Testing the Solow Growth Theory

Dilip Mookherjee

Ec320 Lecture 4, Boston University

Sept 11, 2014

RECAP OF L3: SIMPLE SOLOW MODEL

- Solow theory: deviates from HD theory by assuming diminishing returns to capital, and that labor is productive
- Has two key implications:
- *With respect to disparities between poor and rich countries:* poor countries grow faster, provided they have similar s, n, δ
- *With respect to change in growth rates over time for a given country:* growth tends to slow down, and vanish in the long run

RECAP OF L3: SIMPLE SOLOW MODEL, contd.

- Raising s or lowering n has temporary effects on growth rates (and permanent effects on p.c.i. levels)

L4: EMPIRICAL TESTS OF SOLOW THEORY

- One problem with the Solow theory to start with: predicts zero long-run growth
- We see growth slowing down with prosperity, but is it likely to vanish altogether?
- Solow proposes a fix to this problem: assume TFP A grows at a constant, exogenous, rate π
- This adds one more source to growth in p.c.i.: *technical progress*
- Long-run growth rate is π rather than zero

SOLOW MODEL WITH TECHNICAL PROGRESS

- Same analysis works as before with a reformulation of the production function:

$$x_t \equiv \frac{Y_t}{A_t P_t} = f\left(\frac{K_t}{A_t P_t}\right)$$

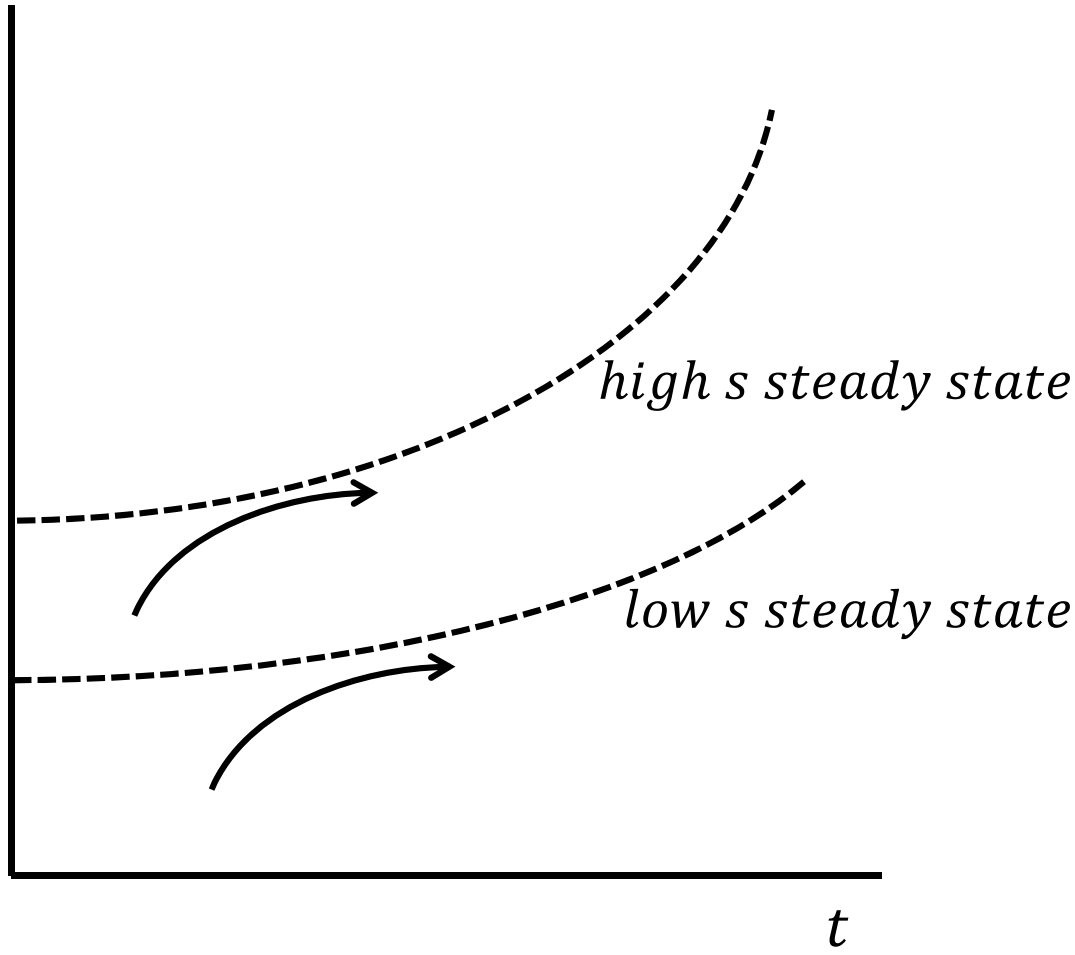
- Think of technical progress augmenting effective units of work done by each person, so total effective labor $= A_t P_t$
- Measure capital-(eff) labor ratio by $\frac{K_t}{A_t P_t}$

SOLOW MODEL WITH TECHNICAL PROGRESS, contd.

