ECON 164: Theory of Economic Growth

Week 1: The questions and facts of growth

Levi Crews

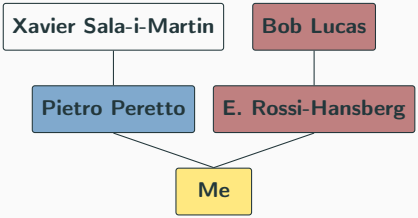
Winter 2026

A bit about me

- **research**: growth $\leftrightarrow$ spatial/trade + heterogeneity
- **timeline**:

2013–17	B.S. Econ + Math at **Duke**
2017–23	Ph.D. at **UChicago**
2023–24	postdoc at **Princeton**
2024–on	assistant professor at **UCLA**

- **why I do what I do**: *a class like this one!*



Course logistics

- **lectures**: MW 9:30–10:45am @ Kaplan Hall 135
- **office hours**: Tue 4:00–5:00pm @ Bunche Hall 8385
- **TA/lab**: *None!*
- All slides, problem sets, and additional readings will be posted on **Bruin Learn**
- Questions, discussions, and announcements will be conducted through **Slack**

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  - *email me at your own risk!* (put "ECON 164" in subject line)
  - post in the public channels unless it's personal, then DM me
  - `#announcements`, `#lectures`, `#problem-sets`, ...
  - if comfortable, use full name and photo

Prerequisites

- **ECON 102**: Macroeconomic Theory
  - GDP, Solow model, two-period consumption-savings problem
- **math background**: You should know how to...
  - **take** partial derivatives

$$\frac{\partial}{\partial K_t}[K_t^{\alpha}(A_t L_t)^{1-\alpha}] = \alpha K_t^{\alpha-1}(A_t L_t)^{1-\alpha}$$

  - **solve** simple constrained optimization problems w/ Lagrangians

$$\max_{c_1, c_2} u(c_1) + \beta u(c_2) \quad \text{s.t.} \quad c_1 + \frac{c_2}{1+r} = y_1 + \frac{y_2}{1+r}$$

  - **understand** basic differential equations

$$\frac{dK_t}{dt} = sY_t - \delta K_t$$

Materials

Main text

Jones and Vollrath (2024)

Supplementary texts

Weil (2016) [*what your friends may have used in ECON 164*]

Kurlat (2020, Ch. 1–5) [*what you may have used in ECON 102*]

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You are responsible for **what's in the slides**, but I'll draw from these texts + more

Grading

Three exams determine your grade:

Feb 02	**Midterm 1**	25%		0%		25%
Mar 09	**Midterm 2**	25%	*OR*	25%	*OR*	0%
Mar 19	**Final**	50%		75%		75%

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Six problem sets are assigned only to help:

- some data exploration, but mostly exam-style questions
- can work in groups ($\leq$3), but must write up solutions independently
- complete **at least four** reasonably well, will get bump if on the border
- complete **all six** reasonably well, will get full half-letter bump

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Attendance/participation is not graded, but highly encouraged

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Three organizing questions

1. **Why are we so rich and they so poor?**
   - *across places at the same time*: income per capita in the US and Western Europe is at around 50$\times$ greater than in much of sub-Saharan Africa
   - *in the same place over time*: 10$\times$ increase in income in the US over the last century

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2. **What is the engine of economic growth?**
   - How is it that economies experience sustained growth in output per worker over the course of a century or more?
   - Why is it that the United States has grown at 1.7% per year since 1870?

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3. **How do "growth miracles" happen?**
   - South Korea, Taiwan, Singapore—fundamentals, policy, luck?

Our approach: The cosmologists of economics

- one universe, one global economy → **no controlled experiments**
- instead a **back-and-forth between observation and theory**

  . . . often the most important constraint on a new theory is not that it should survive this or that new experimental test, but that it should agree with the body of past observations, as crystallized in former theories. . . . The wonderful thing is that the need to preserve successes of the past is not only a constraint, but also a guide.

  Weinberg (2018, Ch. 24)

- but one critical difference: **policy can reshape the economic "universe"**
  → need to judge "opportunities" vs. "necessities", then act on the opportunities!

[advanced reading: Kydland and Prescott (1996)]

How we'll proceed

1. **The facts of economic growth** (Week 1)
2. **Neoclassical growth models**
   - (Week 2) *Solow model*
   - (Week 3) *Ramsey-Cass-Koopmans model*
   - (Week 4) *Neoclassical models* $\leftrightarrow$ *Facts*
3. **Endogenous growth models**
   - (Week 5b) *AK model*
   - (Week 6a) *Ideas and innovation*
   - (Week 6b) *Romer model*
   - (Week 7a) *Schumpeterian model*
   - (Week 7b) *Endogenous models* $\leftrightarrow$ *Facts*
4. **More topics: Tech. diffusion, natural resource use, demographics** (Weeks 8–9)
5. **Growth in the century ahead** (Week 10)

Why take this class?

If you want to get a Ph.D. in economics...

- the neoclassical growth model is the backbone of first-year Ph.D. macro
- headstart in exciting research area: growth $\leftrightarrow$ spatial, trade, labor, environmental, ...

Why take this class?

If you want to work in tech... this is what Silicon Valley is about, in word and action!

- Stripe: "Increase the GDP of the internet"
- Collison & Cowen on *progress*
- SV-funded Institute for Progress
- Roots of Progress Conference 2024 (inc. a talk by Chad Jones!)

Why take this class?

If you want to work in policy/NGOs...

- no higher stake/leverage domain: dwarfs the welfare costs of business cycles (Lucas, 1987)
- GiveWell and Open Philanthropy: *how to best spend the marginal $ to improve welfare?*
- wave of industrial policy (US CHIPS and Science Act): *are we doing it right?*

Why take this class?

