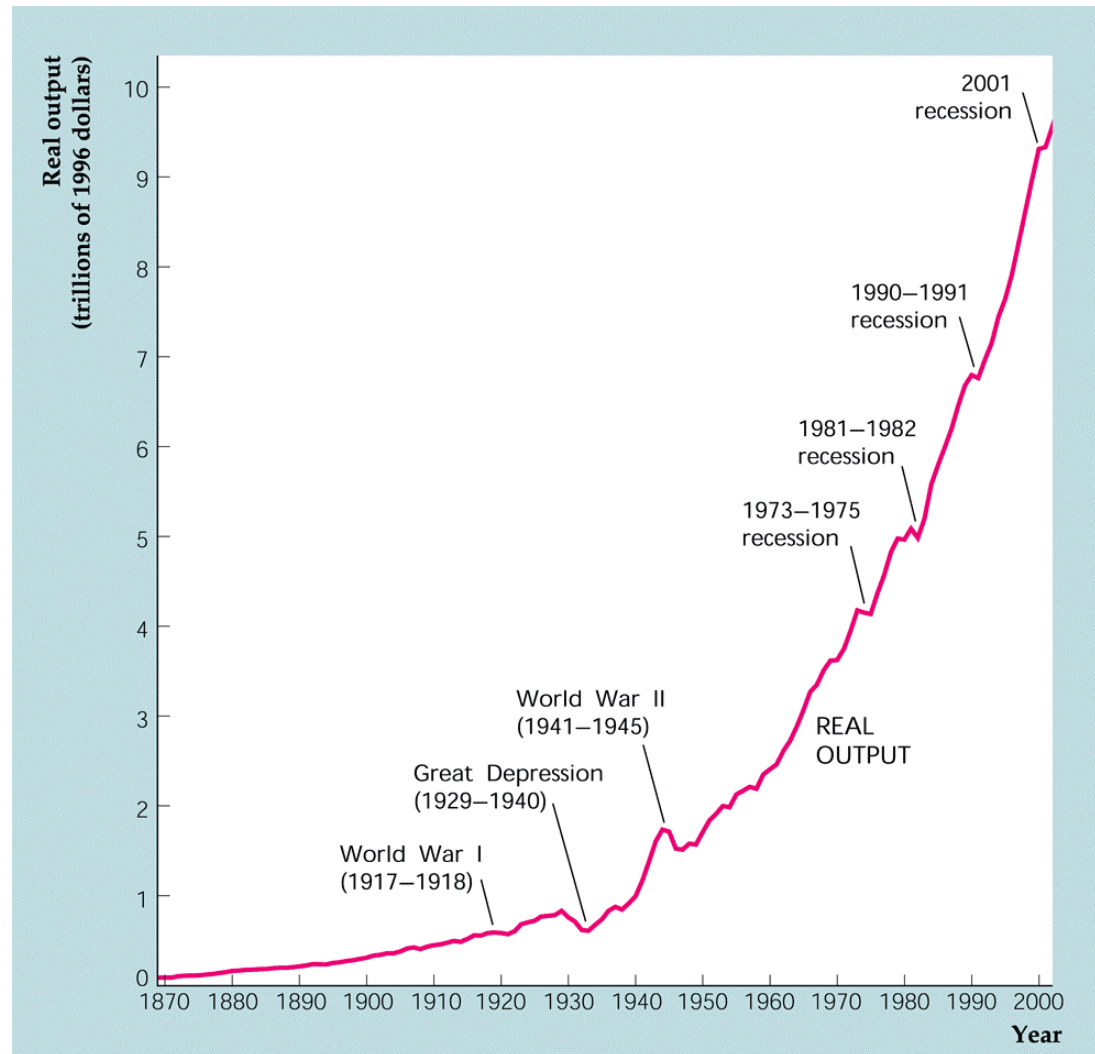


# THE LONG VIEW: ECONOMIC GROWTH

- Important distinction between BUSINESS CYCLES (*cyclical* fluctuations) and LONG-RUN GROWTH (*secular* trend).
- The most striking feature of U.S. economic history since 1870 is the sustained growth in real GDP per capita.
- Central question: What determines the long-run growth rate of an economy?

