Macroeconomics: Economic Growth (Licence 3)
Lesson 5: Human Capital

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Acknowledges: some slides and figures are taken or adapted from the supplemental ressources to the textbook "Introduction to Economic Growth" by Charles I. Jones and Dietrich Vollrath, Third Edition, Norton W.W. Company Inc.

Extensions of the Solow Model

- Extension of the Solow model to include *human capital*.
- Mankiw, Romer, and Weil (1992) "A contribution to the Empirics of Economic Growth", Quarterly Journal of Economics
  - Assess how good is the fit with the data of the predictions of the Solow model with technological progress
  - They augment the model with the human capital and show that this version improves the fit
  - By recognizing that labor in different economies may have different levels of education (skills)

Mankiw, Romer, and Weil (1992): a growth regression

- Mankiw, Romer, and Weil (1992) estimate the Solow growth equation with technical progress with a regression using three different samples of countries
- (1) **Sample 1:** more exhaustive sample of 98 countries (excluding countries for which the oil production is the dominant industry)
- (2) **Sample 2:** excludes countries whose population is lower than 1 million: 75 countries.
- (3) **Sample 3:** 22 OECD countries with a population greater than 1 million. (similar countries but small sample).
- **Dependent variable:** GDP per worker in 1985.

Mankiw, Romer, and Weil (1992): a growth regression

- Recall that in the Solow model with technological progress, we have

$$y^* = A(\frac{s}{\delta + \gamma + n})^{\frac{\alpha}{1-\alpha}} \tag{1}$$

  - If we take the logs, we obtain:

$$ln(y^*) = ln(A) + \frac{\alpha}{1-\alpha} ln(s) - \frac{\alpha}{1-\alpha} ln(\delta + \gamma + n) \tag{2}$$

Mankiw, Romer, and Weil (1992): a growth regression

- Given that A grows at a constant rate γ, we have $A = A_0 e^{\gamma t}$

$$ln(y^*) = ln(A_0) + \gamma t + \frac{\alpha}{1-\alpha} ln(s) - \frac{\alpha}{1-\alpha} ln(\delta + \gamma + n) \quad (3)$$

- Assume that $\delta + \gamma = 0.05$ and both are constant across countries

- Assume that (A_0 is not just technology but also resources endowment, climate, institutions,
- so that we can decompose A_0 in a (a constant) and epsilon, ϵ (a country-specific shock)

Mankiw, Romer, and Weil (1992): a growth regression

- Mankiw, Romer, and Weil (1992) estimate that Solow growth equation with technical progress with a regression using a sample of 98 countries :

$$ln(y_i) = a + \frac{\alpha}{1-\alpha} ln(s_i) - \frac{\alpha}{1-\alpha} ln(n_i + 0.05) + \epsilon_i \qquad (4)$$

- Where i refers to each country
- The dependent variable y_i is the log of GDP per working age person in 1985
- The independent variables are computed as averages over the period 1960-1985 (they repeat the estimation on sub-samples):
- $s_i = I_i / Y_i$ and n_i

Mankiw, Romer, and Weil (1992): a growth regression

- Mankiw, Romer, and Weil (1992) do not impose any constraint that the coefficients on $\ln(si\ )$ and $\ln(ni + 0.05)$ are equal in magnitude and opposite in sign

- Findings: the estimates of both these coefficients have the expected signs : positive and negative, respectively

- They also find that differences in s and n across countries explain a large part of the variation of $R2 = 0.59$

Mankiw, Romer, and Weil (1992): a growth regression

- Then Mankiw, Romer, and Weil (1992) estimate a second specification in order to get an estimate of α:

$$ln(y_i) = a + \frac{\alpha}{1-\alpha}(ln(s_i) - ln(n_i + 0.05)) + \epsilon_i \quad (5)$$

- Findings: the estimated coefficient on $(ln(s_i) - ln(n_i + 0.05))$ is 1.48 (s.e. 0.12),

- which implies that $\alpha = 0.6$: this too large, since α is expected to be 0.33!