If want to be a good citizen...

the choices *you* make about where to live, what and how much to learn, what to consume, and what policies to support *matter* for economic growth

[consider reading Michael (2016)]

The facts of economic growth

Refresher: What is GDP? (ECON 102)

- **G**ross **D**omestic **P**roduct (in a country over a specific period of time)

$$\textbf{GDP} = \text{Total Production} = \text{Total Expenditure} = \text{Total Income}$$

- **what does it miss?** non-market goods, leisure, inequality, natural resource stocks

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- **how to make it comparable . . .**
  - across time: *real* vs. *nominal* (adjust for inflation)
  - across countries: *PPP* (adjust for cost of living)
    - we want "*P*arity in *P*urchasing *P*ower", but exchange rates are volatile
    - "law of one price" for traded, but Balassa-Samuelson effect for non-traded
    - relative price of investment goods is higher in low-income countries (Hsieh and Klenow, 2007)

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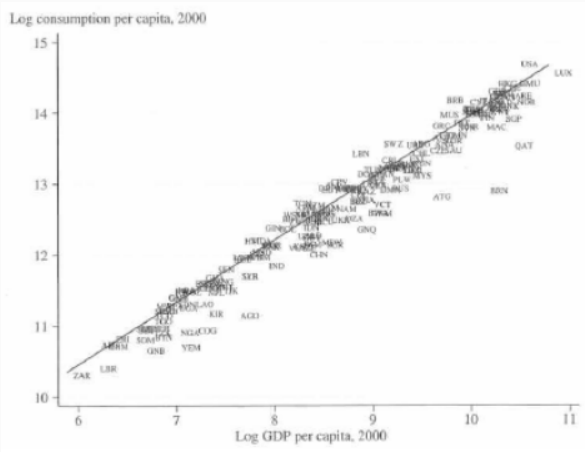
    - relative price of investment goods is higher in low-income countries (Hsieh and Klenow, 2007)
- **how to adjust for pop. size**: "welfare" vs. "productivity" measures

$$\text{GDP per capita} = \frac{\text{GDP}}{\text{Population}} \quad \text{vs.} \quad \text{GDP per worker} = \frac{\text{GDP}}{\text{Labor Force}} = \frac{\text{GDP}}{\text{Population}} \Big/ \frac{\text{Labor Force}}{\text{Population}}$$

GDP per capita—A good measure of welfare?

correlates well with other indicators:

- consumption per capita
- subjective well-being
  - across countries
  - across US income distribution
- life expectancy
- meat consumption
- ...



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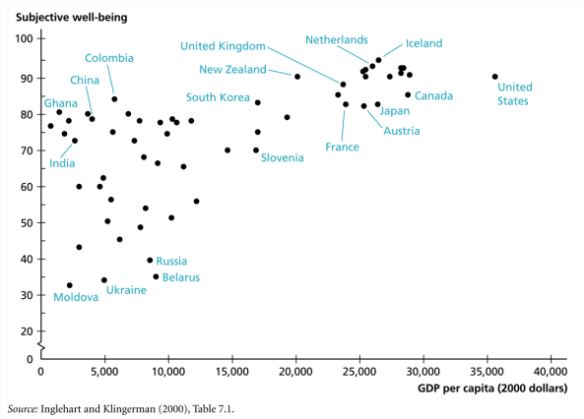

Source: Inglehart and Klingerman (2000), Table 7.1.

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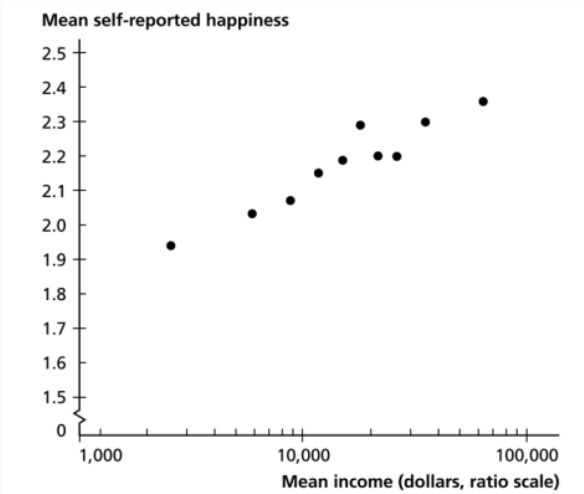

Source: Frey and Sturtzer (2002). Data are for deciles of the income distribution.

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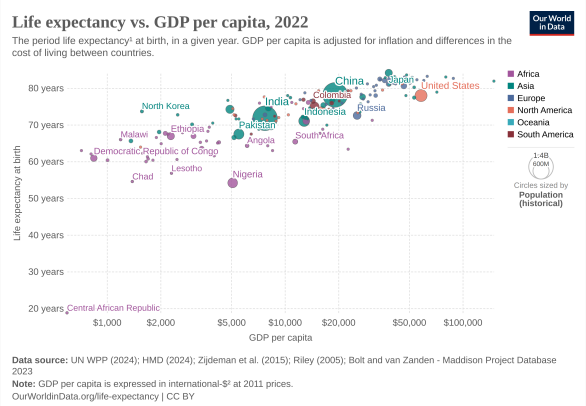

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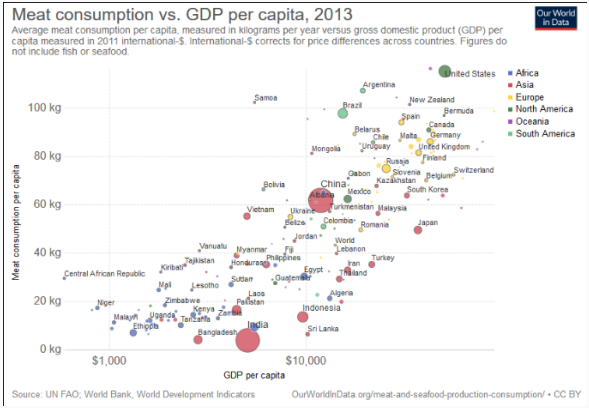

