Econ 5700 slides
Early empirical growth papers

September 19, 2021

Taking growth models to data

Rise in the late 1980's of a new empirical growth literature

Made possible by the compilation by Summers and Heston (QJE 1991) of a new comprehensive data set: the *Penn World Table*

Contains information on many variables found in countries' National Accounts: output, income, prices (deflators), components of output

100+ countries, at different points in time (annually?), starting as early as 1950, depending on country

Hosted on various servers around the world; regularly updated

Latest version described by Feenstra, Inklaar, and Timmer (AER 2015)

Data allow for testing of various predictions of various models

Here: follow Barro (1996)

- Main prediction to be tested: *convergence*. Means poor countries grow faster than (catch up with) rich countries. Holds in most growth model under standard assumptions

- Tested by regressing growth on initial (log) GDP/capita

- Also include other independent variables: control for steady-state level to which economy is converging (see below); and allow us to examine what factors make countries grow faster

- Of huge interest to anyone interested in development economics

Many data series to choose from. Which one to use depends on application

Here:

- Use GDP rather than GNI, or similar: interested in how productive capacities change

- Use GDP/capita or GDP/worker, not total GDP

- To make correct comparisons over time, use real GDP (constant rather than current prices)

- To make international comparisons, the data series should be PPP adjusted; do not use current exchange rates

Regression specification

Notation: try to keep close to the model(s) we want to test

$y_{i,t}$ = GDP/capita at the start of period t in country i

n = number of years in the period (e.g., $n = 10$ if one period is a decade)

y_i^* = steady-state GDP/capita in country i

$g_{i,t}$ = annual growth over period t in country i

$$\frac{\ln y_{i,t+1} - \ln y_{i,t}}{n} = \ln(1 + g_{i,t}) \approx g_{i,t}$$

Note: $g_{i,t}$ is the annual rate; here the (geometric) mean across all years in the period

Start with your favorite growth model (log utility, CD production)

Linear approximation around steady state: $g_{i,t}$ proportional to $\ln y_{i,t} - \ln y_i^*$

$$g_{i,t} = \beta_0 + \beta_1 \left[\ln y_{i,t} - \ln y_i^*\right] + \varepsilon_{i,t}$$

In words: fast growth if $y_{i,t}$ small, and/or y_i^* large

Need to measure y_i^*

Why is this so important? Countries with low initial GDP/capita likely to have low steady-state levels too; not controlling for the latter will bias estimate of β_1 to zero

From model: y^* depends on e.g. n, s, δ

Harder to measure productivity parameter, Z: could depend on taxes, market distortions, rule of law, political freedom, terms of trade

Empirical approach: use measures of all these factors as controls in the regression; slightly *ad hoc* but useful insights

$$g_{i,t} = \beta_0 + \beta_1 \ln y_{i,t} + \text{controls}_{i,t} + \varepsilon_{i,t}$$

Controls measured at start of period over which growth is measures (same as initial GDP/capita)

Note: here allowing controls to be time dependent; slight deviation from model where α, n, s, δ, Z were treated as constant and exogenous

Ways to structure the data

Cross section: unit of observation is the country; can drop time index

y_i = GDP/capita of country i in, say, 1960; g_i = annual growth rate of country i from 1960 to (say) 1990 or 2000

$$g_i = \beta_0 + \beta_1 \ln y_i + \text{controls}_i + \varepsilon_i$$

Panel: unit of observation is a country-period

$$g_{i,t} = \beta_0 + \beta_1 \ln y_{i,t} + \text{controls}_{i,t} + \varepsilon_{i,t}$$

Panel structure has more observations, but other problems

- Do we really add independent observations? Usually addressed with fixed effects.

- Testing long-run growth models: cannot use every year; business cycles issues

Barro's approach:

- Panel with about 100 countries, three periods
- 1965-1975, 1975-1985, 1985-1990 (latest year with data at the time, thus last period shorter)
- Log GDP/capita in 1960, 1970, 1980 used as instruments for initial log GDP/capita (in 1965, 1975, 1985)
- Similar for other variables

Absolute vs. conditional convergence

Examine coefficient on initial log GDP/capita (β_1): is it negative?