Mankiw, Romer, and Weil (1992)'s estimates without human capital

TABLE I
ESTIMATION OF THE TEXTBOOK SOLOW MODEL

Dependent variable: log GDP per working-age person in 1985			
Sample:	Non-oil	Intermediate	OECD
Observations:	98	75	22
CONSTANT	5.48	5.36	7.97
	(1.59)	(1.55)	(2.48)
ln(I/GDP)	1.42	1.31	0.50
	(0.14)	(0.17)	(0.43)
$\ln(n + g + \delta)$	−1.97	−2.01	−0.76
	(0.56)	(0.53)	(0.84)
$\overline{R}^2$	0.59	0.59	0.01
s.e.e.	0.69	0.61	0.38
Restricted regression:			
CONSTANT	6.87	7.10	8.62
	(0.12)	(0.15)	(0.53)
$\ln(I/GDP) - \ln(n + g + \delta)$	1.48	1.43	0.56
	(0.12)	(0.14)	(0.36)
$\overline{R}^2$	0.59	0.59	0.06
s.e.e.	0.69	0.61	0.37
Test of restriction:			
p-value	0.38	0.26	0.79
Implied α	0.60	0.59	0.36
	(0.02)	(0.02)	(0.15)

Mankiw, Romer, and Weil (1992): a growth regression

- Main conclusion of the previous estimations of the Solow model with technology:
  - gives satisfactory results for what it concerns the signs of the effects of s and n
  - gives quite satisfactory results for what it concerns how well observed outcomes are replicated by the estimated model
  - BUT does not give satisfactory results for what it concerns the estimation of α
- To obtain a better fit with the data using a neoclassical growth model, Mankiw, Romer, and Weil (1992) include the human capital in a the Solow model

Mankiw, Romer, and Weil (1992): a growth regression

- To obtain a better fit with the data using a neoclassical growth model, Mankiw, Romer, and Weil (1992) include in the estimations the human capital in a the Solow model
- A better fit since they find that this model specification explains almost the 80% in the variation of incomes ($R2 = 0.78$) and
- the estimated coefficients give $\alpha = 0.31$, which is about the expected value.

Mankiw, Romer, and Weil (1992)'s estimates with human capital

TABLE II
ESTIMATION OF THE AUGMENTED SOLOW MODEL

Dependent variable: log GDP per working-age person in 1985			
Sample:	Non-oil	Intermediate	OECD
Observations:	98	75	22
CONSTANT	6.89	7.81	8.63
	(1.17)	(1.19)	(2.19)
ln(I/GDP)	0.69	0.70	0.28
	(0.13)	(0.15)	(0.39)
$\ln(n + g + \delta)$	−1.73	−1.50	−1.07
	(0.41)	(0.40)	(0.75)
ln(SCHOOL)	0.66	0.73	0.76
	(0.07)	(0.10)	(0.29)
$\overline{R}^2$	0.78	0.77	0.24
s.e.e.	0.51	0.45	0.33
Restricted regression:			
CONSTANT	7.86	7.97	8.71
	(0.14)	(0.15)	(0.47)
$\ln(I/GDP) - \ln(n + g + \delta)$	0.73	0.71	0.29
	(0.12)	(0.14)	(0.33)
$\ln(SCHOOL) - \ln(n + g + \delta)$	0.67	0.74	0.76
	(0.07)	(0.09)	(0.28)
$\overline{R}^2$	0.78	0.77	0.28
s.e.e.	0.51	0.45	0.32
Test of restriction:			
p-value	0.41	0.89	0.97
Implied α	0.31	0.29	0.14
	(0.04)	(0.05)	(0.15)
Implied β	0.28	0.30	0.37
	(0.03)	(0.04)	(0.12)

Note. Standard errors are in parentheses. The investment and population growth rates are averages for the

Extensions of the Solow Model

- To take into account the empirical findings they modify the Solow model to include *human capital*.

- This allows the skills of workers to increase, separately from technological progress.

- Suppose that output, Y, is produce with capital, K, and skilled labor, H under a Cobb-Douglas production function:

$$Y = K^{\alpha}(AH)^{1-\alpha} \tag{6}$$

where A is the labor-augmenting technology that grows exogenously at rate γ and H is the stock of human capital

$$H = e^{\psi u}L. \tag{7}$$

- L is the number of workers.
- u is the amount of time spent acquiring human capital (think of it as years of schooling).

$$H = e^{\psi u} L. \tag{8}$$

- In per worker terms (diving by L both sides we get):

$$h = H/L = e^{\psi u}. \tag{9}$$

$$H = e^{\psi u} L. \tag{10}$$

- Return to education

- What is psi, ψ? The increase in H from one more unit of time acquiring human capital. Take total derivative of H relative to u (increasing one year of schooling):

$$dH/du = (\psi H) \tag{11}$$

- This is the absolute change in H given an increase in u.

