

How Important Is Capital?

Prof. Lutz Hendricks

Econ520

January 17, 2012

Why Are Some Countries Rich and Others Poor?

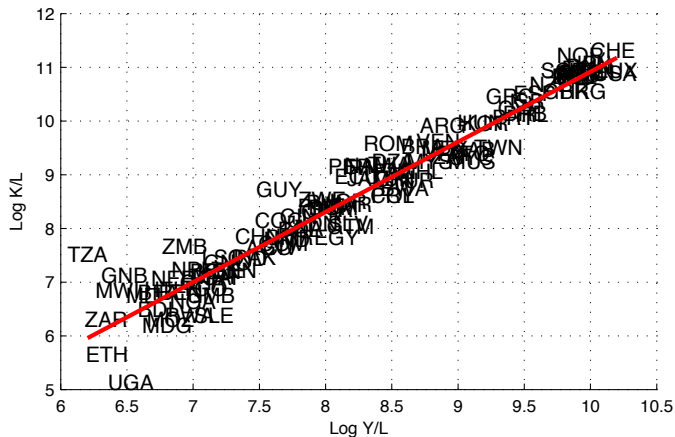
- Fact: Rich countries are 25 times richer than poor countries.
- What do poor countries lack?
- Some candidates...

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?

- 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 ?
- How can we quantify questions like this?

Regression Analysis

- The figure above suggests that output and capital are related by a linear (straight line) relationship.
- We could postulate the (statistical) model:

$$\log(Y_i/L_i) = \alpha + \beta \log(K_i/L_i) + \varepsilon_i \quad (1)$$

- i indexes the country
- The model "explains" the $\alpha + \beta \log(K_i/L_i)$ part of the variation in $\log(Y_i/L_i)$.
- ε_i is the unexplained **residual** – everything we have not modeled.

Ordinary Least Squares (OLS)

- OLS is a method for fitting a line through the data.
- OLS finds the coefficients (α, β) that minimize the sum of squared residuals.
- Formally, OLS solves:

$$\min_{\alpha, \beta} \sum_i (\varepsilon_i)^2 = \min \sum_i (\log(Y_i/L_i) - \alpha - \beta \log(K_i/L_i))^2 \quad (2)$$

- Draw a picture...

The slope coefficient

- What does β mean?

The slope coefficient

- What does β mean?
- A 1 unit increase in $\log(K/L)$ is associated with a β unit increase in $\log(Y/L)$.
- A nice feature of logarithms: a 1% increase in K/L is associated with a $\beta\%$ increase in Y/L .

What would happen if we gave each poor country 100% more capital?

What would happen if we gave each poor country 100% more capital?

- The OLS regression has nothing to say about this.
- Is there an easy way to prove this?

Regressions Do Not Answer Causality Questions

- Proof: I can run the regression in reverse:

$$\log(K_i/L_i) = \hat{\alpha} + \hat{\beta} \log(Y_i/L_i) + \hat{\varepsilon}_i \quad (3)$$

- I will get something close to $\hat{\beta} = 1/\beta = 2$.
- Either regression is equally valid.
- This means the regression says nothing about whether K causes Y or the other way around (or neither).

Fact

OLS does nothing more than describe the data.

OLS answers the question:

If two observations differ by a given x , by how much do their y 's differ on average?

- This has nothing to do with causality.
- We learn nothing about the question:

If Greece increased its K/L by 10%, by how much would Y/L increase?

Fact

*No statistical method can answer cause-effect questions.
(Unless one can run controlled experiments.)*

How Can We Answer Cause/Effect Questions?

How Can We Answer Cause/Effect Questions?

Fact

*Only theories can answer cause-effect questions.
(Unless one can run controlled experiments.)*

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):

$$Y = K^\alpha(AL)^{1-\alpha} \quad (4)$$

- 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).
- How is capital measured?
- The data counterpart of Y is Gross Domestic Product (**GDP**).
- A is a parameter.
- α is a parameter between 0 and 1.

An aggregate production function?

- We have made some really strong assumptions in writing down

$$Y = K^\alpha (AL)^{1-\alpha} \quad (5)$$

- Does this make sense?

What about the functional form?

