How Important Is Capital?

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Outline

We start looking into the question:

Why are some countries rich and others poor?

We start with causes that are relatively easy to measure:

1. physical capital
2. human capital

Then we look at causes that are harder to quantify (institutions).

Objectives

At the end of this section you should be able to:

1. Calculate the effect of varying the capital stock on per capita GDP (for example economies).
2. Explain why this effect is not large.
3. Explain the properties of the Cobb-Douglas production function and derive marginal products and factor income shares.

How important is capital?

- An old hypothesis: Poor countries lack capital.
  - Capital contains machines, equipment, structures, ...
- If capital is scarce, workers are unproductive.
  - Examples ...
- Questions:
  1. How well does this hypothesis line up with the data?
  2. What fraction of cross-country income gaps is due to capital?

Models as Measurement Tools

A key idea

The model as a measurement tool.

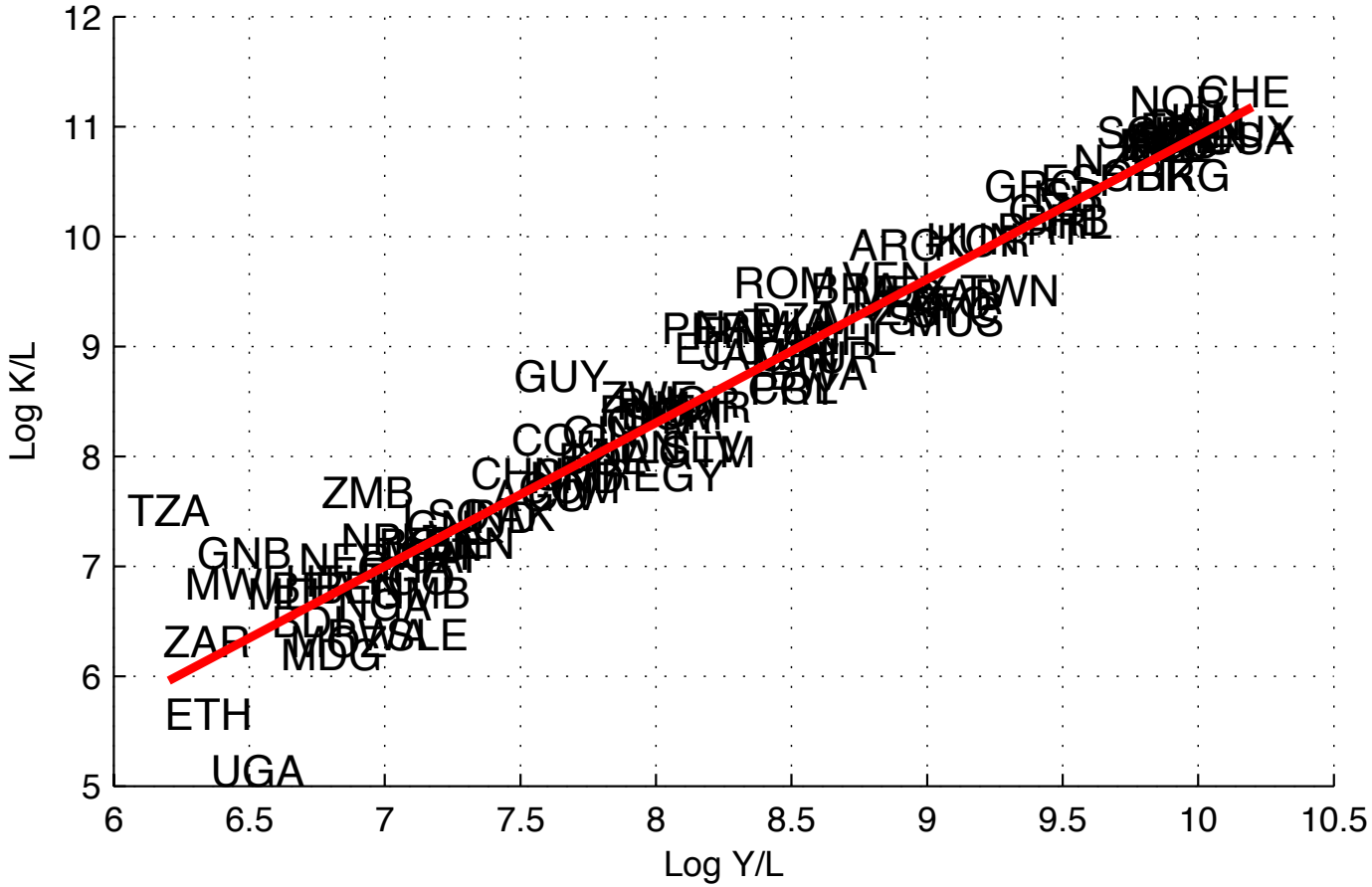
To measure the effect of X on Y, we use the implications of a quantitative model

Later, we discuss the benefits and drawbacks of this method.