Extensions of the Solow Model

The proportional change in H is

$$\frac{dH}{H} = \psi du. \tag{12}$$

- Suppose that u increases by 1 unit (one additional year of schooling)
- Suppose that $\psi = 0.10$
- $\rightarrow H$ rises by 10 percent.
- This formula for human capital is consistent with micro-level evidence on wages and earnings. ψ is the return to one year of schooling.

We solve the model as in the previous lessons, start by writing output in per worker terms (dividing by L and denoting in lowercase letters):

$$y = k^{\alpha}(Ah)^{1-\alpha}. \tag{13}$$

Note that $h = e^{\psi u}$
Take logs and derivatives,

$$\frac{\dot{y}}{y} = \alpha\frac{\dot{k}}{k} + (1-\alpha)\frac{\dot{A}}{A} + (1-\alpha)\frac{\dot{h}}{h}. \tag{14}$$

We assume that

$$\frac{\dot{h}}{h} = 0 \tag{15}$$

$$\frac{\dot{A}}{A} = \gamma \tag{16}$$

or human capital (h) does not have trend growth, but there is trend growth in technology (A).

A balanced growth path, as before, is where $\dot{y}/y$ is constant. That required that $\dot{y}/y = \dot{k}/k$. So again we have that

$$\frac{\dot{y}}{y} = \gamma \tag{17}$$

along the balanced growth path. Human capital doesn't change this.

Extensions of the Solow Model

So in steady state

$$\dot{k}/k = \gamma = s\frac{y}{k} - (\delta + n). \tag{18}$$

Plug in for y to get

$$\gamma = s\frac{(Ah)^{1-\alpha}}{k^{1-\alpha}} - (\delta + n). \tag{19}$$

Solve for

$$\frac{k}{Ah} = \left(\frac{s}{\delta + n + \gamma}\right)^{1/(1-\alpha)} . \tag{20}$$

Extensions of the Solow Model

Given :

$$\frac{k}{Ah} = \left(\frac{s}{\delta + n + \gamma}\right)^{1/(1-\alpha)}. \quad (21)$$

we know that

$$y = k^{\alpha}(Ah)^{1-\alpha} = Ah\left(\frac{k}{Ah}\right)^{\alpha} \quad (22)$$

$$y = Ah\left(\frac{s}{\delta + n + \gamma}\right)^{\alpha/(1-\alpha)} \quad (23)$$

$$y(t) = A(t)e^{\psi u}\left(\frac{s}{\delta + n + \gamma}\right)^{\alpha/(1-\alpha)}. \quad (24)$$

We see here that human capital, as determined by u, influences the level of output per worker, even though it does not change the growth rate of output per worker.

Extensions of the Solow Model

Consider the model in relative terms. Relative to a rich-country standard like the U.S.

$$\hat{y}_i = \frac{y_i}{y_{US}} \tag{25}$$

so that $\hat{y}_i$ is the output per worker of country i relative to that in the U.S.

If output per worker is described as in our modified model, then

$$\hat{y}_i = \frac{A_i e^{\psi u_i} \left(\frac{s_i}{\delta+n_i+g}\right)^{\alpha/(1-\alpha)}}{A_{US} e^{\psi u_{US}} \left(\frac{s_{US}}{\delta+n_{US}+g}\right)^{\alpha/(1-\alpha)}}. \tag{26}$$

where $g = \gamma$

Extensions of the Solow Model

If output per worker is described as in our modified model, then

$$\hat{y}_i = \frac{A_i e^{\psi u_i} \left(\frac{s_i}{\delta + n_i + g}\right)^{\alpha/(1-\alpha)}}{A_{US} e^{\psi u_{US}} \left(\frac{s_{US}}{\delta + n_{US} + g}\right)^{\alpha/(1-\alpha)}}$$

which can reduce to

$$\hat{y}_i = \frac{A_i}{A_{US}} e^{\psi(u_i - u_{US})} \left(\frac{s_i}{s_{US}}\right)^{\alpha/(1-\alpha)} \left(\frac{\delta + n_{US} + g}{\delta + n_i + g}\right)^{\alpha/(1-\alpha)} \quad (27)$$

Note, we've made the assumption that g is identical for all countries.

Explaining Cross-Country Variation

Solow originally assumed that A was identical across countries, as they could share technology. What happensif $A_i = A_{US}$?

$$\hat{y}_i = e^{\psi(u_i - u_{US})} \left(\frac{s_i}{s_{US}} \right)^{\alpha/(1-\alpha)} \left(\frac{\delta + n_{US} + g}{\delta + n_i + g} \right)^{\alpha/(1-\alpha)} \tag{28}$$

Are the differences in u, s, and n sufficient to explain cross-country output per worker differences?