Without controlling for anything else: no; $\beta_1 = 0$ not rejected

Absence of so-called *absolute* convergence

- See Barro (1996, Figure 1), Jones (2016, Figure 26), and plots on course website

Why? Many relatively rich countries have grown fast (Europe, East Asia); many poorer countries have barely grown at all (Africa, Former USSR)

When adding controls (see below): $\widehat{\beta}_1 < 0$ and highly significant; see Barro's Figure 2

- Strong support for *conditional convergence*

- Means that the economy grows fast if it's far below its *own* steady state, i.e., poor conditional on its characteristics

Usually $\widehat{\beta}_1 \approx -.02$ (depending on specification; here about $-.025$)

Implies that the gap between actual and steady-state GDP/capita closes by about 2% per year.

This 2% result is often called Barro's iron law

Alternative exercise to running regressions: use model and data on (possibly time-varying) α, n, s, δ etc., and/or inputs (K_t, L_t), to back out Z

Z called *Solow Residual*, or *Total Factor Productivity*

(Not in this course)

Speed of convergence

Suppose $\widehat{\beta}_1 = -.025$

This means gap closes by 2.5% per year

Gap T years ahead $= (1 - .025)^T$ of gap today.

How long time to half the gap?

Set $(1 - .025)^T = 1/2$. Solving for T gives 27 years

Galton's fallacy

If poor countries grow faster than rich, does that imply a negative time trend in inequality? Not necessarily; called Galton's fallacy

Assume $-1 < \beta_1 < 0$ in regression equation (holds in data) and disregard controls (or treat as deterministic)

Recall $g_{i,t} = (\ln y_{i,t+1} - \ln y_{i,t})/n$

$$\ln y_{i,t+1} - \ln y_{i,t} = n\beta_0 + n\beta_1 \ln y_{i,t} + n\varepsilon_i$$

Say $\varepsilon_i \sim (0, \sigma_\varepsilon)$. Write period-$t+1$ variance in log GDP/capita, as function of that in period t:

$$V_{t+1} = \underbrace{(1 + n\beta_1)^2}_{<1} V_t + n^2\sigma_\varepsilon^2$$

Steady state variance: $V^* = n^2\sigma_\varepsilon/[1 - (1 + n\beta_1)^2]$

Variance may increase or decrease, depending on where V_t is relative to V^* (draw 45°-diagram to see)

If variance decreasing, often called "sigma convergence" (as opposed to "beta convergence")

Interpreting the effect of the control variables

Coefficient on initial "human capital" positive and significant

- See Figure 3

- Human capital measured as fraction males over 25 who finished secondary school or higher

- Similar effect/interpretation for life expectancy at birth (cf. plot Figure 5)

- Surprising results: no/little effect from primary school enrollment, or female schooling at various levels

- Interaction between male schooling and initial GDP/capita negative
  - See Figure 4
  - Interpretation: faster convergence if higher initial human capital
  - Does not necessarily mean that higher levels of human capital imply slower growth: why?

Coefficient on fertility negative and significant

- Very consistent with Solow, Diamond models
- See plot in Figure 6
- Endogeneity issues
  - Preceding/anticipating later literature on transitions from Malthusian stagnation to sustained growth in per-capita incomes (Galor and Weil 2000, Hansen and Prescott 2002)

Coefficient on government consumption negative and significant

- See plot in Figure 7
- Measured as government consumption, excluding defence and education, as share of GDP
- Barro: result suggests “big government is bad for growth”
- Corruption? Endogeneity issues?
- Is the result robust? Seems to contradict well-documented positive effects on development from *state capacity*: ability of government to collect taxes, provide legal protections (Besley and Persson 2011, “Pillars of Prosperity”)

Coefficient on rule of law positive and significant

- See plot in Figure 8
- Data from the International Country Risk Guide (Knack and Keefer 1995)

Coefficient on terms of trade positive and significant

- See plot in Figure 8
- Measured as ratio of export to import prices (in initial year)
- Commodity prices thought to matter for many developing countries; "natural resource curse"
- Note: here measuring growth in output, not income
- Barro: "If the physical quantities of goods produced domestically do not change, then an improvement in the terms of trade [...] would not affect real GDP"

