Economic Dynamics

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Lecture 3: October 19, 2017

Abstract

Last lecture presented Robert Solow's seminal growth model, including the solution, comparative static and dynamic analysis.
This lecture considers implications and extensions of Solow's model, such as the theory with technological progress, the idea of convergence, and empirical analysis.

Midterm Examination

- Date: **November 9, 2017, 12:15–13:30.**
- Past examinations will be made available on the home page, look at "Old News" at the bottom. Will post links in a more convenient place later.
- *Lecture will be held in 4th period, 13:45–15:00.*

Homework

My host is working. Unfortunately, the university has decided to block mail to that host from off-campus, **which seems to include `s.tsukuba.ac.jp`**. For most students there is no way to send mail there, and I don't know when this will get fixed. Send mail to `turnbull@sk.tsukuba.ac.jp`. The **Subject** field should be `"FH 27041 Homework #(hw number)"` in half-width Roman letters, where you replace the string `"(hw number)"` with the appropriate number. Without that exact Subject, my filter may miss your mail.

Please resend homeworks #1 and #2, which were never received (the university's filter apparently throws away your mail with no indication to you or to me).

Homeworks 3, 4, and 5 are at the end of Lecture 2 (updated 2018/10/18).

They are due next week on Friday.

Rich and Poor

- The central question of *development economics* is "Why Are (We) So Rich and (They) So Poor?"
  - Asking the question implies differences in economic status.
  - Why are there differences in economic status?
- Possible explanations:
  - Differing factor endowments (educated labor, natural resources).
  - Different social organization (*e.g.*, the market).
  - Different technology (engineers and installed plant).
- But no one factor explains everything well.

The Convergence Hypothesis

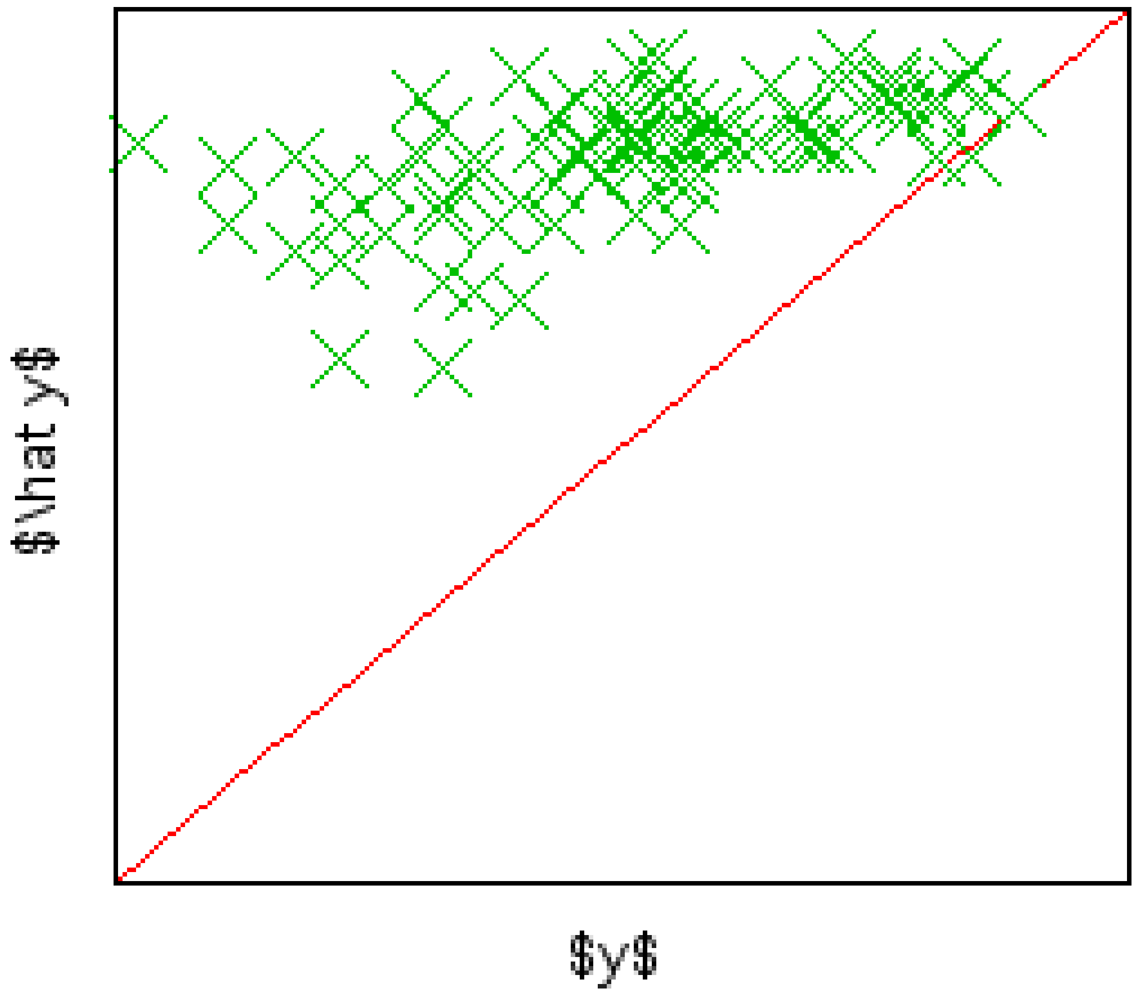
- The *convergence hypothesis* states that in the long run countries will *converge* to similar levels of per capita income, capital stock, and consumption.
  - Macro convergence will not occur, because populations differ.
- The convergence hypothesis depends on common values of f, d, n, and s.
  - f and d are transferable technological parameters.
  - The *demographic transition* is common experience: n should converge.
  - s depends on culture. However, policies to maximize per-capita consumption in the long run will induce the same value of s^* according to the Golden rule.
- Empirical justification for the convergence hypothesis:
  - Technology transfer is occurring.
  - Diminishing returns to capital implies poor countries have higher MP_K, attracting investment.
  - Low income countries are also far below k^*, implying high $\dot{k}$.

