EC569 Economic Growth Measuring Productivity Lecture 6

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Introduction

- Some aspects of factor accumulation –
  - investment rate,
  - population growth rate,
  - human capital

  – explain some variation in income differences across countries.
- Taken together, do the different aspects of factor accumulation explain all of the variation among countries?
  - Answer: **No**
- Productivity explains the remaining part of the variation among countries

Productivity

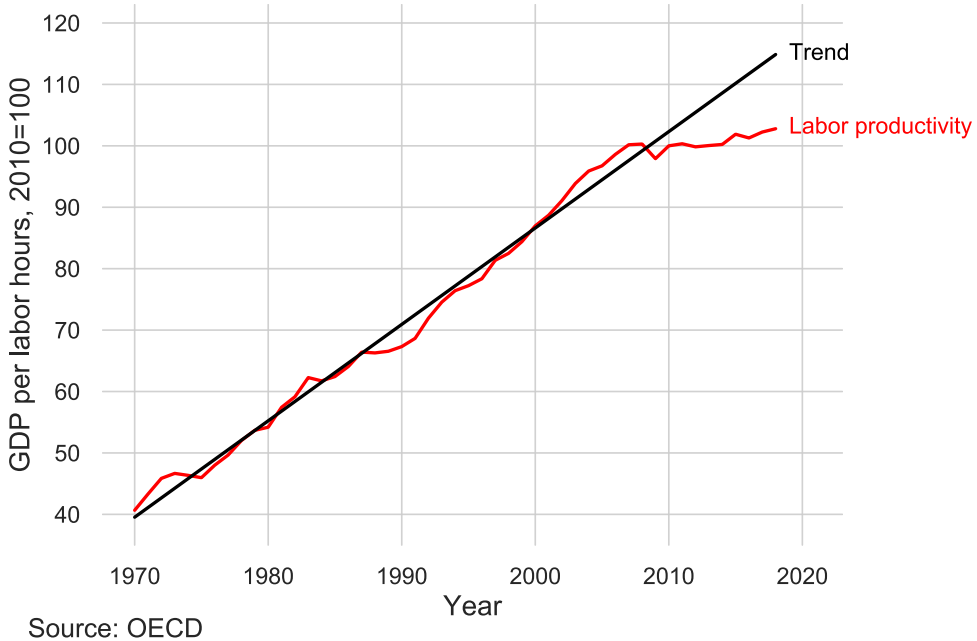
- **Productivity:** Effectiveness with which factors of production are converted into output.
- Productivity = Output / Input
- Output = Nominal GDP / Price Deflator (CPI or PPI)
- Labor productivity = Output / Hours Worked
- Total Factor Productivity (TFP) = Output / Index of all inputs to production
- A in our Cobb-Douglas production functions is an example of TFP

$$y = Ak^{\alpha}h^{1-\alpha} \Rightarrow A = \frac{y}{k^{\alpha}h^{1-\alpha}}$$

- In this module, main focus is on total factor productivity
  - When we say 'productivity', we mean total factor productivity

Labor productivity

- Labor productivity = Output / Hours Worked
- Commonly used measure of productivity
- Easy to calculate and interpret
- Capital accumulation leads to labor productivity gains
- Slowdown in the UK labor productivity growth after 2008
  - Also known as *producitivity puzzle*
  - Avearge annual labor productivity growth from 1970 to 2008: 2.4%
  - Avearge annual labor productivity growth from 2008 to 2018: 0.25%
- Had the labor productivity grown at the pre-crisis level, each household would have earned 12% more.