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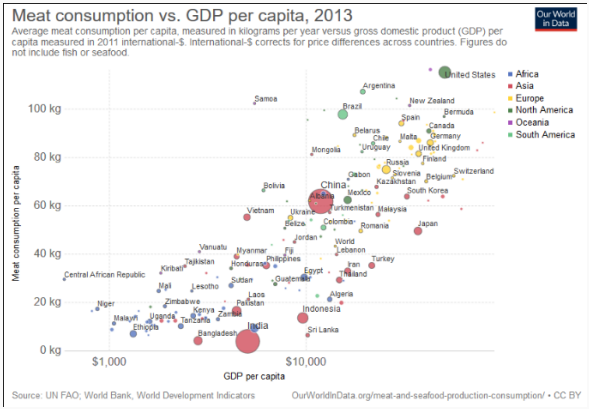

later: **consumption-equivalent welfare** (Jones and Klenow, 2016)

Data

- **Penn World Tables** (PWT): comparable measures of GDP across countries
- **Maddison Project Database**: long-run (1870 and prior) growth and income
- **GGDC Historical National Accounts**: industry-level companion to Maddison
- **Our World in Data**: quick visualizations of economic and social data

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You'll explore these in Problem Set #1! (due by Midterm #1)

Fact 1: Enormous variation in *levels* of GDP per capita across economies

Table 1.1 Statistics on Growth and Development

	GDP per capita, 2019	GDP per worker, 2019	Labor force participation rate, 2019	Average annual growth rate, 1960–2019	Years to double
Relatively rich countries					
United States	$62,589	$130,107	0.48	2.0	35
France	43,755	103,284	0.42	2.3	30
Japan	39,704	71,980	0.55	3.4	21
Middle income countries					
Turkey	26,948	80,044	0.34	2.8	25
Chile	23,253	54,405	0.43	2.5	28
Mexico	18,737	43,465	0.43	1.7	40
Relatively poor countries					
China	14,129	25,360	0.56	4.5	16
India	6,711	18,429	0.36	3.0	24
Malawi	1,161	2,721	0.43	0.4	160
Growth miracles					
Singapore	82,336	127,117	0.65	5.8	12
Taiwan	46,761	95,946	0.49	4.9	15
South Korea	42,219	80,702	0.52	6.0	12
Growth disasters					
Madagascar	1,539	2,977	0.52	−0.1	−918
Niger	1,211	3,182	0.38	−0.9	−80
Venezuela	251	612	0.41	−5.8	−12

SOURCE: Author's calculations from Penn World Tables v10.0, (Feenstra, Inklaar, and Timmer, 2015).

NOTE: GDP is in 2017 PPP dollars. The growth rate is the average annual change in log GDP per capita. A negative number in "years to double" indicates "years to halve."

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- France vs. Japan: different mix of **productivity vs. LFP**
- US GDPpc is **50**× that of Malawi
  - typical Malawi worker works ∼*two months* to produce what typical US worker produces in a *day*
  - life expectancy 14 years less; infant mortality 10× higher
  - ∼50% income spent on food in Malawi vs. 6% in US

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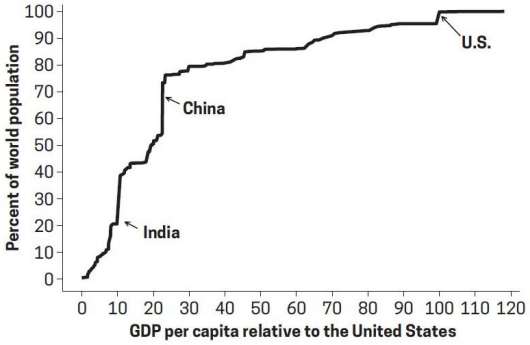
Figure 1.1 Cumulative Distribution of World Population by GDP per Capita, 2019



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NOTE: For a given relative GDP per capita (*x*-axis) the figure indicates the percentage of world population (*y*-axis) with a GDP per capita less than that value.

What fraction of the world's pop. lives with this kind of poverty?

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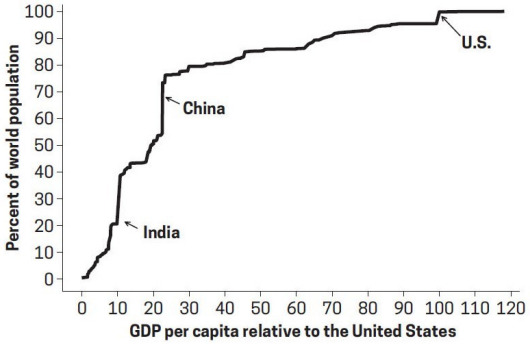
Figure 1.1 Cumulative Distribution of World Population by GDP per Capita, 2019



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What fraction of the world's pop. lives with this kind of poverty?

- **right skewed** (mean > median): 3/4 of world pop. lived where GDPpc <30% of US
- **larger ≠ richer** (per capita): most of that in China and India (40% of world pop.)

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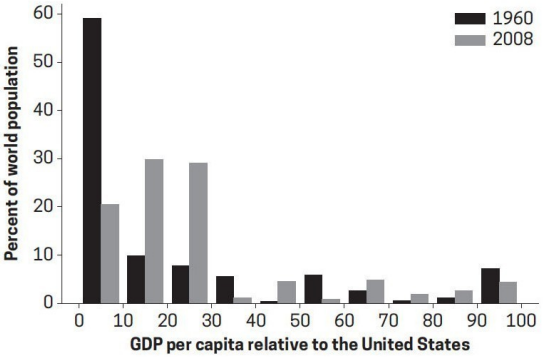
Figure 1.2 World Population by GDP per Capita, 1960 and 2019



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NOTE: The sample includes only 110 countries in order to incorporate the 1960 data.