Transition Dynamics

- With poor medical care, birth rates and death rates are high, population growth rate low.
- With improvements in health, death rates drop quickly, resulting in high population growth, but this is followed by the demographic transition to low birth rates.
  - Advanced countries generally have population growth determined mostly by immigration rate.
- As economic welfare converges (the convergence hypothesis) the primary motivation for migration is removed, so convergence is self-stabilizing.
- Poor countries have higher growth rates
- Poor countries catch up in absolute terms

Cross-Section Comparison of Predicted Income

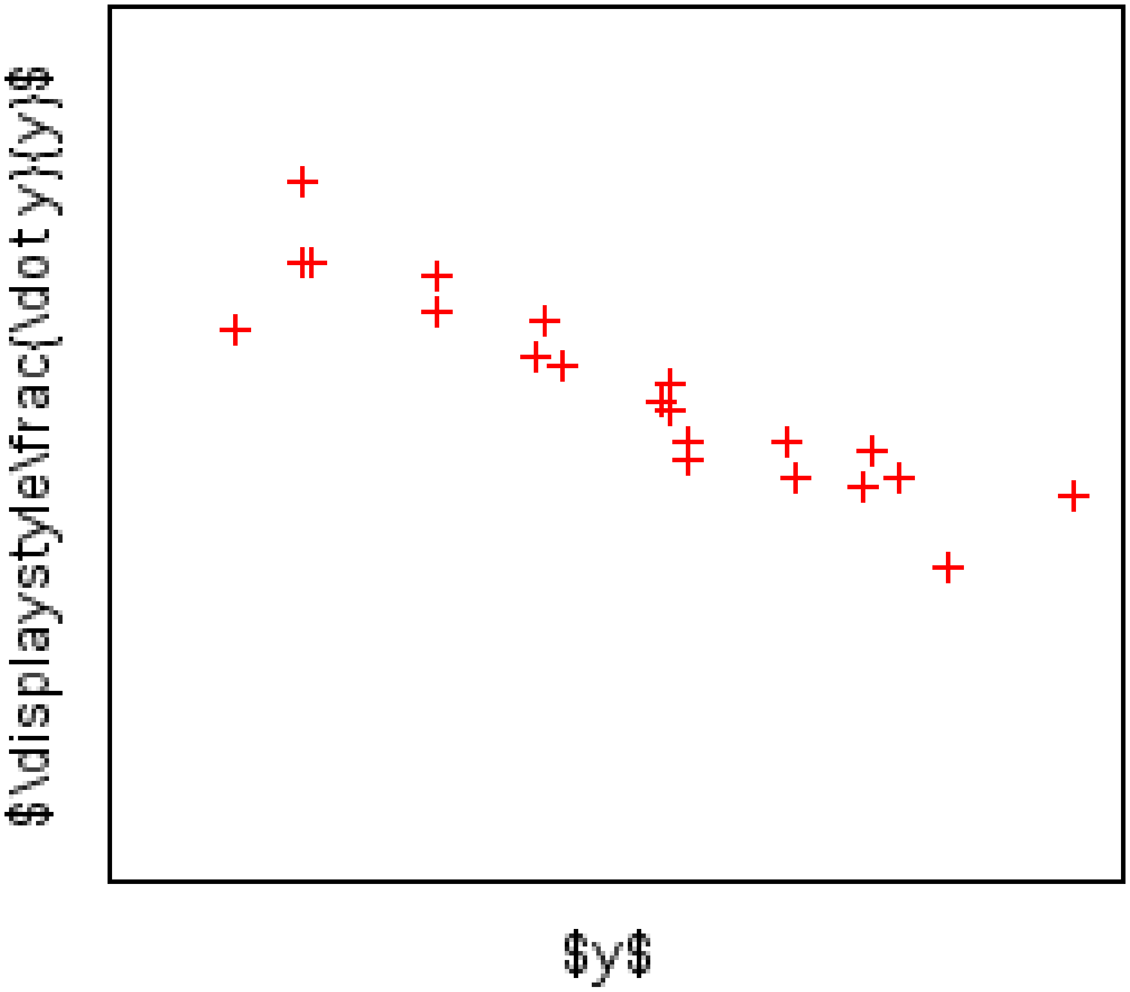
Estimate the production function $f(k)$, predict $\hat{y}$, and compare to y. Predictions are way too high for poor countries (inefficient use of capital).



