

# Economic Growth: Technology, Empirics, and Policy

*Is there some action a government of India could take that would lead the Indian economy to grow like Indonesia's or Egypt's? If so, what, exactly? If not, what is it about the "nature of India" that makes it so? The consequences for human welfare involved in questions like these are simply staggering: Once one starts to think about them, it is hard to think about anything else.*

—Robert Lucas, Jr.

# Tasks

- Make the Solow model more general and realistic
- Move from theory to empirics
- Examine how a nation's public policies can influence the level of growth of its citizens and its standard of living
- Consider what the Solow model leaves out

## Questions to Answer

- Should our society save more or less ?
- How can policy influence the rate of saving?
- Are there some types of investment that policy should especially encourage?
- What institutions ensure that the economy's resources are put to their best use?
- How can policy increase the rate of technological progress?

# The Efficiency of Labor

We return to the production function,

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

Now, we write

$$Y = F(K, L \times E)$$

where  $E$  is the **efficiency of labor**. This reflects society's knowledge of production methods. We can interpret  $L \times E$  as the effective number of workers.

## The efficiency of Labor

- $L \times E$  measures both the number of workers and the technology available to them
- Now,  $Y$  depends on capital and effective workers
- Increases in  $E$  are analogous to increases in the labor force itself
- We'll assume that labor efficiency grows at a constant rate  $g$ . We call this growth **labor-augmenting technological progress**
- Recall the labor force grows at  $n$  and efficiency grows at  $g$ , so the effective number of workers grows at the rate of  $(n + g)$

## Steady State with Technological Progress

In the previous chapter, production was a function of capital per worker. Here, we'll adjust that to capital per *effective worker*.

$$\Delta k = sf(k) - (\delta + n + g)k$$

where  $k = K / (L \times E)$  and  $y = Y / (L \times E)$ .

## Steady-State Growth Rates in the Solow Model With Technological Progress

Variable	Symbol	Steady-State Growth Rate
Capital per effective worker	$k = K / (E \times L)$	0
Output per effective worker	$y = Y / (E \times L) = f(k)$	0
Output per worker	$Y/L = y \times E$	$g$
Total output	$Y = y \times (E \times L)$	$n + g$



# The Effects of Technological Progress

The previous table explains why standards of living change, output per worker grows. *According to the Solow model, only technological progress can explain sustained growth and persistently rising living standards.*

Technological progress also modifies the golden rule.

$$c^* = f(k^*) - (\delta + n + g)k^*$$

Steady-state consumption is maximized if

$$MPK = \delta + n + g$$

or alternatively,

$$MPK - \delta = n + g$$

# From Technology to Empirics

# Balanced Growth

- According to the Solow model, technological progress causes the variables to rise together in a steady-state, *balanced growth*
- U.S. data show that output per worker and capital stock per worker have grown at approximately the same rate over the past 50 years
- Technological progress also predicts the growth in factor prices as well
  - real wage has grown at about the same rate as real GDP growth
  - The real rate of return on capital has been roughly constant
- The Solow model prevailed over Marx's theory that the return on capital would decline over time

# Keynes: Economic Possibilities of Our Grandchildren

- Keynes predicted a 4–8-fold increase in standards of living between 1930-1940
  - Generally true
- He also predicted a tremendous increase in leisure
  - Missed the mark a bit

# Convergence

Do economies move toward each other over time?

- The process of catch-up is called *convergence*
- According to the Solow model, two economies will not converge if they have different steady states —perhaps, different rates of saving
- The evidence for convergence is mixed
  - *The U.S. states as different economies* - convergence appears to be true
  - Internationally - weaker evidence
- Economies may *conditionally converge*

# Factor Accumulation Versus Production Efficiency

- International differences in income per person are attributed to
  - 1 Differences in the factors of production
  - 2 Differences in the efficiency with which economies use their factors of production
- Empirically, the two sources are positively correlated. Why?
  - Efficient economies encourage capital accumulation
  - Capital accumulation induces greater efficiency
  - Production efficiency and capital accumulation are driven by a common third variable (Institutional quality?)