How has the dist. changed since 1960?

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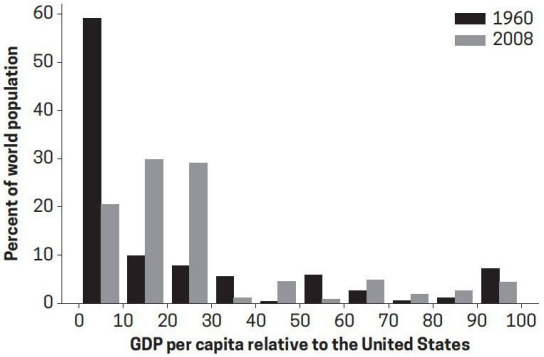

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How has the dist. changed since 1960?

- **China**: 5% of US GDPpc → 22%
- **India**: 6% of US GDPpc → 11%
- **at the top**: South Korea, Taiwan, Singapore (14% → 100%+)

Math interlude: Log differences + Rule of 70

- Often we represent plots in logs. **Why?**
  - In economics many variables (e.g. GDP) turn out to grow multiplicatively
  - Logs transform products into sums and make life (and graphs!) easier
  - **Slope in logs is approximately the growth rate**
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  - Often index axis with value of Y_t instead of value of $\ln Y_t$ for readability
- derivation in **discrete time**: Imagine GDP is Y_t today and was Y_{t-1} last period
  - Growth rate g_t from $t-1$ to t is defined by $Y_t = (1+g_t)Y_{t-1} \iff g_t = Y_t/Y_{t-1} - 1$
  - Log difference: $\ln Y_t - \ln Y_{t-1} = \ln(1+g_t) \approx \ln(1) + g_t = g_t$ (approx. pct. change)

Math interlude: Log differences + Rule of 70

- Often we represent plots in logs. **Why?**
  - In economics many variables (e.g. GDP) turn out to grow multiplicatively
  - Logs transform products into sums and make life (and graphs!) easier
  - **Slope in logs is approximately the growth rate**
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- **rule of 70**: *how long does Y take to double at growth rate g?*
  - need to find t^* s.t. $Y_t = 2Y_0$
  - solve for t^*: $2 = e^{gt^*} \iff t^* = \frac{\ln 2}{g} \approx \frac{0.7}{g} = \frac{70}{g_{\%}}$
  - US: $g = 2\% \rightarrow t^* = 70/2 = \mathbf{35}$ **years**
  - China: $g = 4.5\% \rightarrow t^* = 70/4.5 \approx \mathbf{16}$ **years**

Fact 2: Enormous variation in *growth rates* of GDP per capita, too

Table 1.1 Statistics on Growth and Development

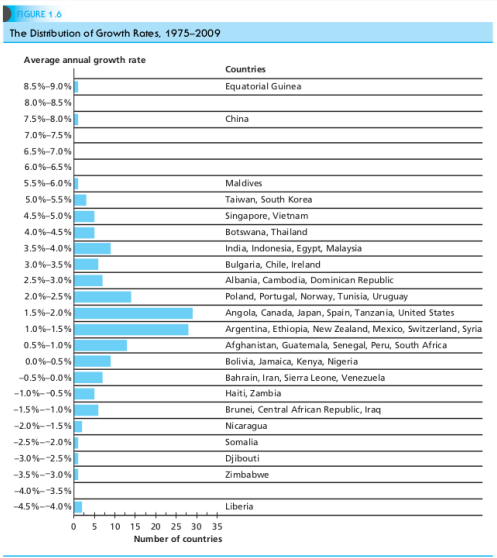
	GDP per capita, 2019	GDP per worker, 2019	Labor force participation rate, 2019	Average annual growth rate, 1960–2019	Years to double
Relatively rich countries					
United States	$62,589	$130,107	0.48	2.0	35
France	43,755	103,284	0.42	2.3	30
Japan	39,704	71,980	0.55	3.4	21
Middle income countries					
Turkey	26,948	80,044	0.34	2.8	25
Chile	23,253	54,405	0.43	2.5	28
Mexico	18,737	43,465	0.43	1.7	40
Relatively poor countries					
China	14,129	25,360	0.56	4.5	16
India	6,711	18,429	0.36	3.0	24
Malawi	1,161	2,721	0.43	0.4	160
Growth miracles					
Singapore	82,336	127,117	0.65	5.8	12
Taiwan	46,761	95,946	0.49	4.9	15
South Korea	42,219	80,702	0.52	6.0	12
Growth disasters					
Madagascar	1,539	2,977	0.52	−0.1	−918
Niger	1,211	3,182	0.38	−0.9	−80
Venezuela	251	612	0.41	−5.8	−12

SOURCE: Author's calculations from Penn World Tables v10.0, (Feenstra, Inklaar, and Timmer, 2015).

NOTE: GDP is in 2017 PPP dollars. The growth rate is the average annual change in log GDP per capita. A negative number in "years to double" indicates "years to halve."