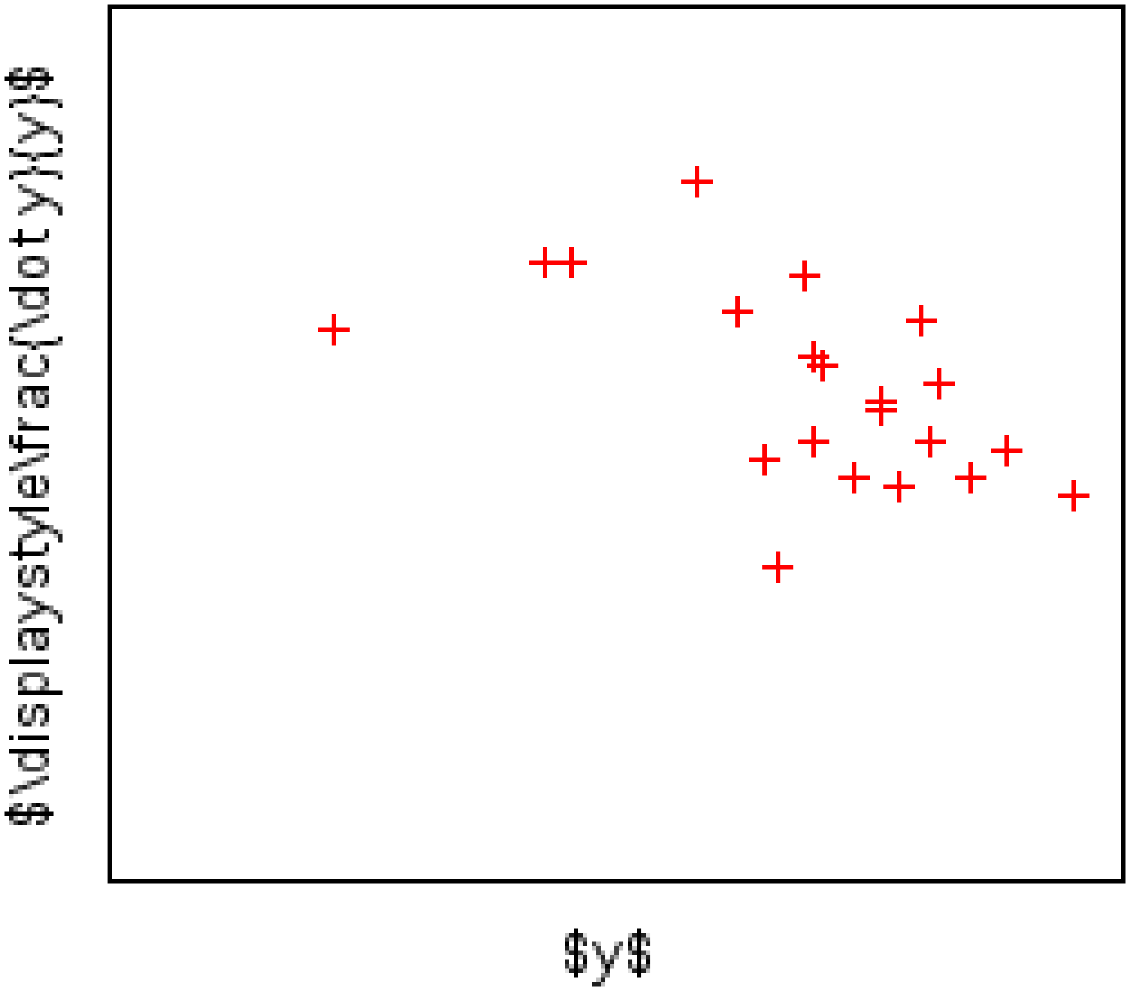
Empirical Evidence on Convergence

- Method: compare income per capita to growth rates, “poor grows faster” implies downward slope of plot
- Baumol showed convergence in OECD for 1870–1994, Fig. 3.3 (see also Fig. 3.4)
- A similar exercise works well for OECD 1960–90, but not for the world.
- Why not?
  - Jones, Fig. 3.2, suggests steady state growth model explains relative income patterns well.
  - Most differences are due to differences in savings rate, population growth, and “technology.” (Estimated TFP tends to rise with income.)

