# Session 3:

# Why Do Economies Grow?

# Inputs?

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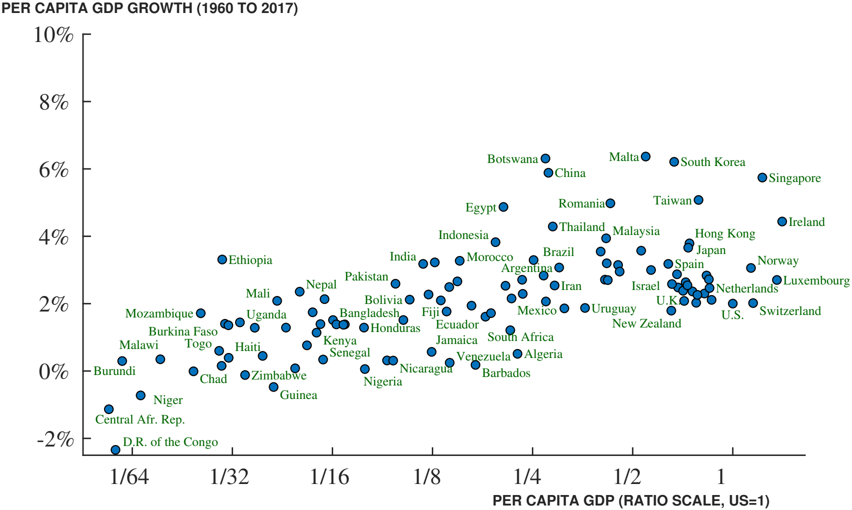
# Levels and Growth Rates of Per Capita GDP



## Outline of Today's Class

- How do we understand sustained U.S. economic growth at 2% per year? What about different growth rates across countries?
- The basics of the Solow Model
- The determination of the real interest rate
- The Solow Diagram
- Economic growth according to Solow

## South Korea and the Philippines

- In 1960, South Korea and the Philippines were quite similar
  - Per capita GDP: Both around \$1500
  - Population: Both about 25 million, 1/2 working age
  - Similar sectoral composition (industry, agriculture)
  - College enrollment: S. Korea=5%, Philippines=13%
- Between 1960 and 2017, macroeconomic performance diverged sharply
  - Growth: S. Korea=6.5%, Philippines=2.5%
  - Per capita GDP in 2017:

    S. Korea=\$36,000, Philippines=\$7,500
- Why?

## The Solow Growth Model

- Robert Solow in 1950s, Nobel prize in 1987
  - Build on production function, endogenize capital
  - Can the accumulation of capital — computers, machine tools, factories — explain sustained economic growth, like U.S. 2%?
- Analogy: A Corn Farm
  - Farm has a silo containing bushels of seed corn
  - Farmers plant the seed, tend the crop, and harvest
  - They eat 3/4ths of the harvest and save the remaining 1/4th in the silo for next year's planting
  - Repeat.
- Key: each seed kernel produces ten ears of corn, each with hundreds of kernels, so harvest grows

# The Economy of Solovia

Production function $Y_t = \bar{A}K_t^{1/3}L_t^{2/3}$

Capital accumulation $\Delta K_{t+1} = I_t - \bar{d}K_t$

Note: $\Delta K_{t+1} \equiv K_{t+1} - K_t$,
so $K_{t+1} = K_t + I_t - \bar{d}K_t$

Labor force $L_t = \bar{L}$

Resource constraint $C_t + I_t = Y_t$

Allocation of resources $I_t = \bar{s}Y_t$

Unknowns: $Y_t, K_t, L_t, C_t, I_t$

## Prices and the Real Interest Rate

- We've left prices — the wage and the rental price of capital — out of the model.
  - Just a simplification, could add them back easily
- Worth pausing to introduce the real interest rate.
- Definition: ???

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- Measured in units of output, or constant dollars
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- What is the real interest rate equal to in the Solow world?

