Week 4

Human Capital in the Solow Model

- Distinction between knowledge capital and human capital
    - Latter is rival and embodied in worker
    - Former relates to nonrival ideas that all share (costlessly)
- Model is motivated by the dominant question: "Why are some countries richer than others?"
    - Solow model says differences in k
        - Not plausible (as Romer shows late in Ch 1)
    - Mankiw, Romer, & Weil: differences in physical and human capital
        - They argue this is plausible; others disagree
    - Differences in A
        - Why would technology be different across countries?
        - Barriers (legal and otherwise) to adoption
        - Non-applicability of advanced technologies in poor countries (climate, unreliable physical infrastructure, etc.)
    - Differences in "social infrastructure"
        - We'll have more to say about this soon
- How to incorporate human capital into model?
    - Many alternative ways; Romer does one (and others in problems 4.8 and 4.9)
    - How does economy "produce" human capital?
        - Process of education or training has two major costs: teachers' time (for which they are paid) and students' time (for which they are not paid)
        - Can use a two-sector model with a production function for education using labor (teachers) and capital (schools) like the one for knowledge in the R&D model
        - Can just deduct some amount of a conglomerate "output" as being education in a one-sector model (like some output is physical capital rather than consumption). This is Romer's 4.8.
        - Can model the process as holding people out of the labor force during an education period. This is Romer's Section 4.1.
            - This doesn't model the cost of teachers and schools.
            - Note that forgone earnings may be higher than teacher/school costs at most schools (if maybe not at Reed)

Simple human-capital model setup

- Let $H(t) \equiv L(t)G(E)$ be the amount of human capital, which is the number of workers $L(t)$ times the amount of human capital per worker $G(E)$, where E is the average education level of current workers.
  - $G'(E) > 0$
  - $G(E) = e^{\phi E}$ is a commonly used functional form
  - We assume that in a steady state with education level E, people live T years, going to school for E years and working for $T - E$ years.
  - In general (but not in this model), human capital includes not just education but training, health and other "acquired" characteristics that affect labor productivity.
- $Y(t) = K(t)^{\alpha}\left[A(t)H(t)\right]^{1-\alpha}$
- $\dot{K}(t) = sY(t) - \delta K(t)$
- $\dot{A}(t) = gA(t)$
- $\dot{L}(t) = nL(t)$

Solving the model

- This model looks (and behaves) similarly to Solow model
- Define $k \equiv \frac{K}{AH} = \frac{K}{ALG(E)}$
- $\dot{k}(t) = sf\left(k(t)\right) - (n + g + \delta)k(t)$
- $\dot{k} = 0 \Rightarrow k = k^* = \left(\frac{s}{n + g + \delta}\right)^{\frac{1}{1-\alpha}}$
- How will a **change in *E*** affect the steady-state growth path?
  - Effects of E↑ (or G↑) on K and Y are equivalent to increase in L
  - Economy moves to higher, parallel steady-state path
  - Level effect, but no growth effect
  - Y and Y/L are higher in steady-state
- But the important variable (living standards) here is Y/N, where N is total population
  - $\left(\frac{Y(t)}{N(t)}\right)^* = y^* A(t)G(E)\left(\frac{L(t)}{N(t)}\right)^*$ on the steady-state path
    - Increase in E does not affect y^* or $A(t)$
    - Increase in E raises $G(E)$
    - Increase in E lowers L/N because more people are in school and fewer in the labor force
    - What will be the net effect?
  - What is L/N?