Plug in values of $\alpha = 1/3$, $\psi = 0.10$, $\delta + g = 0.075$. Use years of education as u_i. Use average savings rate as s_i. Use average population growth as n_i.

Explaining Cross-Country Variation

Plug in values of $\alpha = 1/3$, $\psi = 0.10$, $\delta + g = 0.075$. Use years of education as u_i. Use average savings rate as s_i. Use average population growth as n_i.

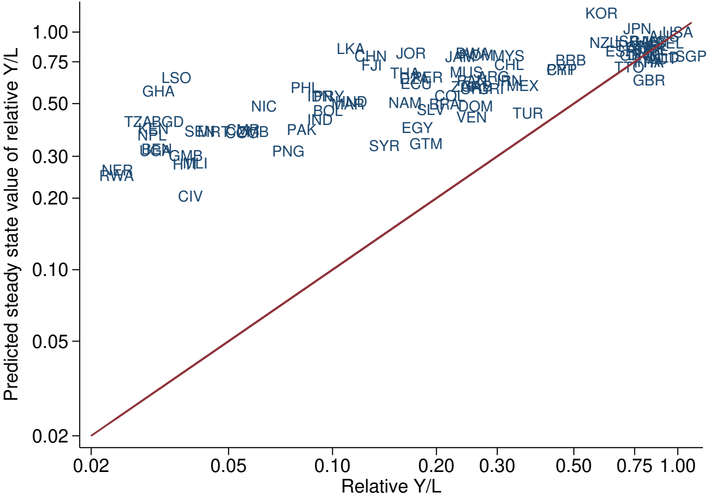
$$\hat{y}_i = e^{\psi(u_i - u_{US})} \left(\frac{s_i}{s_{US}} \right)^{\alpha/(1-\alpha)} \left(\frac{\delta + n_{US} + g}{\delta + n_i + g} \right)^{\alpha/(1-\alpha)} \tag{29}$$

Example: $s_{India} = 0.241$, $u_{India} = 4.23$, $n_{India} = 0.017$. $s_{US} = 0.202$, $u_{US} = 13.24$, $n_{US} = 0.011$. So

$$\hat{y}_{India} = e^{0.10(4.23-13.24)}(0.241/0.202)^{1/2}(0.086/0.092)^{1/2} = 0.429 \tag{30}$$

Based on education, savings, and population growth, India should be 43% as rich as U.S. India is actually about 9% as rich as U.S.

All Countries



- There are a lot of countries where the Solow model does not fit very well the empirical data

The Solow Residual

- **Savings, education, and population growth do not explain all of the variation in output per worker.**
- Those three factors suggest most poor countries should be much better off than they actually are.
- So what's missing?

The Solow Residual

Technology/productivity differences. $A_i \neq A_{US}$ for countries. We cannot measure A_i directly, but we can infer if from data. Take

$$y_i = k_i^{\alpha}(A_i h_i)^{1-\alpha} \tag{31}$$

and re-arrange to

$$A_i = \left(\frac{y_i}{k_i^{\alpha} h_i^{1-\alpha}}\right)^{1/(1-\alpha)}. \tag{32}$$

Given data on y_i, k_i, and h_i we can back out the actual value of A_i.

The Solow Residual

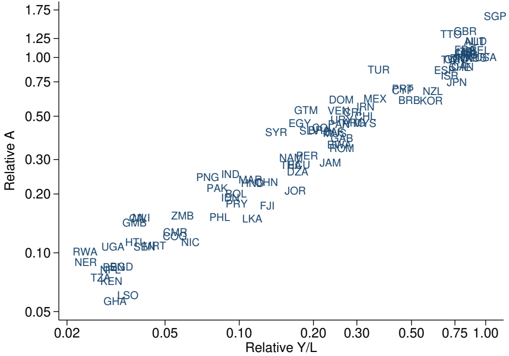
The value of A_i from this is sometimes called "The Solow Residual". It measures everything that matters besides k_i, h_i for output per worker.