GDP and Capital Stock

- Let's measure income as real GDP per person: Y/L.
  - Real: using the same prices for all countries.
- Capital is measured as real capital stock per person: K/L.
- Do countries with high Y/L have high K/L?
- We can only answer that question for years since 1950 (data limitations).
- If the answer is yes, then we might look for models in which poor countries lack capital.

GDP and Capital Stock: 1990 data



How important is capital?

- We want to quantify:

  What fraction of cross-country GDP gaps is due to variation in K/L*?*

- We don't have natural experiments
- So we need a quantiative model

A Model of Production

A Model of Production

We develop a model that links K/L to Y/L.

We estimate its parameters.

Then we can use the model to measure the effect of varying K/L (as it varies in the data) on Y/L.

Then we say: the model's predicted variation in Y/L is the share of the observed variation that is due to capital.

A Model of Production

We use an **aggregate production function.**

- Production function?
- Aggregate?

The economy produces one good (Y):

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

$A > 0$ is a parameter.

α is a parameter between 0 and 1.

Measurement

L: Labor input is measured as **total hours worked**.

- Or, if we don't have data, we use the number of people working (labor force) or the total population of working age (15-64).

Y: Gross Domestic Product (**GDP**).

- from National Income and Product Accounts
- in PPP prices

K: the stock of machines, equipment and structures used in production

- How is capital measured?

An aggregate production function?

- We have made some really strong assumptions in writing down

$$Y = K^{\alpha}(AL)^{1-\alpha} \tag{2}$$

- Does this make sense?

What about the functional form?

This is called a Cobb-Douglas production function

$$Y = K^{\alpha}(AL)^{1-\alpha} \tag{3}$$

It has certain properties that fit the data well for quite a few countries.

1. Constant returns to scale.
2. The capital share is constant (α) (see below).

What happens if we relax the functional form?

- See Practice Problems and Caselli (2005).

Constant returns to scale

Doubling K and L doubles Y.

Returns to scale could be increasing or decreasing.

Why do **decreasing** returns to scale seem unlikely?

What would happen with **increasing** returns?

Marginal products

Let's solve for the marginal product of capital.

It is the derivative

$$dY/dK = \alpha K^{\alpha-1}(AL)^{1-\alpha} \tag{4}$$

$$= \alpha A^{1-\alpha}(K/L)^{\alpha-1} \tag{5}$$

The marginal product of L:

$$dY/dL = (1-\alpha)\ A^{1-\alpha}\ (K/L)^{\alpha} \tag{6}$$

Plot that...

The capital share

How much of total production is paid to K and L?

Assumption: Inputs are paid their marginal products

- Why does this assumption make sense? (see below)

The capital share

Capital income is $MPK \times K = dY/dK \times K$

Recall: $dY/dK = \alpha K^{\alpha-1}(AL)^{1-\alpha}$.

Then capital income is:

$$\begin{aligned} \alpha K^{\alpha-1} K (AL)^{1-\alpha} &= \alpha K^{\alpha} (AL)^{1-\alpha} \\ &= \alpha Y \end{aligned}$$

Capital receives the constant share α of income.

Exercise: Show that labor receives share $1-\alpha$.

The capital share

Why does this result matter?

Because it allows us to estimate α easily:
all we need to do is look up the breakdown of GDP into capital and labor income.

Across countries and over time, we find that capital receives $1/3$, labor receives $2/3$.

Therefore, $\alpha = 1/3$.

Important fact

The share of GDP that goes to capital is near 1/3.

The prices of capital and labor

Why does it make sense to assume that capital is paid dY/dK?

Consider a firm that maximizes profits.

It hires capital at price r and labor at price w.

Revenue is $p\ F(K,L)$.

It maximizes

$$\max_{K,L} pF(K,L) - rK - wL \tag{7}$$

The firm is a price taker in all markets.

How much capital and labor should the firm hire?