  The real interest rate equals the rental price of capital = return on investment = marginal product of capital

  - Saving equals investment in this Solow economy
  - Save one unit $\Rightarrow$ invest one unit $\Rightarrow$ earn the marginal product of capital, which equals the rental price

## Solving the Solow Model

- The equations can be combined and simplified significantly, yielding

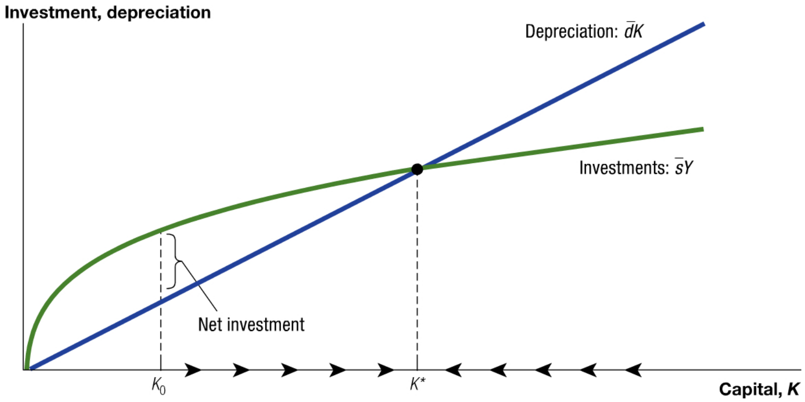
$$\underbrace{\Delta K_{t+1}}_{\text{change in capital}} = \underbrace{\bar{s}\, Y_t - \bar{d} K_t}_{\text{net investment}}$$

$$Y_t = \bar{A} K_t^{1/3} \bar{L}^{2/3}$$

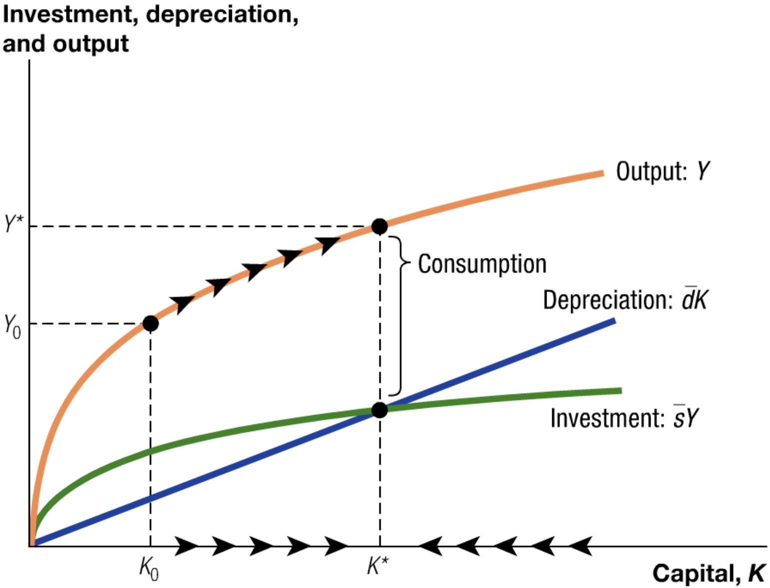
- These two equations govern the dynamics of the Solow model.
- Analyze in a Solow diagram

# The Solow Diagram

$$\Delta K_{t+1} = \bar{s}Y_t - \bar{d}K_t \qquad\qquad Y_t = \bar{A}K_t^{1/3}\bar{L}^{2/3}$$



## The Solow Diagram with Output and Consumption



# Looking at Data using the Solow Model: Capital

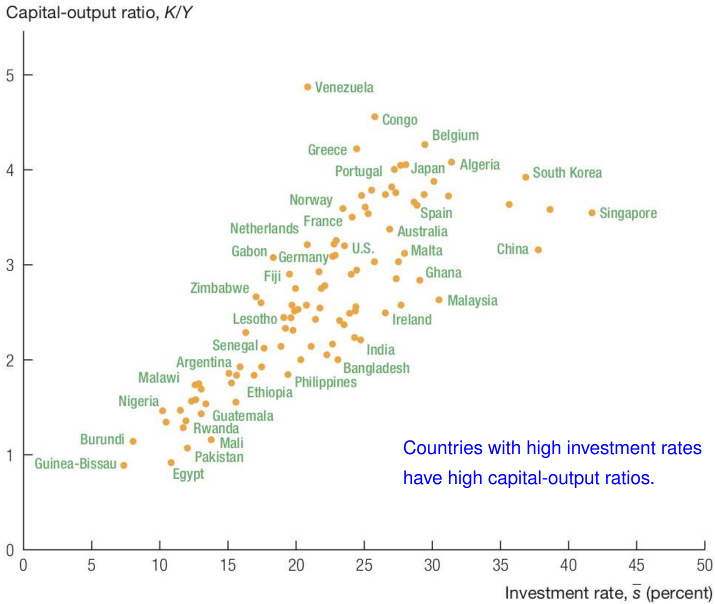
## The Capital-Output Ratio

- The key addition of the Solow model is that it explains where the capital stock comes from.
- Recall that in steady state $\bar{s}Y^* = \bar{d}K^*$, which implies

$$\frac{K^*}{Y^*} = \frac{\bar{s}}{\bar{d}}$$

- Different countries have different investment rates (measured as investment divided by GDP).
    - The Solow framework predicts that these should show up as different capital-output ratios ("capital intensities").