Last, for comparison, calculate the relative productivity

$$\hat{A}_i = \frac{A_i}{A_{US}} \tag{33}$$

The Solow Residual

Values of $\hat{A}_i$ across countries



- The levels of A calculated from the production function are correlated with levels of output per worker
- Rich countries have high levels of A and poor countries low levels
- The correlation is far from perfect: Singapore, Trinidad and Tobago and UK have much higher levels of A than expected from GDP per capita

Technology Drives Differences

- The values of relative productivity, $\hat{A}_i$, do a good job of describing differences in output per worker across countries
- Differences in A_i explain about $1/2$ to $2/3$ of the differences in output per worker across countries.
- Note: estimates of A computed in this way are like residuals from growth accounting: they incorporate any differences in production not explained by production factors.
- E.G: we do not control for differences in institutions, educational system, previous experience, this will be captured in A.
- Differences across countries in A are large: the poorest countries in the world have levels of A that are only 10 to 15 percent those in richest countries

Technology Drives Differences

- The richest countries of the world have an output per worker that is 40 times higher than the poorest countries
- This difference can be associated to:
- (1) Differences in investment rate in K
- (2) Differences in investment rates in human capital (H)
- (3) Differences in productivity (A)

Technology Drives Differences

- The richest countries of the world have an output per worker that is 40 times higher than the poorest countries
- This difference can be associated to:
- (1) Differences in investment rate in K: richest countries have I rates of 25 percent and poorest countries of 5 percent
- (2) Differences in investment rates in human capital (H): workers in rich countries have on average 10 years of education while in poorest countries they have less than 3 years
- (3) Differences in productivity (A): by construction differences in TFP account for the remaining.

Growth Rate Differences

Some countries grow more quickly than others. Why?

One explanation: convergence.

- Catch-up phenomenon: poor countries tend to grow faster than rich countries
- Does the gap between poor and rich countries is getting closer?
- Causes of convergence.

Growth Rate Differences

Some countries grow more quickly than others. Why?.

- Causes of convergence:
- Technology transfer across countries
- The role of international trade: Imports of capital goods and intermediates from rich countries;
- Do we observe convergence in growth rates across countries?

Growth Rate Differences

Some countries grow more quickly than others. Why?

One explanation: convergence. Poor countries grow more quickly than rich countries.

Look at equation for growth rate of $\dot{k}/k$. In steady state is equal to γ

$$\frac{\dot{k}}{k} = s\frac{y}{k} - (\delta + n) \quad (34)$$

$$= s\left(\frac{Ah}{k}\right)^{1-\alpha} - (\delta + n) \quad (35)$$

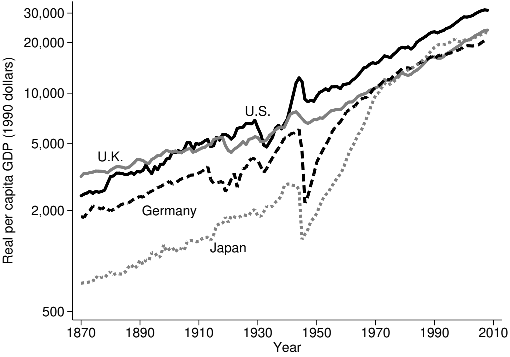
if

$$\frac{k}{Ah} < \left(\frac{s}{\delta + n + \gamma}\right)^{1/(1-\alpha)} \quad (36)$$

then $\dot{k}/k > \gamma$. So if k/Ah is low relative to steady state, country grows quickly.

Long-run Convergence

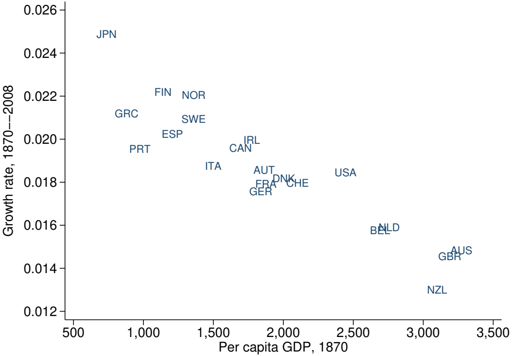
Countries with similar A and h:



- Narrowing of the gap is evident,
- In 1870 UK had the highest GDP per capita
- Around 1950, US surpassed UK and remain the leader.

