2014/2015, week 4

Cross-Country Income Differences

Romer, Chapter 1.6, 1.7, 4.2, 4.5, 4.6

Growth Accounting

- How can we test for the determinants of growth and, thereby, of income differences across countries?
- The Solow model in its log-linear form is one first step
- We will use this model again in order to perform *growth accounting*
- *Growth accounting* assesses the contribution of different factors of production to economic growth

Growth Accounting

- Consider again the production function

$$Y(t) = F(K(t), A(t)L(t))$$

- Taking the total derivative of the above function w.r.t. time we get

$$\dot{Y}(t) = \frac{\partial Y(t)}{\partial K(t)}\dot{K}(t) + \frac{\partial Y(t)}{\partial L(t)}\dot{L}(t) + \frac{\partial Y(t)}{\partial A(t)}\dot{A}(t)$$

Growth Accounting

- Dividing both sides of the equation by $Y(t)$, we get

$$\frac{\dot{Y}(t)}{Y(t)} = \frac{K(t)}{Y(t)} \frac{\partial Y(t)}{\partial K(t)} \frac{\dot{K}(t)}{K(t)} + \frac{L(t)}{Y(t)} \frac{\partial Y(t)}{\partial L(t)} \frac{\dot{L}(t)}{L(t)} + \frac{A(t)}{Y(t)} \frac{\partial Y(t)}{\partial A(t)} \frac{\dot{A}(t)}{A(t)}$$

- Which can be further simplified:

$$\frac{\dot{Y}(t)}{Y(t)} = \alpha_K(t) \frac{\dot{K}(t)}{K(t)} + \alpha_L(t) \left[\frac{\dot{L}(t)}{L(t)} + \frac{\dot{A}(t)}{A(t)} \right]$$

Growth Accounting

- Given that we have CRS,

$$\alpha_K(t) = 1 - \alpha_L(t)$$

- Hence, we have

$$\frac{\dot{Y}(t)}{Y(t)} = \frac{\dot{L}(t)}{L(t)} + \alpha_K(t)\left[\frac{\dot{K}(t)}{K(t)} - \frac{\dot{L}(t)}{L(t)}\right] + (1-\alpha_K(t))\frac{\dot{A}(t)}{A(t)} \qquad \rightarrow$$

$$\frac{\dot{Y}(t)}{Y(t)} - \frac{\dot{L}(t)}{L(t)} = \alpha_K(t)\left[\frac{\dot{K}(t)}{K(t)} - \frac{\dot{L}(t)}{L(t)}\right] + R(t)$$

Empirical Applications

- According to the equation above, economic growth (growth of output per worker) is attributed to
  - Growth in the ratio of capital to labour
  - The Solow residual:
    - Technological progress
    - All other elements

Empirical Applications

- Interesting application is Young (1995)
- Using growth accounting, he derives that economic growth in the NIC's is due to
  - Rising investment
  - Increasing labour force participation
  - Increasing education of workers
- And not to
  - Rapid technological progress

Empirical Applications

- The main weakness of growth accounting:
  - it does not give insight into the ultimate sources of economic growth
- According to the growth accounting formula above, the impact of technological progress on growth is $1 - \alpha_K(t)$, which may be close to 2/3
- Elaborating the Solow model yields that the impact equals 1

Empirical Applications

- The two are different because growth accounting attributes $\alpha_K(t)$ to the growth of capital per worker, thereby suggesting that this stands apart from technological progress
- According to the Solow model, capital per worker grows at rate $\dot{A}(t)/A(t)$ along the balanced-growth path
- Hence, growth accounting may be misleading

Empirical Applications

- To illustrate, take the following version of the growth accounting equation:

$$\frac{\dot{Y}(t)}{Y(t)} = \alpha_K(t)\frac{\dot{K}(t)}{K(t)} + \alpha_L(t)\frac{\dot{L}(t)}{L(t)} + R(t)$$

- The average contributions of the three terms in a number of countries are (rounded):
  - Capital 50%, Labour 20%; Technology 30%
- Correcting for the endogeneity of capital:
  - Capital 0%, Labour 20%; Technology 80%
    - Bron: *Economen kunnen niet rekenen*

Cross-Country Income Differences

- How about extending the approach by including human capital?
- Would that increase the contribution from capital (and decrease the role of technology or, better, the residual)?
- Take the following Cobb-Douglas production function

$$Y(t) = K(t)^{a}(A(t)H(t))^{1-a}$$

Cross-Country Income Differences

- One can think of human capital H as the contribution of skills, expertise or education to the quality of labour
- The more educated, skilled or experienced the labour force, the higher is human capital H