The prices of capital and labor

Take the first order condition to find

$$\begin{aligned} p\ dF(K,L)/dK - r &= 0 \\ p\ dY/dK &= r \\ r/p &= dY/dK \end{aligned} \tag{8}$$

The firm hires capital until the price of capital (r/p) equals the marginal product.

But what happened to p when I said that capital is paid dY/dK?

Summary

The model postulates an aggregate production function: $Y = K^{\alpha}(AL)^{1-\alpha}$.

Key features of the data that motivate this:

1. Constant returns to scale.
2. Constant shares of GDP earned by capital (1/3) and labor (2/3).

The capital share is a constant α

This is how we estimate $\alpha = 1/3$: in NIPA, capital earns 1/3 of GDP.

Robustness

If this seems simple, many assumptions can be relaxed:

- more general production functions
- many types of capital and labor
- many goods produced

The results don't change too much.

Caselli (2005) contains a lot of robustness checks.

The Model as Measurement Device

What are benefits / drawbacks of this method?

Why do we use it?

What can go wrong?

How to ensure that a model gives good answers?

There are many possible models ...

Economics vs. Sociology

Perhaps the defining feature of economics:

We use "one" model to understand many questions.

Benefits:

- discipline
- the model can be tested against lots of data

Drawbacks:

Accounting for cross-country income gaps

Accounting for cross-country income gaps

What is the contribution of low K to cross-country income gaps?

A key idea:

> *We can use a model to* ***measure*** *the effect of one variable* (K) *on another* (Y).

The model in per capita terms

We want to understand variation in output per worker (Y/L).

Production function:

$$\begin{aligned} Y/L &= A^{1-\alpha} K^{\alpha} L^{1-\alpha} / L \\ &= A^{1-\alpha} (K/L)^{\alpha} \end{aligned} \tag{9}$$

Per capita notation: $y = Y/L$ and $k = K/L$.

$$y = A^{1-\alpha} k^{\alpha} \tag{10}$$

Output gap between 2 countries

$$\frac{y_{IND}}{y_{US}} = \left(\frac{A_{IND}}{A_{US}}\right)^{1-\alpha} \left(\frac{k_{IND}}{k_{US}}\right)^{\alpha} \tag{11}$$

This divides output gaps into two components:

1. One we understand / can measure: k.
2. One we don't understand:A - everything else.

We can use the model to measure the importance of capital versus everything else.

How does k affect y?

Recall

$$y = A^{1-\alpha} k^{\alpha}$$

with $\alpha = 1/3$.

Multiply k by factor λ, then y rises by...

How does k affect y?

Example

A country with $\lambda = 1/40$ of U.S. capital has $(1/40)^{1/3} = 0.32$ of U.S. output.

Why is the effect so "small"?