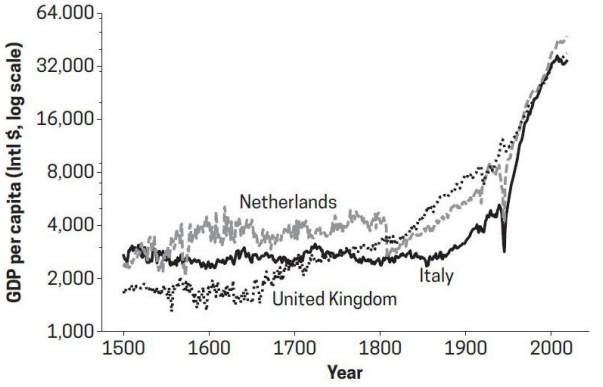
- **miracles**: double income in $\sim 1/2$ gen.
- **disasters**: income actually *falls*

Fact 2: Enormous variation in *growth rates* of GDP per capita, too



Fact 3: Growth rates are not necessarily constant

Figure 1.3 GDP per Capita, 1500–2019, Selected Countries



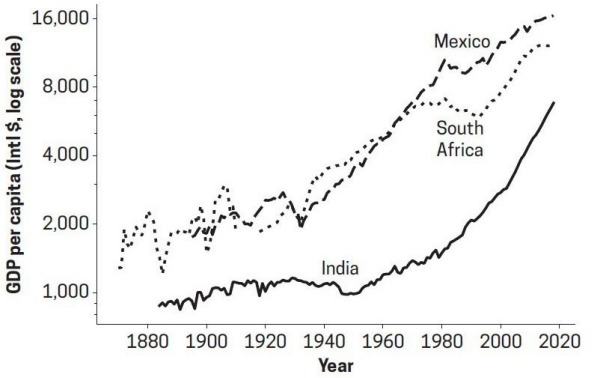
SOURCE: Author's calculations from Broadberry et al. (2015), Malanima (2011), van Zanden and van Leeuwen (2012), and Bolt and van Zanden (2020).

- Most of history: growth rates ≈ 0
- Shot up in 19^{th} and 20^{th} c.

(notice the log scale!)

Fact 3: Growth rates are not necessarily constant

Figure 1.4 GDP per Capita, 1870–2019, Selected Countries



SOURCE: Author's calculations from Barro and Ursua (2008), Broadberry, Custodis, and Gupta (2015), Fourie and Zanden (2013), and Bolt and van Zanden (2020).

- non-frontier countries had same, but delayed
- notice the volatility!

Fact 4: Countries can move from "poor" to "rich" and vice versa

- Singapore vs. Argentina (top-10 in 1913 to 65 in 2019)
- **implies**: not just tracking some global frontier $\rightarrow$ *policy likely plays a role*
- see **Table 12.10** of Barro and Sala-i Martin (2004) w/ Maddison data

Recap + what's ahead

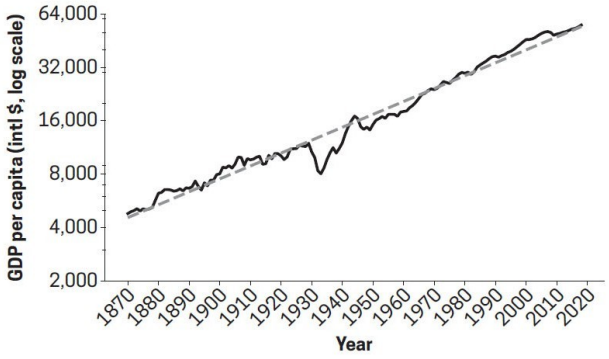
- **three organizing questions**:
  1. Why are we so rich and they so poor?
  2. What is the engine of economic growth?
  3. How do "growth miracles" happen?
- **facts of economic growth**:
  - enormous variation in levels and growth rates of GDP per capita
  - growth rates are not necessarily constant
  - countries can move from "poor" to "rich" and vice versa
- **next**: *Kaldor facts* (what characterizes "frontier" growth?)
- **Weeks 2–3**: *Neoclassical models*
- **Week 4**: *Neoclassical models* $\leftrightarrow$ *Facts*

Kaldor facts (Kaldor, 1961)

What patterns characterize modern US growth?

Fact 5.1: Avg. growth of US GDPpc has been *positive* and relatively *constant*

Figure 1.5 Real GDP per Capita in the United States, 1870–2019



SOURCE: Author's calculations from Bolt and van Zanden (2020).

- likewise for GDP per *worker* ("labor productivity")

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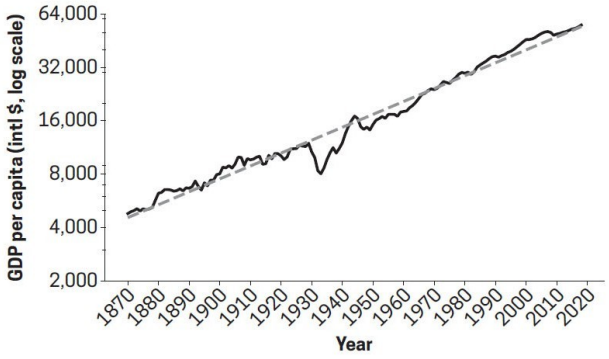
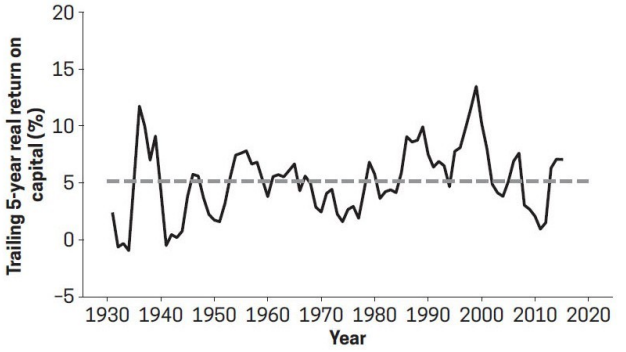


SOURCE: Author's calculations from Bolt and van Zanden (2020).