# Figure 1.1 Output of the U.S. economy, 1869–2002



## UNEQUAL STANDARDS OF LIVING ACROSS COUNTRIES

|        | GDP<br>per capita | Fraction of<br>population<br>in extreme<br>poverty | Fraction of<br>high-school age<br>children<br>in school | Probability<br>of surviving<br>to age 65 |       |
|--------|-------------------|--|---|--|-------|
|        |                   |  |   | Men                                      | Women |
| U.K.   | \$27,650          | Almost zero  | 95%   | 0.83                                     | 0.89  |
| Mexico | \$8,950           | 25%  | 60%   | 0.71                                     | 0.82  |
| Mali   | \$960             | > 50%  | < 10%   | 0.37                                     | 0.41  |

# UNEQUAL STANDARDS OF LIVING ACROSS TIME

John D. Rockefeller, oil entrepreneur who lived from 1839 to 1937, had a net worth of \$200 billion (in today's dollars), twice that of Bill Gates (today's richest American). But he could not:

- Watch TV
- Play video games
- Surf the Internet
- Send an e-mail (let alone a text message)
- Cool his home with air conditioning
- Use antibiotics
- Use a telephone to call his family (for much of his life)
- Travel by car or plane (for much of his life)
- Play golf with a hybrid 5-iron

*ARE YOU RICHER THAN JOHN D. ROCKEFELLER?*

Data on GDP per capita do not fully convey the reality of growth and the accompanying increase in the standard of living. An examination of an annual "workingman's budget" in 1851 Philadelphia gives a much better sense of the improvement (Table 1).

Note how much a family spent on food in 1851: 41% of expenditures. Today's corresponding share—as

reflected in the composition of the consumption basket used to compute the Consumer Price Index—is only 14%. And food at home—as opposed to food in restaurants—accounts for only 8.6% of total consumption today. But perhaps more revealing is the composition of food consumption. Compare the food in the table to the richness and diversity of the food we eat today.

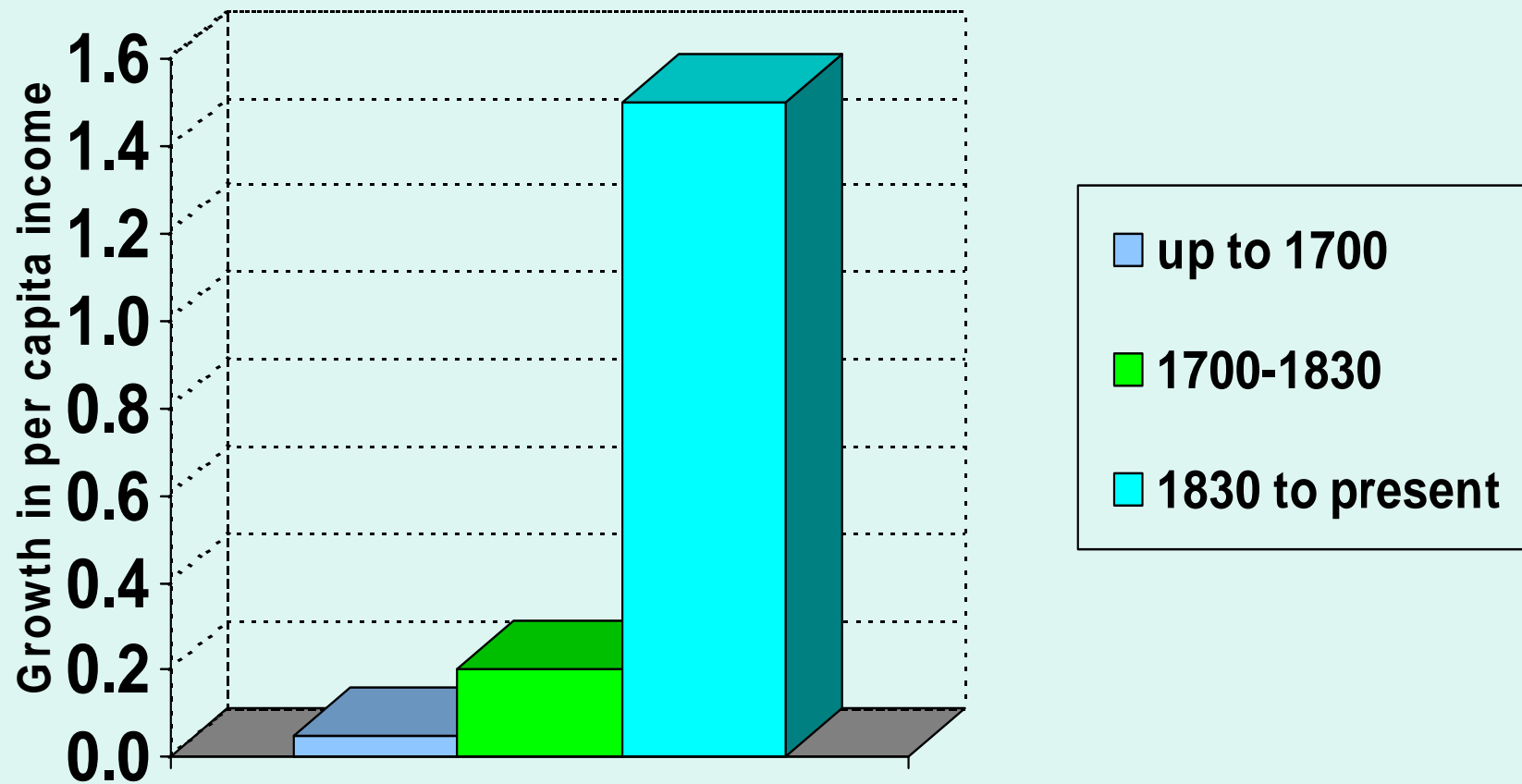
**Table 1 Annual Workingman's Budget, Philadelphia, 1851**