# Policies to Promote Growth

# Evaluating the Rate of Saving

- The saving rate determines the steady-state capital and output
- At the Golden Rule steady state,  $MPK - \delta = n + g$ 
  - $MPK - \delta > n + g \rightarrow$  increase saving
  - $MPK - \delta < n + g \rightarrow$  decrease saving



Real GDP in the U.S. grows an average 3 percent per year so  $(n + g) = 0.03$ . We can estimate the net marginal product of capital from the following three facts.

1 The capital stock is about 2.5 times one year's GDP

2 Depreciation of capital is about 10 percent of GDP

3 Capital income is about 30 percent of GDP

We can write these facts as

$$k = 2.5y \quad (1)$$

$$\delta k = 0.1y \quad (2)$$

$$MPK \times k = 0.3y \quad (3)$$

First solve for depreciation by dividing (2) by (1)

$$\begin{aligned}\delta k/k &= (0.1y)/(2.5y) \\ \delta &= 0.04\end{aligned}$$

We solve for the marginal product of capital by dividing (3) by (1)

$$\begin{aligned}(MPK \times k)/k &= (0.3y)/(2.5y) \\ MPK &= 0.12\end{aligned}$$

We have that net marginal product is 8 percent and growth is 3 percent. Thus, the United States' level of capital is well above Golden Rule level.

# Changing the Rate of Saving

Higher national saving amounts to higher public saving, private saving, or a combination between them. What would be a prudential policy?

## Public

- budget deficit
- budget surplus

## Private

- Incentivize private saving through changes taxes —lower corporate taxes, consumption taxes, increased preferential treatments to Roths and IRAs

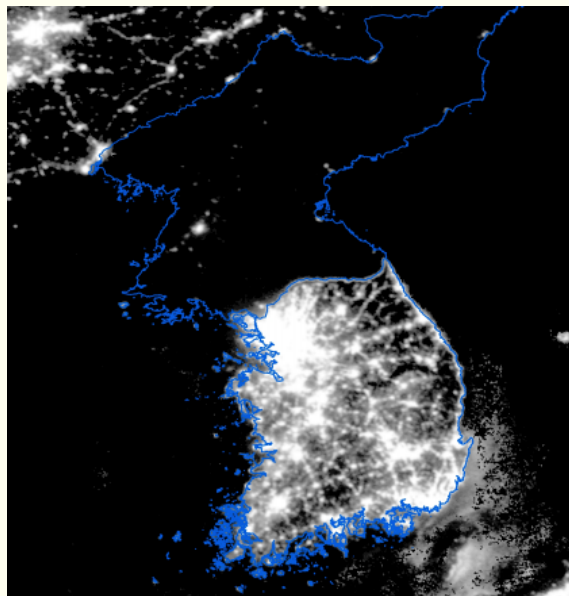
# Allocating the Economy's Investment

- Some forms of capital create *knowledge spillovers*, a by-product of the accumulation of capital (research, medicine, automation)
- Whether the government should grant preferential treatment to these forms of capital remains a contentious normative question
- Additionally, there is inherent difficulty in measuring the value of public capital



# Establishing the Right Institutions

- Creating effective institutions that promote efficient allocation of resources is paramount
- For centuries, South and North Korea were united under a common government
- These satellite shots of electricity utilization proxy for development
- GDP/person in North Korea is 1/10th that of South Korea



# Establishing the Right Institutions

- A nation's legal tradition plays a role shaping institutions
- Governmental history of honesty and corruption



# Colonial Origins of Modern Institutions

- Nations closer to the equator have lower levels of income per person than nations further from the equator
- Potential reasons: agriculture is more difficult, disease more prevalent, cold increases desire to seek warm shelter
- Probable reason: Extractive colonial institutions

## Acemoglu, Johnson, Robinson - Colonial Origins

When Europeans were colonizing other parts of the world, they had a preference to amenable climates. Settler mortality tended to be lower in these areas. Policies were exploitative in places where such a climate did not exist.



## AJR - Colonial Origins

In areas where Europeans settled in greater numbers, there investment was greater. Investments took the form of institutions that protected individual property rights and limited the power of governments.

## AJR - Colonial Origins

The colonial era has long ended but institutional infrastructure laid centuries ago stil remains.

## Takeaway

**The quality of institutions is a key determinant of economic performance. Where property rights are well protected, people have more incentive to make the investments that lead to economic growth.**

## Encouraging Technological Progress

In the model technological growth is exogenous. In general, the determinants of technological progress are hard to pin down. Still there are policies that promote it.