Coefficients on regional dummies (Latin America, Africa, etc.) insignificant

- See Column (2), Table 1

- Other control variables explain why they don't grow

- Not the case in previous work

Summary so far: more schooling, lower fertility, smaller government, better rule of law, better terms of trade, all good for growth

Other variables in Table 1: discussed in later sections of Barro's paper

- Democracy
  - Measured on 0-1 scale
  - Concave relationship? (Squared term insignificant)
  - Relates to a big (ongoing) debate: Seymour Lipset's "modernization theory" says that development causes democracy; Acemoglu and coauthors suggest it's the other way around
- Inflation: negative coefficient

Skip Tables 2-3

Growth projections: see Table 4

- Use growth regressions and known initial values for independent variables to predict growth; here from 1996 to 2000

- How well did Barro's predictions work out?

- Examples: Argentina, Egypt. Since the 1990's they have seen big changes to the same (political) conditions that made them likely to grow in the first place
  - Unobserved country characteristics?
  - What does this say about endogeneity?

Taking stock

Econometric problems with growth regressions (Mankiw 1995)

- Simultaneity: right-hand side variables not exogenous; jointly determined with the growth rate
  - Example: if "culture" makes country grow fast, and also makes it invest in public health, then high life expectancy correlated with growth
  - Solution: find exogenous instruments; advice from the so-called Cowles Commission
  - Often lagged variables, but timing does not ensure exogeneity (e.g., bringing umbrella in the morning does not cause rain later in the day)

– Acemoglu et al. (AER 2001) used European settler mortality rates as instrument for institutions; very controversial

- Multicollinearity: explanatory variables correlated with each other
  - Mankiw: "those countries that do things right do most things right, and those countries that do things wrong do most things wrong"
  - Can bias estimates of coefficients; but how about predicted growth?

- Degrees-of-Freedom: few observations, only about 100 countries
  - Solution: panel regressions; but that gives no new independent observations
  - Also problem with business cycles vs. growth; cf. earlier discussion
  - Alternative solution: look at subnational regions (later)

Converging to convergence

- Kremer, Willis, and You (2021)

- Recent revisit to convergence literature; more (recent) data

- Look at cross-sectional results by decade, all the way to today

- Find that the unconditional estimate of beta has moved from positive to (significantly) negative since the 2000's—"precisely when empirical tests of convergence fell out of fashion"; cf. Figures 1, 2, 8, Table 5

- Also provide summary/taxonomy of growth correlates (control variables, like those used by Barro)

- Four categories: enhanced Solow fundamentals, short/long-run correlates; culture

- Most correlates (control variable candidates) display convergence themselves; cf. Figure 4, Table 3

- Look at difference between conditional and unconditional estimates: $\beta_t - \beta_t^* = \delta_t \lambda_t$; eq. (5)

- Often called omitted variable bias

- Figure 8: "Absolute convergence converging to conditional convergence"

- Driven by change in $\delta_t \lambda_t$; cf. Table 4

Subnational data

Gennaioli et al. (JEG 2014)

Model

- Multi-region version of Solow model; each country has continuum of regions, indexed i

- Limited mobility across regions within countries; no mobility between countries

- Population (labor force) constant, size normalized to one

  - Aggregate and per-capita output the same

Notation:

- $h_{i,t}$ = broad measure of capital (human and physical) *employed* in region i, period t

- $\widehat{h}_{i,t}$ = broad measure of capital *originating* in region i, period t

  – Distinction serves to capture capital mobility

- $h_t = \int \widehat{h}_{i,t} di = \int h_{i,t} di$ = country aggregate of $h_{i,t}$

- $y_{i,t} = A_i h_{i,t}^{\alpha}$ = GDP/capita in region i, period; $\alpha \in (0, 1)$ and A_i = region-specific productivity