Data from OECD, GDP per hour worked

Productivity slowdown

- Many advanced economies experienced slowdown in labor productivity growth in the last decade
- UK experienced the severest slowdown

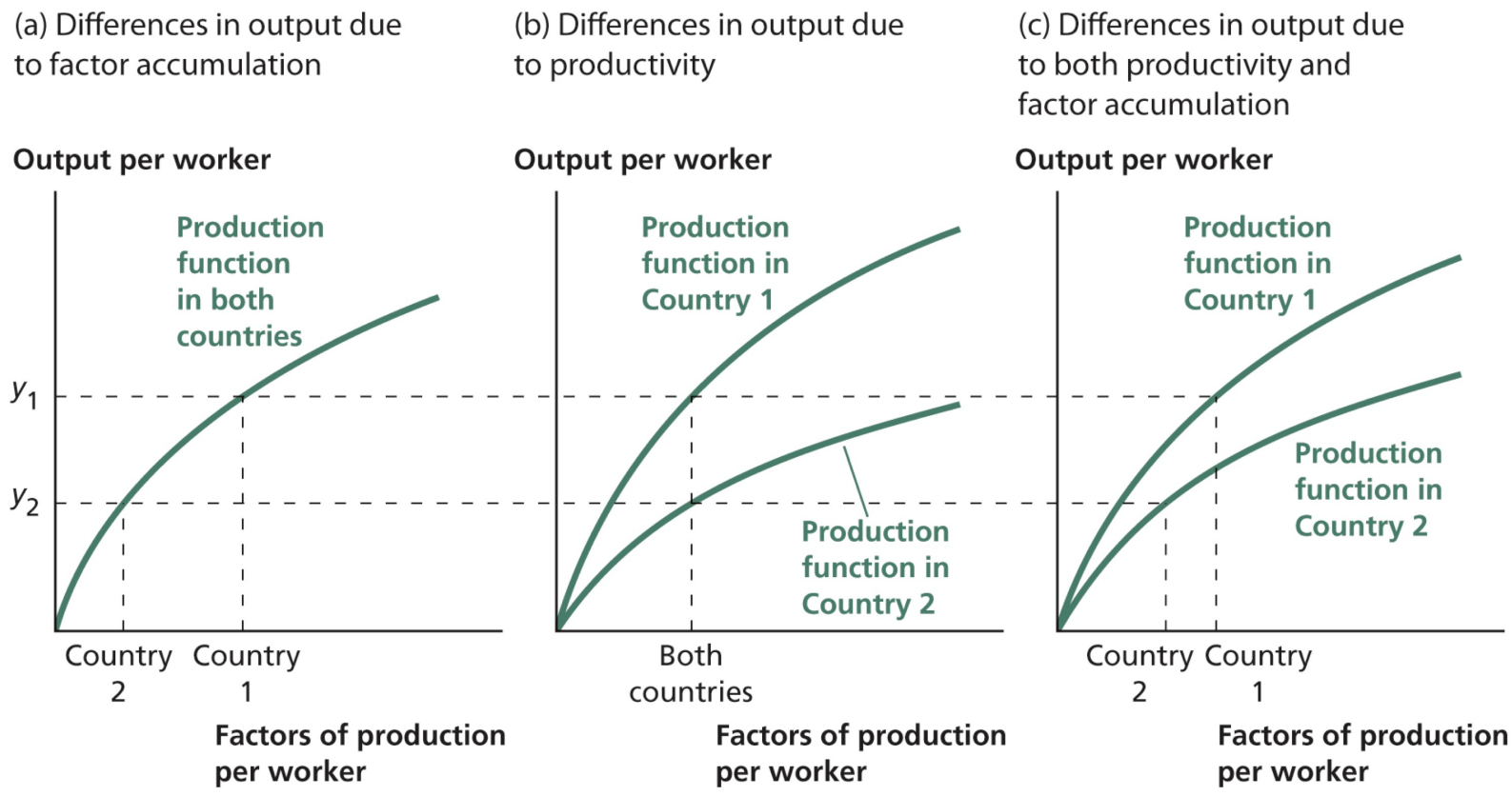
Country	Labor productivity growth (%), 2008-2018
United Kingdom	0.25
Germany	0.72
New Zealand	0.79
Japan	0.84
France	0.88
United States	0.99

Data from OECD, GDP per hour worked

Overview

- Countries differ in their output because of
  - differences in factor accumulation
  - differences in productivity
- In this lecture, we ask:
  - How much does productivity differ across countries?
  - How much of the variation in income per capita among countries is explained by productivity differences?
  - How much does productivity growth differ among countries?
  - How much of the variation in growth rates among countries is explained by variation in productivity growth, and how much by variation in factor accumulation?

