Chapter 2: A Framework for Macroeconomics

Graduate Macroeconomics Slides

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Outline

- Introduction and Main Goals
- The Facts and Interpretations: Real Aggregates
- Growth Accounting
- The Neoclassical Dynamic System
- Stepping-Stone to the Rest of the Text

Chapter Overview

- Provide an overview of key macroeconomic time series (mainly U.S. data).
- Introduce the **neoclassical growth framework** (Solow-type model).
- Discuss the role of technology, capital, and labor in driving growth.
- Present "growth accounting" and examine how it decomposes sources of growth.
- Preview how this framework extends to policy analysis and dynamic general equilibrium.

Objectives of Chapter 2

- **Identify** core empirical regularities ("Kaldor facts"):
  - Steady growth in output per capita.
  - Roughly constant capital–output ratio.
  - Stable factor income shares, etc.
- **Develop** the aggregate production function viewpoint.
- **Motivate** the Solow growth model and the concept of balanced growth.
- **Introduce** the idea of *growth accounting* and TFP.
- **Preview** how households' saving and labor-supply decisions can be rationalized.

The Facts: Real Aggregates

- We begin by documenting key long-run properties of output, capital, labor, and productivity.
- Time series emphasize broad trends (rather than just short-run fluctuations).
- Much of the data are from U.S. sources (FRED, Maddison Project, etc.).
- Similar patterns hold for many advanced economies.

Output Grows Steadily

- A striking fact: **U.S. real GDP per capita** has grown at a nearly constant rate for over a century.
- Historical data from Maddison Project show:

$$\log(\text{GDP per capita}) \approx \text{linear trend over time.}$$

- Short-run recessions (e.g., Great Depression, Great Recession) are small when viewed from a long-run perspective.
- We aim to *account* for this growth using a production-side perspective.

Figure: U.S. GDP Per Capita

- **Source:** Maddison Project dataset.
- Almost constant growth rate $\sim$ 1.8%–2.0% per year.
- Recessions are barely visible on a log scale.

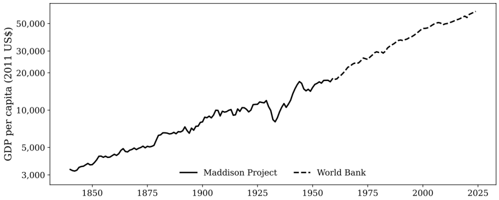

Figure 2.1: GDP per capita in the U.S.

Notes: The figure plots GDP per capita in 2011 prices in the U.S. 1840-2018.
Source: Maddison project.

Basic Inputs: Capital

- Capital accumulation is a central driver of growth.
- Empirically, the **capital–output ratio** in the U.S. hovers near 3 (fixed assets + consumer durables).
- Broader measures of **wealth** (including land, housing) yield a ratio $\sim$ 4–5 (Piketty, 2014).

Capital–Output Ratio in the U.S.

- **Capital–Output ratio** ≈ 3 post-WWII.
- Remarkably stable over time aside from major shocks (Great Depression).

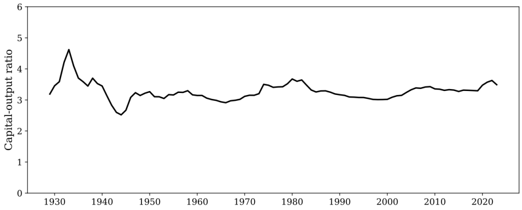

Figure 2.2: Capital-output ratio in the U.S., 1929-2022.

Source: FRED. Numerator: Current-Cost Net Stock of Fixed Assets and Consumer Durable Goods (K1WTOTL1ES000), Annual, Not Seasonally Adjusted, converted to billions of dollars. Denominator: Nominal GDP (GDPA), Annual, Not Seasonally Adjusted, reported in billions of dollars. The figure plots the ratio between fixed capital and consumer durables relative to the GDP.

Wealth–Output Ratio

- Wealth includes broader assets: real estate, land, etc.
- U.S. **wealth–output** ratio ≈ 4–5 over long horizons (Piketty, 2014).
- Composition of wealth changes over time: e.g., share of housing has risen.

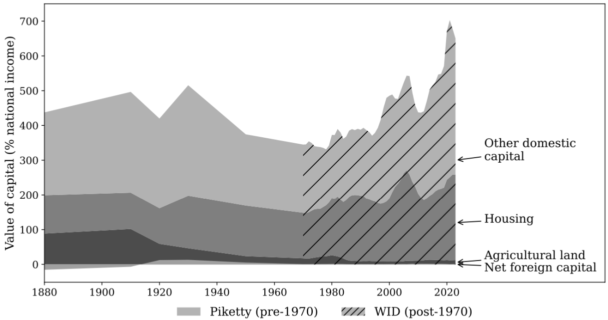

Figure 2.3: Wealth-output ratio in the U.S.

