Testing the Solow Growth Theory

Dilip Mookherjee

Ec320 Lecture 5, Boston University

Sept 16, 2014

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 (CC))

[Contrast CC with simpler hypothesis of Unconditional Convergence (UC): that disparities in pci levels between rich and poor countries narrow over time]

EMPIRICAL PREDICTIONS OF SOLOW MODEL WITH TECHNICAL PROGRESS, contd.

3. Disparities in pci levels 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 or levels cross-country growth regression:
- Dependent variable: g_y, growth rate in p.c.i from year 0 to 1

$$g_y = b_0 + b_1 y_0 + b_2 s + b_3 n + \epsilon$$

where $b_0 > 0$ is long-run TFP growth rate

- $b_1 < 0$ is the Conditional Convergence hypothesis $b_2 > 0, b_3 < 0$ the other prediction regarding effects of s, n on short run growth

TEST OF UNCONDITIONAL 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 starts by examining stronger hypothesis of unconditional convergence: that poor countries grow faster
- Regression drops s, n from the set of regressors: simple regression of g_y on initial pci level

REJECTION OF UNCONDITIONAL CONVERGENCE 1960-85

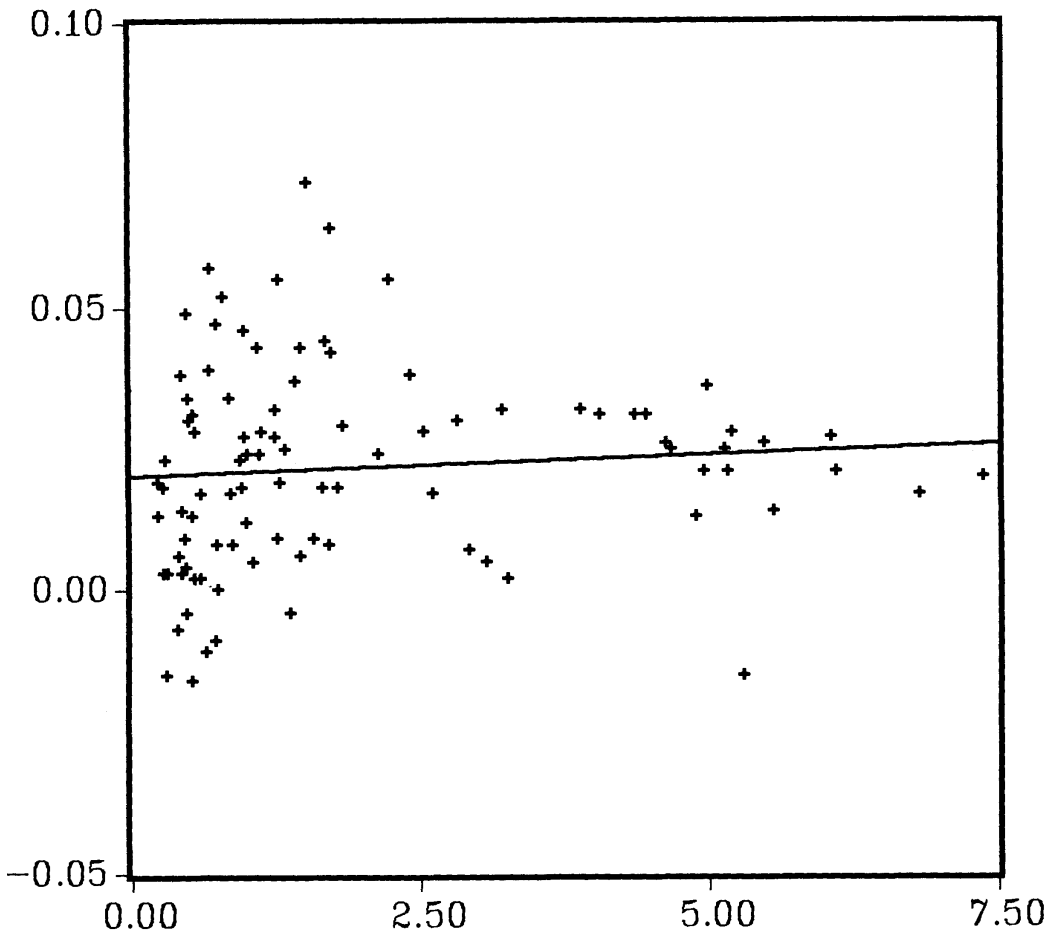
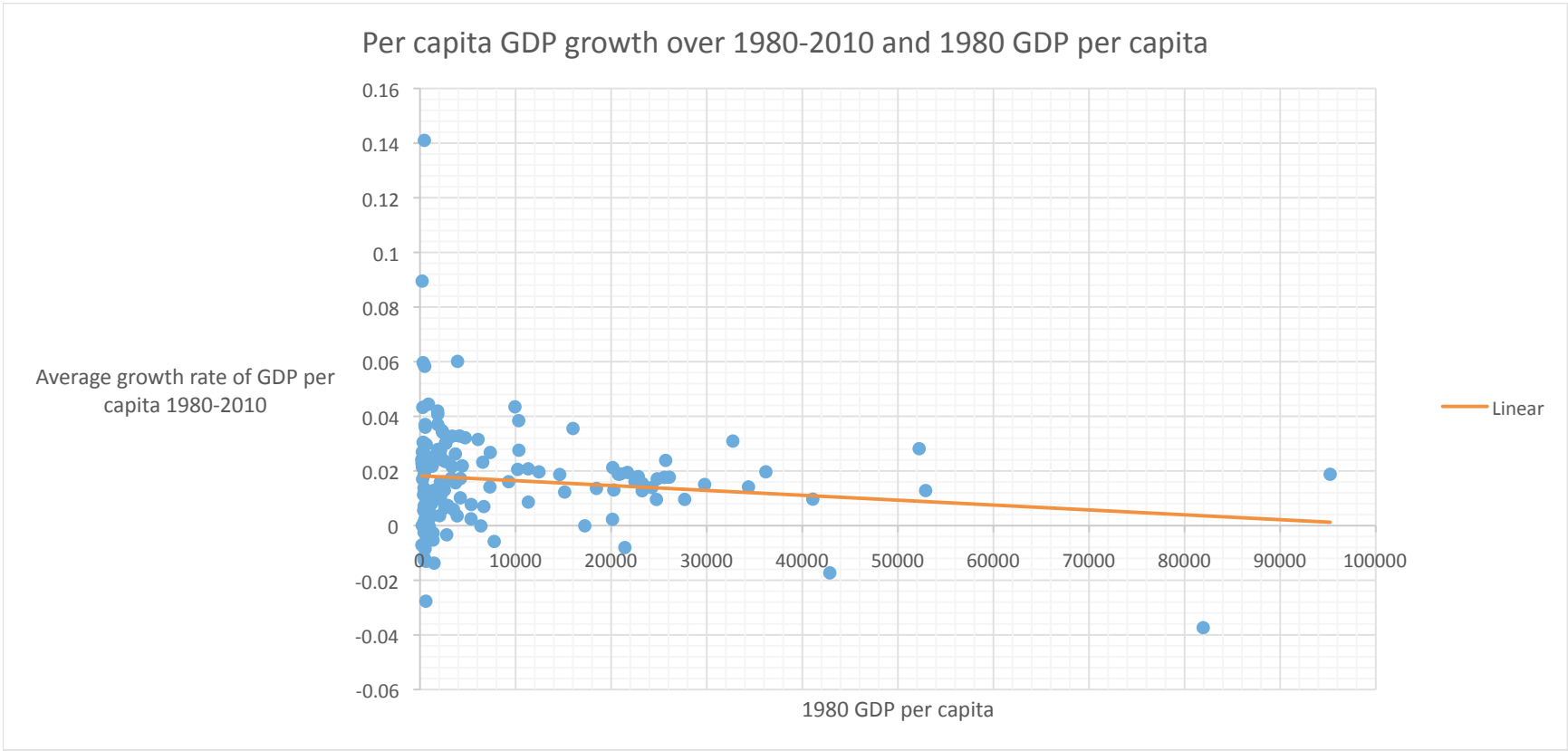


FIGURE I
Per Capita Growth Rate Versus 1960 GDP per Capita

REJECTION OF UNCONDITIONAL CONVERGENCE 1980-2010



TEST OF CONDITIONAL CONVERGENCE

- So Barro adds s, n to the regression
- 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, even when controlling for savings and population growth rates*
- Suggests that CC is rejected?

