Advanced Economic Growth: Lecture 1, Introduction

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Cross-Country Income Differences (1)

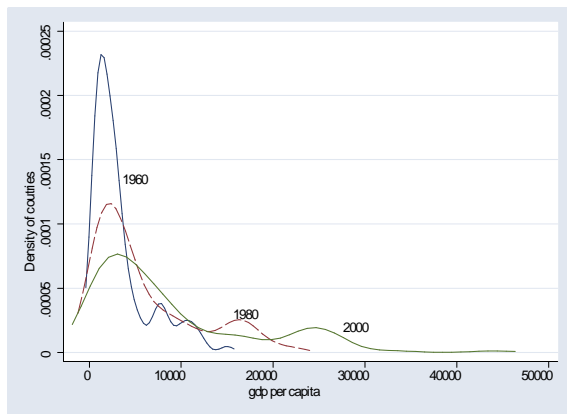- There are very large differences in income per capita and output per worker across countries today.

Figure: Estimates of the distribution of countries according to PPP-adjusted GDP per capita in 1960, 1980 and 2000.

Cross-Country Income Differences (2)

- Part of the spreading out of the distribution in the figure is because of the increase in average incomes.
- It is more natural to look at the log of income per capita when growth is approximately proportional
  - when $x(t)$ grows at a proportional rate, $\log x(t)$ grows linearly,
  - that is, if $x_1(t)$ and $x_2(t)$ both grow by 10% over a certain period of time, $x_1(t) - x_2(t)$ will also grow, while $\log x_1(t) - \log x_2(t)$ will remain constant.
- The next figure shows a similar pattern, but now the spreading-out is more limited.
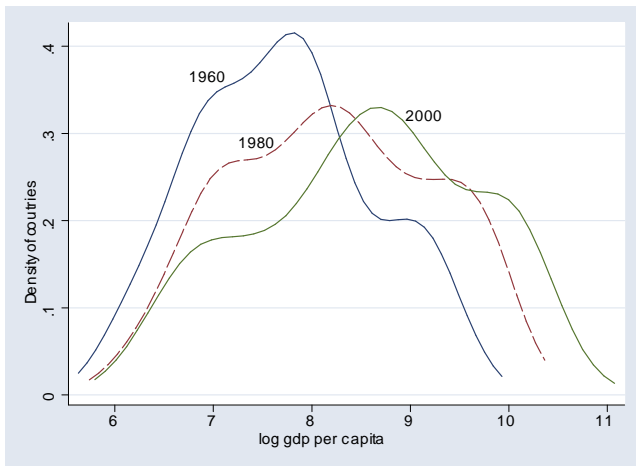
Cross-Country Income Differences (3)

Figure: Estimates of the distribution of countries according to log GDP per capita (PPP-adjusted) in 1960, 1980 and 2000.

Cross-Country Income Differences (4)

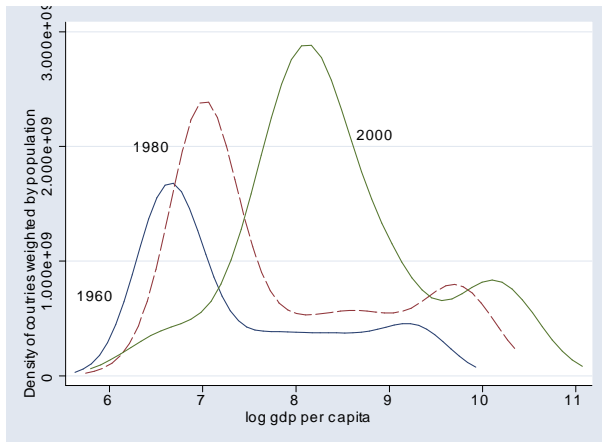- Inequality among nations, or inequality among individuals?

Figure: Estimates of the population-weighted distribution of countries according to log GDP per capita (PPP-adjusted) in 1960, 1980 and 2000.

Cross-Country Income Differences (5)

- Theory is easier to map to data when we look at output (GDP) *per worker*. Moreover, key sources of difference in economic performance across countries are national policies and institutions.
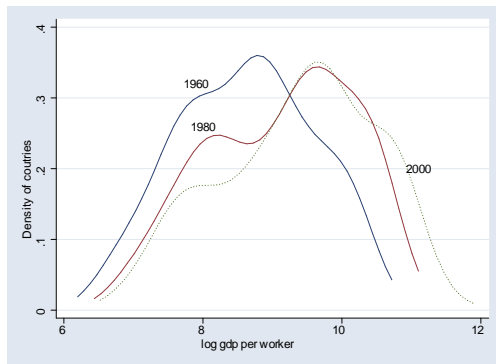

Figure: Estimates of the distribution of countries according to log GDP per worker (PPP-adjusted) in 1960, 1980 and 2000.