Long-run Convergence

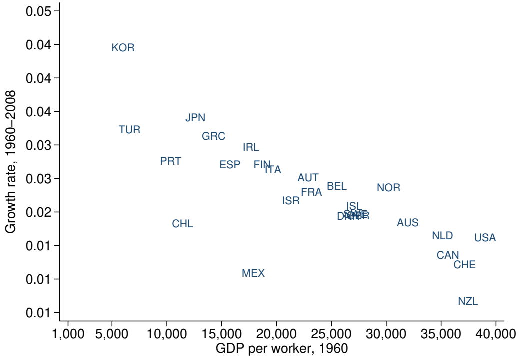
Countries with similar A and h:



- Ability of convergence hypothesis
- Countries like UK and Australia (rich in 1870) grew slowly
- Japan (poor in 1870) grew faster

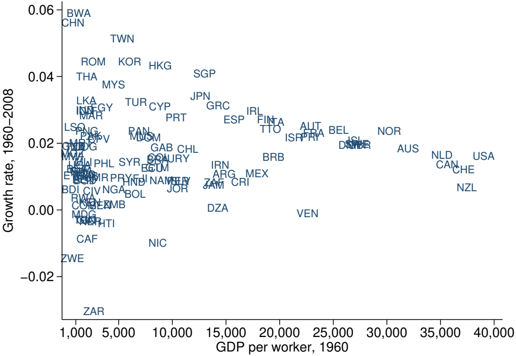
Convergence in the OECD

Countries with similar A and h:



- Convergence hypothesis works very well for OECD countries
- But new members Chile and Mexico
- has low grow rates than expected

Lack of Convergence



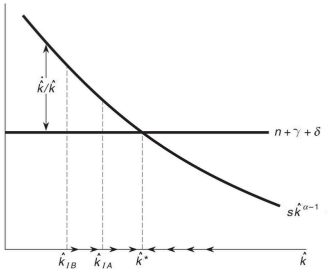
- Convergence hypothesis fails to explain differences in growth rates across the world as a whole
- Baumol (1986) study shows that in a large sample of countries:
- poor countries do not grow faster than rich ones

Conditional Convergence

The poor countries are not closing the gap

- Why do we observe convergence among some set of countries but lack of convergence among all countries in the world?
- The Solow growth model has an answer.

Transition dynamics



- The difference between both curves is the growth rate of k, and the growth rate of y is proportional
- An economy starting at $k_0 < k_*$ will experience a growing capital per worker
- The further to the left of the steady state (the lower the capital per worker), the higher is the growth rate of the capital per worker (K_{IB})

Conditional Convergence

- The difference between both curves is the growth rate of k, and the growth rate of y is proportional
- Since the growth rate of technology A is constant
- Any change in growth rates of k and y is due to changes in growth rates of capital per worker and output per worker
- Among countries with the same steady state: the convergence hypothesis should hold: poor countries should grow faster on average than rich countries

Conditional Convergence

Not all countries seem to fit. They grow very slowly even though they are poor.

Conditional convergence:

- Countries grow faster, the farther they are **from their own steady state**.
- The further the economy is *above the steady state, the slower the economy should grow*.
- **Poor countries have low steady states, so they are already close to their steady state, and grow slowly.**.

Conditional Convergence

Can we see this in the data? Compute the steady state for each country as

$$y_i^* = A_i h_i \left(\frac{s_i}{\delta + g + n_i} \right)^{\alpha/(1-\alpha)} \tag{37}$$

using data on h_i, s_i, and n_i like before. Use the value of A_i from 1970.

Then compute how far each country is from steady state

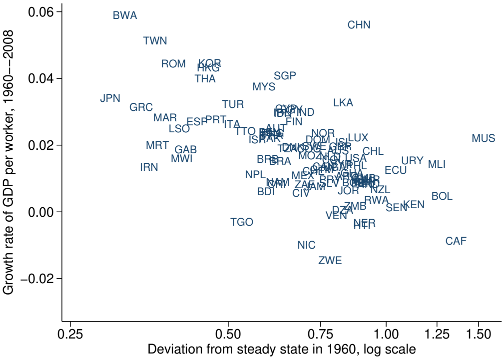
$$\frac{y_i}{y_i^*} \tag{38}$$

and graph growth from 1960–2008 versus this relative value.

Conditional Convergence

- Mawkin, Romer and Weil (1992) and Barro and Sala-i-Martin (1992) show that:
- the prediction of the Solow model: "The further an economy is below its steady state, the faster the economy should grow and the further the economy is above the steady state the slower the economy should grow "
- can explain differences in growth rates across countries of the world

Conditional convergence for the world



- Plot the growth rate of GDP per worker from 1960 to 2008 against the deviation of GDP per worker relative to US from its steady state value
- countries that are poor relative to their own steady state do tend to grow rapidly
- In 1960, Japan, Botswana and Taiwan were consider poor in 1960 and growth rapidly.