Possible sources of differences in output per worker



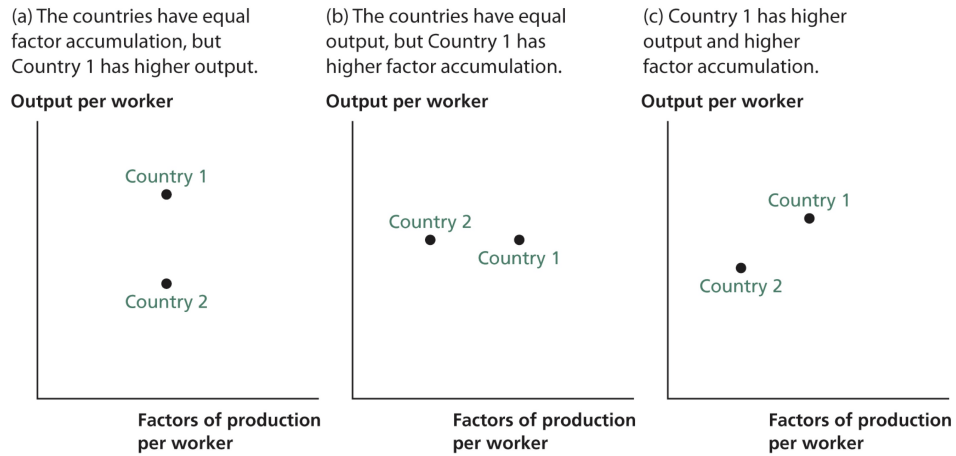
Graphic from Weil (2013)

Inferring productivity from data on output and factor accumulation

a. Country 1 is more productive than country 2

b. Country 2 is more productive than country 1

c. Need to know the production function to make a comparison



Graphic from Weil (2013)

Differences in the level of productivity among countries

- Analyze productivity differences quantitatively
- How much of the variation among countries' income per capita is explained by the variations in productivity?
- How much is explained by the accumulation of factors of production?

Measuring productivity differences among countries

- Assume production function is a Cobb-Douglas

$$Y = AK^{\alpha}(hL)^{1-\alpha}$$

- Output per worker $y = Ak^{\alpha}h^{1-\alpha}$
- factors of production = $k^{\alpha}h^{1-\alpha}$
- output = productivity $\times$ factors of production

Productivity differences

- Output per worker of country 1 and country 2

$$y_1 = A_1 k_1^{\alpha} h_1^{1-\alpha}$$

$$y_2 = A_2 k_2^{\alpha} h_2^{1-\alpha}$$

- Output per worker ratios:

$$\frac{y_1}{y_2} = \left(\frac{A_1}{A_2}\right)\left(\frac{k_1^{\alpha} h_1^{1-\alpha}}{k_2^{\alpha} h_2^{1-\alpha}}\right)$$

$$\text{ratio of output per worker} = \text{ratio of productivity} \times \text{ratio of factors of production}$$

- Ratio of productivity

$$\text{ratio of productivity} = \frac{A_1}{A_2} = \frac{\text{ratio of output per worker}}{\text{ratio of factors of production}} = \frac{\left(\frac{y_1}{y_2}\right)}{\left(\frac{k_1^{\alpha} h_1^{1-\alpha}}{k_2^{\alpha} h_2^{1-\alpha}}\right)}$$

Numerical example

$$\frac{A_1}{A_2} = \frac{\left(\frac{y_1}{y_2}\right)}{\left(\frac{k_1^{\alpha} h_1^{1-\alpha}}{k_2^{\alpha} h_2^{1-\alpha}}\right)}$$

$$\text{ratio of productivity} = \frac{\text{ratio of output}}{\text{ratio of factors of production}}$$

	Output per worker, y	**Physical capital per worker,** k	**Human capital per worker,** h
Country 1	24	27	8
Country 2	1	1	1

$$\frac{A_1}{A_2} = \frac{\left(\frac{24}{1}\right)}{\left(\frac{27^{1/3} \times 8^{2/3}}{1^{1/3} \times 1^{2/3}}\right)} = \frac{24}{\left(\frac{3 \times 4}{1}\right)} = 2$$