Country examples

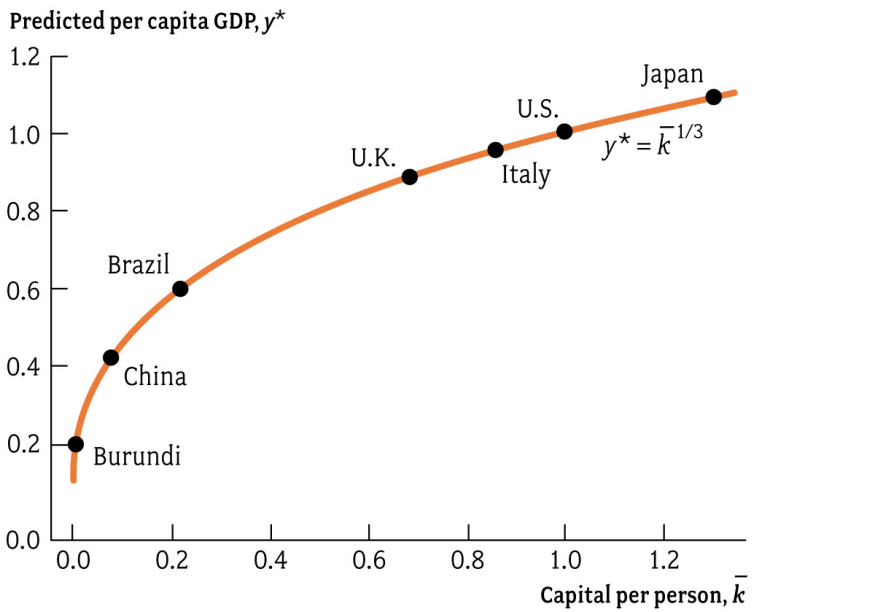


FIGURE 4.4 Predicted Per Capita in the Production Model

Macroeconomics, Charles I. Jones

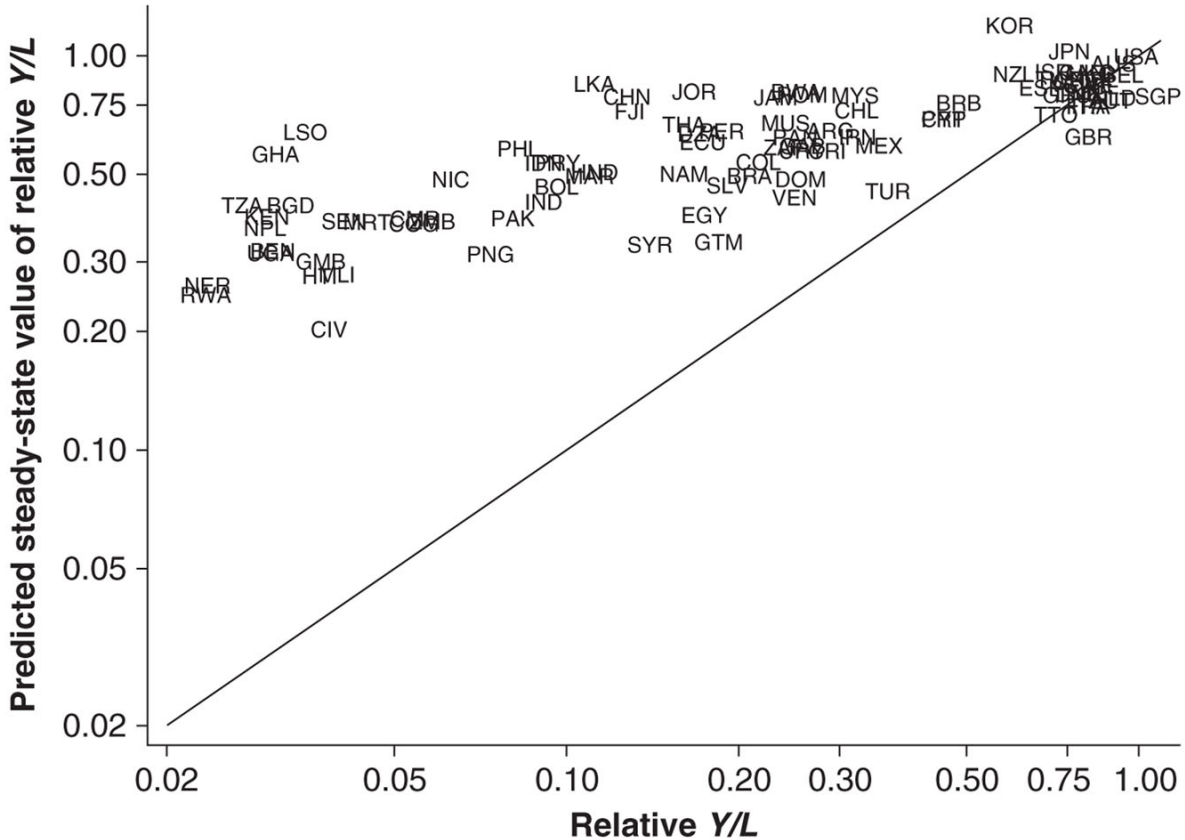
Thought experiment: Hold A constant and vary k.

Key: Even with very small k, output is 20% of US.

What would this graph look like with $\alpha = 0.99$?

The contribution of k to y gaps

FIGURE 3.1 THE "FIT" OF THE NEOCLASSICAL GROWTH MODEL, 2008



Predicted y: $\hat{y}_i = A_{US}^{1-\alpha} k_i^{\alpha}$.

Result: k gaps account for y gaps "only" up to 1/4 of US y.

The model as a measurement tool

A key idea

Models can be used to measure unobservable quantities and prices.

Think of the model as measuring $\bar{A}$ for each country i:

$$\bar{A}_i = A_i^{1-\alpha} = \frac{y_i}{k_i^{\alpha}} \tag{12}$$

Measuring Productivity

Country	Per capita GDP (y)	$\bar{k}^{1/3}$	Implied TFP ($\bar{A}$)
United States	1.000	1.000	1.000
Switzerland	0.793	1.106	0.717
Japan	0.741	1.092	0.679
Italy	0.654	0.951	0.688
United Kingdom	0.666	0.881	0.756
Spain	0.542	0.883	0.614
Brazil	0.216	0.591	0.365
South Africa	0.227	0.512	0.443
China	0.113	0.422	0.266
India	0.074	0.328	0.227
Burundi	0.016	0.190	0.083

Calculations are based on the equation $y = \bar{A}\,\bar{k}^{1/3}$. Implied productivity $\bar{A}$ is calculated from data on y and $\bar{k}$ for the year 2000, so that this equation holds exactly as $\bar{A} = y/\bar{k}^{1/3}$.