- It seems like it should be $(T-E)/T$ since that is the ratio of working years to total life years for each individual
- That is correct if $n = 0$
- If the population is growing, then the cohort in education is larger than the cohort that is working.
- Romer (and Coursebook) shows that in steady state
$$\frac{L(t)}{N(t)} = \frac{e^{-nE} - e^{-nT}}{1 - e^{-nT}}$$
- It is intuitively clear (and mathematically easy) that $\frac{\partial(L/N)}{\partial E} < 0$

Dynamics of increase in E

- Initial effect lowers Y because fewer people in labor force but no immediate increase in the education of those who are working
- In steady state, the two effects noted above are in conflict and we don't know which will dominate
  - $$\frac{\partial(Y/N)}{\partial E} = \frac{\partial(Y/N)}{\partial E} + \frac{\partial(Y/N)}{\partial(L/N)}\frac{\partial(L/N)}{\partial E}$$
  - The first term depends mostly on $G'(E)$ and the second is negative.
  - If $G'(E)$ is large, then Y/N is likely to rise with an increase in E
  - This makes intuitive sense: if education is highly productive it will raise per-capita income; if it is not, then it drains people who could be working into useless education.

Growth Accounting

Origins and framework

- Effort first tried by Solow in late 1950s to decompose growth of GDP into components attributable to labor-force growth, capital-stock growth, and growth in "total-factor productivity."
  - We have no direct data on productivity, so it must be inferred as the part of GDP growth that cannot be explained through growth in inputs.
  - This is called the "Solow residual."
- Consider Cobb-Douglas approximation to production function with A brought outside of L term
  - $Y = AK^{\alpha}L^{1-\alpha}$ (With Cobb-Douglas, we can just define this A to be the old one to the $1/(1-\alpha)$ power to reconcile with the usual Harrod-neutral form
  - $\ln Y = \ln A + \alpha \ln(K) + (1-\alpha)\ln L$

- o $\frac{\dot{Y}}{Y} = \alpha \frac{\dot{K}}{K} + (1-\alpha)\frac{\dot{L}}{L} + \frac{\dot{A}}{A}$ defines Solow residual
  $\frac{\dot{A}}{A} = \frac{\dot{Y}}{Y} - \alpha \frac{\dot{K}}{K} - (1-\alpha)\frac{\dot{L}}{L}$

- We can approximate α as capital's share of GDP
- We can estimate the growth rates of GDP and of capital and labor input
  - Note the difficulty of measuring the capital stock
  - Should labor-force growth be adjusted for increase in human capital? (Probably)
- Growth accounting is the process of estimating all of these growth factors and calculating a Solow residual, which is "unexplained increase in TFP."