# Explaining Capital in the Solow Model




Countries with high investment rates have high capital-output ratios.

# Economic Growth in the Solow Model

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- What is the growth rate of the economy in the long run according to the Solow model?

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  Zero! There is no long-run growth in Solow!!

- Why?

## Understanding the Steady State Result

- Why does the economy settle down to a steady state?
  - $\bar{s}Y^* = \bar{d}K^*$ — investment equals depreciation.
  - The new investment we make is just enough to offset the wear-and-tear that depreciates the existing capital
- Because investment — the $\bar{s}Y$ curve — exhibits diminishing returns.
  - As we increase capital, output rises by a smaller and smaller amount.
  - But a constant fraction of capital depreciates.

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- Because investment — the $\bar{s}Y$ curve — exhibits diminishing returns.
  - As we increase capital, output rises by a smaller and smaller amount.
  - But a constant fraction of capital depreciates.

So diminishing returns to capital is at the heart of why growth eventually ceases in the Solow model.

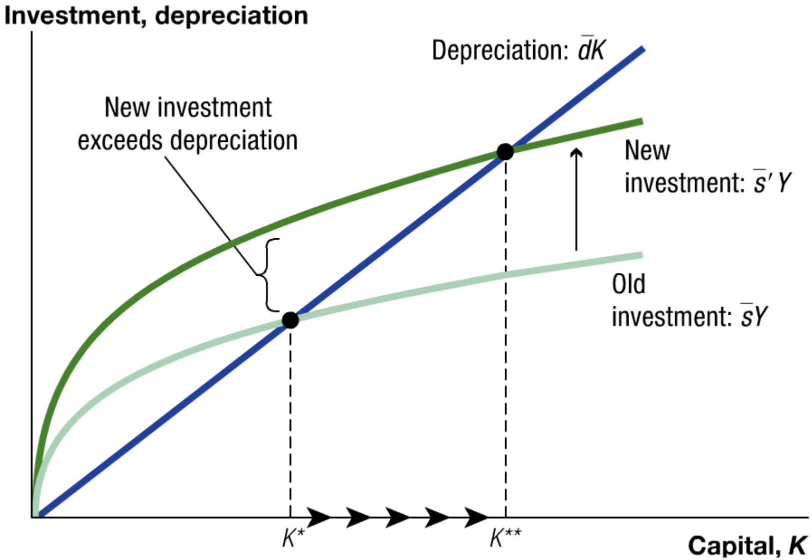
— A huge, disappointing failure...

## Growth and Transition Dynamics

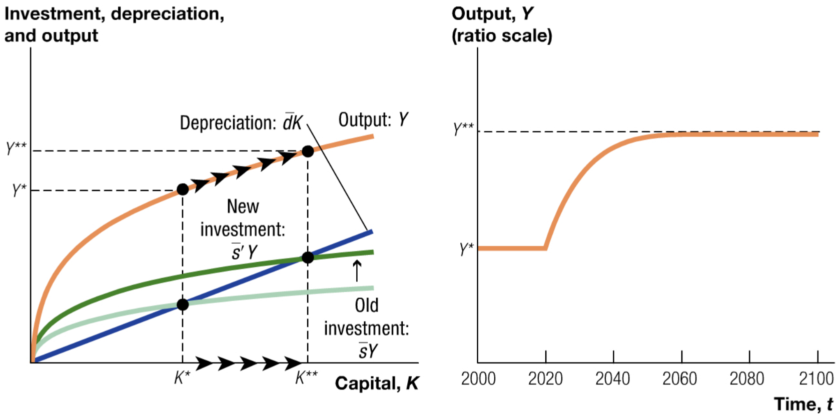
- Despite this negative result on long-run growth, the Solow framework is extraordinarily useful (see “Nobel Prize”)
- The reason is related to Transition Dynamics
- And this is most easily studied by considering an “experiment” in Solovia:

  Suppose Solovia begins in steady state in the year 2000 with an investment rate of 10%. What happens if the investment rate then increases permanently in the year 2020 to 15%?