- Same dynamic equations obtain for y_t, now income per effective worker becomes constant in long run
- P.c.i. in year t is A_t times x_t, hence grows in the long run at rate of technical progress π

SOLOW MODEL WITH TECHNICAL PROGRESS, contd.

- While long-run growth rate is now positive, it is independent of s, n, δ
- Why the Solow theory is considered an *Exogenous Growth* theory (for the long-run)
- In the short-run, growth rate of p.c.i. is the sum of two forces:
  - capital deepening
  - technical progress
- Because P.c.i. in year t is A_t times x_t, and x_t grows due to capital deepening


high s steady state
low s steady state
t

SOLOW MODEL WITH TECHNICAL PROGRESS, contd.

- (Short-run) Rate of growth of p.c.i equals (exogenous) rate of technical progress plus (endogenous) growth due to capital deepening
- Endogenous component is higher if s is higher, or n, δ are lower, or initial capital per worker is lower (because of diminishing returns to capital deepening)
- This generates predictions that can be empirically tested

EMPIRICAL PREDICTIONS OF SOLOW MODEL WITH TECHNICAL PROGRESS

1. For any given country over time:
   - growth slows down if s, n, δ fixed
   - accelerates (temporarily) if s rises or n falls

2. Comparing across countries at a point of time: poorer countries grow faster if they have same s, n, δ and rate of technical progress (Conditional Convergence)

EMPIRICAL PREDICTIONS OF SOLOW MODEL WITH TECHNICAL PROGRESS, contd.

3. Disparities in long-run living standards can be explained by disparities in s and n, assuming all countries have access to same rate of technical progress

EMPIRICAL TESTS

- Convert these predictions into regression equations, which are then estimated using data on cross-section p.c.i. growth rates and levels
- Dependent variable: growth rate in p.c.i from year 0 to 1, can be approximated by $\log y_1 - \log y_0$

$$\log y_1 - \log y_0 = b_0 + b_1 y_0 + b_2 s + b_3 n + \epsilon$$

where $b_0 > 0$ is long-run TFP growth rate, $b_1 < 0, b_3 < 0,\ b_2 > 0$

- $b_1 < 0$ is the Conditional Convergence hypothesis

TESTS OF CONDITIONAL CONVERGENCE

- Most scholars (e.g., Barro, Mankiw-Romer-Weil (MRW)) estimate this regression using PPP-adjusted p.c.i. from World Penn Tables for over 100 countries, for growth between 1960 and 1985
- Barro estimates s by calculating percent of GDP invested in physical capital
- Finds that estimate of b_1 is zero rather than negative: *no tendency for poorer countries to grow faster, controlling for savings and population growth rates*

REJECTION OF CONVERGENCE PREDICTION?