- Country 1 is twice as productive as country

Development accounting

Development accounting

Development Accounting: Breaking down income differences into parts accounted for by

- productivity differences
- factor accumulation differences

Development accounting, algorithm

Using data in a given year, say t:

1. Pick a base country
2. Find output per worker of country i relative to the base country, $\frac{y_i}{y_{base}} = ?$
3. Find physical capital per worker of country i relative to the base country, $\frac{k_i}{k_{base}} = ?$
4. Find human capital per worker of country i relative to the base country, $\frac{h_i}{h_{base}} = ?$
5. Find factors of production of country i relative to the base country, $\frac{k_i^\alpha h_i^{1-\alpha}}{k_{base}^\alpha h_{base}^{1-\alpha}} = ?$
6. Find productivity of country i relative to the base country, $\frac{A_i}{A_{base}} = ?$
7. Comment on the values you found in above steps

Development accounting, cont'd

- Large differences in productivity
- South Korean productivity = 64% of US productivity
- Japan has significantly higher level of physical capital, but it's productivity is 70% of the US productivity.
- Canada and UK: similar income, UK more productive, Canada higher factor accumulation

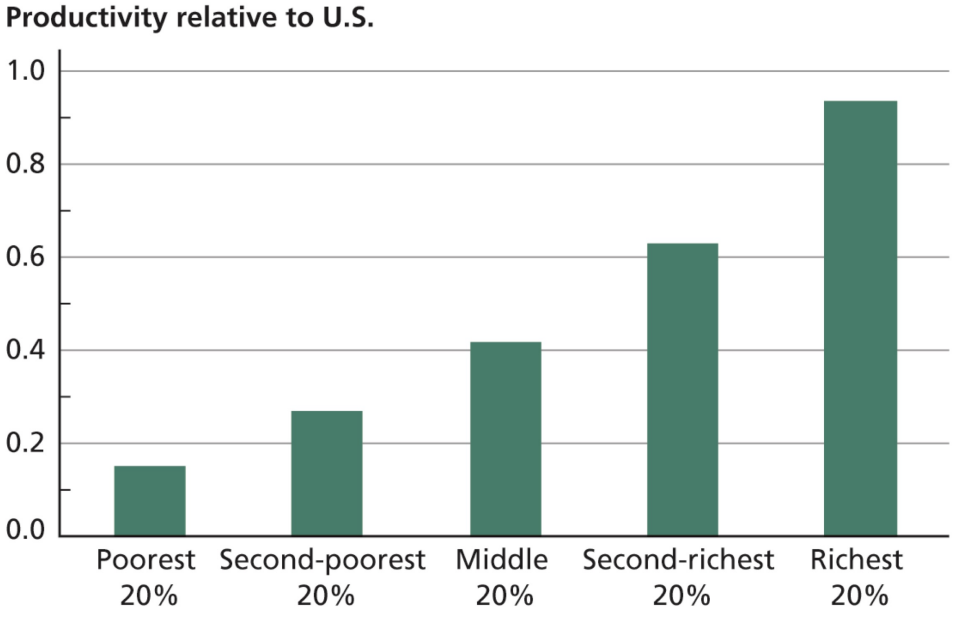
Country	Output per Worker, y	Physical Capital per Worker, k	Human Capital per Worker, h	Factors of Production, $k^{1/3}h^{2/3}$	Productivity, A
United States	1.00	1.00	1.00	1.00	1.00
Norway	1.12	1.32	0.98	1.08	1.04
United Kingdom	0.82	0.68	0.87	0.80	1.03
Canada	0.80	0.81	0.96	0.91	0.88
Japan	0.73	1.16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

Sources: Output per worker: Heston, Summers, and Aten (2011); physical capital: author's calculations; human capital: Barro and Lee (2010). 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.

Table from Weil (2013)

Roles of factors of production and productivity in determining output per Worker, 2009

For sources, see Table 7.2.



For sources, see Table 7.2.