Income, Growth and Welfare

- Overall, two important facts:
  1. there is a large amount of inequality in income per capita and income per worker across countries;
  2. there is a slight but noticeable increase in inequality across nations (though not necessarily across individuals in the world economy).

- Why care about income differences?
  1. Welfare.
  2. Understanding the structure and efficiency of production and market mechanisms.
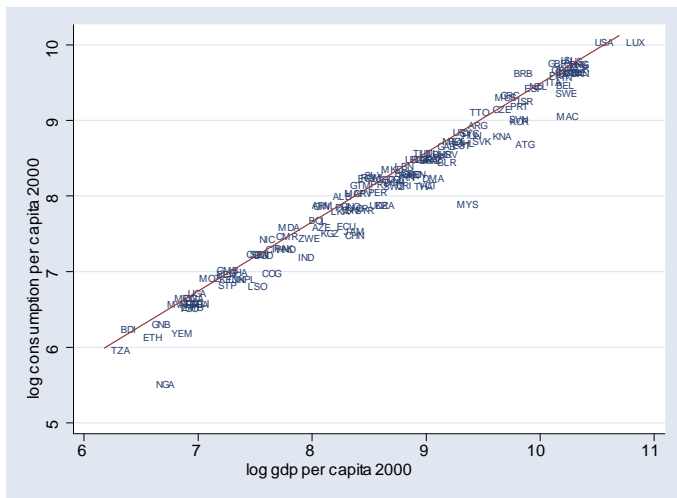
Income and Welfare (1)

Figure: The association between income per capita and consumption per capita in 2000.
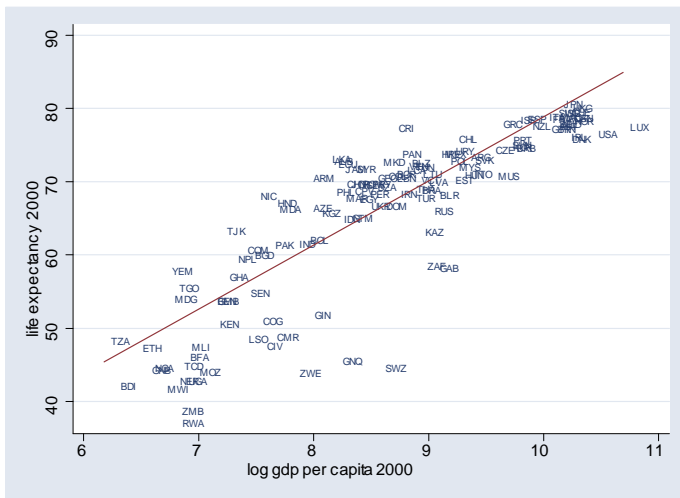
Income and Welfare (2)

Figure: The association between income per capita and life expectancy at birth in 2000.

Caveats

- Understanding how some countries can be so rich while some others are so poor a major question for economics and social sciences in general.

- But, income per capita not a "sufficient statistic" for the welfare of the average citizen.

  - Economic growth is generally good for welfare but it often creates "winners" and "losers". (Joseph Schumpeter's *creative destruction;* Simon Kuznet's structural transformations; political economy analyses of economic growth).
  - A stark illustration: South Africa under Apartheid.
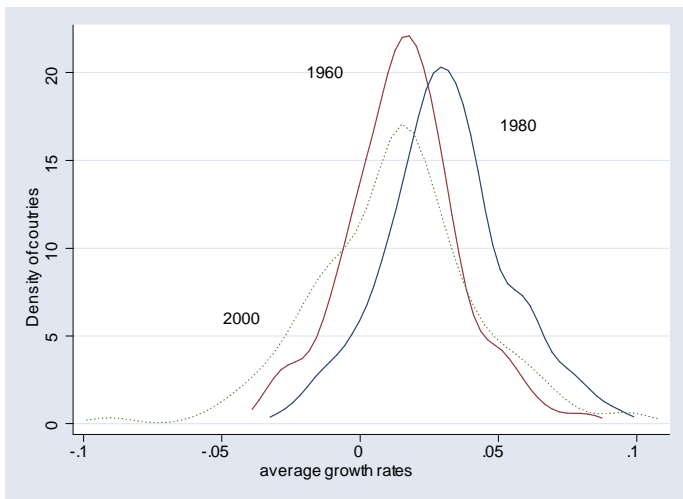
Postwar Growth Patterns

Figure: Estimates of the distribution of countries according to the growth rate of GDP per worker (PPP-adjusted) in 1960, 1980 and 2000.