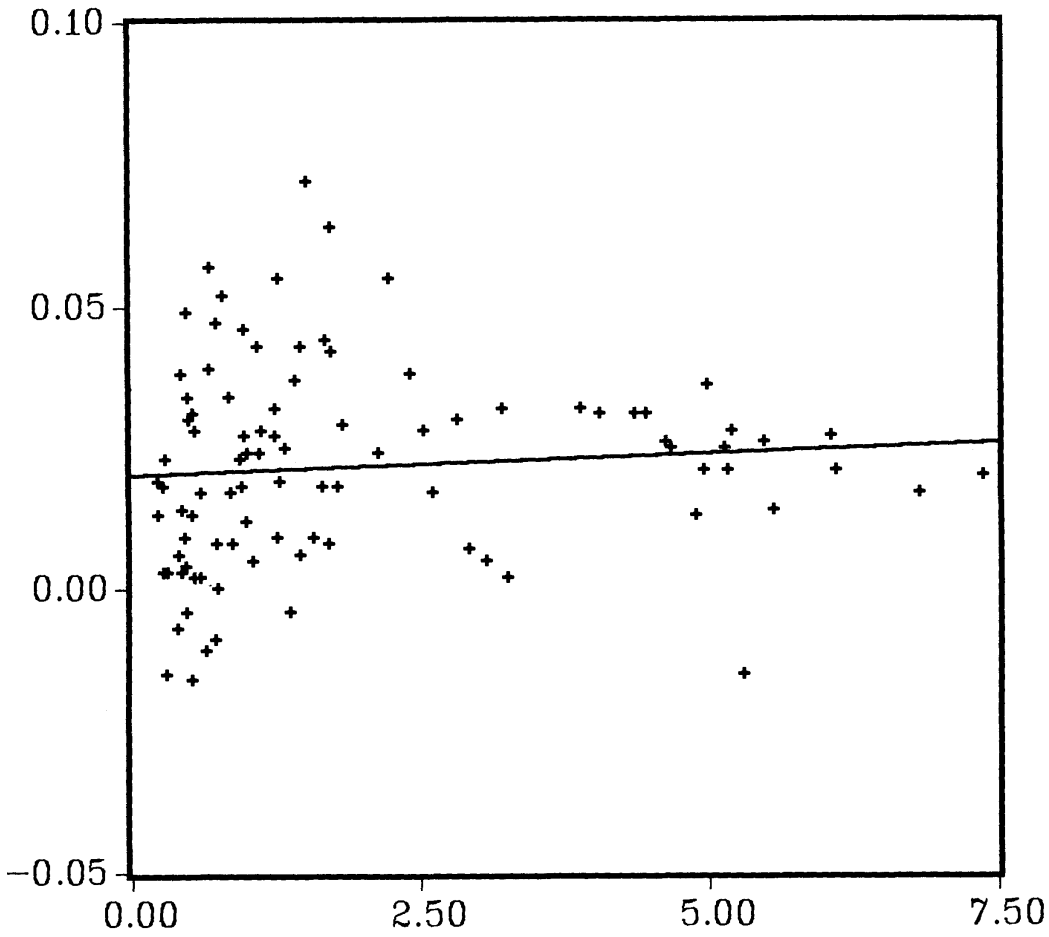


FIGURE I
Per Capita Growth Rate Versus 1960 GDP per Capita

ENTER HUMAN CAPITAL

- Barro then argues that the regression didn't measure capital properly by focusing only on physical capital
- Need to also measure and control for *investment in education*
- Once Barro includes controls for education (school enrollment rates), the CC hypothesis passes the test:

CROSS-COUNTRY GROWTH REGRESSION 1960-85

In country c:

- g_c denotes p.c.i. growth rate between 1960 and 1985
- y_c denotes p.c.i. level in 1960
- PE_c, SE_c denote primary and secondary enrollment rates in 1960
- s_c, n_c denote investment rate and net fertility rate in 1960

CROSS-COUNTRY GROWTH REGRESSION 1960-85

$$
\begin{aligned}
g_c = \quad & 0.0494 - 0.0077^{*}(0.0009)y_c \\
& +0.0100(.0087)SE_c + 0.0118^{*}(.0057)PE_c \\
& +0.064^{*}(.032)s_c - 0.0043^{*}(.0014)n_c
\end{aligned}
$$

with $R^2 = 0.62$, (.) denoting standard errors, and * denoting statistically significant at 5% level