| Item of expenditure                                      | Amount (dollars) | Percent of total |
|--|------------------|------------------|
| Butcher's meat (2 lb a day)                              | 72.80            | 13.5             |
| Flour (6-1/2 lb a year)                                  | 32.50            | 6.0              |
| Butter (2 lb a week)                                     | 32.50            | 6.0              |
| Potatoes (2 pk a week)                                   | 26.00            | 4.8              |
| Sugar (4 lb a week)                                      | 16.64            | 3.0              |
| Coffee and tea   | 13.00            | 2.4              |
| Milk   | 7.28             | 1.4              |
| Salt, pepper, vinegar, starch, soap, yeast, cheese, eggs | 20.80            | 3.9              |
| <b>Total expenditures for food</b>                       | <b>221.52</b>    | <b>41.0</b>      |
| Rent   | 156.00           | 29.0             |
| Coal (3 tons a year)                                     | 15.00            | 2.8              |
| Charcoal, chips, matches                                 | 5.00             | 0.9              |
| Candles and oil  | 7.28             | 1.4              |
| Household articles (wear, tear, and breakage)            | 13.00            | 2.4              |
| Bedclothes and bedding                                   | 10.40            | 1.9              |
| Wearing apparel  | 104.00           | 19.3             |
| Newspapers   | 6.24             | 1.2              |
| <b>Total expenditures other than food</b>                | <b>316.92</b>    | <b>58.9</b>      |

Source: *Productivity and American Leadership*; (Chapter 3, Table 3.2), by William Baumol et al., Cambridge, MA: MIT Press, 1989. The composition of expenditures today comes

from Table 712 (average annual income and expenditures of all consumer units, 1995) in the *Statistical Abstract of the United States, 1997*.

# Growth in per capita income (average, percent per year)



Data for Western Europe from Angus Maddison

| United States per capita GDP |                 | Country at this level in 2004 |
|------------------------------|-----------------|-------------------------------|
| Year                         | Level (2004 \$) |                               |
| 1800                         | 1,195           | Kenya                         |
| 1850                         | 1,700           | Bangladesh                    |
| 1900                         | 4,391           | Morocco                       |
| 1910                         | 5,408           | China                         |
| 1916                         | 6,189           | Algeria                       |
| 1920                         | 6,180           | Ukraine                       |
| 1930                         | 7,002           | Namibia                       |
| 1940                         | 8,539           | Romania                       |
| 1950                         | 12,783          | Argentina                     |
| 1960                         | 15,099          | Hungary                       |
| 1970                         | 20,065          | South Korea                   |
| 1980                         | 24,729          | Spain                         |
| 1990                         | 31,016          | UK                            |
| 2000                         | 37,814          | Ireland (almost)              |
| 2005                         | 40,718          | US, Norway                    |

# GROWTH AND HUMAN WELFARE

Is there some action a government of India could take that would lead the Indian economy to grow like Indonesia's or Egypt's? If so, what exactly? If not, what is it about the "nature of India" that makes it so? The consequences for human welfare involved in questions like these are simply staggering: Once one starts to think about them, it is hard to think of anything else.

R.E. Lucas, Jr. (1988), "On the Mechanics of Economic Development," *Journal of Monetary Economics*.