Economic Growth in Selected Countries
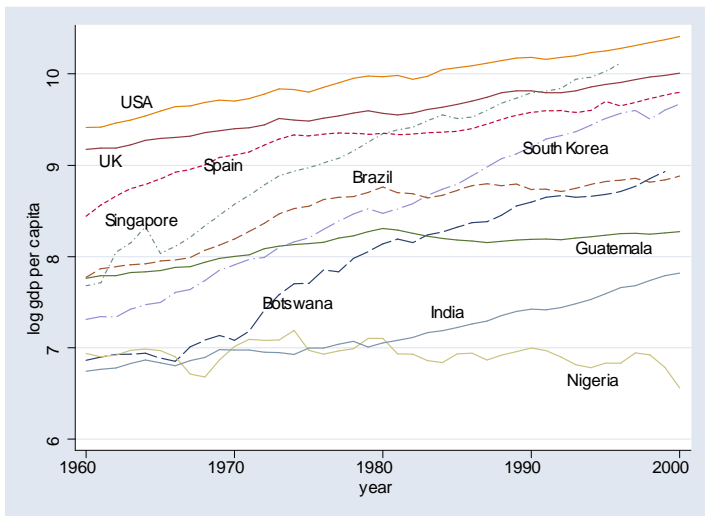
Figure: The evolution of income per capita in selected countries, 1960-2000.

Economic Growth and Income Differences

- Why is the United States richer in 1960 than other nations and able to grow at a steady pace thereafter?

- How did Singapore, South Korea and Botswana manage to grow at a relatively rapid pace for 40 years?

- Why did Spain grow relatively rapidly for about 20 years, but then slow down? Why did Brazil and Guatemala stagnate during the 1980s?

- What is responsible for the disastrous growth performance of Nigeria?

Origins of Income Differences and World Growth (1)

- Growth responsible for current cross-country income differences. But postwar growth by itself is not.
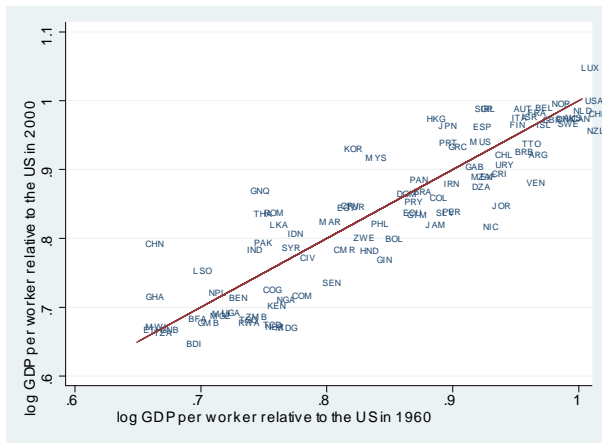
Figure: Log GDP per worker in 2000 versus log GDP per worker in 1960.

Origins of Income Differences and World Growth (2)
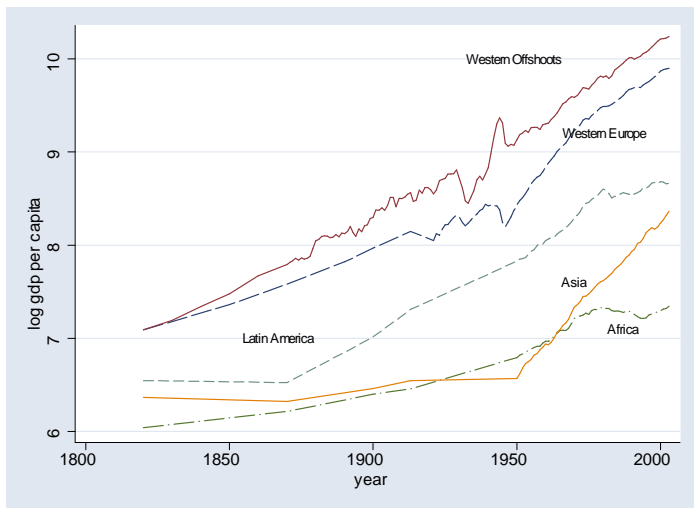
Figure: The evolution of average GDP per capita in Western Offshoots, Western Europe, Latin America, Asia and Africa, 1820-2000.

Origins of Income Differences and World Growth (3)
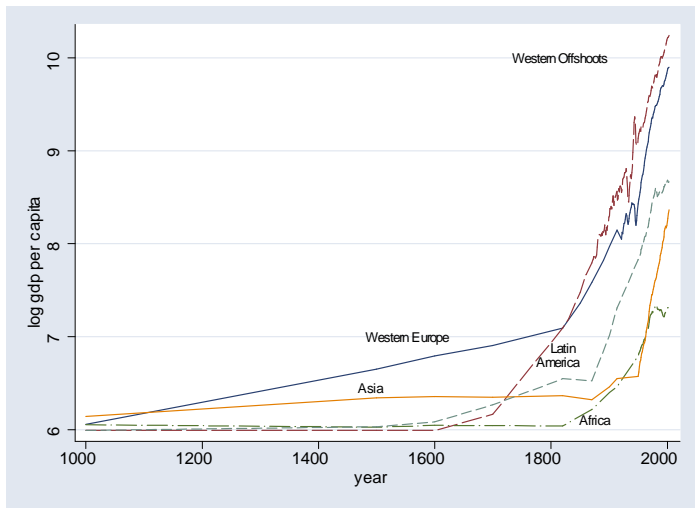
Figure: The evolution of average GDP per capita in Western Offshoots, Western Europe, Latin America, Asia and Africa, 1000-2000.