Cross-Country Income Differences

- To see how the introduction of human capital improves the ability of the model to explain income per capita growth and, hence, cross-country income differences, consider our new production function (in per capita terms) in logs

$$\ln \frac{Y_i}{L_i} = a \ln \frac{K_i}{L_i} + (1-a) \ln \frac{H_i}{L_i} + (1-a) \ln A_i$$

Cross-Country Income Differences

- The above equation can be further rearranged as
  - $ln\frac{Y_i}{L_i} = \frac{a}{1-a}ln\frac{K_i}{Y_i} + ln\frac{H_i}{L_i} + lnA_i$

Cross-Country Income Differences

- Empirical Results; the hard part is to find a good proxy for the human capital term *H*
  - In empirical studies, it is proxied with years of schooling
- Hall & Jones (1999) compare the five richest countries in their sample with the five poorest ones
- Average Y/L in the rich group exceeds that in the poor group by 31.7 (or 3.5 in logs)
- The contribution of $(a/(1-a))\ln(K/Y)$ is 0.6, that of $\ln(H/L)$ is 0.8, and that of $\ln(A)$ is 2.1

Cross-Country Income Differences

- That is, only about a sixth in the gap between the richest countries and the poorest ones is due to differences in physical capital intensity
- Only a slightly larger fraction is due to differences in schooling
- The largest part of country differences in income per capita is due to differences in technology or other factors included in the Solow residual

Cross-Country Income Differences

- Extensions:
  - Human capital also depends on nationality worker (Klenow and Rodríguez-Claire 1997, Hendricks 2002)
  - Return to education may be different for different types of education
  - Low-skilled labour and high-skilled labour may be complements in production
- Conclusion does not change:
  - The inclusion of human capital into the production function does not lead to dramatically different results

Differences in Growth Rates

- The Solow Growth model predicts convergence to a state of balanced growth
- Hence, countries starting below their long-run paths grow faster than those starting above
- To see that consider a case where differences in Y/L stem only from physical capital per worker K/L. That is, human capital per worker and output for given inputs are the same across countries

Differences in Growth Rates

- Verdeling van inkomen en economische groei in geïndustrialiseerde landen

	BBP per hoofd van de bevolking, 1970 (in $)	BBP per hoofd van de bevolking, 2009 (in $)	Economische groei per jaar, 1970-2009 (in %)
VS	20.480	41.102	1,8
Nederland	19.050	40.566	2,0
Duitsland	16.236	32.487	1,8
Verenigd Koninkrijk	15.829	33.386	1,9
Frankrijk	15.676	30.821	1,7
Italië	14.371	27.692	1,7
Spanje	11.981	27.632	2,2
Zuid-Korea	3.018	25.029	5,6

Bron: *Economen kunnen niet rekenen*

Differences in Growth Rates

- Verdeling van inkomen en economische groei in de wereld

	BBP per hoofd van de bevolking, 1970 (in $)	BBP per hoofd van de bevolking, 2009 (in $)	Economische groei per jaar, 1970-2009 (in %)
VS	20.480	41.102	1,8
Nederland	19.050	40.566	2,0
Venezuela	8.934	9.115	0,1
Madagascar	950	753	-0,6
India	886	3.238	3,4
China	865	7.431	5,7
Oeganda	817	1.152	0,9
Zimbabwe	339	143	-2,2

Bron: *Economen kunnen niet rekenen*

Differences in Growth Rates

- Assume again the CRS production function

$$Y(t) = F(K(t), A(t)L(t))$$

- Recall the adjustment equation for capital per effective worker:

$$\dot{k} = \lambda \left[k_i^* - k_i(t) \right]$$

- Where $\lambda > 0$ measures the rate of convergence

Differences in Growth Rates

- This says that the farther is the economy below its balanced growth path, the faster does K/L grow
- For Y/L a similar expression applies
- Hence, also Y/L grows faster the more Y/L differs from its steady-state level

Differences in Growth Rates

- However, we have two alternatives about the value of k^*
- One is that it is the same in all countries
  - In this case, all countries grow towards the same Y/L
  - The lower is Y/L, the faster is its growth. This is called *unconditional convergence*