## MAKING A MIRACLE

How does one acquire knowledge about reality by working in one's office with pen and paper? (...) [I] think this inventive, model-building process we are engaged in is an essential one . . . . If we understand the process of economic growth—or anything else—we ought to be capable of demonstrating this knowledge by *creating* it in these pen and paper (and computer-equipped) laboratories of ours. If we know what an economic miracle is, we ought to be able to *make* one.

R.E. Lucas, Jr. (1993), "Making a Miracle," *Econometrica*.

# SIMPLE MATHEMATICS OF GROWTH RATES

- Define:  $Y_t =$  U.S. GDP in year  $t$ .
- Suppose the growth rate of GDP is  $g$ :  $Y_{t+1} = (1 + g)Y_t$ .
- In the U.S.,  $g$  (on average) is about 0.03, or 3%.
- Let  $\log(x)$  denote the natural logarithm, or the log to the base  $e$ , of  $x$  ( $\log(x)$  is sometimes also denoted  $\ln(x)$ ).
- A useful fact:  $\log(ax) = \log(a) + \log(x)$ .
- A useful approximation:  $\log(1 + g) \approx g$  if  $g$  is close to 0.

## SIMPLE MATHEMATICS OF GROWTH RATES (cont'd)

- A simple derivation...

$$\begin{aligned}\log(Y_{t+1}) &= \log((1 + g)Y_t) \\ &= \log(1 + g) + \log(Y_t) \\ &\approx g + \log(Y_t)\end{aligned}$$

$$\Rightarrow \log(Y_{t+1}) - \log(Y_t) \approx g$$

- ...yields a useful approximation: *The difference in the logs is (approximately) equal to the growth rate.*

## EXPONENTIAL GROWTH

- Question: If U.S. GDP grows at a constant rate  $g$ , how long does it take for U.S. GDP to double?
- Let the base year be year 0. Then:

$$Y_1 = (1 + g)Y_0$$

$$Y_2 = (1 + g)Y_1 = (1 + g)^2Y_0$$

$$Y_3 = (1 + g)Y_2 = (1 + g)^2Y_1 = (1 + g)^3Y_0$$

- The general formula is:  $Y_t = (1 + g)^tY_0$ .

# LOGARITHMIC GRAPHS

- Another useful fact:  $\log(x^a) = a \log(x)$ .
- Recall that  $Y_t = (1 + g)^t Y_0$  if U.S. GDP grows at a constant rate  $g$ .
- Take logs of both sides:

$$\begin{aligned}\log(Y_t) &= \log\left((1 + g)^t Y_0\right) \\ &= \log\left((1 + g)^t\right) + \log(Y_0) \\ &= t \log(1 + g) + \log(Y_0) \\ &\approx \log(Y_0) + gt\end{aligned}$$