- likewise for GDP per *worker* ("labor productivity")
- ***capital* per worker** also grows over time at roughly *same* rate
  → capital-output ratio *constant*

Fact 5.2: The real rate of return on capital shows no trend

Figure 1.6 Real Rate of Return on Capital in the United States, 1930–2019

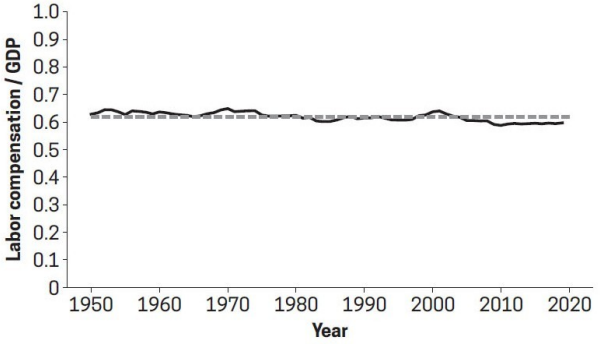


SOURCE: Author's calculations from Jordà et al. (2019). The grey dashed line represents the average return over the entire period, 5.1 percent.

- source: Jordà et al. (2019)
- "capital": risk-free government bonds, housing, equities, ...
- 5-year trailing real rate of return

Fact 5.3: The share of GDP earned by labor shows no trend

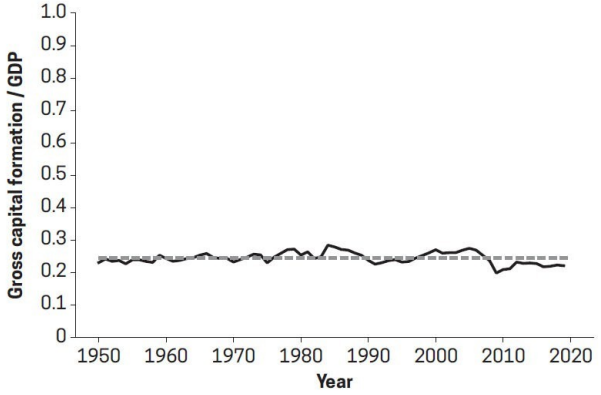
Figure 1.7 Labor Compensation as a Share of GDP in the United States, 1948–2019



SOURCE: Author's calculations from Penn World Tables v10.0 (Feenstra, Inklaar, and Timmer, 2015).

Fact 5.4: The share of GDP spent on (gross) investment shows no trend

Figure 1.8 Gross Capital Formation as a Share of GDP in the United States, 1948–2019



SOURCE: Author's calculations from Penn World Tables v10.0 (Feenstra, Inklaar, and Timmer, 2015).

- gross I: new K + replacement

A preview of the neoclassical model

In an economy where capital (K) and labor (L) are the only inputs, ...

1. output per worker ($y = Y/L$) should grow at a constant rate (g_y) [#5.1]
2. capital per worker ($k = K/L$) should grow at a constant rate (g_k) [#5.1 (capital)]
3. the capital-output ratio (K/Y) should be constant $\rightarrow g_k = g_y$ [#5.1 (capital)]
4. the rate of return on capital (r) should be constant [#5.2]
5. the share of income going to labor (wL/Y) should be constant [#5.3]
6. the share of expenditure going to capital (s) should be constant [#5.4]
7. wages (w) should grow at the same rate as output per worker [#5.1 + #5.3]

Are the Kaldor "facts" still *facts*?

- **Some deviations have been documented** (Herrendorf, Rogerson, and Valentinyi, 2019)...
  - the growth rates of real GDP per worker and of real capital per worker have slowed down in the US and the UK since the 1970s
  - the capital-to-output ratio has increased in the UK
  - the share of income paid to labor has decreased in the US since 1990

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  - the capital-to-output ratio has increased in the UK
  - the share of income paid to labor has decreased in the US since 1990**?**
- **The "fall" of the labor share has been hotly debated** (Grossman and Oberfield, 2022):
  - falling rel. price of investment goods b/c ICT (Karabarbounis and Neiman, 2014)
  - rising profits b/c market power (De Loecker, Eeckhout, and Unger, 2020)
  - rising "factorless income" (Karabarbounis and Neiman, 2019)
  - change in national accounts (Koh, Santaeulàlia-Llopis, and Zheng, 2020)
  - ...

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  - change in national accounts (Koh, Santaeulàlia-Llopis, and Zheng, 2020)
  - ...
- **...as has the growth slowdown—Week 10!**

“New” Kaldor facts (Jones and Romer, 2010)

What other patterns characterize modern growth?

JR Fact 1: Increases in the extent of the market

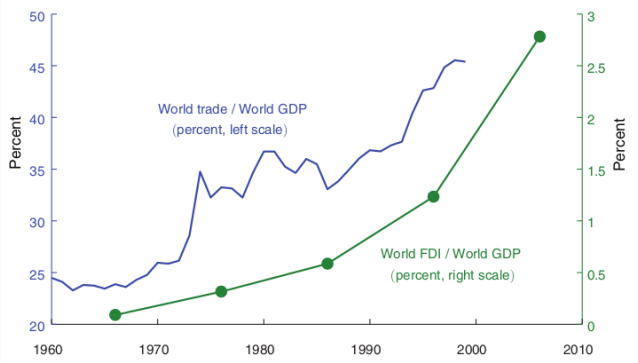

FIGURE 1. THE RISE IN GLOBALIZATION

Note: World trade is the sum of world exports and imports as a share of world GDP from the Penn World Tables 6.1. FDI as a share of GDP is from the World Bank's *World Development Indicators*.

Increased flows of goods, ideas, finance, and people—via globalization, as well as urbanization—have increased the extent of the market for all workers and consumers.