Long-Run Growth in Selected Countries
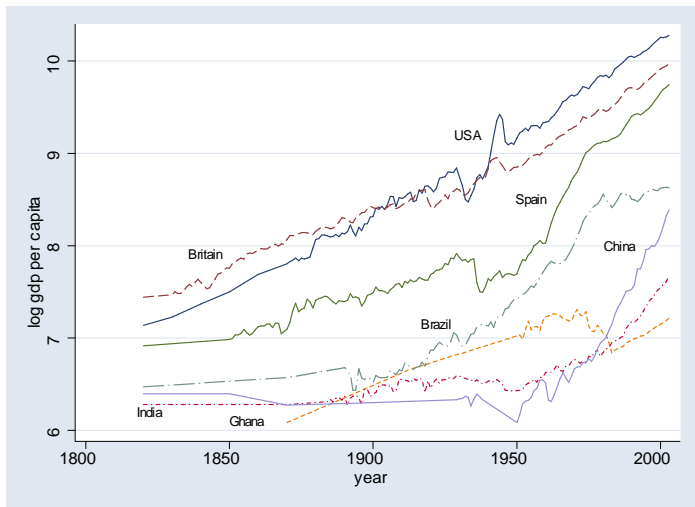
Figure: The evolution of income per capita in the United States, Britain, Spain, Brazil, China, India and Ghana, 1820-2000.

No Unconditional Convergence

- Consistent with the post-war patterns presented so far.

Figure: Annual growth rate of GDP per worker between 1960 and 2000 versus log GDP per worker in 1960 for the entire world.

But a Different Picture Among Relatively Similar Countries

- Convergence among (original) OECD countries.

Figure: Annual growth rate of GDP per worker between 1960 and 2000 versus log GDP per worker in 1960 for core OECD countries.

Conditional Convergence

- Barro (1991): focus on "conditional convergence": the income gap between countries that share the same characteristics.
- Consider a typical "Barro growth regression":

$$g_{t,t-1} = \beta \ln y_{t-1} + \mathbf{X}'_{t-1}\boldsymbol{\alpha} + \varepsilon_t \tag{1}$$

- Useful for describing the data, but not for estimating causal effects of the variables in $\mathbf{X}_{t-1}$.
- These variables typically correlated with growth, but not necessarily exogenous (e.g., investment, human capital, life expectancy,...).

Correlates of Economic Growth (1)
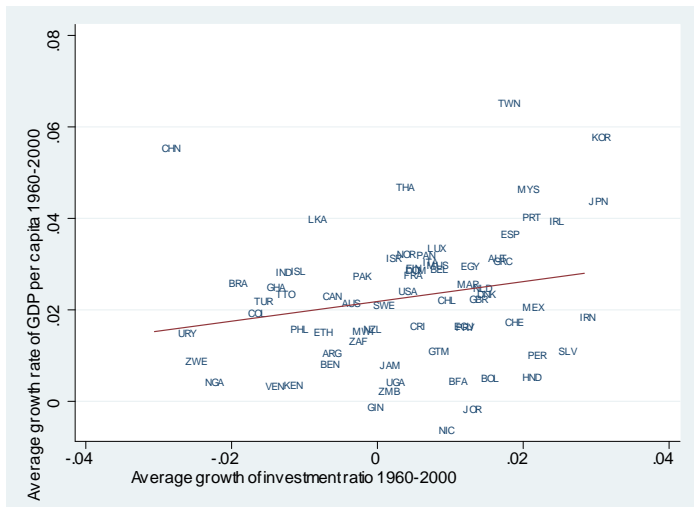
Figure: The relationship between average growth of GDP per capita and average growth of investments to GDP ratio, 1960-2000.