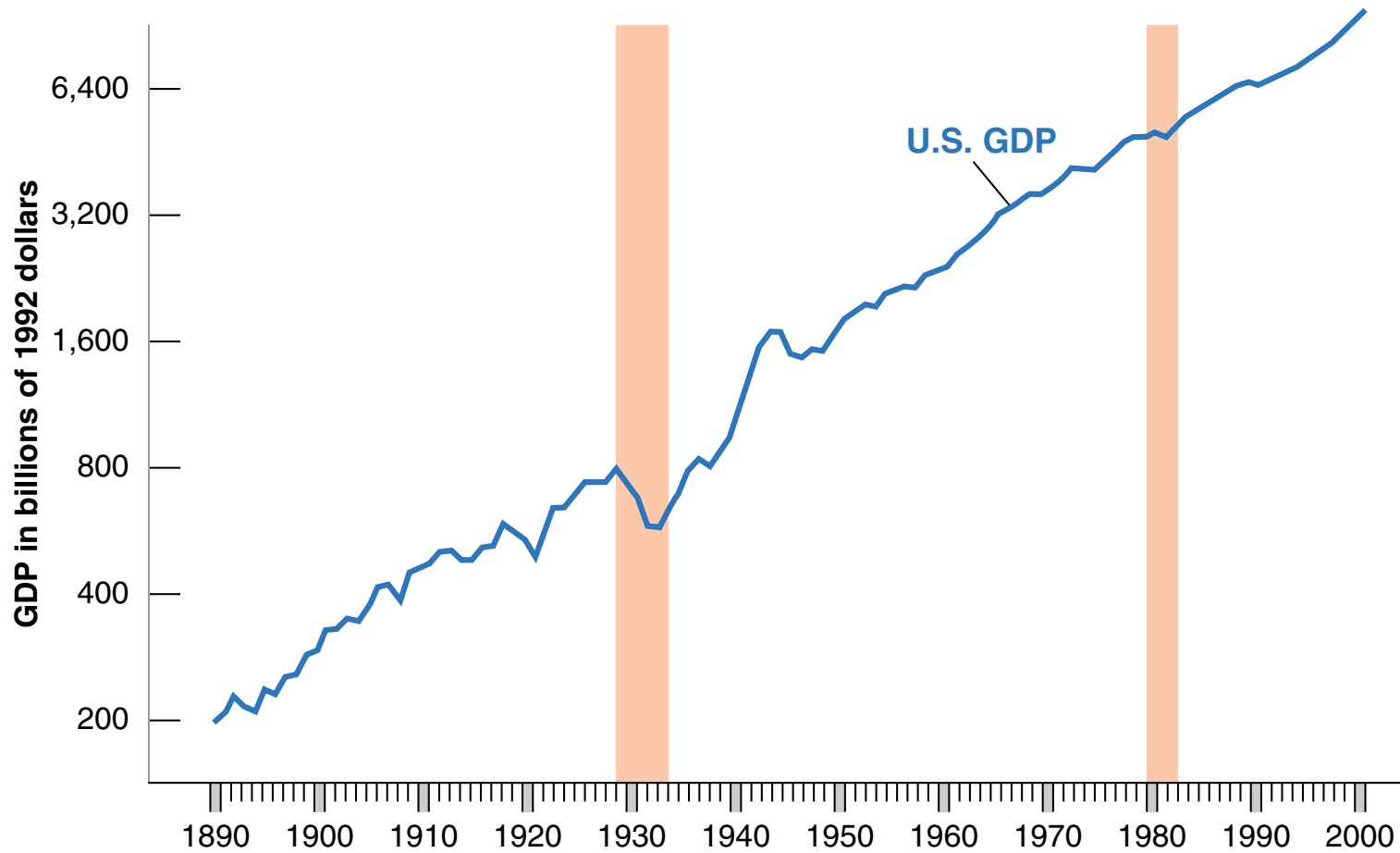
*If GDP grows at a constant rate, then the log of GDP, graphed against time  $t$ , is a straight line with slope equal to the growth rate  $g$ .*