CONFIRMING CONVERGENCE, WITH EDUCATION CONTROLS

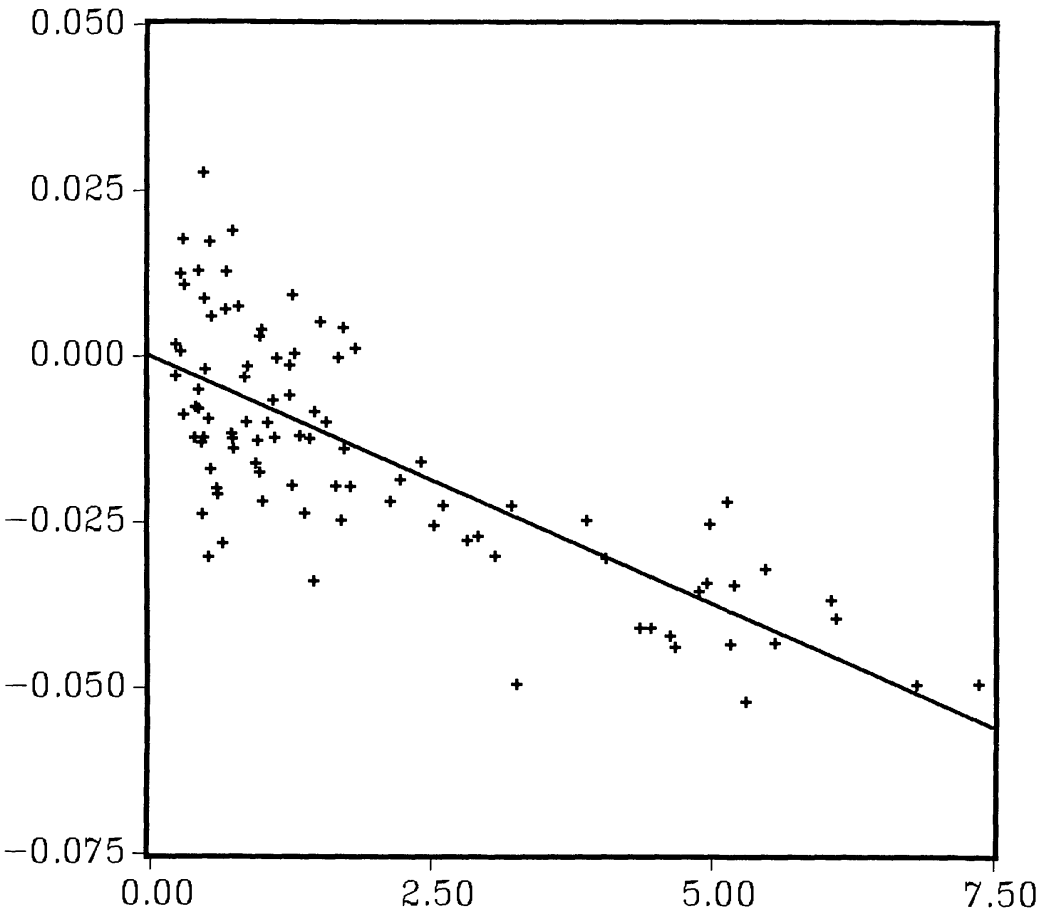


FIGURE II
Partial Association Between per Capita Growth and 1960 GDP per Capita (from regression 1 of Table I)

INTUITIVE EXPLANATION

- Poor countries do not automatically catch up with rich countries
- In order to do so, they need to invest at least at the same rate as rich countries
- As a matter of fact, they weren't doing so with regard to investment in primary education
- Thats why they were failing to catch up
- If they were investing in physical and human capital at least at the same rates (as East Asian miracle countries did), then they grew faster than rich countries

PCI LEVEL CROSS-COUNTRY REGRESSION 1985 (MRW)

- With Cobb-Douglas technology, can express **long run steady state p.c.i. level** as

$$\log y_t = \log A_0 + \pi . t + \frac{\alpha}{1-\alpha}[\log s - \log(n + \delta + \pi)]$$

- This implies that with $\alpha = \frac{2}{3}$, the theory predicts: long run p.c.i should have elasticity of
  - 0.5 with respect to savings rate
  - -0.5 with respect to population growth rate

PCI LEVEL CROSS-COUNTRY REGRESSION 1985 (MRW)

- MRW test this on 1985 data, using investment rate in physical capital to measure s
- They find elasticity w.r.t. savings of 1.42
- and w.r.t. population growth rate of -1.97
- — unbalanced, and too large!

ENTER HUMAN CAPITAL AGAIN

- Rework the steady state equation by adding human capital H_t as a third factor of production:

$$Y_t = K_t^{\alpha} H_t^{\beta} [A_t L_t]^{1-\alpha-\beta}$$

- Long run steady state pci now reduces to (s_k, s_h: investment rates in physical, human capital):

$$\begin{aligned} \log y_t = & \quad \log A_0 + \pi . t \\ & + \frac{\alpha}{1-\alpha-\beta} \log s_k \\ & + \frac{\beta}{1-\alpha-\beta} \log s_h \\ & - + \frac{\alpha+\beta}{1-\alpha-\beta} \log(n + \delta + \pi) \end{aligned}$$

PCI LEVEL CROSS-COUNTRY REGRESSION 1985 (MRW)

$$\begin{aligned}\log y = \; & 6.89^{*}(1.17) + 0.69^{*}(0.13)\log s_k \\ & +0.66^{*}(.07)\log s_c \\ & -1.73^{*}(.41)\log(n+\pi+\delta)\end{aligned}$$

with $\bar{R}^2 = .78, n - 98$, and now the theory fits very nicely (implied $\alpha = 0.31, \beta = 0.28$

LESSONS LEARNT

1. Solow theory is successful in explaining 60% variation in growth rates, and 80% of variation in p.c.i across countries
2. By just four variables:
   - initial per capita income
   - investment rate in physical capital
   - investment rate in education
   - population growth rate
3. Cannot neglect human capital

LESSONS LEARNT, contd.

4. Conditional (not unconditional) convergence: poor countries catch up, provided they invest and bring down population growth rates
5. Remaining part of growth attributed to technical progress, which is more important in developed countries