Differences in Growth Rates

- Second is that k^* varies across countries
  - In this case, there is a persistent component of cross-country income differences
  - Poor countries (e.g., with low saving rates) may not grow faster than other countries
  - There is still convergence towards the own balanced growth path
  - This is called *conditional convergence*

Differences in Growth Rates

- Unconditional convergence gives a good description of differences in growth among industrialized countries in the post-war period
  - This is so since saving rates, levels of education and other factors related to long-run fundamentals are similar across industrialized countries
- For the same reason, it does not work that well for countries all over the world
  - In terms of the Solow Growth model, s, n and g can differ a lot between countries

Convergence

- Baumol (1986) addresses the question whether the growth performance of countries features convergence
- Baumol (1986) examines convergence from 1870 to 1979 among 16 industrialized countries
  - He regresses output growth over this period on a constant and initial income
  - Model specification:

$$\ln\left[\left(\frac{Y}{N}\right)_{i,1979}\right] - \ln\left[\left(\frac{Y}{N}\right)_{i,1870}\right] = a + b\ln\left[\left(\frac{Y}{N}\right)_{i,1870}\right] + \varepsilon_i$$

Convergence

- $\ln(Y/N)$ is log income per person, ε is an error term, and i indexes countries
- Convergence if $b < 0$: countries with higher initial incomes have lower growth
- Perfect convergence if $b = -1$
- No convergence if $b = 0$

Convergence

- Estimation result:

$$\ln\left[\left(\frac{Y}{N}\right)_{i,1979}\right] - \ln\left[\left(\frac{Y}{N}\right)_{i,1870}\right] = 8.457 - \underset{(0.094)}{0.995} \ln\left[\left(\frac{Y}{N}\right)_{i,1870}\right],$$

$$R^2 = 0.87, \qquad \text{s.e.e.} = 0.15,$$

Weaknesses in Baumol Study

- DeLong (1988) shows that Baumol's finding is largely spurious, due to
  - Sample selection: since historical data are constructed retrospectively, the countries that have long data series are generally those that are the most industrialized today
  - Measurement error: estimates of real income per capita in 1870 are imprecise. Measurement error creates bias toward finding convergence

Convergence

- One way to tackle the first problem is to increase the sample and compare the richest countries as of 1870
- DeLong (1988) creates a sample that consists of all countries at least as rich as the second poorest country in Baumol's sample in 1870, Finland
- Hence, he adds 7 countries (Argentina, Chile, East Germany, Ireland, New Zealand, Portugal, and Spain) and drops one (Japan)
- Result: the estimate of b of -0.995 drops to -0.566 and becomes less statistically significant (see Figure on next slide).

Convergence

- Way to tackle the second problem (i.e. measurement error) is to estimate:

$$\ln\left[\left(\frac{Y}{N}\right)_{i,1979}\right] - \ln\left[\left(\frac{Y}{N}\right)_{i,1870}\right]^* = a + b\ln\left[\left(\frac{Y}{N}\right)_{i,1870}\right]^* + \varepsilon_i,$$

$$\ln\left[\left(\frac{Y}{N}\right)_{i,1870}\right] = \ln\left[\left(\frac{Y}{N}\right)_{i,1870}\right]^* + u_i.$$

Convergence

- ln[(Y/N)1870]* is the true value of log income per capita in 1870
- ln[(Y/N)1870] is the measured value
- ε and u are assumed to be uncorrelated with each other and with ln[(Y/N)1870]*
- Result: depending on the guess for the standard deviation of the estimation error, the estimate for b drops further, to 0 or even 1, thereby eliminating all of the remainder of Baumol’s estimate of convergence

Cross-Country Income Differences

- Where do income differences (i.e., differences in Y/L) between countries stem from?
- Similarly, what makes income differ between time periods?
- According to the Solow model, there are two candidate factors:
  - Differences in the capital per worker (K/L)
  - Differences in the effectiveness of labour (A)

Cross-Country Income Differences

- Take the production function. This reads as follows:
  - $Y = F(K, AL) \qquad \rightarrow \qquad y = F(k, A)$
  - Where y and k are defined as output and capital respectively per worker (!):
  - $y = \frac{Y}{L}; \, k = \frac{K}{L}$