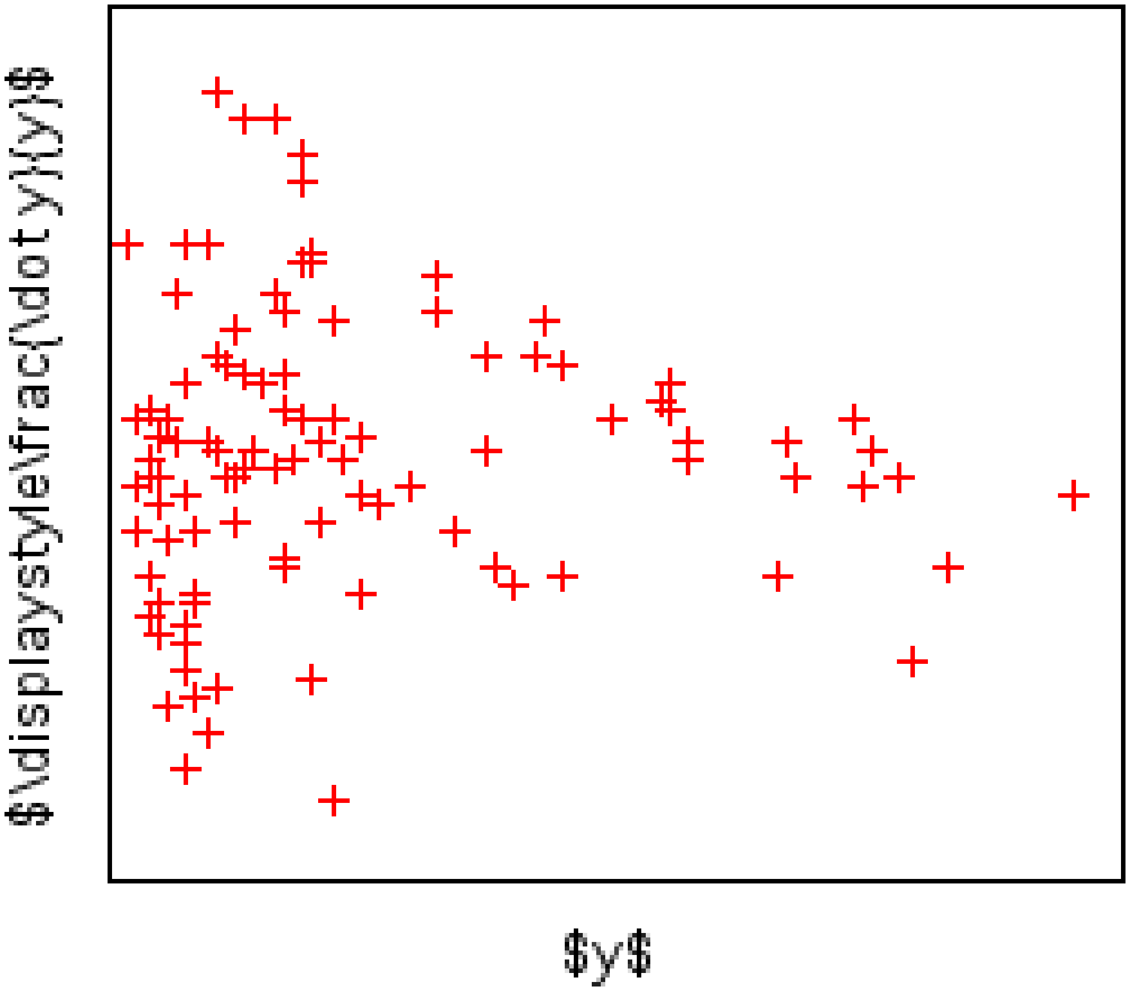
OECD Convergence 1960



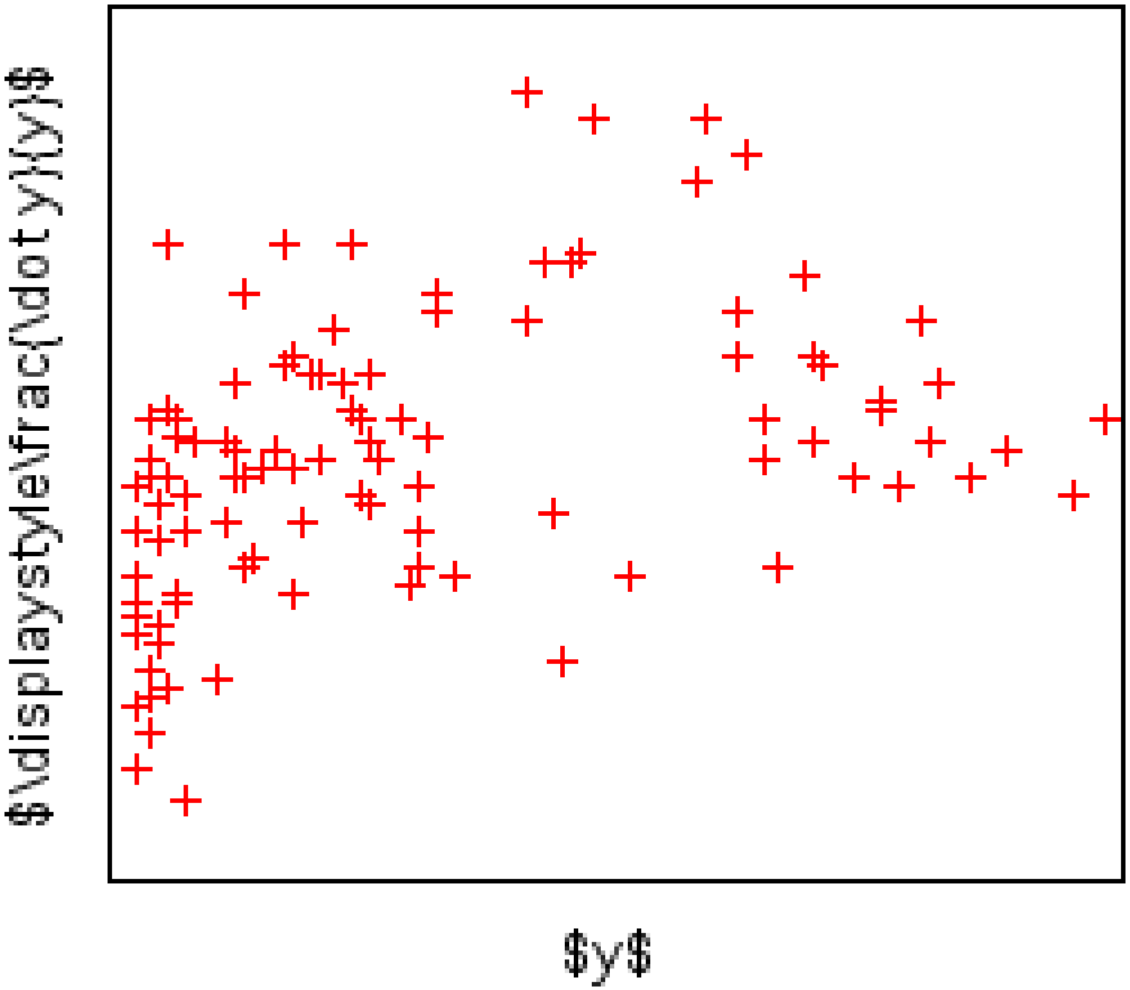
OECD Convergence 1990



World Non-convergence 1960



World Non-convergence 1990



A Standard of Comparison: The U.S.

- What does *typical long term growth* look like? Let's look at the best example of a mature economy, the U.S.'s.
  - growth takeoff around 1850 (like Japan)
  - no war damage to capital stock during the modern period (unique)
- The *real rate of return* to capital shows no upward or downward trend in the U.S., 1850–1990.
- The shares of capital and labor in income ($\frac{wL}{Y}$ *vs.* $\frac{rK}{Y}$) show no trend.
- This pattern of economic progress is called *balanced growth*, and it is consistent with Solow's model.
- *But* the average rate of output growth per worker is positive and seems constant over the period (Solow predicts zero).

Empirical Patterns of Growth: Other Patterns

These facts can't be analyzed in the Solow model because it has only one country.

- Growth in output is positively related to trade growth.
- Skilled and unskilled workers migrate from poor to rich countries. The former is a paradox: skills are "human capital" and poor countries have little capital. Returns to capital should be high in poor countries.
- In fact, until recently, capital of all kinds has tended to flow out of poor countries.