## A Permanent Increase in the Investment Rate



# The Response of Output to a Rise in Investment



## The Principle of Transition Dynamics

- As suggested by the Solow Diagram and by the last example, a key prediction of the Solow framework is

  The Principle of Transition Dynamics: the farther below its steady state an economy is, the faster it will grow; similarly, the farther above its steady state, the faster it will decline (the slower it will grow).

*Differences in growth rates across countries largely reflect how near or far countries are from their steady state.*

## Examples: The United States and China

- United States
  - Growth at a constant rate of 2% per year for more than a century

- China
  - Rapid growth at more than 8% per year during the last 25 years

- Think about Japan after World War II...

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  - We'll understand this more after the next two lectures.
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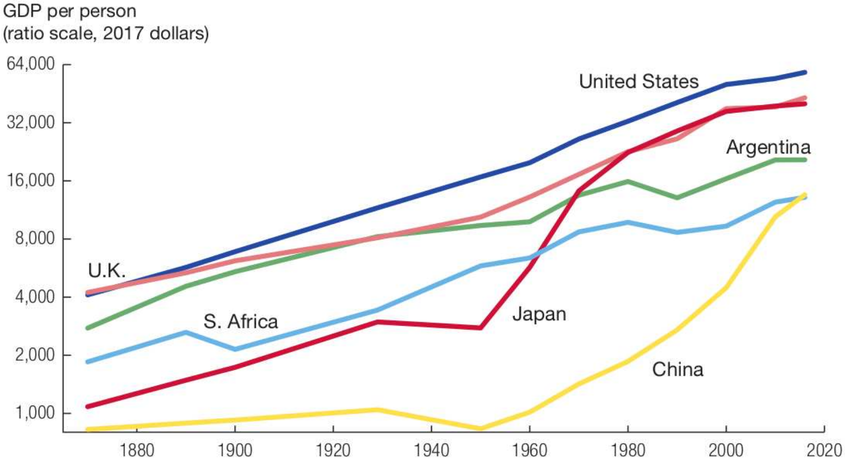
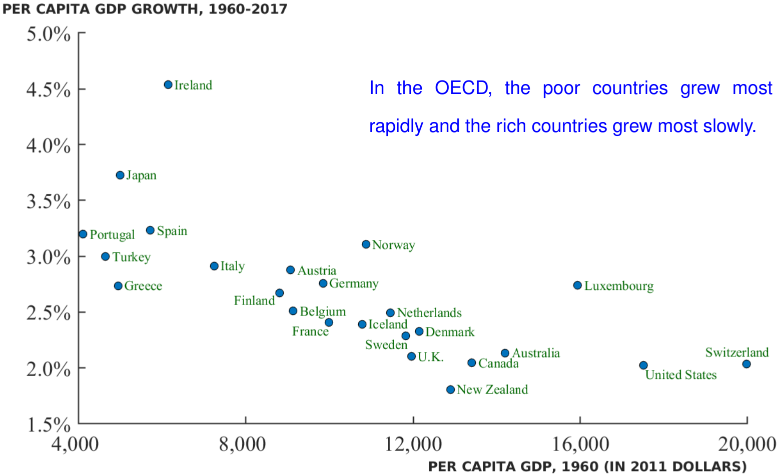
- China
  - Rapid growth at more than 8% per year during the last 25 years
  - Suggests China is below its steady state and therefore growing rapidly
  - Why might this be true?
- Think about Japan after World War II...