Determination of $h_{i,t}$ given $\widehat{h}_{i,t}$ and h_t

- If *no mobility* (complete barriers): $h_{i,t} = \widehat{h}_{i,t}$
- If *perfect mobility* (no barriers), returns to capital equalize across regions: $\alpha A_i h_{i,t}^{\alpha-1} = w_t$, where w_t is constant across i. Solve for $h_{i,t}$, integrate. This gives:

$$h_{i,t} = \widehat{A}_i h_t = \widehat{A}_i \int h_{i,t} di$$

$$\widehat{A}_i = \frac{A_i^{\frac{1}{1-\alpha}}}{\int A_i^{\frac{1}{1-\alpha}} di}$$

- *Intermediate mobility*: let $\tau \in [0,1]$ be a measure of barriers; then

$$h_{i,t} = \upsilon_t \left(\widehat{h}_{i,t}\right)^{\tau} \left(\widehat{A}_i h_t\right)^{1-\tau}$$

$$\upsilon_t = \frac{h_t^{\tau}}{\int \left(\widehat{h}_{i,t}\right)^{\tau} \left(\widehat{A}_i\right)^{1-\tau} di}$$

where υ_t is a sclaing factor, such that $\upsilon_t = 1$ if $\tau = 1$

Let s denote rate of saving/investment rate

Capital dynamics in region i:

$$\widehat{h}_{i,t+1} = s y_{i,t} = s A_i h_{i,t}^{\alpha}$$

Implies the following expression for dynamics of GDP per capita (see problems):

$$\frac{y_{i,t+1}}{y_{i,t}} = \upsilon_{t+1}^{\alpha} s^{\alpha} A_i \widehat{A}_i^{\alpha(1-\tau)} y_{i,t}^{\alpha\tau-1} y_t^{\alpha(1-\tau)}$$

Logging, rerranging, adding error term gives regression equation:

$$\begin{aligned}
\ln\left(\frac{y_{i,t+1}}{y_{i,t}}\right) &= \ln\left(\upsilon_{t+1}^{\alpha} s^{\alpha}\right) + \underbrace{\ln\left(A_i \widehat{A}_i^{\alpha(1-\tau)}\right)}_{\text{Captured by region cntrls}} \\
&\quad -(1-\alpha\tau) \times \underbrace{\ln\left(y_{i,t}\right)}_{\text{Init. GDP/cap. region}} + \alpha(1-\tau) \times \underbrace{\ln\left(y_t\right)}_{\text{Init. GDP/cap. country}} \\
&\quad + \epsilon_{i,t+1}
\end{aligned}$$

Data

- Various sources on GDP/capita across regions within countries

- E.g., US states, Canadian provinces, German länder...

- 1,528 regions from 83 countries

  - 5-year intervals

  - Different coverage by country, mostly from 1990

- Regional-level controls: schooling; population density; geography (latitude, malaria, oil/gas, and more); dummy for whether the capital is in region

Model implies:

- coefficient on $\ln\left(y_{i,t}\right)$ negative

- coefficient on $\ln\left(y_t\right)$ positive

Not rejected in most (many) specifications in Table 5

Rate of convergence close to 2%, similar to Barro

Implied values for α, τ both close to one

- Note "broad" concept of capital
  - Includes all inputs, except raw labor
  - Maybe $\alpha \approx 1$ is not too strange
- $\tau \approx 1$ implies large barriers, little mobility
  - Plausible?

Taking longer perspective

Cross-country growth comparisons from 1870 until today: Pritchett (1997)

1870 earliest year from when we have any “hard” data

Many countries born as nation states around 1870, making it a natural starting point

First focus on 17 “advanced capitalist” countries (Pritchett 1997, Table 1)

Source: Angus Maddison (1995); celebrated for brave data mining projects

Selection problem: data set consists of currently rich countries

Either...