### Figure 10-1

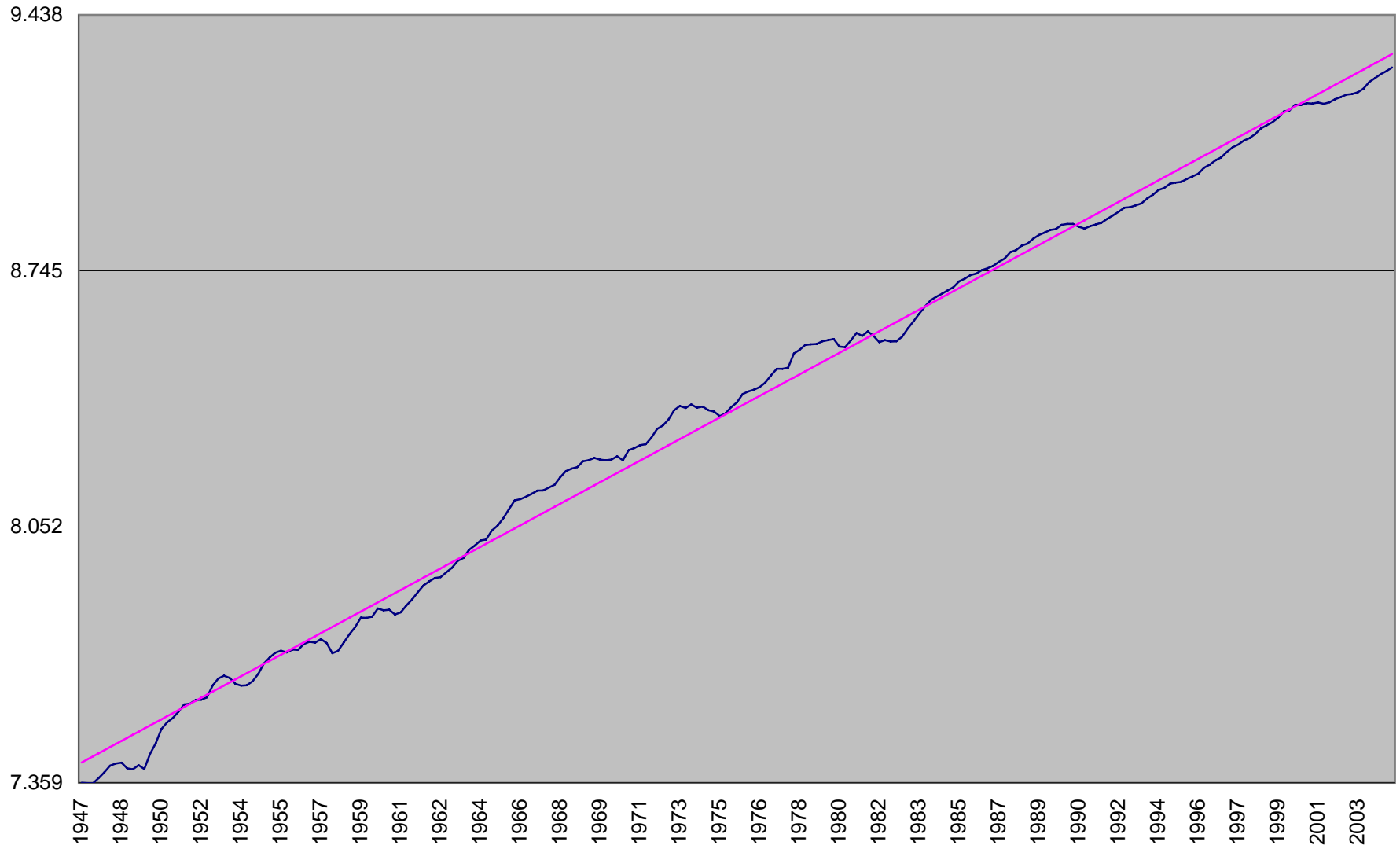
#### U.S. GDP Since 1890

Aggregate U.S. output has increased by a factor of 43 since 1890.

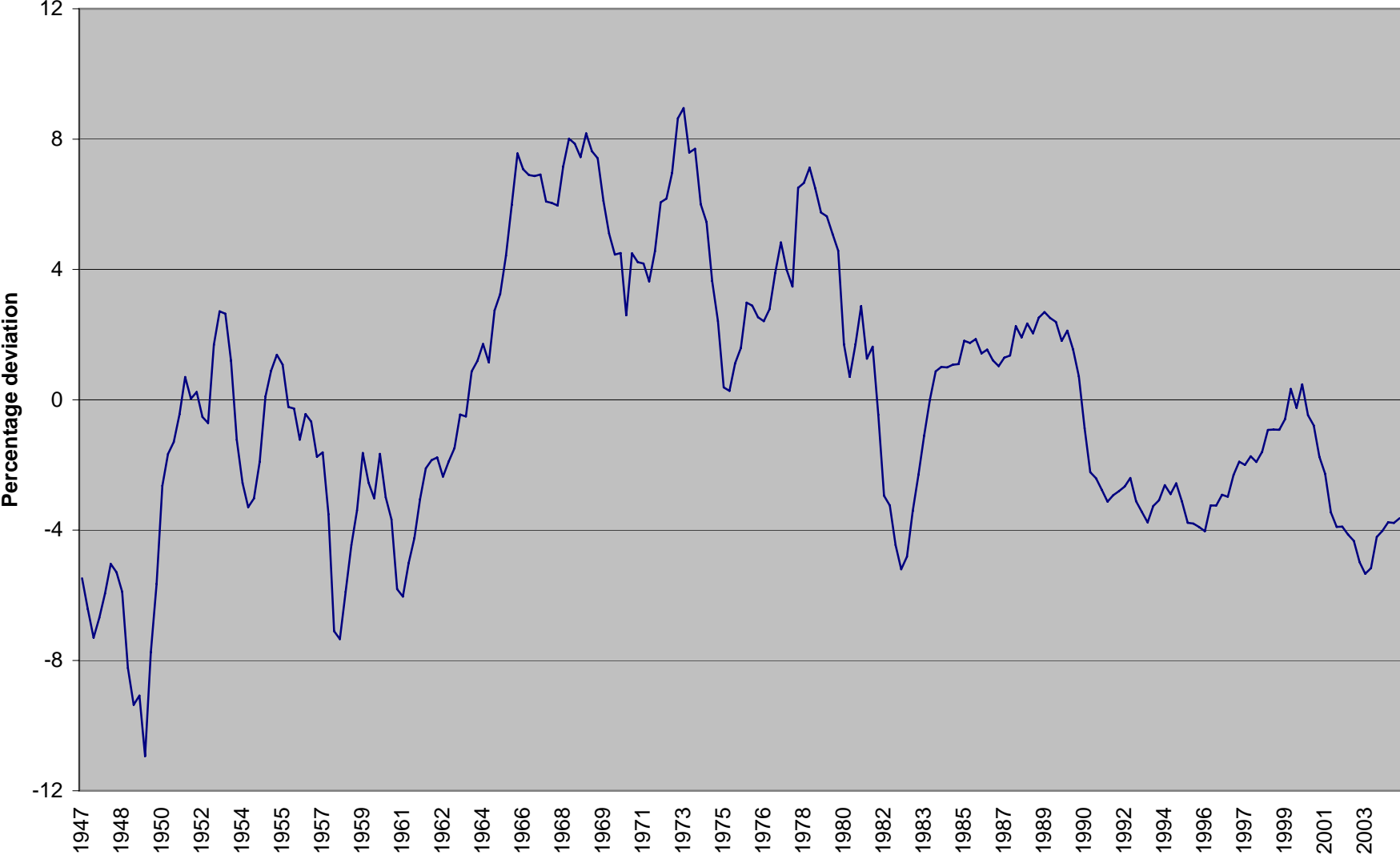
Source: 1890–1929: *Historical Statistics of the United States*; 1929–2000: *National Income and Product Accounts*.