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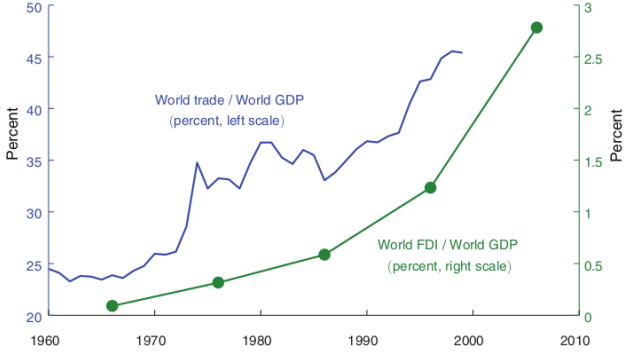

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Not just trade and FDI...

- 30pp. drop in share of US patents to US grantees → more to ROW
- urbanization (30% in 1950 → 70% in 2050)

JR Fact 2: Accelerating growth

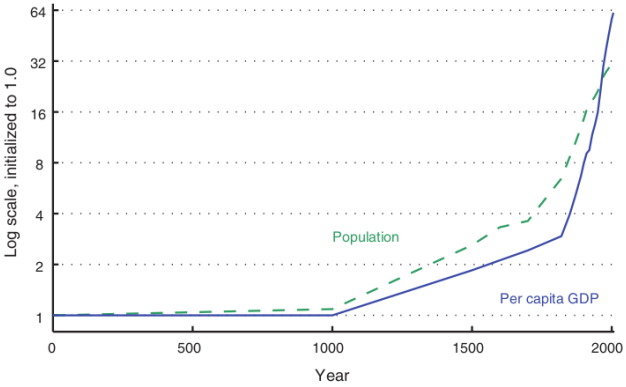

FIGURE 2. POPULATION AND PER CAPITA GDP OVER THE VERY LONG RUN

Notes: Population and GDP per capita for "the West," defined as the sum of the United States and 12 western European countries. Both series are normalized to take the value 1.0 in the initial year, 1 AD.

Source: Maddison (2008).

For thousands of years, growth in both population and per capita GDP has accelerated, rising from virtually zero to the relatively rapid rates observed in the last century.

(notice the log scale!)

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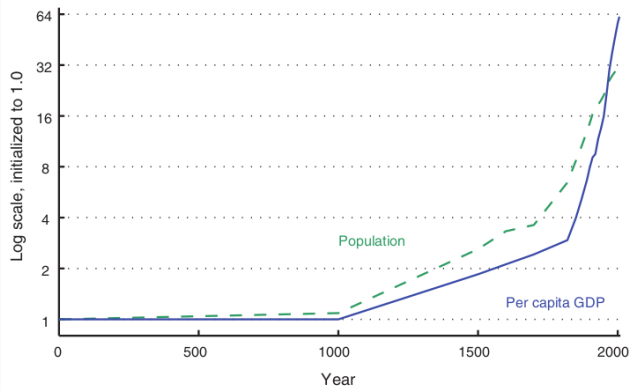

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- Kremer (1993) on world pop.
- Nordhaus (1997) on "price of light"

(notice the log scale!)

JR Fact 3: More variation in modern growth rates *away* from the frontier

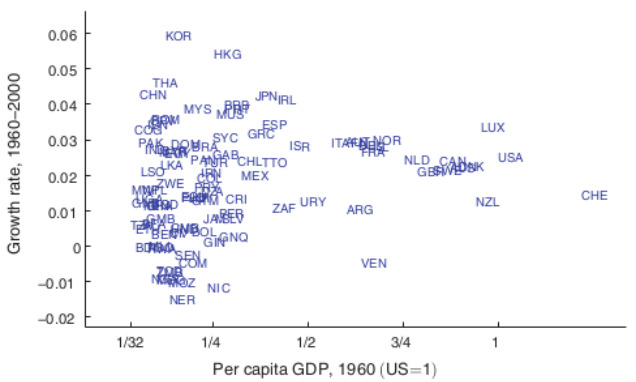

FIGURE 3. GROWTH VARIATION AND DISTANCE FROM THE FRONTIER

Source: Penn World Tables 6.1.

Can you spot our "miracles" and "disasters"?

JR Fact 4: Large income *and* TFP differences

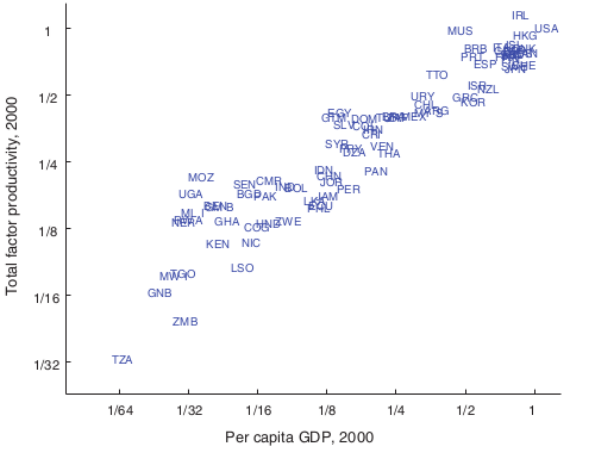

FIGURE 4. LARGE INCOME AND TFP DIFFERENCES

Notes: Both TFP and per capita GDP are normalized so that the US values are 1.0. TFP is reported in "labor-augmenting" form and is constructed following the methodology of Hall and Jones (1999) using the Penn World Tables 6.1 and the education data of Barro and Jong-Wha Lee (2000).