  - Conservatives argue that this is due to poor capital markets, and unstable and ineffective governments.

Partial explanations

For each of the following camparisons, ask

- which has the theoretical advantage? then
- which has had higher growth?

Resources: Argentina, Russia *v.* Japan The natural resources of Argentina or Russia are vastly greater than those of Japan in the 20th century.

Capitalism: "Tigers" *v.* USA Japan and the Asian "tigers" probably have more corruption, are definitely far less market-oriented (especially in the capital and labor markets), and have far more intrusive and obstructive bureaucracies than that of the U.S.

Technology: North *v.* South Advanced technology *is* connected with high growth rates. But it is still a puzzle why technology is not easily transferred to emerging economies.

Current research in economic growth theory, as well as in international busines and in management of technology, addresses these issues.

The Solow residual

- Recall that a stylized fact of U.S. economic growth is that per-worker output has grown at 1.5%–2% per year for around 150 years.
- Solow's model predicts 0. The difference is called "the (Solow) residual," which is a good name for it because it doesn't imply an explanation. Solow himself called it "a measure of our ignorance" (about the details of the mechanism of economic growth).
- Of course we know that in the modern age "technological progress" is occurring around us all the time.
- But how should *economics* model it? Can its rate be explained by economics, or is it some sort of arbitrary natural law like population growth from the point of view of economics?
- Economists have chosen to represent technological progress by *productivity improvements*.
  - This summary figure ignores actual innovations in favor of measuring economic effects. Compare the *cost function* for production.

Estimating the Production Function

- We assume a Cobb-Douglas production function:

$$Y = F(K, L) = AK^{\alpha}L^{1-\alpha}.$$

- A and α can be estimated using the linear regression specification:

$$\ln Y = \ln A + \alpha \ln K + (1 - \alpha) \ln L + \epsilon.$$

- In country-specific analysis, we use time-series analysis. A convenient specification is *Hicks-neutral* technological progress with $A = A_0 e^{\lambda t}$. Then the regression equation is

$$\ln Y = \ln A_0 + \lambda t + \alpha \ln K + (1 - \alpha) \ln L + \epsilon,$$

  which is very convenient.

  – Here the variables are *dated.* With technological progress, the production function is dated, and changes over time: $Y_t = F_t(K_t, L_t)$.

- In the "convergence" analysis, we use a cross-section estimation assuming all the countries have the same technology. (We could also use panel data, and assume common λ as well.)