Unconditional Convergence

- Barro and Sala-i-Martin (1991, 1992) show that:
- the US states, regions of France and Japan exhibit unconditional convergence similar to the OECD
- This matches the prediction of the Solow model **if regions within a country are similar in terms of investment and population growth.**

Differences in growth rates across countries

- How does the Solow model account for differences in growth rates across countries?
- The principle of transition dynamics: countries that have not reached their steady states are not expected to grow at the same rate
- Those below their steady state will grow rapidly and those above their steady state will grow slowly
- **Why countries may not be in the steady state?**

Differences in growth rates across countries

- **Different shocks that make that countries may not be in the steady state:**
- (1) An increase in investment rate (**saving rate**)
- (2) Change in **population growth rate**
- (3) World War II destroyed capital stock (**depreciation rate**)
- (4) Changes in TFP (**technological progress**)

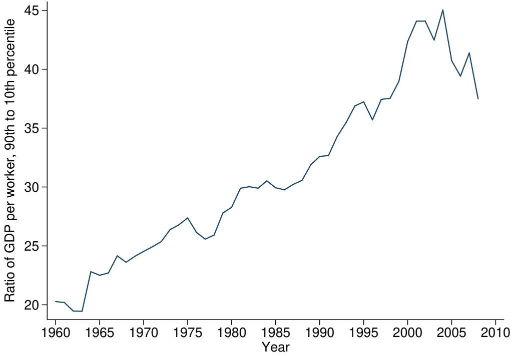
Equality?

- If there were **absolute convergence** (like in the OECD),
- then countries are getting **more equal.**
- If there is **conditional convergence** (like in the whole sample),
- then countries may be getting **more unequal.**
- These questions are about **income distribution** around the world.

Equality?

- If we look at income distribution across the world (**in relative terms**) it seems that it become more **unequal**
- From the world as a whole the big gaps in income per capita across countries have not narrowed over time.

Income ratios



- Ratio of GDP per worker for the country of 90th percentile of the world distribution to the country of 10th percentile
- In 1960, GDP per worker in the country of the 90th percentile was about twenty times that of the country at the 10th percentile
- By 2000, this ratio has risen by 40

Equality?

- However, **in absolute numbers of people, world looks like it is getting more equal.**
- Sala-i-Martin (2006): In 1970, 534 million people (15% of world population) lived on less than $1 per day.
- In 2000 only 321 million people (6% of world population) lived on less than $1.
- Absolute poverty has been decreasing over time for the world population.
- This fall can be attributed to the increase in GDP per capital in China and India.

Mankiw, Romer, and Weil (1992)'s test for convergence

- Mankiw, Romer, and Weil (1992)'s test for convergence predictions of the Solow model by:
- Regressing the change in the log of income per capita between 1960 and1985 on the log of income per capita in 1960
- with and without controlling for investment growth, population and years of education

Mankiw, Romer, and Weil (1992)'s test for convergence

TABLE III
TESTS FOR UNCONDITIONAL CONVERGENCE

Dependent variable: log difference GDP per working-age person 1960–1985			
Sample:	Non-oil	Intermediate	OECD
Observations:	98	75	22
CONSTANT	−0.266	0.587	3.69
	(0.380)	(0.433)	(0.68)
ln(Y60)	0.0943	−0.00423	−0.341
	(0.0496)	(0.05484)	(0.079)
$\overline{R}^2$	0.03	−0.01	0.46
s.e.e.	0.44	0.41	0.18
Implied λ	−0.00360	0.00017	0.0167
	(0.00219)	(0.00218)	(0.0023)

Note. Standard errors are in parentheses. Y60 is GDP per working-age person in 1960.

- Reproduces the results of other studies on the failure of income convergence (unconditional), non significant effect and R2 almost zero for full sample,
- But shows convergence in OECD countries

Mankiw, Romer, and Weil (1992)'s test for convergence

TABLE IV
TESTS FOR CONDITIONAL CONVERGENCE

Dependent variable: log difference GDP per working-age person 1960–1985			
Sample:	Non-oil	Intermediate	OECD
Observations:	98	75	22
CONSTANT	1.93	2.23	2.19
	(0.83)	(0.86)	(1.17)
ln(Y60)	−0.141	−0.228	−0.351
	(0.052)	(0.057)	(0.066)
ln(I/GDP)	0.647	0.644	0.392
	(0.087)	(0.104)	(0.176)
$\ln(n + g + \delta)$	−0.299	−0.464	−0.753
	(0.304)	(0.307)	(0.341)
$\overline{R}^2$	0.38	0.35	0.62
s.e.e.	0.35	0.33	0.15
Implied λ	0.00606	0.0104	0.0173
	(0.00182)	(0.0019)	(0.0019)

Note. Standard errors are in parentheses. Y60 is GDP per working-age person in 1960. The investment and population growth rates are averages for the period 1960–1985. $(g + \delta)$ is assumed to be 0.05.

