Material on Growth Part II: Productivity and Technology

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We see these huge income differences among countries
We see a good degree of historical persistence
We have all sorts of theories
Maybe we can learn more by looking directly at income differences
Key tool will be “Development Accounting” (cross-sectional analogue of Solow-style growth accounting)
Productivity and Factor Accumulation

(a) Differences in output due to factor accumulation

Output per worker

Production function in both countries

$y_1$

$y_2$

Country 1

Country 2

Factors of production per worker

(b) Differences in output due to productivity

Output per worker

Production function in Country 1

Production function in Country 2

Both countries

(c) Differences in output due to both productivity and factor accumulation

Output per worker

Production function in Country 1

Production function in Country 2

Country 1

Country 2

Factors of production per worker
We need

- a production function (functional form and parameters)
- measurements of the relevant factors of production (physical and human capital)
Measuring Physical Capital

Perpetual Inventory Method

\[ K_{i,t+1} = (1 - \delta)K_{i,t} + I_{i,t} \]

\( K_{i,1970} \) will be some sort of informed guess, like \( 2 \times Y_{i,1970} \)

\( \delta \) most frequently taken to be 6%

- potential problems:
  - mis-measurement of investment (see below)
  - cross-country differences in depreciation rates (i.e. old cars in developing countries)
Data on educational attainment of working age population widely available (Barro and Lee, 2013)

Mincerian approach allows for conversion into years of schooling
Aggregate Production: $Y_i = A_i K_i^\alpha H_i^{1-\alpha}$

Human Capital Aggregate: $H_i = \sum_{j=1}^{L} h_{ij}$

where $i$ indexes countries and $j$ indexes individuals

Return to one unit of human capital: $w_i = \frac{dY_i}{dH_i} = (1 - \alpha) A_i \left( \frac{K_i}{H_i} \right)^\alpha$

Wages for individual: $ln(w_{i,j}) = ln(w_i) + ln(h_{i,j}) + \eta_{i,j}$

Human capital and schooling: $ln(h_{i,j}) = \phi(s_{i,j}) = \beta s_{i,j}$

- We can recover $\beta$ by regressing individual log wages on years of schooling ($s_i$) within a country
- Once we know $\beta$, we can construct $H_i$ based on aggregate data on schooling
## Two Approaches to Human Capital in the Production Function

<table>
<thead>
<tr>
<th>Approach</th>
<th>Mincer</th>
<th>Mankiw, Romer, Weil (1992)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production function in general form</td>
<td>$Y = F(K, hL)$</td>
<td>$Y = F(K, H, L)$</td>
</tr>
<tr>
<td>Production function in CD, CRS form</td>
<td>$Y = AK^{\alpha}(hL)^{1-\alpha}$</td>
<td>$Y = AK^{\alpha}H^{\beta}L^{1-\alpha-\beta}$</td>
</tr>
<tr>
<td>Salient Characteristic</td>
<td>human capital and raw labor are really the same thing</td>
<td>human capital and raw labor are different things</td>
</tr>
<tr>
<td>return to human capital</td>
<td>return to human capital is invariant to quantity</td>
<td>As H increases, return to human capital declines</td>
</tr>
<tr>
<td>big advantage</td>
<td>can learn mapping from education to $h$ from micro data</td>
<td>dynamics are much easier easier to to analyze if we treat H like K</td>
</tr>
<tr>
<td>nagging worry</td>
<td>try to move a piano with one Ph.D. vs four uneducated guys</td>
<td>Hard to believe that raw labor’s share of income is constant</td>
</tr>
</tbody>
</table>
Well known property of Cobb-Douglas production function that if factors are paid their marginal products, the capital share of national income is invariant to the $K/L$ ratio.

- Holds for US time series
- Gollin (2002) and Bernanke and Gurkaynak (2002) find something similar in cross section
- We take this as “permission” to use Cobb-Douglas
## Development Accounting Results