Correlates of Economic Growth (2)
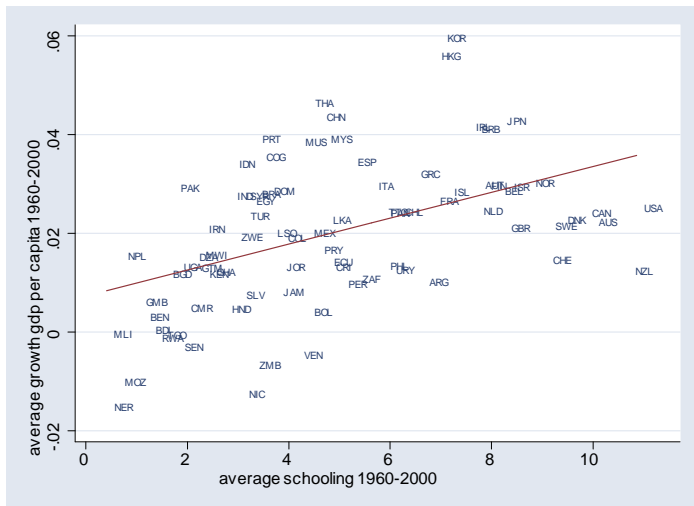
From Correlates to Fundamental Causes (1)

- The correlates of economic growth, such as physical capital, human capital and technology, are the first topic of study in economic growth analyses.

- But these are only *proximate causes* of economic growth and economic success.

- Why do certain societies fail to improve their technologies, invest more in physical capital, and accumulate more human capital?

  - ▶ how did South Korea and Singapore manage to grow, while Nigeria failed to take advantage of the growth opportunities?
  - ▶ If physical capital accumulation is so important, why did Nigeria not invest more in physical capital?
  - ▶ If education is so important, why are education levels in Nigeria still so low and why is existing human capital not being used more effectively?

- The answer to these questions is related to the *fundamental causes* of economic growth.

From Correlates to Fundamental Causes (2)

- We can think of the following list of potential causes:
  1. luck (or multiple equilibria)
  2. geographic differences
  3. institutional differences (political economy)
  4. cultural differences

- Important to link different approaches to the process of economic growth to possible fundamental causes of long-run development.

Cross-Country Income Differences: Regressions (1)

- For a better understanding of proximate causes, let us consider an extended Solow model with human capital (see Chapter 3 of the book).

- Assume that country $j = 1, ..., N$ has the aggregate production function

$$Y_j(t) = K_j(t)^\beta H_j(t)^\alpha (A_j(t) L_j(t))^{1-\alpha-\beta}.$$

- Notice the somewhat unusual form of the production function (human capital as a separate factor of production; is this reasonable?)

- Countries differ in terms of their investment (saving) rates in physical and human capital, $s_{k,j}$ and $s_{h,j}$, population growth rates, n_j, and technology growth rates $\dot{A}_j(t) / A_j(t) = g_j$. As usual, define $k_j \equiv K_j / A_j L_j$ and $h_j \equiv H_j / A_j L_j$.

Cross-Country Income Differences: Regressions (1)

- Unique steady state for each country, with physical and human capital to effective labor ratios

$$
k_j^* = \left(\left(\frac{s_{k,j}}{n_j + g_j + \delta_k} \right)^{1-\alpha} \left(\frac{s_{h,j}}{n_j + g_j + \delta_h} \right)^{\alpha} \right)^{\frac{1}{1-\alpha-\beta}}
$$

$$
h_j^* = \left(\left(\frac{s_{k,j}}{n_j + g_j + \delta_k} \right)^{\beta} \left(\frac{s_{h,j}}{n_j + g_j + \delta_h} \right)^{1-\beta} \right)^{\frac{1}{1-\alpha-\beta}}.
$$

- Therefore, the balanced growth path of income for country $j = 1, ..., N$ can be expressed as:

$$
\ln y_j^* (t) = \ln \bar{A}_j + gt + \frac{\beta}{1-\alpha-\beta} \ln \left(\frac{s_{k,j}}{n_j + g + \delta_k} \right) \quad (2)
$$
$$
+ \frac{\alpha}{1-\alpha-\beta} \ln \left(\frac{s_{h,j}}{n_j + g + \delta_h} \right).
$$

Cross-Country Income Differences: Regressions (2)

- How to take this equation to data? Mankiw, Romer and Weil (1992) assume:

Orthogonal technology assumption $\bar{A}_j = \varepsilon_j A$, with ε_j orthogonal to all other variables.

- And they take:
    - $\delta_k = \delta_h = \delta$ and $\delta + g = 0.05$.
    - $s_{k,j}$=average investment rates (investments/GDP).
    - $s_{h,j}$=fraction of the school-age population that is enrolled in secondary school.

- MRW first estimate equation (2) without the human capital term

$$\ln y_j^* = \text{constant} + \frac{\beta}{1-\beta} \ln(s_{k,j}) - \frac{\beta}{1-\beta} \ln(n_j + g + \delta_k) + \varepsilon_j.$$

- Then, the full version with human capital.