- This is called a Cobb-Douglas production function

$$Y = K^\alpha (AL)^{1-\alpha} \quad (6)$$

- It has certain properties that fit the data well for quite a few countries.
 - 1 Constant returns to scale.
 - 2 Capital and labor receive incomes that amount to constant shares of Y (across countries and over time).
- What happens if we relax the functional form? See Practice Problems.

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?

Properties of the production function

Diminishing marginal products:

- Let's solve for the marginal product of capital.
- It is the derivative

$$dY/dK = \alpha K^{\alpha-1} (AL)^{1-\alpha} \quad (7)$$

$$= \alpha (K/[AL])^{\alpha-1} \quad (8)$$

- Plot that...
- The marginal product of L :

$$dY/dL = (1 - \alpha) A^{1-\alpha} (K/L)^{1-\alpha} \quad (9)$$

The capital share

- How much of total production is paid to K and L ?
- Assumption: Each unit of K is paid dY/dK and each unit of L is paid dY/dL .
- Why does this assumption make sense?

The capital share

- Capital income is rental price $\times K = dY/dL \times K$
- 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 ?

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

$$\max_{K,L} pF(K, L) - rK - wL \quad (10)$$

- 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

$$p \, dF(K, L)/dK - r = 0$$

$$p \, dY/dK = r$$

$$r/p = dY/dK \tag{11}$$

- 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 ?

- 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).
- What is the capital share?
 - Competition in factor markets: capital and labor are paid their marginal products.
 - $MPK = \alpha K^{\alpha-1}(AL)^{1-\alpha} = \alpha Y/K$.
 - Capital share: $MPK \times K/Y = \alpha Y/K \times K/Y = \alpha = 1/3$.
- This is how we estimate $\alpha = 1/3$: in NIPA, capital earns 1/3 of GDP.

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.

Accounting for cross-country income gaps

Accounting for cross-country income gaps

- Why are some countries so much richer than others?
- What is the contribution of low K to poverty?
- A key idea:

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

- How else could we answer such questions?

The model in per capita terms

- Right now the model links aggregate K to aggregate Y .
- This is not interesting: China's Y is high just because it has lots of people
- We want to understand variation in output per worker (Y/L).
- Production function:

$$\begin{aligned} Y/L &= A^{1-\alpha} K^\alpha L^{1-\alpha} / L \\ &= A^{1-\alpha} (K/L)^\alpha \end{aligned} \tag{12}$$

- This divides output gaps into two components:
 - ① One we understand: K/L .
 - 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/L affect Y/L ?

- Recall

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

with $\alpha = 1/3$.

- Multiply K/L by factor λ , then Y/L rises by...

How does K/L affect Y/L ?

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

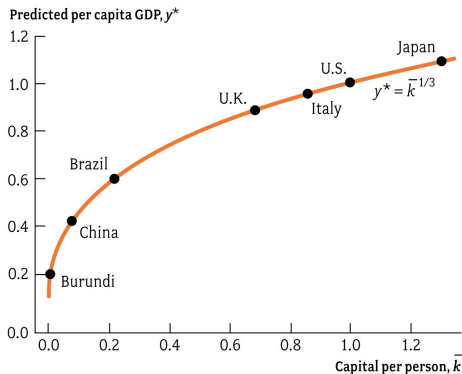
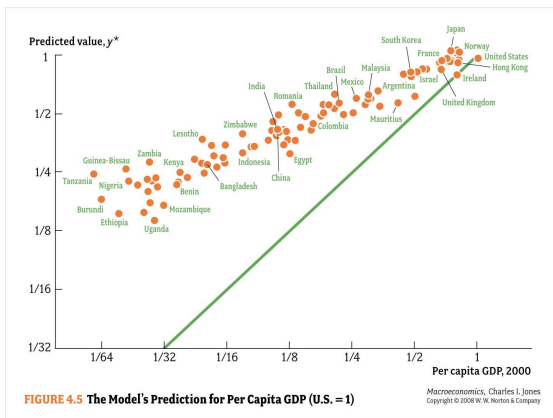


FIGURE 4.4 Predicted Per Capita in the Production Model

Macroeconomics, Charles I. Jones
Copyright © 2008 W. W. Norton & Company

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

How well does the model fit the data?



Assumption: $A = 1$ in all countries.
Is the model a disaster?