- ...rich in 1870 and rich today (Europe); or

- ...poor in 1870 and rich today (Japan)

Poor data for countries that were rich 1870, but (relatively) poor today (Argentina), or countries which were poor in 1870, and poor today (African countries)

Convergence almost tautological: poor in 1870 must have grown faster since they've joined the "rich today" club

Prichett's approach: when 1870 data not available, set it at lower bound for per-capita income (subsistence level for people to survive)

Calculate various measures of dispersion of *implied* income distribution in 1870

Compare to the same measures in 1960, 1990 – which we know from data

Estimating the lower bound

Idea: "even deprivation has its limits"

Think of Malthusian framework: if living standards are too low in any given period, population is falling; continues until living standards stabilize at some higher level

But how low? Some guides:

1. Lowest levels observed in modern data (typically African countries); early 19th-century Maddison data (e.g., India), preindustrial Europe (better data available these days)

2. Subsistence: To be able to work humans require 2000-2400 calories per day and person; slightly lower levels observed during famines (Somalia 1975, China 1961); can use data to calculate what it would cost to buy 2000 calories

3. Mortality: Demographers claim population cannot be stable if child mortality (0-5 years) exceeds 60%. (Why? Due to maximum number of children per woman?) Use cross-country data on child mortality and GDP/capita to see for what level of GDP/capita that mortality exceeds 60% (possibly out-of-sample prediction)

Conclusion: lower bound for GDP/capita equals $250 in 1985 prices and PPP adjusted

For countries lacking data in 1870: assign GDP/capita = \$250 in 1870; let grow at the rate that takes them to their actual levels in 1960

Results: Table 2

- Gaps between richest (US) and poorest in 1870, 1960, 1990
- Standard deviation in log GDP/capita for the same years
- Other measures of dispersion

Conclusion: dispersion has increased; no convergence but "divergence, big time"

Table 3: growth rates, now using only countries with data in 1870

Total 56 countries, including the 17 advanced capitalist, and 28 less developed

Not representative sample, but at least some poor countries

Initially poor countries grow at slower rates than rich: again, divergence

My reflections: still not controlling for anything; might still have conditional convergence from 1870; using an early start date does not mean there were no initial differences in culture, institutions, state capacity

Divergence in the Americas

One example of cross-country divergence: the Americas from 1700 to today

Sokoloff and Engerman (2000, Table 1):

- In 1700 the richest countries were Barbados and Cuba; richer than the US
- By 1997, complete reversal

Why? One not so good explanation:

- British heritage/institutions better than French and Spanish
- But many of today's poor countries in the Americas are former English colonies

Sokoloff and Engerman's explanation:

$$\begin{gathered}\text{Factor endowments}\\ \Downarrow \\ \text{Initial inequality} \\ \Downarrow \\ \text{Inequality, underdevelopment today}\end{gathered}$$

Factor endowments $\Rightarrow$ initial inequality:

Carribean:

- Soil and climate in the Carribean made it possible to grow staple crops (e.g., coffee, sugar).
- Exhibited economies of scale, partly because they were shipped to a world market.
- Labor intense production. Scare labor in the Americas overall. Few natives, many died from diease when European arrived. Solution: import slaves.

Spanish Americas:

- When Europeans arrived there were large existing civilizations (e.g., Mexico, Peru). Natives paid tributes to local elites. Less scarce labor.
- Spanish crown sold land grants for extraction of tributes, taxes, natural resources, and large scale agriculture (e.g. Argentina).
- Restricted immigration until the late 1800's.

USA and Canada:

- Very sparse population, even compared to the rest of the sparsely populated Americas.
- Climate did not allow staple crop production. Slave economy not viable.
- British authorities allowed for large-scale immigration of Europeans.
- Relatively homogenous population.
- Exception that proves the rule: the US South.

Initial inequality $\Rightarrow$ inequality, underdevelopment today:

The elites in the Carribean and Spanish America were able to shape rules, laws, policies to their advantage. Less successful in the USA and Canada.

How?

- Land policy and related factors: restricting and regulating who could buy/own land, mine natural resources, start a business.
- Delaying extension of the franchise: see Table 2. Wealth, literacy requirements.
- Delaying school reform: see Table 3.

Related theoretical work: Galor. Moav, and Vollrath (REStud 2006)

- Four production factors: land, physical capital, low-skilled labor human capital
- Land and low-skilled labor are complements
- Physical and human capital complements
- Interest of capitalists to encourage schooling (raises return to physical capital)
- Interest for landowners to resist schooling (lowers return to land)

Other readings: Acemoglu and Robinson "Why Nations Fail"