TABLE 4.4 Measuring TFP So the Model Fits Exactly

The model as a measurement tool

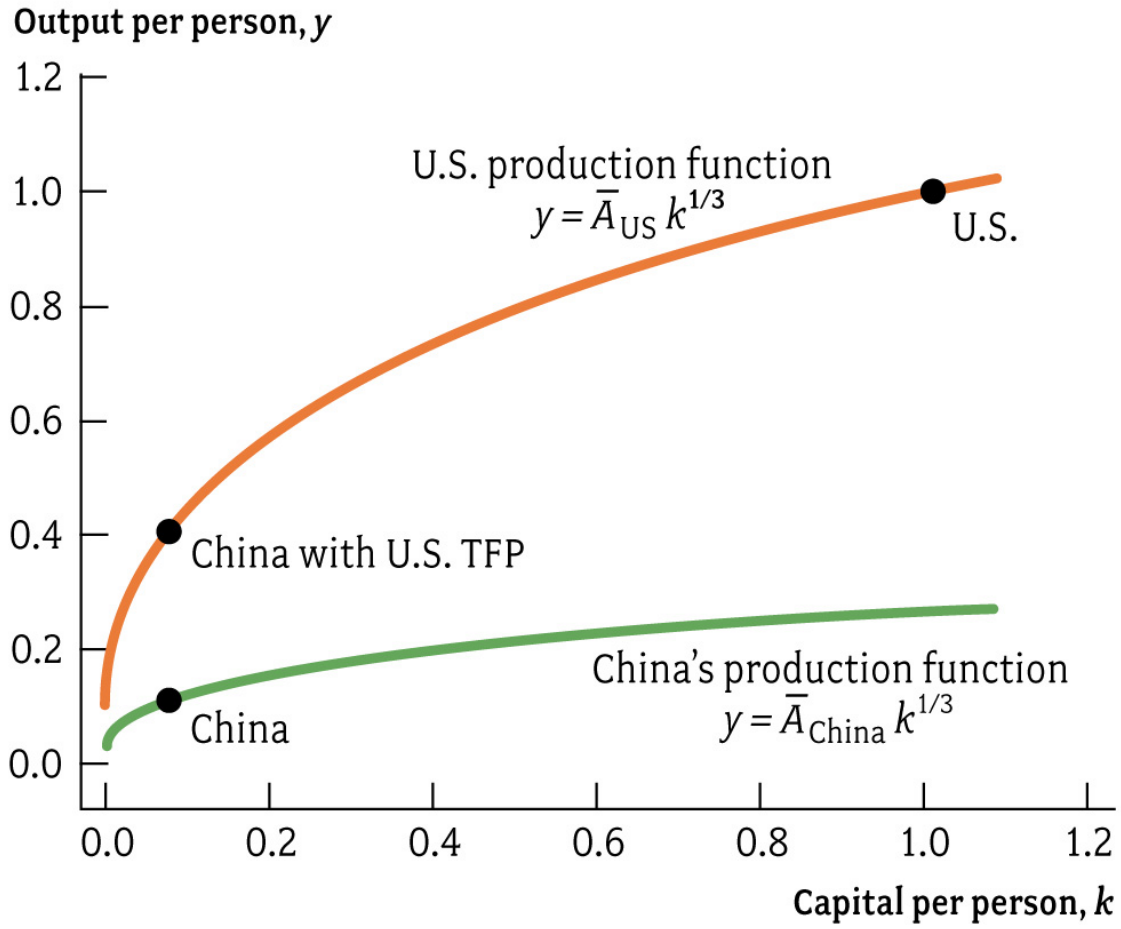
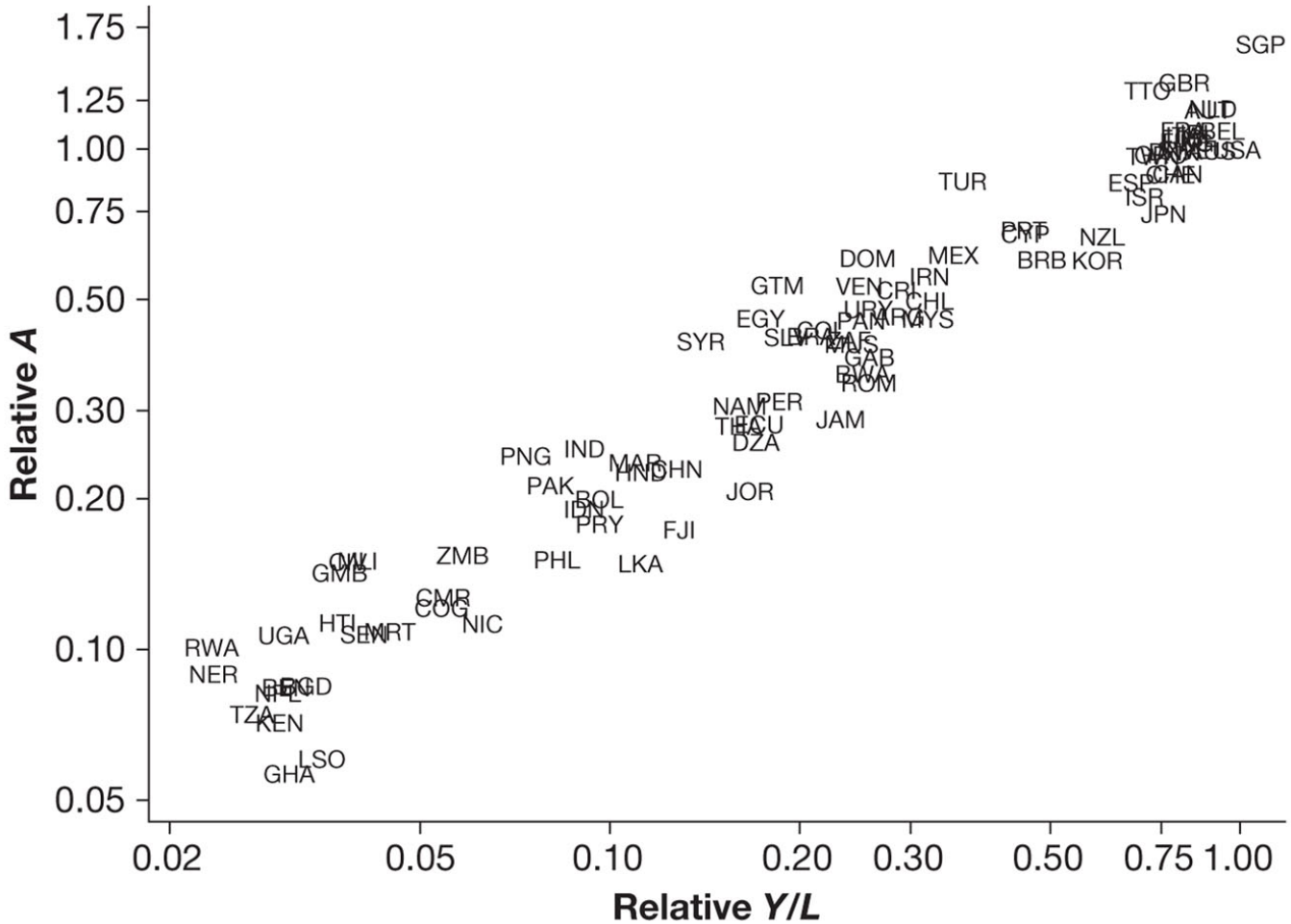