Cross-Country Income Differences: Regressions (3)

Estimates of the Basic Solow Model

	MRW	Updated data	
	1985	1985	2000
$\ln(s_k)$	1.42	1.01	1.22
	(.14)	(.11)	(.13)
$\ln(n + g + \delta)$	-1.97	-1.12	-1.31
	(.56)	(.55)	(.36)
Adj R^2	.59	.49	.49
Implied β	.59	.50	.55
No. of observations	98	98	107

Cross-Country Income Differences: Regressions (4)

- Their estimates for $\beta/(1-\beta)$, implies that β must be around $2/3$, but should be around $1/3$.
- The most natural reason for the high implied values of β is that ε_j is correlated with $\ln(s_{k,j})$,
  - either because the orthogonal technology assumption is not a good approximation to reality
  - or because there are also human capital differences correlated with $\ln(s_{k,j})$—so that there is an *omitted variable bias*.

Cross-Country Income Differences: Regressions (5)

Estimates of the Augmented Solow Model

	MRW	Updated data	
	1985	1985	2000
$\ln(s_k)$	.69	.65	.96
	(.13)	(.11)	(.13)
$\ln(n + g + \delta)$	-1.73	-1.02	-1.06
	(.41)	(.45)	(.33)
$\ln(s_h)$	.66	.47	.70
	(.07)	(.07)	(.13)
Adj R^2	.78	.65	.60
Implied β	.30	.31	.36
Implied α	.28	.22	.26
No. of observations	98	98	107

Cross-Country Income Differences: Regressions

- If these regression results are reliable, they give a big boost to the augmented Solow model.
- The Adjusted R^2 suggests that over (or close to) three quarters of income per capita differences across countries can be explained by differences in their physical and human capital investment behavior.
- The immediate implication is that technology (TFP) differences have a somewhat limited role, confined to at most accounting for about a quarter of the cross-country income per capita differences.
- But...

Challenges to the Regression Analyses I

1. Technology differences across countries are not orthogonal to all other variables. $\bar{A}_j$ is correlated with measures of s_j^h and s_j^k for two reasons.

   1. *omitted variable bias* problem: societies with high levels of $\bar{A}_j$ will be those that have invested more in technology for various reasons; it is then natural to expect the same reasons to induce greater investment in physical and human capital as well.
   2. *reverse causality* problem; complementarity between technology and physical or human capital imply that countries with high $\bar{A}_j$ will find it more beneficial to increase their stock of human and physical capital.

   In terms of the regression above, this implies that the key right-hand side variables are correlated with the error term, ε_j. Consequently, OLS estimates of α and β and R^2 are biased upwards.

2. α is too large relative to what we should expect on the basis of microeconometric evidence.

Challenges to the Regression Analyses II

- The working age population enrolled in school ranges from 0.4% to over 12% in the sample of countries. The predicted log difference in incomes between these two countries is

$$\frac{\alpha}{1 - \alpha - \beta} \left(\ln 12 - \ln \left(0.4 \right) \right) = 0.66 \times \left(\ln 12 - \ln \left(0.4 \right) \right) \approx 2.24.$$

  Thus a country with schooling investment of over 12 should be about $\exp \left(2.24 \right) - 1 \approx 8.5$ times richer than a country with a level of schooling investment of around 0.4.

- This gap is too large in view of the micro evidence on the returns to human capital.

Returns to Human Capital and Cross-Country Evidence I

- How to go from micro returns to human capital to cross country evidence?

- Take Mincer regressions of the form:

$$\ln w_i = \mathbf{X}_i' \gamma + \phi S_i, \qquad (3)$$

  Micro evidence suggests ϕ is between 0.06 and 0.10

- In practice, the difference in average years of schooling between any two countries in the Mankiw-Romer-Weil sample is less than 12.

- Can we deduce from this information how much richer a country with 12 more years of average schooling should be? The answer is yes, but we need to assume:

  1. That the micro-level relationship as captured by (3) applies identically to all countries.
  2. That there are no *human capital externalities*.

Returns to Human Capital and Cross-Country Evidence II

- Suppose that each firm f in country j has access to the production function

$$y_{fj} = K_f^{1-\alpha} \left(A_j H_f \right)^{\alpha},$$

- Suppose also that firms in this country face a cost of capital equal to R_j. With perfectly competitive factor markets,

$$R_j = (1-\alpha) \left(\frac{K_f}{A_j H_f} \right)^{-\alpha}. \tag{4}$$

This implies that all firms ought to function at the same physical to human capital ratio, and consequently, all workers, irrespective of their level of schooling, ought to work at the same physical to human capital ratio.

Returns to Human Capital and Cross-Country Evidence III

- Another direct implication of competitive labor markets is that in country j, wages per unit of human capital will be equal to

$$w_j = \alpha \left(1 - \alpha\right)^{(1-\alpha)/\alpha} A_j R_j^{-(1-\alpha)/\alpha}.$$

  Consequently, a worker with human capital h_i will receive a wage income of $w_j h_i$.