Log of US Real GDP (with trend line)



US Real GDP: Percentage Deviations from Trend





## THE RULE OF 70

- Suppose that GDP doubles in exactly  $T$  years:  $Y_T = 2Y_0$ . We want to solve for  $T$  in the equation:  $(1 + g)^T = 2$ .
- Take logs of both sides:  $\log\left((1 + g)^T\right) = \log(2) \approx 0.693$ .
- Also:  $\log\left((1 + g)^T\right) = T \log(1 + g) \approx Tg$ .
- Result:

$$T \approx \frac{0.693}{g} \quad \left( \text{or: } T \approx \frac{70}{100g} \right).$$

## THE RULE OF 70 (cont'd)

| Annual growth rate of GDP | Doubling time |
|---------------------------|---------------|
| 1%                        | 70 years      |
| 2%                        | 35 years      |
| 3%                        | 23 years      |
| 5%                        | 14 years      |

- *Moral:* Small changes in growth rates have dramatic long-run effects!

## U.S. GROWTH HISTORY

- U.S. GDP doubled between 1947 and 1965: 18 years.  
Average growth rate during this period:  $70/18 \approx 3.9\%$ .
- U.S. GDP doubled again between 1965 and 1987: 22 years.  
Average growth rate during this period:  $70/22 \approx 3.2\%$ .

# POPULATION GROWTH

- What we *really* care about is GDP per capita (or GDP per person).
- Define:  $N_t =$  U.S. population in year  $t$ .
- Suppose the population growth rate is  $n$ :  $N_{t+1} = (1 + n)N_t$ .
- The U.S. population roughly doubled between 1950 and 2006 (from 150,000,000 to 300,000,000).
- Average annual growth rate  $n = 70/56 \approx 1.3\%$  (or 0.013).

# GROWTH IN GDP PER CAPITA

- GDP per capita in year  $t$  is:  $Y_t/N_t$ .
- Final useful fact:  $\log(x/y) = \log(x) - \log(y)$ .

- Growth in GDP per capita is (approximately):

$$\begin{aligned}\log\left(\frac{Y_{t+1}}{N_{t+1}}\right) - \log\left(\frac{Y_t}{N_t}\right) &= \log(Y_{t+1}) - \log(Y_t) - \\ &\quad (\log(N_{t+1}) - \log(N_t)) \\ &\approx g - n.\end{aligned}$$

- Annual growth rate of U.S. GDP per capita since 1950:  
 $3.5\% - 1.3\% = 2.3\%$ .
- Doubling time =  $70/2.3 \approx 35$  years.

## DETERMINANTS OF GROWTH

- Formation of physical capital: machines, buildings, infrastructure.

Let  $K$  be the aggregate (or total) stock of physical capital.

- Human resources: labor supply, education, motivation.

Let  $L$  be the aggregate (or total) supply of human resources.

