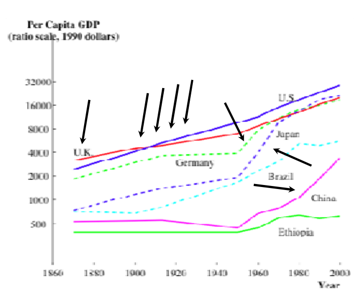
In 1870, the UK was the richest country

But the U.S. grew more rapidly!

Postwar Germany and Japan caught up

China is growing fast!

Figure 3.6. Per Capita GDP since 1870



Note: Data from Angus Maddison, *The World Economy: Historical Statistics* (Paris: OECD Development Center, 2003). Observations are presented every decade after 1950 and less frequently before that as a way of smoothing the series.

Properties of growth rates

1. Ratios become differences:

   If $z = x/y$, then $g_z = g_x - g_y$

2. Products become sums:

   If $z = x \times y$, then $g_z = g_x - g_y$

3. Powers become multiples:

   If $z = x^a$, then $g_z = a \times g_x$

(If this looks like logarithms to you, that's no accident!)

Suppose that x grows at rate $g_x = 0.10$ while y grows at rate $g_y = 0.03$. Then what is g_z when...

$$z = x \times y \qquad g_z = g_x + g_y = .13$$

$$z = x / y \qquad g_z = g_x - g_y = .07$$

$$z = y / x \qquad g_z = g_y \quad g_x = \quad .07$$

A key example that will turn up later in the course:

- Suppose we know that

$$Y_t = A_t K_t^{1/3} L_t^{2/3}$$

- What is the growth rate of Y_t in terms of the growth rates of A_t, K_t, and L_t?
- The growth rate of a product is the sum of the growth rates

$$g(Y_t) - g(A_t) + g(K_t^{1/3}) + g(L_t^{2/3})$$

(More:) If x grows at rate $g_x = 0.10$ while y grows at rate $g_y = 0.03$. Then what is g_z when...

$$z = x^2 \qquad g_z = 2 \times g_x = .20$$

$$z = y^{1/2} \qquad g_z = .5 \times g_y = .015$$

$$z = x^{1/2} y^{-1/4}$$
$$g_z = .5 \times g_x - .25 \times g_y = .0125$$

$$g(Y_t) = g(A_t) + g(K_t^{1/3}) + g(L_t^{2/3})$$

- The growth rate of a power is the power times the growth rate

$$g(Y_t) = g(A_t) - \frac{1}{3} \times g(K_t) + \frac{2}{3} \times g(L_t)$$

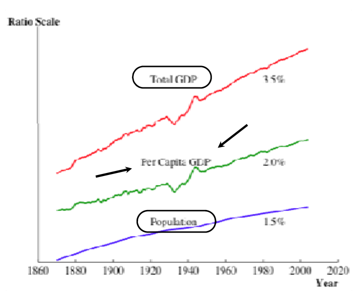
- We will later learn about this function; it tells us that growth in income (Y) comes from
  - Growth in productivity (A) <u>plus</u>
  - Growth in physical inputs (capital, K; and labor, L)

Here's where we see properties of growth rates in action:

The growth rate of GDP/person ...

is equal to the growth rate of GDP *minus* the growth rate of "person," a.k.a. population

Figure 3.9: Population, GDP, and Per Capita GDP for the United States



Note: Data from Maddison (2003) and the Bureau of Economic Analysis. The average annual growth rate is reported next to each data series.

What about the **costs** of economic growth?

- Can growth be bad? <u>Yes</u>
  - Environmental degradation
  - Income inequality
  - Loss of jobs in declining industries
- Do these costs outweigh the benefits?
- It doesn't seem so, at least in the long run
  - Pollution gets worse and then gets better during growth
  - Income inequality <u>may be widening</u>, but growth ameliorates poverty
  - Jobs are lost, but jobs are created. (A key issue is <u>retraining</u>)

What's next?

- We have seen what growth has looked like
- Next we will develop theories and models that help us understand these facts
- Chapter 4 focuses on cross-country income differences and understanding them using an aggregate production function
- Chapter 5 develops the (old) Solow Growth Model
- Chapter 6 develops New Growth Theory: understanding the "why's" in addition to modeling them
- Chapters 7 and 8: inflation and unemployment