Endogenous Growth, Human Capital, and Education

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Exogenous vs. Endogenous ~~Growth Models~~

- Exogenous model
  - $Y = AK^{\alpha} L^{1-\alpha}$
  - Productivity levels (A) are given/residual
  - Diminishing returns inhibit sustained growth (limited to a steady-state)
- Endogenous models
  - Productivity accounted for within the model; an explanation for A
    - R&D, Human Capital
  - Constant marginal productivity
  - Absence of steady-state behavior

Romer's Model of Human Capital

- Human capital as an input in productivity growth
  - New technologies invented within economy
  - Time divided between production and innovation
  - Focus is on product variety
- Ideas directly increase A
  - Nonrivalrous, partially excludable, increasing returns Imperfect competition, patents and copyrights
- If human capital stock too small, there is no allocation to R&D; must be above threshold level

$$H_A = \begin{cases} 0, & \text{if } H \le H_0 \\ ?(H-H_0), & \text{if } H > H_0 \end{cases}$$

Adapting Romer's Model for ~~Technology Transfer~~

- A is viewed as technological frontier; model based on adapting outside technologies
  - Labour can be used for skill accumulation or production
  - Technology transfer is effortless and technological frontier is exogenous
  - Growth rate of economy given by growth rate of skill
- The number of capital goods a worker is able to use is limited by skill level
  - Skill accumulation slows as skill level approaches frontier

Implications for Solow Model

- Mankiw, Romer, Weil
  - Variations in per capita income and growth rates 1960-1985 consistent with Solow model once augmented to include human capital
- Solow model still useful; easy to endogenize
- Human capital affects economic growth through accumulating new technology and facilitating technology diffusion
  - Need to model both effects
  - Some countries may focus on utilizing spillovers, while others focus on innovation

Cost Benefit Analysis

F = one time cost for human capital accumulation (or transfer of technology)

Π = the expected present discounted value of the profit stream

$\Pi > F \rightarrow$ Invest

$\Pi < F \rightarrow$ Do not invest

- Individuals and firms will invest in human capital if incentives are there (high profits and/or low costs are necessary)
- Rates of return to society: compare the additional earnings of better-educated individuals to the additional social cost of investing in more education