Cross-Country Income Differences

- Assume the production function is Cobb-Douglas:
  - $Y = K^{\alpha}(AL)^{1-\alpha} \quad \rightarrow$
  - $y = k^{\alpha}A^{1-\alpha}$
- Income difference between countries A and B:
  - $y = k^{\alpha}A^{1-\alpha}$
  - $\left(\frac{y^A}{y^B}\right) = \left(\frac{k^A}{k^B}\right)^{\alpha}\left(\frac{A^A}{A^B}\right)^{1-\alpha}$

Cross-Country Income Differences

- Can differences in the stocks of capital per worker explain income differences between countries?
- In order to account for the difference in income between a rich country and a poor country of a factor 10, the stocks of capital need to differ a factor $(10)^{1/\alpha}$
  - Formally, solve $\left(\frac{y^A}{y^B}\right) = 10 = \left(\frac{k^A}{k^B}\right)^{\alpha} \rightarrow \left(\frac{k^A}{k^B}\right) = (10)^{1/\alpha}$

Cross-Country Income Differences

- Standard elasticity of output w.r.t. capital
- α =1/3: $\left(\frac{k^A}{k^B}\right) = (10)^{1/\left(\frac{1}{3}\right)} = 1000$
- Elasticity using broad measure of capital
- α =1/2: $\left(\frac{k^A}{k^B}\right) = (10)^{1/\left(\frac{1}{2}\right)} = 100$
- Capital stocks differ not more than a factor 20 to 30 between rich and poor countries

Cross-Country Income Differences

- The marginal product of capital in the Cobb-Douglas case:
  - $y = f(k) = k^{\alpha} \qquad \rightarrow$
  - $f'(k) = \alpha k^{\alpha-1} = \alpha y^{(\alpha-1)/\alpha}$
- In order to account for the difference in income between a rich country and a poor country of a factor 10, the marginal products of capital differ a factor $(10)^{(\alpha-1)/\alpha}$

Cross-country Income Differences

- Standard elasticity of output w.r.t. capital
- α =1/3: $\left(\frac{f'(k)^A}{f'(k)^B}\right) = (10)^{\left(\frac{-2}{3}\right)/\left(\frac{1}{3}\right)} = 0{,}01$
- Elasticity using broad measure of capital
- α =1/2: $\left(\frac{f'(k)^A}{f'(k)^B}\right) = (10)^{\left(\frac{-1}{2}\right)/\left(\frac{1}{2}\right)} = 0{,}1$
- Rates of return do not differ a factor 10 or 100 between countries
- If they did so, we would observe massive capital flows from rich to poor countries

Cross-Country Income Differences

- For differences in income over time, the same holds true as for differences in income between countries:
  - In the data, capital stocks and rate of return on capital do not differ enough to account for the output differences
- This implies
  - That countries and time periods differ a lot in terms of A
  - Or, that capital is much more valuable than is reflected in its price

Growth in the Solow Growth model

- Along the balanced growth path, Y/L and K/L grow at rate g
- But g is exogenous
- So the Solow model describes long-run growth by just imposing it!
- In addition, the model is very abstract as regards the description of knowledge (or effectiveness of labour)

Cross-Country Income Differences

- The fact that knowledge is not well defined makes the empirical analysis tough. Why?
- Because we are interested in knowing about the determinants of growth. What are they, and how they are formed
- In fact, we need to specify what the knowledge term A captures (econometrically speaking, we need the right proxy). We need to analyse the determinants of knowledge over time
- By doing so, we are able to understand worldwide growth and cross-country differences in real incomes

Other Factors

- A bunch of other possible factors exist that can contribute to an explanation of economic growth:
  - Abstract knowledge, expertise
  - Education and skills of the labour force
  - Strength of property rights
  - Quality of infrastructure
  - Cultural attitudes towards entrepreneurship and work

Other Factors

- A useful distinction is the following one:
  - Social infrastructure
  - Geography
  - Colonization strategies

Other Factors

- Social infrastructure
  - Taxes, subsidies, regulations
  - Values and norms, work attitude, religion
  - Corruption, bribery, dictatorship versus democracy, government expropriation

Other Factors

- Geography
  - Possibilities to develop agriculture, tropical diseases
- Colonization strategies (Acemoglu, Johnson, Robinson)
  - Establishment of “extractive states” with a focus on exploitation and without establishment of democratic institutions (Latin American countries)
  - Establishment of “settler colonies” (United States, Australia, New Zealand)

Other Factors

- The precise role of all these factors is still unknown, but currently widely investigated
- Hopefully, we will reach more definitive conclusions in the future
- Economists may not succeed in this goal, hampered by lack of the right data and lack of social experiments