- Technology: science, engineering, management techniques.

Let  $A$  be the level of technology.

## DETERMINANTS OF GROWTH (cont'd)

- Natural resources: land, oil, minerals, quality of the environment.
- Institutions: property rights, enforceable contracts (legal system), patent and copyright law.
- Culture: social capital, entrepreneurial energy, the Protestant work ethic and the spirit of capitalism (Max Weber).

# THE AGGREGATE PRODUCTION FUNCTION

- Basic economic models of growth set aside natural resources, institutions, and culture and focus instead on:  $K$  (stock of physical capital),  $L$  (employment), and  $A$  (technology).
- How much can an entire economy produce? Economists use the abstraction of an *aggregate (or economywide) production function*  $F$ :

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

- A simple yet empirically plausible choice for  $F$  is the *Cobb-Douglas* production function:

$$Y = AK^\alpha L^{1-\alpha},$$

where  $\alpha$  (pronounced “alpha”) is roughly 1/4.



# WHAT ARE THE SOURCES OF GROWTH?

- Fundamental Question: What accounts for the observed growth of U.S. GDP?
- How much of the growth in GDP can be attributed to:
  - (a) Capital formation (changes in  $K$ )?
  - (b) Growth in employment (changes in  $L$ )?
  - (c) Growth in technology (changes in  $A$ )?
- Another useful approximation: Suppose  $Y_t = (1 + g_t)Y_{t-1}$ , where the growth rate,  $g_t$ , is allowed to change over time. Then:

$$\log(Y_t) - \log(Y_{t-1}) = \log(1 + g_t) \approx g_t.$$

# GROWTH ACCOUNTING

- Take logs of both sides of the aggregate production function:

$$\begin{aligned}\log(Y_t) &= \log(A_t) + \alpha \log(K_t) + (1 - \alpha) \log(L_t) \\ \log(Y_{t-1}) &= \log(A_{t-1}) + \alpha \log(K_{t-1}) + (1 - \alpha) \log(L_{t-1})\end{aligned}$$

- Subtract the second equation from the first:

$$\begin{aligned}\log(Y_t) - \log(Y_{t-1}) &= \log(A_t) - \log(A_{t-1}) + \\ &\quad \alpha(\log(K_t) - \log(K_{t-1})) + \\ &\quad (1 - \alpha)(\log(L_t) - \log(L_{t-1}))\end{aligned}$$

- This delivers the **growth accounting equation**:

$$g_t^Y = g_t^A + \alpha g_t^K + (1 - \alpha)g_t^L$$

- Rearrange to get:  $g_t^A = g_t^Y - \alpha g_t^K - (1 - \alpha)g_t^L$ .

# WHAT IS THE RATE OF TECHNOLOGICAL CHANGE?

- In the U.S. for the time period 1948–2001:

Average annual growth rate of GDP,  $g^Y$ , is 3.6%.

Average annual growth rate of capital,  $g^K$ , is 4.4%.

Average annual growth rate of employment,  $g^L$ , is 1.4%.

Set  $\alpha = 1/4$  and “back out” the rate of technological change:

$$\begin{aligned}g^A &= g^Y - \alpha g^K - (1 - \alpha)g^L = 3.6\% - (1/4)(4.4\%) - (3/4)(1.4)\% \\ &= 3.6\% - 1.1\% - 1.1\% \\ &= 1.4\%\end{aligned}$$

- Increases in inputs ( $K$  and  $L$ ) account for  $(1.1+1.1)/3.6 = 61\%$  of the growth in GDP.
- Technological change (or *total factor productivity growth*) accounts for  $1.4/3.6 = 39\%$  of the growth of GDP.

# GROWTH RATE OF GDP PER WORKER

- Rearrange the growth accounting equation:

$$g_t^Y - g_t^L = g_t^A + \alpha(g_t^K - g_t^L)$$

- $g_t^Y - g_t^L$  is the growth rate of GDP per worker ( $Y/L$ ), sometimes called *labor productivity*.
- $g_t^K - g_t^L$  is the growth rate of the *capital-labor ratio* ( $K/L$ ).
- Increases in  $K/L$  are called “capital deepening”: each worker has more capital to work with.
- In U.S. data,  $g^Y - g^L \approx 2.2\%$ ,  $g^A \approx 1.4\%$ , and  $g^K - g^L \approx 3.0\%$ .

## U.S. Productivity Growth in the 20<sup>th</sup> Century