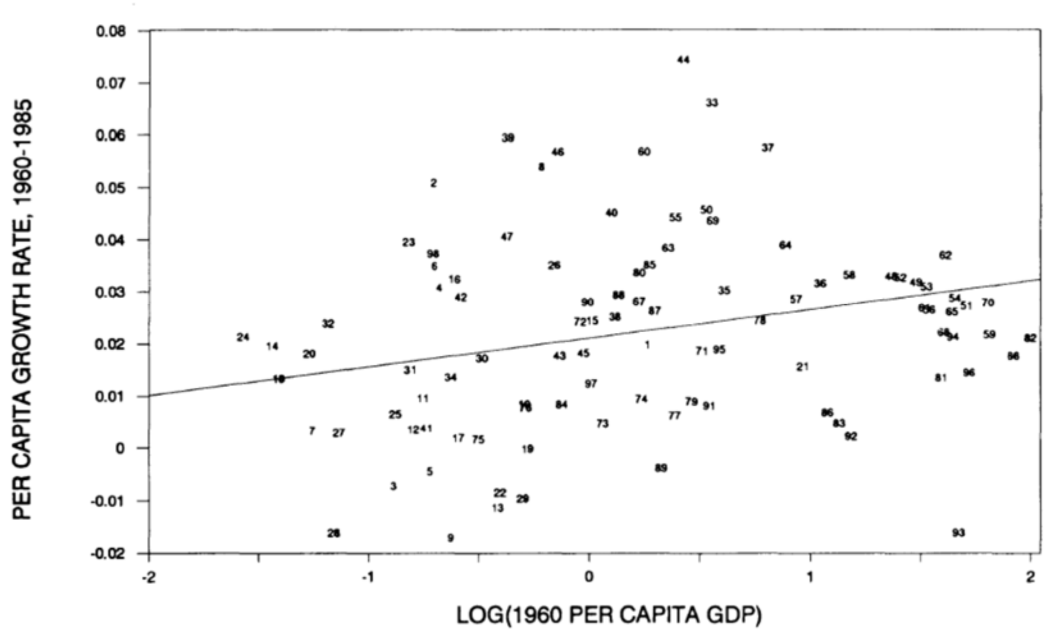
Examples of growth accounting

- Denison's table (Coursebook Ch 6, Table 1, p. 6-5)
  - Emphasize general magnitudes of capital, labor, and TFP contributions
  - Dramatic decline in TFP growth after 1973
    - Oil embargo and price increase
    - Globalization, rise of Japanese imports and decline of US manufacturing
    - Common to other Western countries (as we will see)
  - Led to endogenous-growth theory as economists tried to explain the decline in TFP growth
- Maddison's table (Coursebook Ch 6, Table 2, p. 6-6)
  - Differences and similarities across 6 advanced countries
    - Post-WWII "Golden Age" (convergence)
    - Where did Japan's growth come from?
    - All except UK had large decline after 1973.
- Other countries (Coursebook Ch 6, Table 3, p. 6-7)
  - Note differences in TFP growth across countries
    - Peru and Venezuela vs. other Latin American countries
    - Singapore vs. other Asian tigers
- Impact of information technology (Coursebook Ch 6, Table 4, p. 6-8)
  - Solow quip: "Computers are everywhere except in the productivity statistics."
  - Recovery in TFP growth since 1995 fueled by IT
  - Typical technological progression:
    - Productivity effects come decades after the technology is first implemented
    - S curve of adoption and productivity effect

Cross-Country Studies of Growth and Income Differences

Absolute vs. conditional convergence

- Solow and Ramsey models predict that (*ceteris paribus*) poorer countries will grow faster than rich ones and that countries will same parameters will end up with same level of per-capita income.
- Endogenous growth models often predict no convergence: gaps in per-capital income will remain over time even between countries with same parameters.
- Absolute convergence: $g_i(0,t) = \alpha - \beta y_i(0)$
    - Countries that start with higher income at 0 will grow more slowly between 0 and *t*
    - Plotting growth against initial per-capita income should yield downward-sloping curve.
    - Show states, regions from Barro & Sala-i-Martin (Coursebook, Ch 6, Figure 4, p. 6-19 and following figures)
    - Barro diagram for all countries: p. 21/242 of *JPE* paper
        - No evidence of convergence for large, heterogeneous sample of countries
    - Pritchett's evidence from extrapolating U.S. growth (1.5%) backward to 1870 from current level of per-capita income for poor countries: people could not have survived at the implied levels of income (<$100 per-capita GDP compared with $250 estimate for current cost of sufficient caloric intake to survive)



- Conditional convergence: $g_i(0,t) = \alpha - \beta y_i(0) + \gamma \mathbf{X}_i$
  - Countries with different values of **X** variables will converge to higher or lower growth paths, so convergence is "conditional" on having the same **X**
  - What variables should be in **X**?
    - Table 7 of Coursebook Ch 6 (p. 35) summarizes Sala-i-Martin's evidence from millions of regressions using a large pool of variables that others have proposed.
  - "Institutions" as determinants of growth
    - Democracy, rule of law, absence of corruption, prices reflect scarcity, absence of war, revolutions, coups, and assassinations, educated labor force, etc.
    - Abramovitz's "social capability" or what others have called "social infrastructure"
    - Does growth → wealth → good institutions or do good institutions → growth?
      - Acemoglu et al.: Instrumental variable of colonial survival rates to examine causality
        - Countries in which colonists survived in 1500 got good institutions and strong growth
        - Growth could not have caused the good institutions that far back
  - Other interesting hypotheses:
    - Ashraf & Galor: Genetic diversity encourages growth
    - Comin, Easterly, & Gong: Strong intertemporal persistence in technology adoption: 1000BC – 0AD, 0AD – 1500AD, and most of

the countries with most advanced technology in 1500AD are richest today.