Source: Piketty (2014), Chapter 4, Figure 4.10[3].

The Price of Capital (Rental Rate, Returns)

- Market **rental** data are limited historically.
- Alternatively measure *cost of capital* via:

$$r \approx \text{(stock-market returns), or } r = \text{interest rate} + \delta - \dot{p}_K,$$

- Long-run **real returns** show no strong trend.
- Short-run fluctuations are large, but long averages are roughly stable.

Long-Run Stock Market Returns

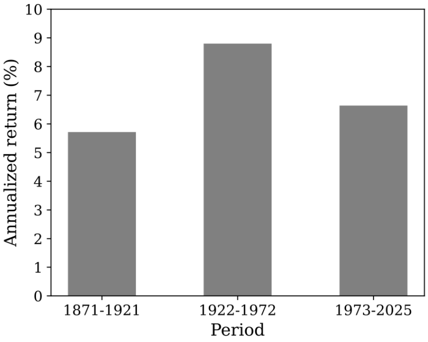

Figure 2.4: Return on capital.

Source: Shiller (2000). Data is annual, geometrically compounded returns to U.S. stock markets[5].

Source: Robert Shiller's online data.

- Averages over long periods: no obvious drift.

Labor Input: Hours Worked

- Hours per week (age 14+ or 16+) have declined since early 1900s.
- Post-WWII: hours per adult show relatively **no strong trend** in the U.S.
- Large cyclical swings (e.g., Great Depression).
- Unemployment fluctuation is a key driver of these swings.

Hours Worked

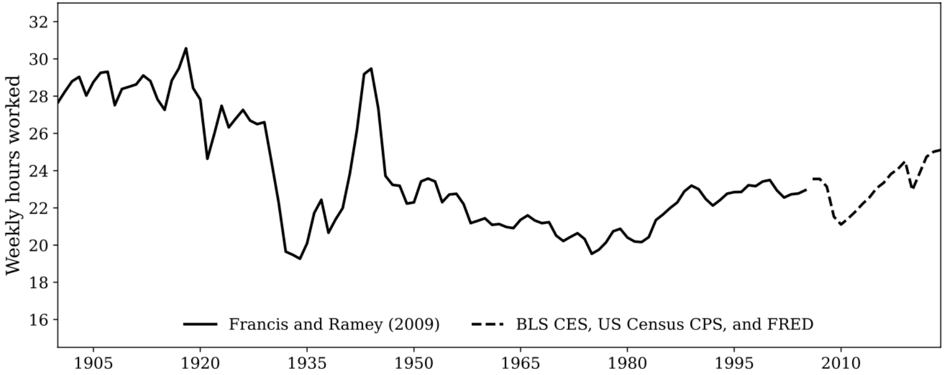

Figure 2.5: Average weekly hours worked in the U.S. (age 14+).

Source: Ramey and Francis (2009)[7].

Historical Hours and Wages

- **Hours** (Manufacturing) declined ∼50% since 1800s.
- Real **wages** grow at about the same rate as output, ∼ 2%.
- Over long horizons, wage share of income is stable.

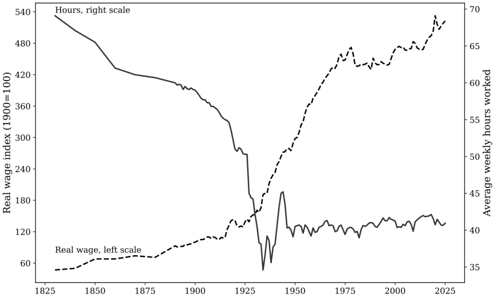

Figure 2.6: Average weekly hours worked in the U.S. (manufacturing).

Sources: Period 1830-1880: Whaples (1990), Table 2.1. Period 1890-1970: Bureau (1975) Series 765 and 803. Period 1970-2023: FRED, monthly series AWHMAN, annualized. Wage data source: Period 1830-1888: Williamson (1995) Table A1.1, (1900=100). Period 1890-2023: FRED, quarterly series LES1252881600Q, annualized (1982-84 CPI Adjusted Dollars) **Note:** Converted wage index in 1982-84 dollars from FRED to 1900=100 index by multiplying the FRED series by the ratio of wage index in 1983 from Williamson (1995) with wage index in 1983 from the FRED.