<table>
<thead>
<tr>
<th>Country</th>
<th>Output per Worker, y</th>
<th>Physical Capital per Worker, k</th>
<th>Human Capital per Worker, h</th>
<th>Factors of Production, $k^{1/3}h^{2/3}$</th>
<th>Productivity, A</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Norway</td>
<td>1.12</td>
<td>1.32</td>
<td>0.98</td>
<td>1.08</td>
<td>1.04</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>0.82</td>
<td>0.68</td>
<td>0.87</td>
<td>0.80</td>
<td>1.03</td>
</tr>
<tr>
<td>Canada</td>
<td>0.80</td>
<td>0.81</td>
<td>0.96</td>
<td>0.91</td>
<td>0.88</td>
</tr>
<tr>
<td>Japan</td>
<td>0.73</td>
<td>1.16</td>
<td>0.98</td>
<td>1.04</td>
<td>0.70</td>
</tr>
<tr>
<td>South Korea</td>
<td>0.62</td>
<td>0.92</td>
<td>0.98</td>
<td>0.96</td>
<td>0.64</td>
</tr>
<tr>
<td>Turkey</td>
<td>0.37</td>
<td>0.28</td>
<td>0.78</td>
<td>0.55</td>
<td>0.68</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.35</td>
<td>0.33</td>
<td>0.84</td>
<td>0.61</td>
<td>0.56</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.20</td>
<td>0.19</td>
<td>0.78</td>
<td>0.48</td>
<td>0.42</td>
</tr>
<tr>
<td>India</td>
<td>0.10</td>
<td>0.089</td>
<td>0.66</td>
<td>0.34</td>
<td>0.31</td>
</tr>
<tr>
<td>Kenya</td>
<td>0.032</td>
<td>0.022</td>
<td>0.73</td>
<td>0.23</td>
<td>0.14</td>
</tr>
<tr>
<td>Malawi</td>
<td>0.018</td>
<td>0.029</td>
<td>0.57</td>
<td>0.21</td>
<td>0.087</td>
</tr>
</tbody>
</table>

Sources: Output per worker: Heston, Summers, and Aten (2011); physical capital: author’s calculations; human capital: Barro and Lee (2016). The data set used here and in Section 7.3 is composed of data for 90 countries for which consistent data are available for 1975 and 2009.

Productivity differences are really large!
I will follow Caselli (2005). Other related treatments are Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999).

production function in per-worker terms:

\[ y = A k^{\alpha} h^{1-\alpha} \]

define

\[ y_{KH} = k^{\alpha} h^{1-\alpha} \]

This is the part of output due to factor accumulation. So...

\[ y = A \times y_{KH} \]
Measures of Success of the Factor-Only Model

Variance decomposition:

\[ \text{var}(\ln(y)) = \text{var}(\ln(A)) + \text{var}(\ln(y_{KH})) + 2\text{cov}(\ln(A), \ln(y_{KH})) \]

\[ \text{Success}_1 = \frac{\text{var}(\ln(y_{KH}))}{\text{var}(\ln(y))} \]

\[ \text{Success}_2 = \frac{y_{KH}^{90}/y_{KH}^{10}}{y^{90}/y^{10}} \]

<table>
<thead>
<tr>
<th>\text{var}(\ln(y))</th>
<th>1.297</th>
<th>\text{y}<em>{KH}^{90}/\text{y}</em>{KH}^{10}</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>\text{var}(\ln(y_{KH}))</td>
<td>0.500</td>
<td>\text{y}<em>{KH}^{90}/\text{y}</em>{KH}^{10}</td>
<td>7</td>
</tr>
<tr>
<td>\text{success}_1</td>
<td>0.39</td>
<td>\text{success}_2</td>
<td>0.34</td>
</tr>
</tbody>
</table>

\[\Rightarrow\] to some extent Caselli’s approach overstates the role of factor accumulation because of “induced factor accumulation”. To see this: imagine that all countries had the same saving rate.
Biases in These Calculations

- Pritchett “CUDIE is not Capital” (2000)
  - Investment overstated in poor countries; gaps in physical capital are thus larger than indicated in the data.

- Education quality (Hanushek)
  - Rich countries have higher test scores; gaps in human capital are thus larger than indicated in the data.

- In both cases, productivity gaps are over-stated.

- Neither of these will overturn the basic conclusion of development accounting that productivity differences are very important
Weil Framework

- Income Differences
  - Factor Accumulation
    - Technology
    - Productivity
    - Efficiency
We are comfortable with thinking about productivity growth over time in the leading countries as being due to technological progress (i.e. Jones analysis)

- we observe new inventions that clearly raise productivity
- productivity growth in “catching up” countries is some combination of technological progress and efficiency improvements
- not clear why we should believe that efficiency is really constant in lead countries like US.
  - could be rising (less discrimination leads to more efficient allocation of labor: Hsieh, Hurst, Jones, and Klenow, 2013: 0.2% per year rise in labor productivity since 1960)
  - could be falling (growth of government, larger tax wedges (Prescott), more regulation, etc.)