Graphics from Weil (2013)

Accounting for output per worker differences

- Productivity among the poorest one-fifth of countries is 15% of the US level.
- Similar contributions of productivity and factor accumulation to ouput per worker differences
- Productivity is slightly more important (except the richest 20%)
- 47% of variation in output per worker is due to factor accumulation
- 53% of the variation is due to productivity

Growth accounting

Differences in the growth rate of productivity among countries

Growth accounting: Breaking a country's growth into parts accounted for by

- growth in productivity
- growth in the quantity of factors of production

We ask

- How much income growth on average is accounted for by the productivity growth?
- How much income growth on average is accounted for by increases in factors of production?

Measuring a country's productivity growth

$$\text{output} = \text{productivity} \times \text{factors of production}$$

- growth rate of output = growth rate of productivity + growth rate of factors of production
- growth rate of productivity = growth rate of output -growth rate of factors of production
- Assume a Cobb-Douglas production function
- Output per worker, $y = Ak^{\alpha}h^{1-\alpha}$
- Take natural log of each side of equation

$$\ln(y) = \ln(Ak^{\alpha}h^{1-\alpha}) = \ln(A) + \alpha\ln(k) + (1-\alpha)\ln(h)$$

- Differentiate with respect to time

$$\frac{\frac{dy}{dt}}{y} = \frac{\frac{dA}{dt}}{A} + \alpha\frac{\frac{dk}{dt}}{k} + (1-\alpha)\frac{\frac{dh}{dt}}{h}$$

$$\hat{y} = \hat{A} + \alpha\hat{k} + (1-\alpha)\hat{h},$$

where $\hat{x}$ is the growth rate of x.

Growth accounting, algorithm

For a country, i, from year t to year $t+n$, find

1. the average annual growth rate of income per worker, $\hat{y} = \frac{\ln y_{i,t+n} - \ln y_{i,t}}{n}$
2. the average annual growth rate of physical capital per worker, $\hat{k} = \frac{\ln k_{i,t+n} - \ln k_{i,t}}{n}$
3. the average annual growth rate of human capital per worker, $\hat{h} = \frac{\ln h_{i,t+n} - \ln h_{i,t}}{n}$
4. the average annual growth rate of factors of production per worker, $\hat{f.o.p.} = \alpha\hat{k} + (1-\alpha)\hat{h}$
5. the average annual growth rate of productivity, $\hat{A} = \hat{y} - \hat{f.o.p}$

Comment on the above stats, in particular highlight

1. percentage of output per worker growth accounted for by the productivity growth, $\frac{\hat{A}}{\hat{y}}$
2. percentage of output per worker growth accounted for by the factors of production, $\frac{\hat{f.o.p}}{\hat{y}}$
   - percentage of output per worker growth accounted for by the physical capital accumulation, $\frac{\alpha\hat{k}}{\hat{y}}$
   - percentage of output per worker growth accounted for by the human capital accumulation, $\frac{(1-\alpha)\hat{h}}{\hat{y}}$

Numerical example

$$\hat{A} = \hat{y} - \alpha\hat{k} - (1-\alpha)\hat{h}$$

	Output per worker, y	**Physical capital per worker, k**	**Human capital per worker, h**
Erewhon in 1975	1	20	5
Erewhon in 2010	4	40	10
Annual growth rate	4%	2%	2%

$$\text{growth rate of output} = \left(\frac{\ln(\text{output in 2010}) - \ln(\text{output in 1975})}{35} \right) = .04$$