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

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

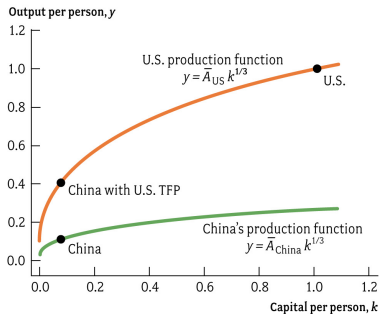
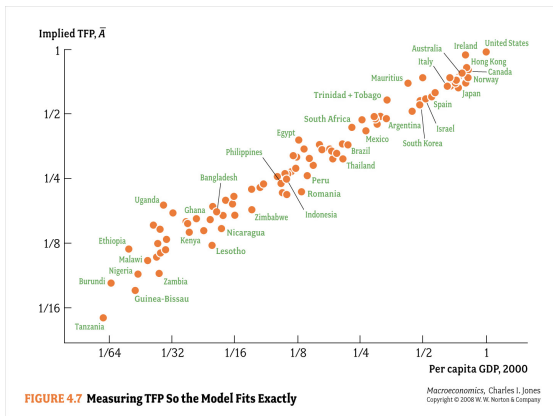


FIGURE 4.6 The U.S. and Chinese Production Functions

Macroeconomics, Charles I. Jones
Copyright © 2008 W. W. Norton & Company

The model as a measurement tool



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 figure 4.7:

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

Why does TFP differ across countries?

- We will look into this question in detail later.
- For now, we just list some possible reasons.

Reasons for TFP differences

Human capital

- Human capital: any knowledge or skills learned by workers that increase productivity.
- Not just education, but also ...

Production Model with Human Capital

- For any country, the production function is now

$$Y = K^\alpha (AhL)^{1-\alpha} \quad (13)$$

or

$$y = (Ah)^{1-\alpha} k^\alpha \quad (14)$$

- 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} ?

Measuring Human Capital

- One idea: estimate how much a year of schooling raises wages within a country.
- Assume: $h = \exp(\phi s)$ where s is years of schooling.
 - What does this say in words?
- **Example:** $\phi = 0.1$ then
 - a worker with 16 years (college) of schooling has $h(16) = \exp(1.6) = 5$.
 - a worker with 12 years of schooling (high school) has $h(12) = \exp(1.2) = 3.3$.
 - 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 measure 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.: $s_{US} =$
- Average years of schooling in a typical country with 1/30 of U.S. output per worker: $s_{poor} =$
- Gap in years of schooling: $s_{US} - s_{poor} =$
- Human capital of typical U.S. worker: $h_{US} =$
- Human capital of typical low income country worker: $h_{poor} =$
- Productivity gap between U.S. and poor country worker:

$$h_{US}/h_{poor} =$$

- Human capital roughly accounts for a productivity gap of 2.
- Redo levels accounting with human capital.

$$\frac{y_{US}}{y_{poor}} = \left(\frac{A_{US}}{A_{poor}} \frac{h_{US}}{h_{poor}} \right)^{1-\alpha} \left(\frac{k_{US}}{k_{poor}} \right)^{\alpha}$$
$$32 = 5 \times 1.6 \times 4$$

- 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:
 - ① Property rights protection
 - ② Rule of law
 - ③ Corruption
 - ④ Market orientation

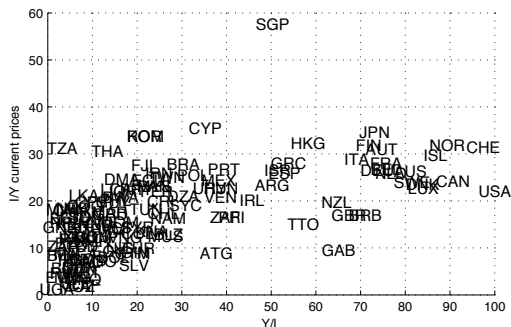
Why is K/L low in poor countries?

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 saving rates.



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 Regressions (or other statistical tools) only describe the data.
- 2 The production model shows:
 - 1 Capital accounts for a small fraction of cross-country income gaps.
 - 2 The main reason: diminishing returns.

- Jones, Introduction to Economic Growth, ch. 1
- Jones, Macroeconomics, ch. 3