Including Country-Specific Technology

- The next step in improving fit is to adjust country by country for differences in technology, using panel data. A *panel data* set is one where you have a time series for each individual, with each variable measured in the same way for all individuals.

- We simply estimate a separate coefficient A (total factor productivity) for each country i:

$$\ln Y = \ln A_i + \alpha \ln K + (1 - \alpha) \ln L + \epsilon$$

  α is still common across countries, but we allow for different levels of productivity.

Including Country-Specific Characteristics

The next step in improving fit is to adjust country by country for differences in saving behavior and human capital.

- Savings and fertility behavior is simple: just find out the gross savings rate s and labor force growth rate n for each country. These country-specific characteristics are just historical averages.

- It is convenient to use the Cobb-Douglas production function $F(K, L) = AK^{\alpha}L^{1-\alpha}$. We assume a common level of $\alpha = 0.3$, but allow each country to have a different A.
  - In a competitive economy, $\frac{rK}{Y} = \alpha$ and $\frac{wL}{Y} = 1 - \alpha$, so α is easy to estimate.

- Finally we adjust for "human capital" by assuming human capital can be measured by education u, and putting $\hat{L} = e^{\phi u}L$, and then $Y = F(K, \hat{L})$.

Production Function with Human Capital

	act	pred	s	u	n	$\hat{A}_{90}$
U.S.A.	1.00	1.00	0.210	11.8	0.009	1.00
W. Germany	0.80	0.83	0.245	8.5	0.003	1.02
Japan	0.61	0.71	0.338	8.5	0.006	0.76
France	0.82	0.85	0.252	6.5	0.005	1.28
U.K.	0.73	0.76	0.171	8.7	0.002	1.10

act and **pred** are the *actual* and *predicted* levels of output per worker relative to the U.S., **s** is the gross saving rate, **n** the labor force growth rate, and $\hat{A}_{90}$ the estimated productivity for 1990.

The figures for Japan and France are interesting:

- France's technology parameter is extremely high, much higher than the U.S., which is not plausible.
- Japan's is much too low.

Human Capital

- *Human capital* is the result of investment in skills and knowledge of workers. It is *capital* because it persists for the working life of the worker.
  - It comes in two types: *general* and *firm-specific*. This distinction is extremely important in labor economics, but we will ignore it.
- In growth theory, human capital is most conveniently represented as a labor-enhancing factor: $F(K, A(E)L)$, where the variable E is the level of training, or more generally, *education*.
- Depending on assumptions, convergence to *steady state balanced growth* may occur, leading to a constant average level of education, and constant levels of all per-capita variables (though at higher levels than without education).
- Alternatively, the "education stock" may grow at a constant rate like general labor-enhancing technological progress, and the results are as described earlier. Unfortunately, this seems implausible.

Growth Accounting

- "Growth accounting" is a simple idea: decompose the overall rate of economic growth according to its sources.
  - Factor growth
  - Technological growth
- In steady state balanced growth, it is trivial.
  - All factors grow at the same rate (which is the labor force growth rate).
  - The difference between the rate of growth of GDP and the common factor growth rate is the *residual*, also called *total factor productivity (TFP) growth*.
  - TFP growth is interpreted as technological progress.

Growth Accounting, cont.

- Outside of steady state balanced growth, factors grow at different rates.
  - Use econometrics to estimate the production function.
  - Use the production function to estimate the contribution of each factor.
  - Any residual is TFP growth (by *definition*).
- TFP can be included in any production function regression simply by multiplying by $e^{\lambda t}$ (*Hicks-neutral technical progress)*:

$$\hat{F}(K, L, t) = e^{\lambda t} F(K, L),$$

  $\hat{F}$ includes the effects of time, *i.e.*, technological progress. With a Cobb-Douglas function, linearizing via the logarithm gives:

$$\ln Y = \ln A + \alpha \ln K + (1 - \alpha) \ln L + \lambda t + \epsilon.$$

Growth Accounting: Example

- Assume a Cobb-Douglas production function with $\alpha = .25$: $Y = K^{.25}L^{.75}$.
- In one year, labor force grew by 2%, capital stock by 4%, and output by 3%.
- Then, comparing to the base year we have

$$\begin{aligned}(1.04K)^{.25}(1.02L)^{.75} &= 1.04^{.25}1.02^{.75}K^{.25}L^{.75} \\ &= 1.04^{.25}1.02^{.75}Y = \hat{Y},\end{aligned}$$

so $\lambda = 1.03 - 1.04^{.25}1.02^{.75} = 0.005036$ where λ stands for TFP growth, and is approximately 0.5%.