*Differences in measured inputs explain **less than half** of the enormous cross-country differences in per capita GDP.*

(**Week 4**: how to measure TFP)

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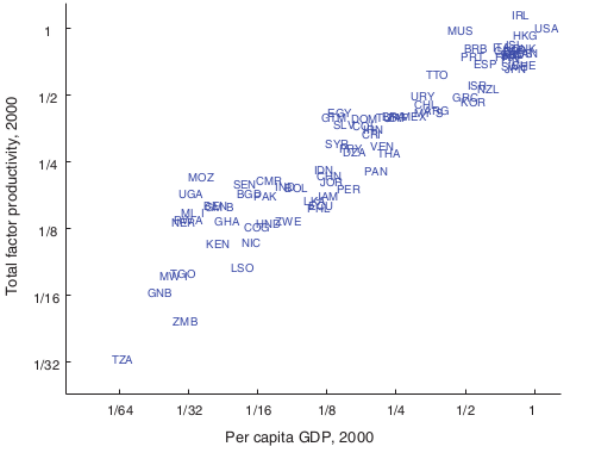

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- not just fewer inputs, but worse at using
- w/ JR #3: big gaps, but can close fast

(**Week 4**: how to measure TFP)

JR Fact 5: Increases in human capital per worker

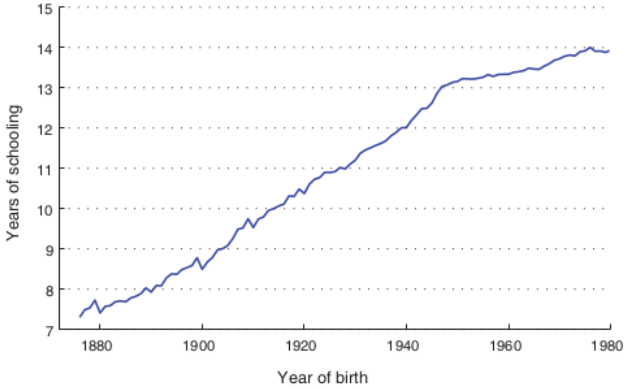


FIGURE 5. YEARS OF SCHOOLING BY BIRTH COHORT, UNITED STATES

Source: Claudia Goldin and Lawrence F. Katz (2007), Figure 7.

- for LF, avg. edu +1 year per decade
- cf. Kaldor on *physical* capital per worker

JR Fact 6: Long-run stability of *relative* wages

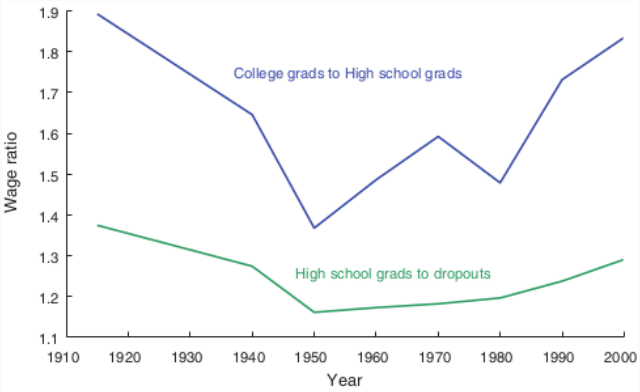
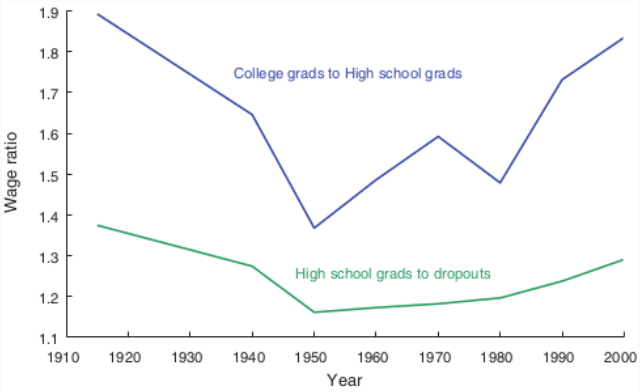


FIGURE 6. THE US COLLEGE AND HIGH SCHOOL WAGE PREMIUMS

Source: Goldin and Katz (2008), Table D1.

The rising quantity of human capital relative to unskilled labor has not been matched by a sustained decline in its relative price.

JR Fact 6: Long-run stability of *relative* wages



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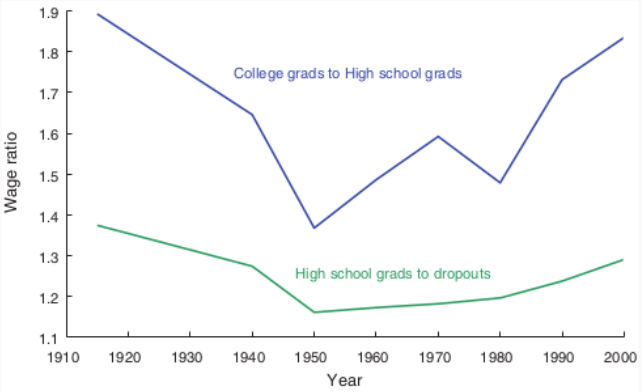

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- cf. Kaldor on constant r despite K/L growth
- suggests skill is more in demand, too (Katz and Murphy, 1992)
- *still true?* since 1980s, big vs. small cities (Eckert, Ganapati, and Walsh, 2022)

Recap + next week

- **Kaldor facts** make precise predictions about model outcomes:
  1. output per worker ($y = Y/L$) should grow at a constant rate (g_y)
  2. capital per worker ($k = K/L$) should grow at a constant rate (g_k)
  3. the capital-output ratio (K/Y) should be constant $\rightarrow g_k = g_y$
  4. the rate of return on capital (r) should be constant
  5. the share of income going to labor (wL/Y) should be constant
  6. the share of expenditure going to capital (s) should be constant
  7. wages (w) should grow at the same rate as output per worker
- first, we'll develop the **neoclassical models** to match these facts [**Weeks 2–3**]
- later, we'll return to the **"new" Kaldor facts** to try to match them, too [**Weeks 5–9**]

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