Quality of Human Capital

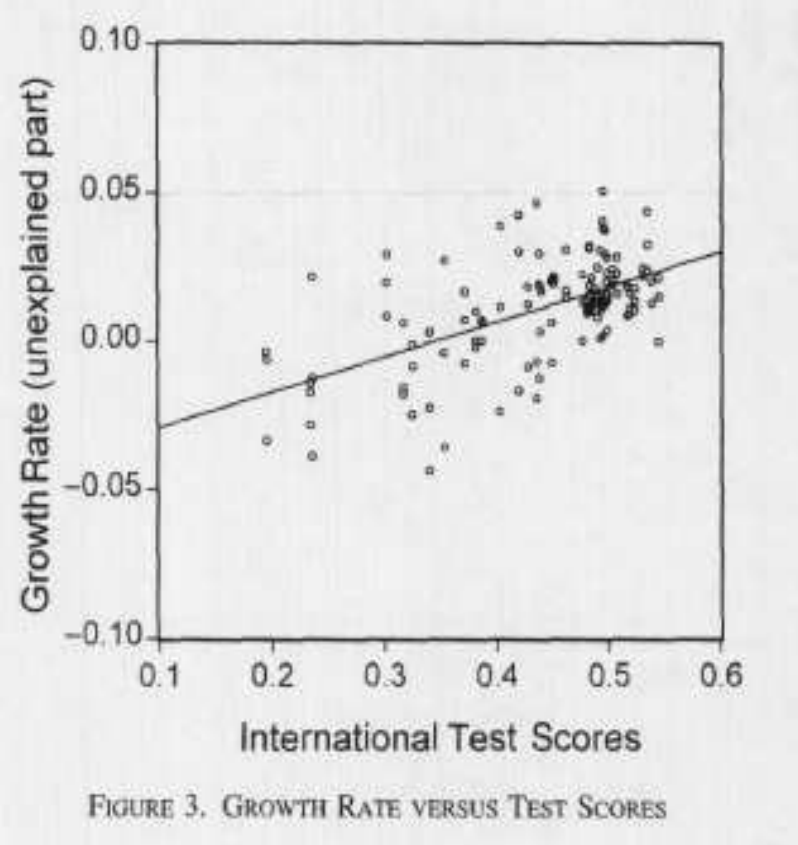

FIGURE 3. GROWTH RATE VERSUS TEST SCORES

Robert Barro; *The American Economic Review;* May 2001

- Quality education is important for growth
- One standard deviation increase in international test scores (generalized) impacts growth rate by 1% per year
- 1% rise in literary scores compared to the international average associated with 2.5% rise in productivity and 1.5% rise in GDP per capita

Quantity of Education

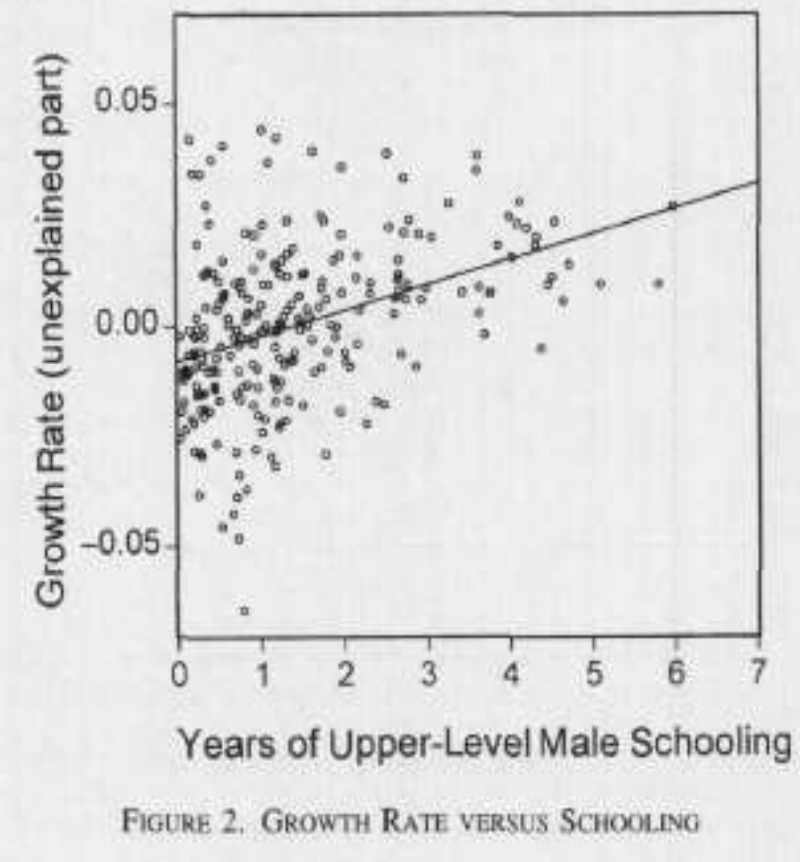

FIGURE 2. GROWTH RATE VERSUS SCHOOLING

Robert Barro; *The American Economic Review;* May 2001

- Initial stock of human capital measured by secondary and post-secondary completion
- An additional year in school raises the growth rate by .44% per year
- Secondary education contributed an annual 0.6% to productivity growth in OECD (1960-1995)
- Quality and quantity of education important for growth

More Evidence

- Engelbrecht
  - Level of education plays important role in technological catch-up
  - Productivity growth is more rapid where countries have higher levels of average schooling
  - Human capital has largest effects when specific to subcategories important for technological diffusion (science, math, engineering)
- Growth accountants find that increases in education account for perhaps one fifth of growth in output per worker

Peter Howitt

- Growth depends on both the rate and size of innovations
- 2 kinds of innovations: frontier and implementation
  - Human capital doesn't affect 2 types of innovation in the same way
  - Education policies need to be appropriate to country's position in relation to the frontier
    - Post-secondary education spending and growth in 48 US states
    - May explain discrepancies in correlations between education and growth
- Effects of liberal trade policy on domestic innovation