- Controls for investment growth and population growth
- the coefficient becomes significant and negative showing evidence of conditional convergence

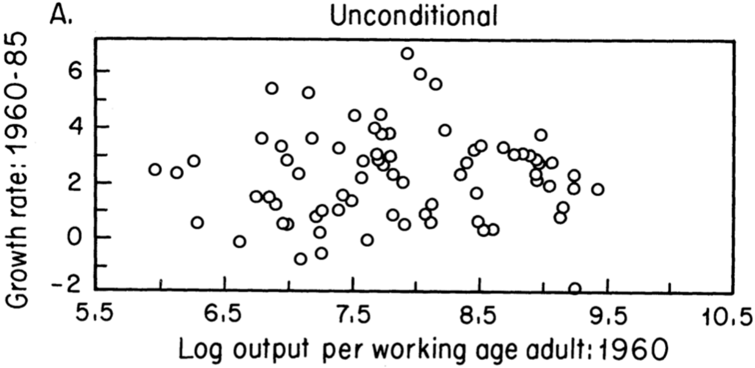
Mankiw, Romer, and Weil (1992)'s test for convergence

TABLE V
TESTS FOR CONDITIONAL CONVERGENCE

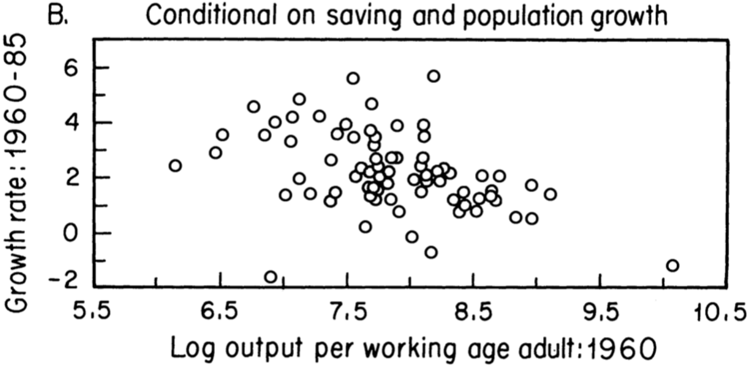
Dependent variable: log difference GDP per working-age person 1960–1985			
Sample:	Non-oil	Intermediate	OECD
Observations:	98	75	22
CONSTANT	3.04	3.69	2.81
	(0.83)	(0.91)	(1.19)
ln(Y60)	−0.289	−0.366	−0.398
	(0.062)	(0.067)	(0.070)
ln(I/GDP)	0.524	0.538	0.335
	(0.087)	(0.102)	(0.174)
$\ln(n + g + \delta)$	−0.505	−0.551	−0.844
	(0.288)	(0.288)	(0.334)
ln(SCHOOL)	0.233	0.271	0.223
	(0.060)	(0.081)	(0.144)
$\overline{R}^2$	0.46	0.43	0.65
s.e.e.	0.33	0.30	0.15
Implied λ	0.0137	0.0182	0.0203
	(0.0019)	(0.0020)	(0.0020)

- Controls also for human capital besides controlling for investment growth and population growth
- improves the fit of the regression showing evidence of conditional convergence

Mankiw, Romer, and Weil (1992)'s test for convergence



Mankiw, Romer, and Weil (1992)'s test for convergence



Mankiw, Romer, and Weil (1992)'s test for convergence

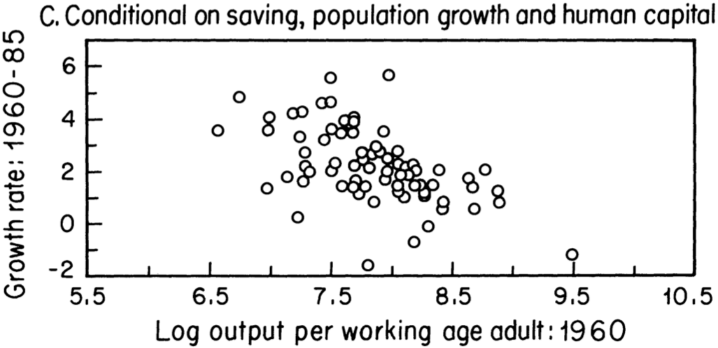


FIGURE I
Unconditional versus Conditional Convergence