Money in Growth Models

- How can we build a macro model without money?
  - "Classical dichotomy" says that real side operates independently of monetary forces: "money is a veil"
- How would we add money?
  - Need a reason to hold it
  - Balancing cost of making transactions with less money against forgone interest
- Definition of money
  - Means of payment or medium of exchange
  - M1 = narrow money (checking accounts and currency)
  - M2 = broader money (savings accounts, small CDs, etc.)
- Supply of money
  - Central bank controls issue of "monetary base"
  - Ratio of money supply to monetary base is money multiplier that depends on public's propensity to hold currency and banks' propensity to hold reserves
  - Central bank controls *B* and thus attempts to control *M*
- Demand for money
  - Balancing benefits (cheaper transactions) against costs (forgone interest)
  - $M^d = P \cdot L(Y, i, TC) = PY^{\eta} i^{\varepsilon} TC^{\xi}$
- Monetary equilibrium in a growth model
  - Suppose that Y grows at $n + g$
  - Central bank increases money supply at rate μ
  - In equilibrium: $\mu = \frac{\dot{M}^s}{M^s} = \frac{\dot{M}^d}{M^d} = \frac{\dot{P}}{P} + \eta\frac{\dot{Y}}{Y} + \varepsilon\frac{\dot{i}}{i} + \xi\frac{\dot{TC}}{TC}$
    - In steady state:
      - $\frac{\dot{P}}{P} = \pi$
      - $\frac{\dot{Y}}{Y} = n + g$
      - i and TC are unchanging
    - $\mu = \pi + \eta(g + n)$
    - Some evidence that $\eta = 1$, so $\pi = \mu - (n + g)$
    - If growth of money supply exceeds growth of money demand, inflation makes up the difference
  - Steady-state properties:
    - $\frac{\partial \pi}{\partial \mu} = 1$
    - $\frac{\partial \pi}{\partial (g + n)} = -\eta \approx -1$

- Note that we assume that the real economy affects monetary conditions (inflation) but not vice versa
- Change in interest rate?
    - If r↑ then (given π) i↑, so M^d↓, $M^d < M^s$, P↑ and W↑
    - Similar kind of adjustment occurs to raise or lower prices and wages after change in Y or M^s
    - Note that Y↑ implies P↓, which means that prices are countercyclical in RBC framework
- Roles of price in economy
    - Monetary role: aggregate P balances M^s and M^d
    - Resource allocation role: relative prices signal scarcity
        - This role is masked in RBC because there is only one good, but it is crucially important in microeconomics
- Can all prices adjust at once?
    - Our model suggests that it is a simple matter for P to move up or down
    - In a world with perfect information and perfect coordination, all prices could instantly adjust upward or downward
    - In the real world, there is no such coordination
        - Prices and wages may be sticky
        - Some may be stickier than others
        - This can lead to relative prices changes that alter resource allocation and cause inefficiency
- Keynesian models: stickiness of P and/or W
    - Prices in different markets adjust at different speeds
        - Stock market: very fast
        - Goods market: much slower
        - Labor market: probably very slow
    - If P cannot establish $M^s = M^d$ quickly, then other variables are likely to respond to this imbalance in the short run
    - For example, a change the interest rate could re-establish equilibrium between M^s and M^d immediately, whereas a change in P and W could take months or years
    - This is the essence of Keynesian model
- **Modeling strategy for second half of course:**
    - Start by examining behavior of economy with fixed prices/wages
    - Examine microeconomic basis for price/wage stickiness
    - (Consider empirical evidence on stickiness)