Growth Accounting Results

U.S.

Assume Cobb-Douglas production function with $\alpha = 1/3$. Rows do not add due to rounding. Numbers are percentage growth rates of GDP, except the numbers in parentheses are factor growth rates.

		Contribution to GDP			
Period	GDP	Capital	Labor	TFP	GDP/L
1960–70	4.0	0.8 (2.4)	1.2 (1.8)	1.9	2.2
1970–80	2.7	0.9 (2.7)	1.5 (2.3)	0.2	0.4
1980–90	2.6	0.8 (2.4)	0.7 (1.1)	1.0	1.5
1960–90	3.1	0.9 (2.7)	1.2 (1.8)	1.1	1.4

TFP and Recession in Japan

- Estimated production function: $Y = AK_o^{0.1321}K_h^{0.1267}K_s^{0.0522}L^{0.689}$

	Y	K_o	K_h	K_s	L	TFP
1975-1999	3.09	0.75	1.18	0.65	0.65	-0.14
1975-1980	4.24	1.24	0.79	1.02	1.20	0.01
1981-1985	3.50	0.72	1.53	0.71	1.06	-0.56
1986-1990	5.06	1.02	1.71	1.06	1.22	0.09
1991-1995	1.49	0.27	0.88	-0.10	0.15	0.28
1996-1999	0.40	0.34	1.01	0.45	-0.79	-0.66

Homework 6: November 2, 2017

Note: Homework 6 is due on *Friday*, as usual, although there is a change of lecture date to Wednesday, October 31, because of *Gakuensai*.

1. Recall the introductory macroeconomic identity $Y = C + I$. Explain how to compute s (the savings rate) given data for Y, C, and I.

2. In data for real economies, the identity needs to be generalized to $Y = C + I + G + (X - M)$, where G denotes government expenditure, X exports, and M imports. Discuss how to compute s in this more complex context. (There may be more than one correct answer; give one and explain your idea.)

3. For some recent year, find the values for the following variables and parameters:

   - Y (GDP), C, I, G, $X - M$, K, L, s, d, n.

   of each of the following economies:

   - Japan, U.S., England, Germany, China, (South) Korea

   For each country, it doesn't matter what year, but all the values should be for the same year. Different countries may have different years, but it is better if all the countries use the same year's data.

4. Assume that each country's production function is of the Cobb-Douglas form: $F(K, L) = AK^{\alpha}L^{1-\alpha}$. Find data (for the same year as part 3) for Japan's capital stock K, labor force L, the income received as compensation to labor (W), and for income that is return to capital (R). Estimate $\alpha = \frac{R}{R+W}$.

5. Using the data above, for each country:

   - Display the phase diagram of the Solow model on a graph.
   - Estimate the current value of $\dot{k}$.
   - Estimate the steady state k^*.
   - Estimate the optimal $s*$ using Solow's Golden Rule.

Good data sources include

- the "Keizai Hakusho" of the government,
- the home pages of the Bank of Japan, the Ministry of the Economy, Trade, and Industry,
- various agencies of the United Nations,
- the Bureau of Economic Analysis (BEA) of the United States,
- the Central Intelligence Agency (CIA) of the United States, and
- the Penn World Tables.

The last four sources don't have Japanese pages, but they are well-organized so a little bit of English goes a long way.

Ministry of Economy, Trade and Industry	`http://www.meti.go.jp/statistics/`
	Also in English:
	`http://www.meti.go.jp/english/statistics/`

(continued on next page)

Bank of Japan	http://www.boj.or.jp/statistics/index.htm/ http://www.imes.boj.or.jp/hstat/index.html Also in English: http://www.boj.or.jp/en/statistics/index.htm/ http://www.imes.boj.or.jp/english/hstat/index.html
Ministry of Internal Affairs	http://www.e-stat.go.jp/ Also in English: (go to the page above and click on English)
United Nations (UNESCO)	http://www.uis.unesco.org/
Penn World Tables	http://www.ggdc.net/pwt
BEA	http://bea.gov/
CIA	https://www.cia.gov/