# Per capita GDP in Several Countries

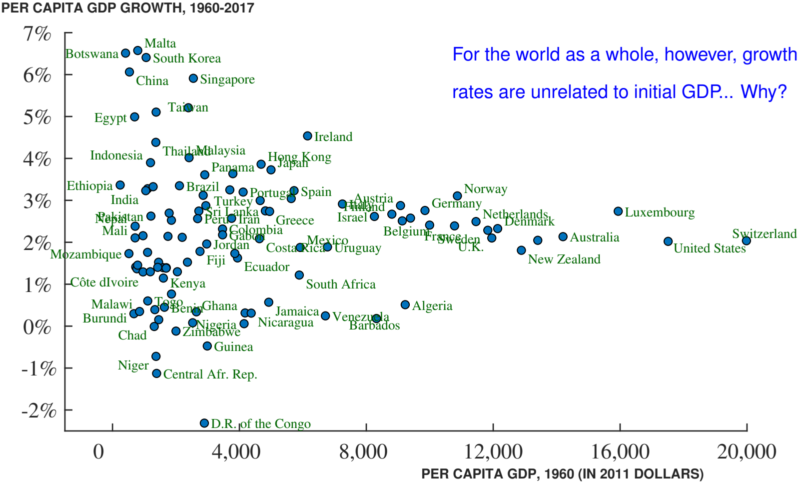


## Growth Rates in the OECD, 1960–2017



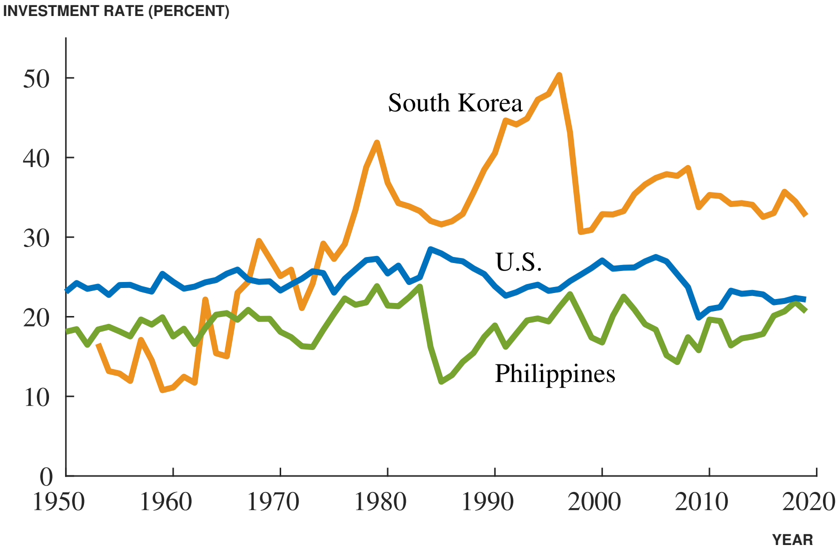

In the OECD, the poor countries grew most rapidly and the rich countries grew most slowly.

# Growth Rates around the World, 1960–2017




For the world as a whole, however, growth rates are unrelated to initial GDP... Why?

# Investment in South Korea and the Philippines



## Can investment be too high?

- What investment rate would maximize steady state consumption?
  - $s = 0 \Rightarrow c^* = 0$: no investment, means no capital, so GDP falls to zero
  - $s = 100\% \Rightarrow c^* = 0$: if you investment everything, you never consume!

  $\Rightarrow$ answer is somewhere in between.

- Simple math gives (if $Y = K^{\alpha} L^{1-\alpha}$)

$$s^* = \alpha = 1/3$$

Intuition: $\alpha$ is capital's share of income. If you are saving *more* than your capital earns, you are saving too much (you never eat the reward!)

*A country should never have an investment rate permanently greater than 1/3. So we know investment rates will decline!*

## What we learn from the Solow Framework

- In the long run, a country is rich or poor in part based on what fraction of its output it invests for the future.
  - Similar reasoning suggests that the fraction of the population employed, the number of hours worked per person, and investment in human capital play a similar role.
- Through the principle of transition dynamics, the model helps us understand why some countries grow rapidly and others slowly.
- Capital accumulation — the accumulation of more machine tools, computers, and factories per worker — is not a mechanism that leads to sustained long-run growth.

## Shortcomings of the Solow Framework

- The question of why countries have different investment rates remains on the table
  - Similarly, TFP differences actually become more important. Why? Think about what happens in the Solow diagram if there is an increase in TFP...
- How do we understand long run economic growth?
  - The Solow model does not answer...
  - But see the next several classes!

## Reading: No Need to Dig (The Economist)

- Questions:
  - What is the main point of the reading?
  - How does it relate to the Solow model?

## Questions for Review

- What is the mechanism in the Solow model that generates growth?
- Why does it fail to sustain growth in the long run?
- What determines the real interest rate in an economy?
- How does the Solow framework explain differences in growth rates across countries?
- Why do poor countries in the OECD grow faster than rich countries in the OECD, but poor countries in the world do not grow faster than rich countries in the world?
- What is the principle of transition dynamics?