- Patents
- Tax breaks for R&D
- Direct subsidization of research

# Is Free Trade Good for Economic Growth?

- Adam Smith → yes
- David Ricardo → yes
- Today's economist (except Peter Navarro) → yes
- Evidence: Open economies grew 2.3 percent per year. Closed economies grew at 0.7 percent per year. Open developed nations grew at 4.5 percent per year. Closed developed nations grew at 0.7 percent per year.
- **Correlation does not imply causation**

# What Happens When Closed Economies Lift Trade Restrictions

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- Japan in the 1850s
- South Korea in the 1960s
- Vietnam in the 1990s
- **All experienced substantial growth afterward**
- Caveat: Trade liberalization is often accompanied by other reforms

# Measuring the Impact of Trade on Growth

Some countries are exogenously disadvantaged simply due to geography. e.g. New Zealand is farther from more populous countries than Belgium.

- Using a statistical technique known as *instrumental variables* Frankel and Romer find a “one percentage point increase in the ratio of trade to GDP increases income per person by at least one-half percentage point. Trade appears to raise income by spurring the accumulation of human and physical capital and by increasing output for given levels of capital.”

# Endogenous Growth Theory

## A Joke, possibly

A chemist, a physicist, and an economist are all trapped on a desert island, trying to figure out how to open a can of food.

"Let's heat the can over the fire until it explodes," says the chemist.

"No, no," says the physicist, "let's drop the can onto the rocks from the top of a high tree."

"I have an idea," says the economist. "First, we assume a can opener..."

# The Basic Model

Start with a production function,

$$Y = AK \quad (4)$$

Note, no diminishing returns to capital in this model. As before we assume we save a fraction of output and some of the capital is used up.

$$\Delta K = sY - \delta k \quad (5)$$

As stated previously, this equation states that the change in capital is equal to investment net of depreciation.

Let's combine (4) with (5) to get

$$\Delta Y/Y = \Delta K/K = sA - \delta$$

If  $sA > \delta$ , then the economy's income grows forever, even without the assumption of exogenous technological progress.

- A simple change in the production technology dramatically alters the growth predictions.

## Two-Sector Model

We can suppose that the economy has two sectors —manufacturing firms and research universities. Firms produce goods and services. Universities produce “knowledge” which is freely used in both sectors.

$Y = F[K, (1 - u)LE]$  (production function of manufacturing firms),

$\Delta E = g(u)E$  (production function in research universities),

$\Delta K = sY - \delta K$  (capital accumulation)

where  $u$  is the fraction of the labor force in universities,  $E$  is the stock of knowledge, and  $g$  is a function that shows how the growth in knowledge depends on the fraction of the labor force in universities.

- the manufacturing production function exhibits CRS
- the economy exhibits constant returns to capital (similar to  $Y = AK$ )
- growth endogenously arises because of continuous knowledge creation
- It is also similar to the Solow model if we assume  $u$  is held constant (implies constant growth of knowledge)



# The Microeconomics of Research and Development

Even the two-sector model is fairly crude.

- Knowledge is largely a public good, within firm knowledge is driven by profit
- Research is profitable because innovations give firms temporary monopolies
- When one firm innovates other firms build on that innovation to produce the next generation of innovation

Not getting into these mostly microeconomic issues, the social returns to research are often in excess of 40% per year.

# The Process of Creative Destruction

Joseph Schumpeter suggested that economic progress comes through **creative destruction**. Think of how the CD displaced the cassette, which was then displaced by the mp3 which to some extent has been displaced by streaming services.

- This is both good for the consumer (increased quality) and the firm (potential for monopoly profits)
- History tends to agree with Schumpeter's assertion
- Example: Walmart and now Amazon

## Summary

- Long-run economic growth is the single most important determinant of the economic well-being of a nation's citizens
- The Solow and endogenous growth models display how saving, population growth, and technological progress interact in determining the level and growth of a nation's standard of living
- Policymakers can promote economic growth by setting up the appropriate legal and financial institutions to allocate resources efficiently and by ensuring proper incentives to encourage research and technological progress (and the protection of property rights)