Taking Stock: A “Neoclassical” Picture

- Capital–output ratio $\approx$ constant
- Labor does **not** vanish, despite rising wages
- Real interest rate stable
- Suggests decreasing marginal returns to each input (“neoclassical”):

$$F(K, L) \quad \text{with} \quad F_K > 0, F_{KK} < 0, \ldots$$

- (Solow, 1956) emphasized **labor-augmenting** technological progress to reconcile these facts.

Growth Accounting (Solow, 1957)

- Decompose output growth into contributions from:

$$Y_t = F(K_t, L_t, t).$$

- Under perfect competition and constant returns:

$$\frac{\dot{Y}_t}{Y_t} = \underbrace{\frac{\partial F/\partial t}{F}}_{\text{Solow residual}} + \alpha\frac{\dot{K}_t}{K_t} + (1-\alpha)\frac{\dot{L}_t}{L_t}.$$

- The residual captures shifts in technology (TFP).

Hicks-Neutral vs. Labor-Augmenting

- Often assume $F_t(K, L) = Z_t F(K, L)$ (**Hicks-neutral**).

$$\dot{y}_t / y_t = \dot{Z}_t / Z_t + \alpha(\dot{k}_t / k_t).$$

- Or **labor-augmenting**: $F(K, Z_t L)$.

$$\text{Solow residual} \;=\; (1-\alpha)\frac{\dot{Z}_t}{Z_t}.$$

- Data often favor a labor-augmenting representation for balanced growth.

Evidence on Productivity Growth

- **Labor Productivity** grows at $\sim$ 2% per year in the U.S.
- **TFP** also grows, but typically at a slightly lower rate.
- Periods of faster TFP growth (1950s–60s) vs. slower (1970s–80s, post-2000).

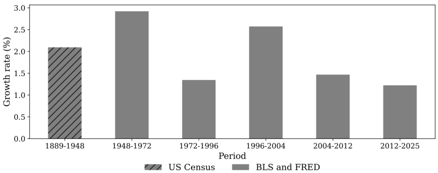

Figure 2.7: Labor productivity in the U.S., sub-periods.

Source: Period 1889-1948: Bureau (1975), Part II, Series W 1, pp. 948.. Period 1948-2023: U.S. Bureau of Labor Statistics and FRED Quarterly total economy hours worked (in billions of hours) series are from BLS "Hours Worked in Total U.S. Economy and Subsectors." Quarterly real GDP (in billions of 2017 dollars) is from FRED Real gross domestic product (GDPC1).
Note 1: Data constructed following Gordon (2012)[10] Percentage logarithmic growth rates are calculated between the first quarter of each of the listed years, e.g., 1948:Q1 to 1972:Q1. To extend the series back from 1948 to 1891, annual NIPA data on real GDP prior to 1929 are ratio-linked to the real GDP data of Balke and Gordon (1989), and the BLS hours data prior to 1948 are ratio-linked to the man-hours data of Kendrick (1961) (see pp. 330-32)." Unlike Gordon (2012), to extend the series back from 1948, we used Census Bureau Hisitorical Statistics. Then the series for both periods are then re-indexed to 1948=100.

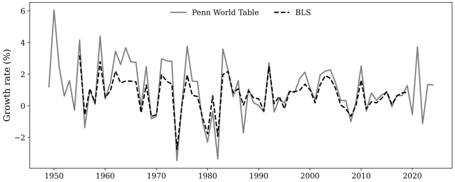

Figure 2.9: TFP in the U.S., two measures.

Sources: Series 1: FRED, "Total Factor Productivity at Constant National Prices for United States (RTFPNAUSA632NRUG)," reported by Penn World Tables. Available for 1955-2019 Series 2: Utilization-adjusted quarterly TFP series for the U.S. Business Sector, 1948-2022 from Fernald (2012).

TFP and Labor Productivity

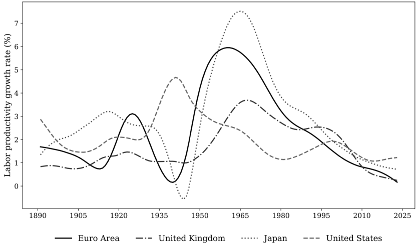

Figure 2.8: Labor productivity for a selection of countries.

Note: Hodrick-Prescott-filtered annual growth of labor productivity per hours worked. Following Bergeaud et al. (2016), we focus on 30-year cycles, which implies an HP-filter value of 500 for lambda.

Labor Productivity for a Selection of Countries

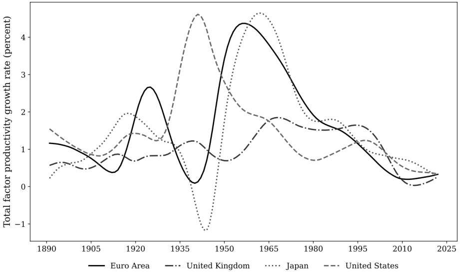

Figure 2.10: Historical TFP for a broader set of countries.