- Substituting for capital from (4), total income in country j is

$$Y_j = \left(1 - \alpha\right)^{(1-\alpha)/\alpha} R_j^{-(1-\alpha)/\alpha} A_j H_j,$$

  where H_j is the total efficiency units of labor in country j.

- In view of this, a country with 12 more years of average schooling should have a stock of human capital somewhere between $\exp\left(0.10 \times 12\right) \simeq 3.3$ and $\exp\left(0.06 \times 12\right) \simeq 2.05$ times greater and thus have income per capita about twice or three times greater.

- Much lower than the over eightfold differences implied by the regression analysis.

Calibrating Productivity Differences I

- Use the same Mincer approach for calibration.
- Suppose that each country has access to the Cobb-Douglas aggregate production function:

$$Y_j = K_j^{1-\alpha} \left(A_j H_j \right)^\alpha. \qquad (5)$$

- Notice that this is a more conventional production function, with *efficiency units of labor* as a factor of production.
- Suppose that each worker in country j has S_j years of schooling. Then using the Mincer equation (3) ignoring the other covariates and taking exponents, H_j can be estimated as

$$H_j = \exp \left(\phi S_j \right) L_j,$$

Calibrating Productivity Differences II

- This approach however does not take into account differences in other "human capital" factors, such as experience, in the quality of schooling and the amount of post-schooling human capital, and in the rate of return to schooling.

- Let the rate of return to acquiring the Sth year of schooling be $\phi(S)$. A somewhat better estimate of the stock of human capital can be constructed as

$$H_j = \sum_S \exp\{\phi(S) S\} L_j(S)$$

where $L_j(S)$ now refers to the total employment of workers with S years of schooling in country j.

- A series for K_j can be constructed from Summers-Heston dataset using investment data and the perpetual invented method.

$$K_j(t+1) = (1-\delta) K_j(t) + I_j(t),$$

Let us assume, following Hall and Jones that $\delta = 0.06$.

Calibrating Productivity Differences III

- Finally, with the same arguments as before, we choose a value of $2/3$ for α.

- Given series for H_j and K_j and a value for α, we can construct "predicted" incomes at a point in time using the following equation

$$\hat{Y}_j = K_j^{1/3} \left(A_{US} H_j \right)^{2/3}$$

for each country j, where A_{US} is computed so that this equation fits the United States perfectly, i.e., $Y_{US} = K_{US}^{1/3} \left(A_{US} H_{US} \right)^{2/3}$.

- Once a series for $\hat{Y}_j$ has been constructed, it can be compared to the actual output series. The gap between the two series represents the contribution of technology. Alternatively, we could explicitly back out country-specific technology terms (relative to the United States) as

$$\frac{A_j}{A_{US}} = \left(\frac{Y_j}{Y_{US}} \right)^{3/2} \left(\frac{K_{US}}{K_j} \right)^{1/2} \left(\frac{H_{US}}{H_j} \right).$$

Calibrating Productivity Differences IV

Figure: Calibrated technology levels relative to the US technology (from the Solow growth model with human capital) versus log GDP per worker, 1980, 1990 and 2000.
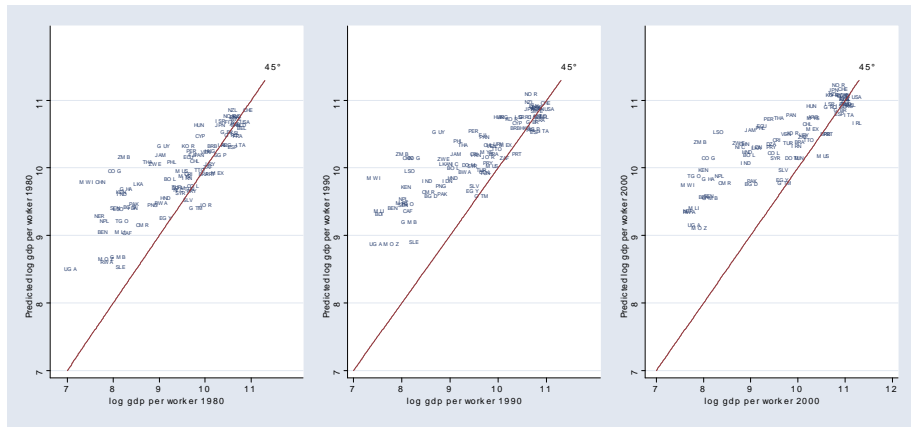
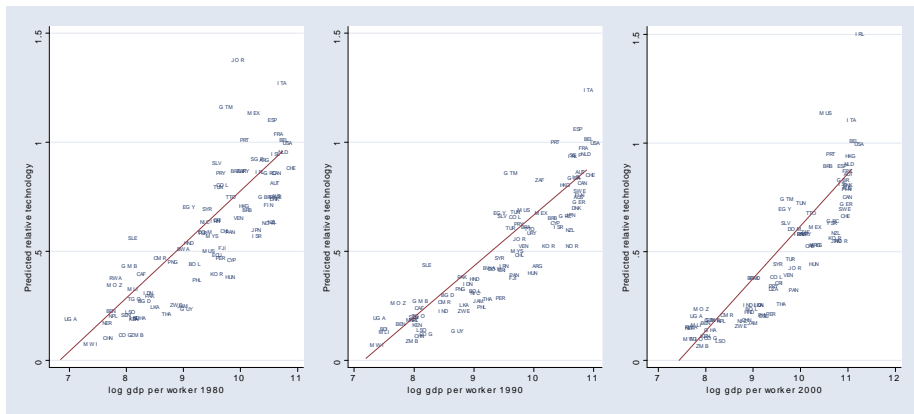# Calibrating Productivity Differences V