ENTER HUMAN CAPITAL

- Barro then argues that the regression didn't measure capital properly by focusing only on physical capital
- Need to broaden notion of capital to include *human capital*
- Hence savings concept ought to involve *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

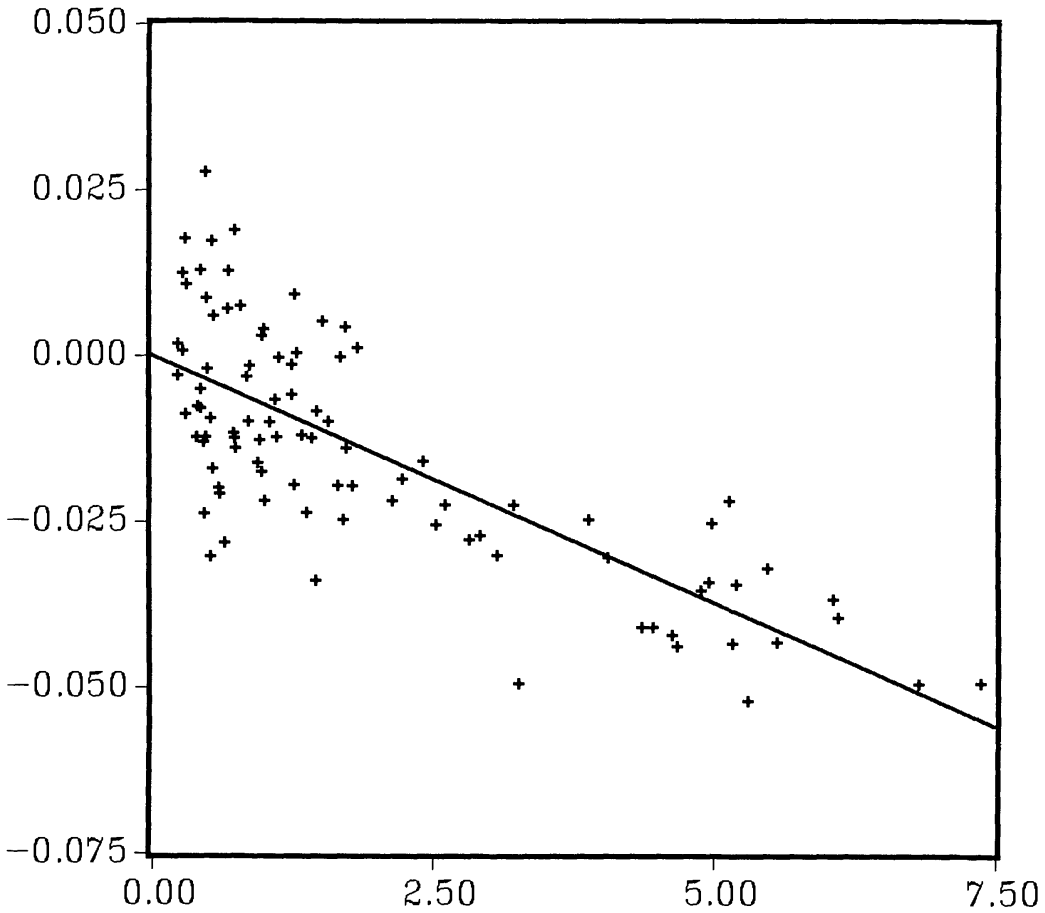


FIGURE II
Partial Association Between per Capita Growth and 1960 GDP per Capita (from regression 1 of Table I)

ANALOGOUS C-C GROWTH REGRESSION 1980-2010

Source	SS	df	MS
Model	0.002468	2	0.001234
Residual	0.0479618	129	0.0003718
Total	0.0504298	131	0.000385

Number of obs	132
F(2, 129)	3.32
Prob > F	0.0393
R-squared	0.0489
Adj R-squared	0.0342
Root MSE	0.01928

gdppcgr8010	Coef.	Std. Err.	t	P>|t|	[95% Confidence Interval]	
gdppc80	-3.06E-07	1.89E-07	-1.62	0.108	-6.80E-07	6.84E-08
saving8000	0.0003392	0.0001369	2.48	0.014	0.0000684	0.0006101
_cons	0.0130589	0.0027325	4.78	0	0.0076524	0.0184653

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 coefficients, and too large!

ENTER HUMAN CAPITAL AGAIN

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

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

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

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

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

IMPORTANT QUALIFICATION

- The Solow theory helps narrow down focus to a few key variables associated with variations in growth: savings, education, population growth, and technical progress
- But it does **NOT**:
  - establish any causal connections
  - explain what determines savings, fertility, technical progress etc
- Need to supplement by (micro and macro) theories of underlying behavior, and how these are affected by policies and institutions