Source: Following Bergeaud et al. (2016), we focus on 30-year cycles, which implies an HP-filter value of 500 for lambda. TFP growth rate for years after 2012 is from the OECD data series Multifactor productivity. Aggregate TFP growth rate for EU19 countries is calculated by taking a weighted average of the growth rates of each country where weights are the share of each country in the total GDP of the EU19 in each year. Data obtained from OECD Gross domestic product (GDP).

Historical TFP for a Broader Set of Countries

Sources: Penn World Tables, (Fernald, 2012), FRED, etc.

The Dynamic System (Solow Model)

- Capital evolves via

$$K_{t+1} = (1-\delta)K_t + I_t, \quad \text{where } I_t = sY_t.$$

- At steady state (balanced growth), K_t, Y_t, C_t all grow at the same rate γ (the rate of TFP-labor efficiency growth).

Mechanics of Balanced Growth

- Normalize $k_t = K_t/(A_t L_t)$ with A_t representing labor-augmenting tech.
- Solow's key insight:
$$\dot{k}_t = sf(k_t) - (n + g + \delta)k_t,$$
converges to a unique k^*.
- "Why is K/Y stable at ≈ 3?"
$\implies$ Because the system has a **convergence property** to a steady state ratio.

Input Shares

- Under a Cobb–Douglas production function $Y = K^{\alpha}(AL)^{1-\alpha}$:

$$\alpha \approx \frac{rK}{Y}, \quad 1-\alpha \approx \frac{wL}{Y}.$$

- Empirically, **capital share** ~ 0.3–0.4, **labor share** ~ 0.6–0.7.
- Historical data show near-constancy for much of the 20th century, some decline in the labor share post-1990s in many countries.

Figures: TFP and Labor Productivity

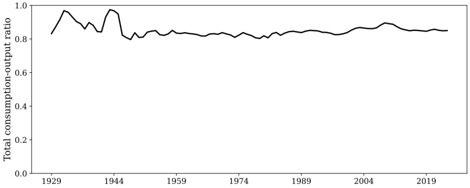

Figure 2.11: Ratio of total consumption to output.

Source: BEA, NIPA Table 1.1.5 Calculated as the ratio of two series: Numerator: Sum of Personal consumption expenditures (DPCERC) and Government consumption expenditures and gross investment (A822RC), Annual, Millions of dollars Denominator: Gross domestic product (A191RC), Annual, Millions of dollars The figure plots the ratio between total consumption expenditures (sum of all goods and services) relative to the GDP.

Ratio of Total Consumption to Output

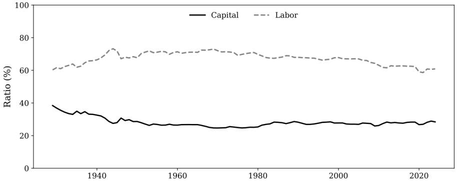

Figure 2.12: U.S. factor shares over time.

Source: NIPA Table 2.1 Factor shares are calculated as compensation of employees and capital income divided by personal income. Capital income is calculated as proprietors income with inventory valuation and capital consumption adjustments plus rental income of persons with capital consumption adjustment plus personal income receipts on assets.

US Factor Shares Over Time

Sources: Penn World Tables, (Fernald, 2012), FRED, etc.

Summing Up the Stylized Facts

1. Output per capita grows at a roughly constant rate.
2. Capital–output ratio is roughly constant.
3. Consumption–output ratio roughly constant.
4. Real wages grow at the rate of output; real interest rate is roughly constant.
5. Factor shares do not show large trends (until recently).
6. Hours per capita stable (in postwar U.S.) or slightly declining over the century.

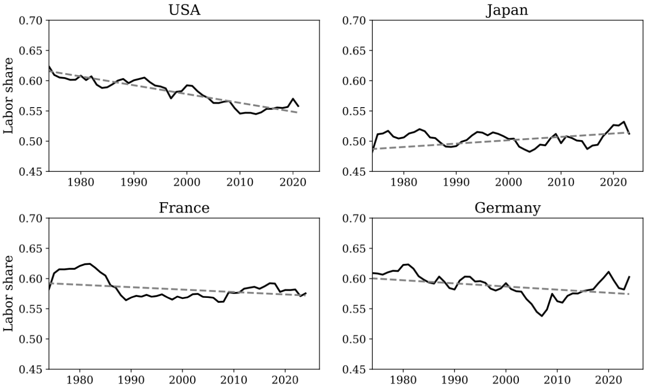

Figure 2.13: Labor share.