$$\hat{A} = .04 - \frac{1}{3} \times .02 - \frac{2}{3} \times .02 = .02$$

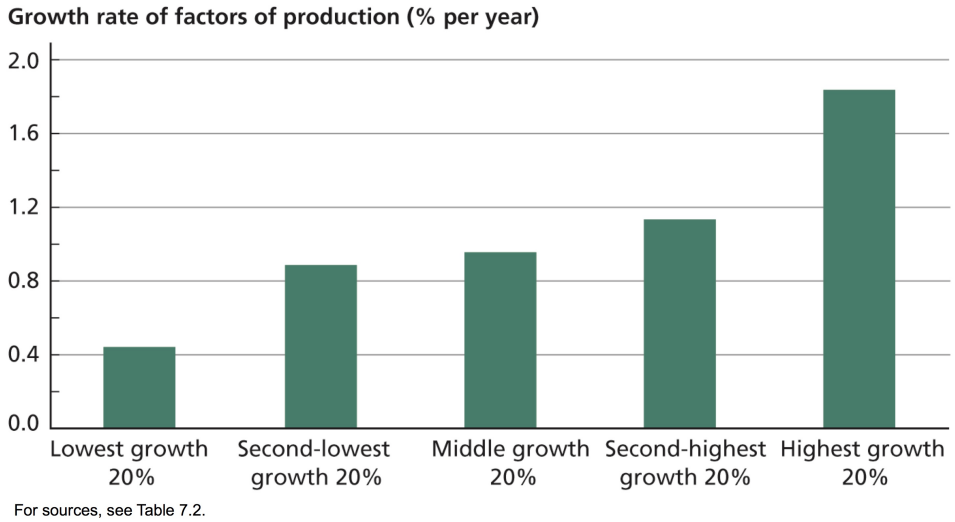
Growth Accounting for the US

- Years 1975 – 2009
- 1.34% output growth annually
- physical capital stock growth rate of 2.20% per year
- human capital growth rate of .11% per year
- $\alpha = 1/3$

$$\hat{A} = .0134 - \frac{1}{3} \times .022 - \frac{2}{3} \times .0011 = .0054$$

- Productivity growth explains 40% of income growth (.0054/0.0134 = 40%)
- 60% of growth is explained by the accumulation of factors of production

Roles of Factors of Production and Productivity in Determining Growth, 1975 – 2009



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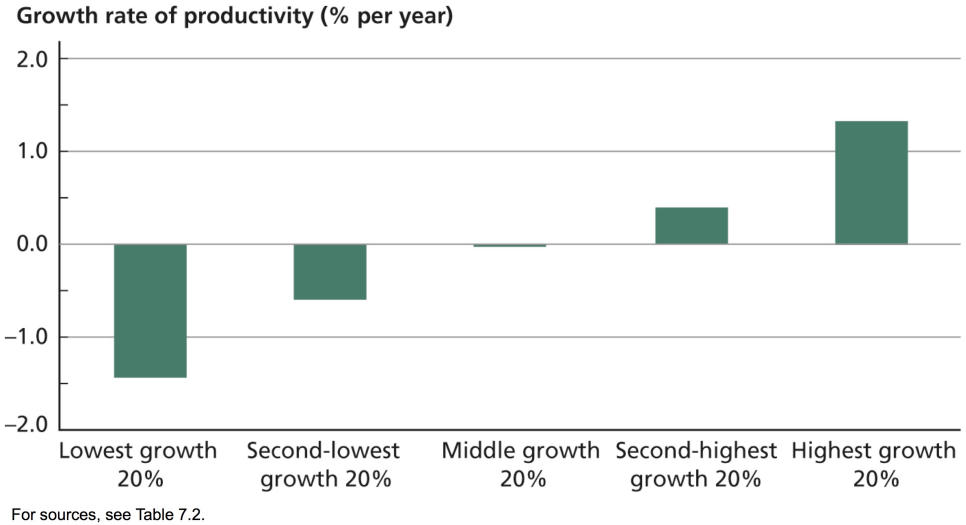

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Growth accounting

- Growth rate of factors of production ranges from .43% to 1.83% (1.40% gap)
- Productivity growth in the fastest growing one-fifth of countries is 1.33% per year
- Productivity growth in the slowest growing one-fifth of countries is -1.42% per year
- Gap between highest and lowest productivity growth is 2.75%
- Productivity growth is much more important source of income growth
- 68% of variation in the growth rates is the result of variation in productivity growth
- 32% of the variation is due to variation in factor accumulation

Problems with measuring productivity

- Quality of schooling
- Misreporting of investment
- Many different types of assets
- Quality differences across different versions of same asset
- Finding appropriate weights to sum up real quantities of different assets
- Production function is not necessarily constant
- Factor shares vary across countries

Summary

- **Development Accounting:** Breaking down income differences into parts accounted for by
  - productivity differences
  - factor accumulation differences
- **Growth accounting:** Breaking a country's growth into parts accounted for by
  - growth in productivity
  - growth in the quantity of factors of production