What about productivity differences among countries at a point in time?
Productivity = Technology × Efficiency

\[ A = T \times E \]

\[ \frac{A_{\text{India},2013}}{A_{\text{US},2013}} = \frac{T_{\text{India},2013}}{T_{\text{US},2013}} \times \frac{E_{\text{India},2013}}{E_{\text{US},2013}}, \]

Let \( g \) be the growth rate of technology in the US and let \( B \) be the technology gap between India and the US, measured in years

\[ T_{\text{US},2013} = T_{\text{US},2013} - B(1 + g)^B = T_{\text{India},2013}(1 + g)^B \]

\[ \frac{T_{\text{India},2013}}{T_{\text{US},2013}} = (1 + g)^{-B} \]
Calculation of Efficiency Gap India vs. US

\[
\frac{E_{\text{India},2013}}{E_{\text{US},2013}} = \frac{A_{\text{India},2013}}{A_{\text{US},2013}} \times \frac{T_{\text{India},2013}}{T_{\text{US},2013}} = \frac{A_{\text{India},2013}}{A_{\text{US},2013}} \times (1 + g)^B
\]

Data: \( \frac{A_{\text{India}}}{A_{\text{US}}} = 0.31 \) \( g = 0.54\% \) (this is US average 1975-2009)

<table>
<thead>
<tr>
<th>Years India Lags US in Technology (B)</th>
<th>( T_{\text{India}} / T_{\text{US}} )</th>
<th>( E_{\text{India}} / E_{\text{US}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0.31</td>
</tr>
<tr>
<td>10</td>
<td>0.95</td>
<td>0.33</td>
</tr>
<tr>
<td>20</td>
<td>0.90</td>
<td>0.35</td>
</tr>
<tr>
<td>30</td>
<td>0.85</td>
<td>0.36</td>
</tr>
<tr>
<td>40</td>
<td>0.81</td>
<td>0.38</td>
</tr>
<tr>
<td>50</td>
<td>0.76</td>
<td>0.41</td>
</tr>
<tr>
<td>75</td>
<td>0.67</td>
<td>0.46</td>
</tr>
<tr>
<td>100</td>
<td>0.58</td>
<td>0.53</td>
</tr>
</tbody>
</table>
This suggests that poor countries can’t be that far behind technologically; gap in $A$ must be due to efficiency.

caveat: Appropriate Technology (Basu and Weil, 1999; Acemoglu and Zilibotti, 2001).

- technological progress is not a general shift in the production function, but is specific to certain factor intensities.

- And maybe certain institutions as well.
Capital Biased Technological Change

Output per worker

Production function

Poor country  Rich country  Capital per worker
What is this Efficiency Thing Anyway?

Delicious DELRICH

E-Z COLOR PAK Margarine

ENDS MIXING BOWL MESS!

America’s Finest Margarine with “Sealed-In” Flavor and Freshness

Your first taste of the delicate flavor of Delrich convinces you! Here’s America’s Finest Margarine! You enjoy flavor as sweet as clover, dewy-fresh. It’s the perfect spread for toast, hot biscuits. A flavor-luxury for your cooking!

And, Delrich E-Z Color Pak Margarine is the new table spread that gives you “Sealed-In” flavor and freshness!

Thousands Are Switching to Delrich

There’s no mess—no mixing bowl is needed! Delrich quickly blends to a luscious golden yellow right inside the sealed bag.

Enriched with 15,000 units of Vitamin A per pound—Delrich supplies abundant natural food energy. Try it today. See why thousands of women are switching to Delrich E-Z Color Pak Margarine—America’s Finest!

• Delrich and E-Z Color Pak are trademarks of The Cudahy Packing Co., for its margarine. Whether you ask for “Delrich” or “E-Z Color Pak”—they both mean America’s Finest Margarine.

The CUDAHY Packing Co.
A Tentative Taxonomy of Inefficiency

1. unproductive activities (rent seeking, theft, hiring guards, insurrection)
2. idle resources (cyclical unemployment, featherbedding)
3. misallocation of factors among sectors (formal-informal, regional, family farms, finance in the US)
4. misallocation of factors among firms (Hsieh and Klenow, 2007)
5. technology blocking (patent trolls, margarine)
What Underpins Low Efficiency in Poor Countries?

- institutional framework (security of property, enforcement of laws)
- trade restrictions (legal or physical)
- barriers to mobility (of factors)
- monopolies
- government ownership of firms
- poorly functioning financial system
- tax wedges
- etc.

This is economics of Adam Smith rather than Malthus, Solow, or Technology (Arrow, P. Romer, Aghion and Howitt, Jones, Grossman and Helpman).