Source: Karabarbounis and Neiman (2014). **Note**: No corporate labor share data is available for Japan, thus total labor share is plotted instead.

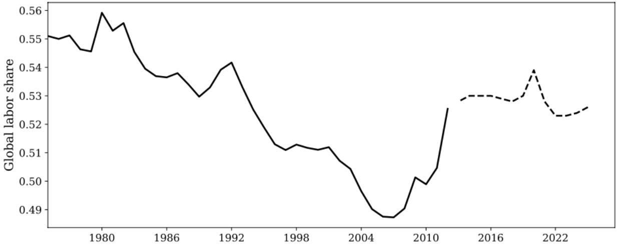

Figure 2.14: Global labor share.

Source: Solid line (1975-2012): Karabarbounis and Neiman (2014). Global labor share is the average of country-level labor shares weighted by GDP measured in US dollars at market exchange rates. Dashed line (2013-2025): International Labour Organization (ILO), Sustainable Development Goals Indicator 10.4.1, world.

Rationalizing Saving & Labor Supply

- The Solow model takes s as exogenous. But in modern macro, s (the saving rate) comes from **optimization**.
- Households maximize intertemporal utility:

$$\max_{\{c_t\}} \sum_{t=0}^{\infty} \beta^t \, u(c_t, \ell_t).$$

- Consumption vs. saving leads to the **Euler Equation**:

$$u_c'(c_t) = \beta(1 + r_{t+1}) \, u_c'(c_{t+1}).$$

- Balanced growth requires specific functional forms for u (e.g. CRRA).

The Euler Equation in Steady Growth

$$\underbrace{u'_c(c_t)}_{\text{MU of current consumption}} = \beta(1 + r_{t+1}) \underbrace{u'_c(c_{t+1})}_{\text{MU of future consumption}} .$$

- Constant r implies constant growth of c if $u(\cdot)$ is **log** or **CRRA** type.
- This is consistent with stable saving rates and balanced growth.

Leisure and Labor Supply

- Similarly, if households choose hours h_t:

$$u'_h(c_t, h_t) = w_t \, u'_c(c_t, h_t),$$

- Balanced growth typically requires **labor-augmenting** technical change.
- Empirically in the U.S., hours have not trended strongly in the postwar era, suggesting particular preference forms (e.g. additive-separable CRRA in consumption and leisure).

Implications for Macro Theory

- Households' **optimal choices** of saving and labor can rationalize stable ratios if:
  - Preferences are CRRA-type in consumption,
  - Technological progress is labor-augmenting,
  - Markets are **competitive**, so factor prices reflect marginal products.
- This leads to a stable balanced-growth path with convergence features.

Forthcoming Chapters

- Chapters 3–9: **Core Macro Tools**
  - Solow model, dynamic optimization, general equilibrium, welfare, uncertainty.
- Chapters 10–23: **Applications and Extensions**
  - Consumption, labor markets, growth, business cycles, monetary/fiscal policy, heterogeneity, international macro, etc.
- Chapter 24: **Sustainability and Climate Change**

Upcoming Chapter: Solow Growth Model

- We will **formalize** the Solow model's convergence argument.
- Explore **transitional dynamics** vs. balanced growth path.
- Provide **quantitative** exercises and calibrations.
- Set the stage for **micro-founded** consumption choices (Ramsey model) in subsequent chapters.

Chapter Highlights

- Empirical macro facts strongly suggest stable **neoclassical** patterns.
- **Growth accounting** reveals technology (TFP) as a major driver.
- **Capital accumulation** complements labor and TFP to sustain growth.
- Balanced growth requires **labor-augmenting** technology in the simplest setups.
- Household **optimizing behavior** (saving, labor) underpins these outcomes in modern theory.

Critical Reflections

- Are factor shares truly stable in the long run, or is there a *secular shift*?
- What are the roles of **human capital** and **institutions** in growth?
- How do **heterogeneous agents** affect aggregate saving behavior?
- Endogenous technological change: can we model the micro-foundations of TFP growth?
- These questions will be addressed in future chapters.

References

Fernald, J. (2012). A quarterly, utilization-adjusted series on total factor productivity. *Working Paper Series 2012-19*.

Piketty, T. (2014). *Capital in the Twenty-First Century*. Harvard University Press.

Solow, R. M. (1956). A contribution to the theory of economic growth. *The Quarterly Journal of Economics*, pages 65–94.

Solow, R. M. (1957). Technical change and the aggregate production function. *The Review of Economics and Statistics*, pages 312–320.

Thank you!

Questions or comments?

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