Figure: Calibrated technology levels relative to the US technology (from the Solow growth model with human capital) versus log GDP per worker, 1980, 1990 and 2000.

Calibrating Productivity Differences VI

The following features are noteworthy:

1. Differences in physical and human capital still matter a lot.

2. However, differently from the regression analysis, this exercise also shows that there are significant *technology (productivity) differences*.

3. The same pattern is visible in the next three figures, which plot, the estimates of the technology differences, A_j/A_{US}, against log GDP per capita in the corresponding year.

4. Also interesting is the pattern that the empirical fit of the neoclassical growth model seems to deteriorate over time.

Challenges to Callibration I

- In addition to the standard assumptions of competitive factor markets, we had to assume no human capital externalities, a Cobb-Douglas production function, and also make a range of approximations to measure cross-country differences in the stocks of physical and human capital.

- The calibration approach is in fact a close cousin of the growth-accounting exercise (it is sometimes referred to as "levels accounting") and can be done in a more general way as in growth-accounting exercises.

- Imagine that the production function that applies to all countries in the world is given by

$$F\left(K_j, H_j, A_j\right),$$

and countries differ according to their physical and human capital as well as technology—but not according to F.

Challenges to Callibration II

- Let us a rank countries in descending order according to their physical capital to human capital ratios, K_j/H_j Then we can write

$$\hat{x}_{j,j+1} = g_{j,j+1} - \bar{\alpha}_{K,j,j+1} g_{K,j,j+1} - \bar{\alpha}_{Lj,j+1} g_{H,j,j+1}, \qquad (6)$$

where $g_{j,j+1}$ is the proportional difference in output between countries j and $j+1$, $g_{K,j,j+1}$ is the proportional difference in capital stock between these countries and $g_{H,j,j+1}$ is the proportional difference in human capital stocks.

- In addition, $\bar{\alpha}_{K,j,j+1}$ and $\bar{\alpha}_{Lj,j+1}$ are the average capital and labor shares between the two countries.

- The estimate $\hat{x}_{j,j+1}$ is then the proportional TFP difference between the two countries.

Challenges to Callibration

- This levels-accounting exercise faces two challenges. One is data-related and the other one theoretical:

  1. Data on capital and labor shares across countries are not widely available. Almost all calibration or levels-accounting exercises that estimate technology (productivity) differences use the Cobb-Douglas approach with a constant value of α_K equal to $1/3$.

  2. The differences in factor proportions, e.g., differences in K_j/H_j, across countries are large. An equation like (6) is a good approximation when we consider small (infinitesimal) changes.

Summary

- Regression and calibration analyses suggest that TFP differences are important in accounting for cross-country income differences.

- These are not necessarily *pure technology* differences, but differences in technology broadly construed, including differences in the efficiency of production (e.g., due to market failures).

- Other evidence, for example, estimating productivity differences using trade data, consistent with this conclusion (see Chapter 3).

- We will therefore pay special attention to models generating technology/TFP differences across countries.

  - Endogenous technology.
  - Market failures and differences in the efficiency of production.

- Also look for fundamental causes that can lead to technology differences.

- But, it is useful to bear in mind that human and physical capital differences also important and we should look for approaches that can account for these differences as well.

The Rest of the Course (1)

- Develop a range of models and different theoretical approaches useful for answering the set of questions raised here.

- Three areas of emphasis:

  1. Understanding technology differences.
  2. Investigation of the process of economic development and structural transformation.
  3. Linking proximate causes to fundamental causes (e.g., political economy).

- Also, additional important topics related to growth:

  - Growth and the environment.
  - The role of policy.

The Rest of the Course (2)

- The next two lectures: review of basic models of endogenous technology.
- Recitation this week: review of optimal control.
- The rest of the course divided between me and Philippe Aghion focusing on various topics within this agenda (see syllabus).