FIGURE 4.6 The U.S. and Chinese Production Functions

Macroeconomics, Charles I. Jones

The model as a measurement tool

FIGURE 3.2 **PRODUCTIVITY LEVELS, 2008**



Source: Jones (2013b)

What fraction of cross-country income gaps is due to capital?

The answer varies across countries.

For poor countries: about 1/3 is due to capital, 2/3 are yet unexplained (due to A).

Look back to the figure on the previous slide:

Y/L rich/poor	$(K/L)^{\alpha}$ rich/poor	$A^{1-\alpha}$ rich/poor
32	4	8
8	1.6	5
2	1	2

Adding human capital to the model

The goal: understand large differences in productivity A across countries.

We start with human capital.

Definition

Human capital: any knowledge or skills learned by workers that increase productivity.

Not just education, but also

- learning from parents, peers, on the job,
- health, ...

Production Model with Human Capital

For any country, the production function is now

$$Y_i = K_i^{\alpha}(A_i h_i L_i)^{1-\alpha} \tag{13}$$

or

$$y_i = (A_i h_i)^{1-\alpha} k_i^{\alpha} \tag{14}$$

New: h = human capital of a typical worker.

Cross-country Output Gaps

Output relative to the U.S.

$$\frac{y_{US}}{y_{poor}} = \left(\frac{A_{US}}{A_{poor}}\frac{h_{US}}{h_{poor}}\right)^{1-\alpha}\left(\frac{k_{US}}{k_{poor}}\right)^{\alpha}$$

How to measure h_{US}?

One idea: estimate how much a year of schooling raises wages within a country.

- Mincer approach (see Hall and Jones 1999)

Measuring Human Capital

Assume: $h = \exp(\phi s)$ where s is years of schooling.

- What does this say in words?
- $\phi > 0$ is a parameter ("Mincer return")

Example: $\phi = 0.1$ then

- college graduate: $h(16) = \exp(1.6) = 5$.
- high school graduate $h(12) = \exp(1.2) = 3.3$.
- the college grad is $5/3.3 = 1.5$ times as productive as the high school grad.

Measuring Human Capital

We can use data on U.S. wages by schooling to estimate ϕ:

- Regress $\log(h) = \phi s$ on years of schooling
- Assumption: wages are proportional to h.

We find that ϕ is near 0.1.

- On average a year of schooling raises wages by 10%.

How Important Is Human Capital for Y/L?

Average years of schooling in the U.S.: $s_{US} = 13$

Average years of schooling in a typical country with 1/30 of U.S. output per worker: $s_{poor} = 3$

Gap in years of schooling: $s_{US} - s_{poor} = 10$

Gap in $\log(h)$: $0.1 \times 10 = 1$

h gap between U.S. and poor country worker:

$$h_{US}/h_{poor} = e^1 = 2.7$$

Levels Accounting

$$\underbrace{\frac{y_{US}}{y_{poor}}}_{32} = \underbrace{\left(\frac{A_{US}}{A_{poor}}\right)^{1-\alpha}}_{4} \underbrace{\left(\frac{h_{US}}{h_{poor}}\right)^{1-\alpha}}_{2} \underbrace{\left(\frac{k_{US}}{k_{poor}}\right)^{\alpha}}_{4}$$

Contribution of h: $2.7^{1-\alpha} = 2$

Human capital

Does this calculation sound convincing?

What might it be missing?

Reasons for TFP differences

Technology

- We will talk about that in detail.
- The idea is that poor countries use old technologies.
  - Oxen and plows in Egypt instead of tractors.
- But that's only half of an explanation!

Reasons for TFP differences

- We think that countries are poor because they lack
  1. Capital (1/3)
  2. Human capital (1/6)
  3. Technology (??)
- These are "proximate causes" of poverty.
- They reflect different choices people make:
  1. Save less
  2. Go to school less
  3. Invest less in technology adoption and development
- We need to look for "deep" causes.
  - Why do people in poor countries make "bad" choices?

Reasons for TFP differences

Institutions

- We do not fully understand the deep causes of poverty.
- We know that an important deep cause is institutions.
- Institutions are a vague collection of "rules of the game" - hard to define but obvious when you see them.
- Examples:
  - Freedom of expression.
  - Right to participate in elections.

Why do we think institutions matter?

There are "obvious" historical examples:

Why do we think institutions matter?

- We also observe that countries with different institutions, that were established hundreds of years ago, systematically differ in Y/L.
- Important institutions are:

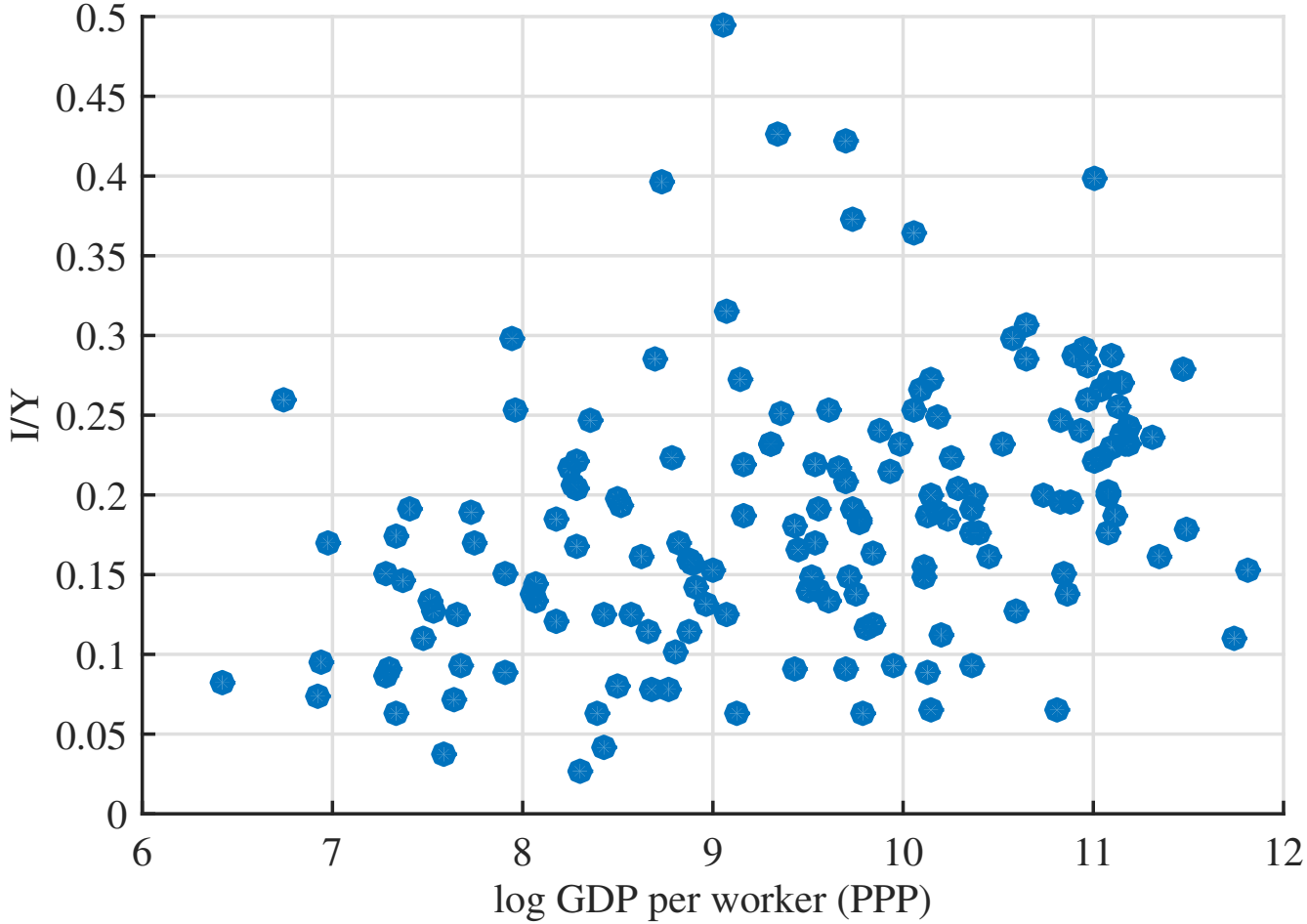
Why is K/L low in poor countries?

Why is K/L low in poor countries?

- We have treated K/L as exogenous - now we need to move beyond that.
- We know that K/L and Y/L are correlated in the data.
- Why might that be?

Why is K/L low in poor countries?

Poor countries have low investment rates.



Source: Penn World Tables

Is that why K/L is low?

Why is K/L low in poor countries?

Why is K/L low in poor countries?

- Low saving rates?
- A consequence of low income?
- Something else causes low K/L and low Y/L?

A General Lesson

It is impossible to figure out causality by looking at data alone. Only theory can say something about causality.

That's why we now work on a model of capital accumulation.

Summary of Key Points

1. We need a model to answer questions of the type: "How much does X affect Y?"
   1.1 Regressions (or other statistical tools) only describe the data.
2. The production model shows:
   2.1 Capital accounts for a small fraction of cross-country income gaps.
   2.2 The main reason: diminishing returns.

Reading

- Jones (2013b), ch. 1

Additional reading:

- Jones (2013a), ch. 3
- Caselli (2005) shows that the contribution of human capital does not increase too much when quality is taken into account (via education spending or test scores)

References I

Caselli, F. (2005): "Accounting for Cross-Country Income Differences," in *Handbook of Economic Growth*, ed. by P. Aghion and S. N. Durlauf, Elsevier, vol. 1B, chap. 9.

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