PRINCIPLES OF MACROECONOMICS
LECTURE PLAN:

THE SUPER SIMPLE SOLOW MODEL AND CONDITIONAL CONVERGENCE
PART 1

MRUniversity

1   Lecture Objective

• Students will be able to identify different inputs to growth, those modeled and those not modeled by the Solow model, and their characteristics

• Students will be able to solve for the steady state in the super simple Solow model

• Students will be able to identify factors that lead to conditional convergence

• Optional: Students will be able to extend the super simple model to include more complexity

2   Pre-Class Assignment

Students should watch the following videos before class:

Video: Introduction to the Solow Model | Marginal Revolution University | Principles of Macroeconomics course

Video: Physical Capital and Diminishing Returns | Marginal Revolution University | Principles of Macroeconomics course

Video: The Solow Model and the Steady State | Marginal Revolution University | Principles of Macroeconomics course

Video: Human Capital and Conditional Convergence | Marginal Revolution University | Principles of Macroeconomics course

Video: The Solow Model and Ideas | Marginal Revolution University | Principles of Macroeconomics course

3   Lecture Plan

Introduction

1. Introduction to the Solow Model video introduces some of the questions that motivate a study of economic growth. Why did Germany and Japan grow quickly after WWII? Why is China growing quickly today even though it has worse institutions than the United States? The key variables in the Solow model, A (ideas), eL (education and labor), and K (capital) are introduced. The Solow model is another tool to help students understand mechanisms that encourage economic growth. Remind students about the great divergence with the following graph (from Cowen and Tabarrok).
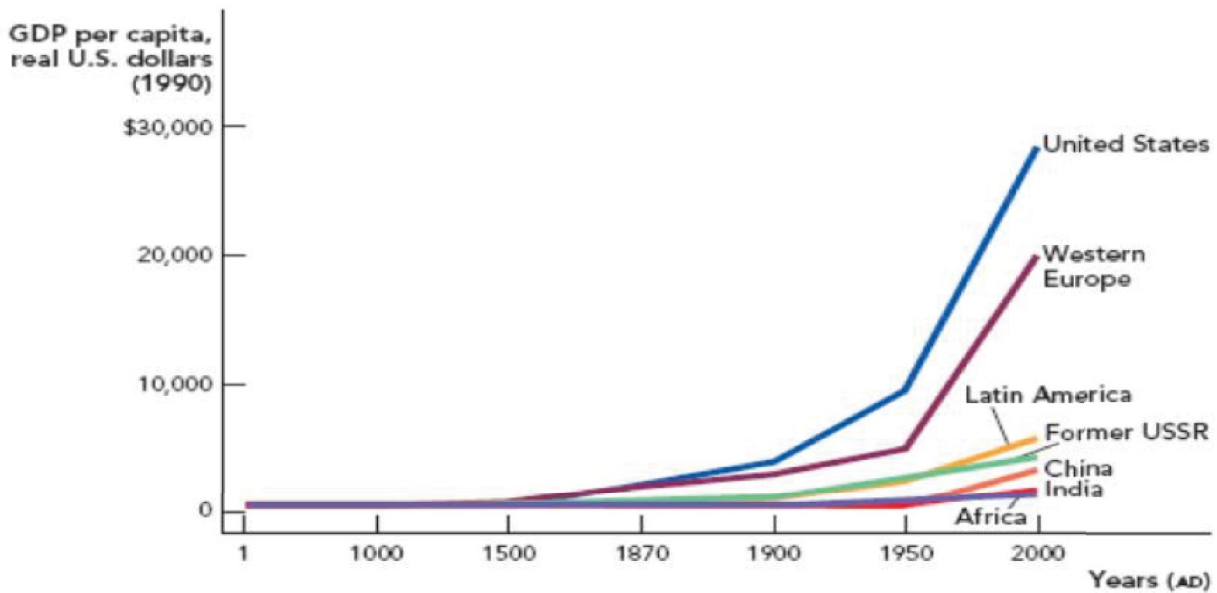
Economic Growth in Major World Regions

Source: Maddison, Angus. 2007. *Contours of the World Economy: 1-2030 AD*. Oxford University Press, Oxford.
Note: Timeline is not to scale.

2 Next provide students with some statistics on variations in countries' economic growth rates. You can find annual GDP growth rates from the World Bank via Google's Public Data Interface.

Alternate Exercises

🧠 **Check for Understanding:** Practice Question #1

Given a list of countries and their growth rates, have students calculate how often each country's standard of living would double using the rule of 70. Though it seems obvious, students may no fully grasp what it means for a country to double living standards. Make it concrete in their terms. Simplistically, look at the mean/median income of the US (Table H-10) or GDP per capita of some developed countries and double these figures. Or ask students to imagine what their life would look like if their family's income was twice as large.

🧠 **Check for Understanding:** Practice Question #2

Review the importance of institutions, noting that it's not the only answer given the list of countries we saw above. Those growing fastest, don't always seem to be the ones with the best institutions.

The Super Simple Solow Model, the Basics

1 In Physical Capital and Diminishing Returns the idea of a production function is discussed. Intuition is built by focusing on the super simple Solow model case where A and eL are constant and using $Y=\sqrt{K}$, a function exhibiting diminishing returns that students understand and are familiar with.

2 In The Solow Model and the Steady State, we introduce capital depreciation and demonstrate how capital depreciation and capital investment offset each other in the steady state such that capital, and by extension, output stays constant.
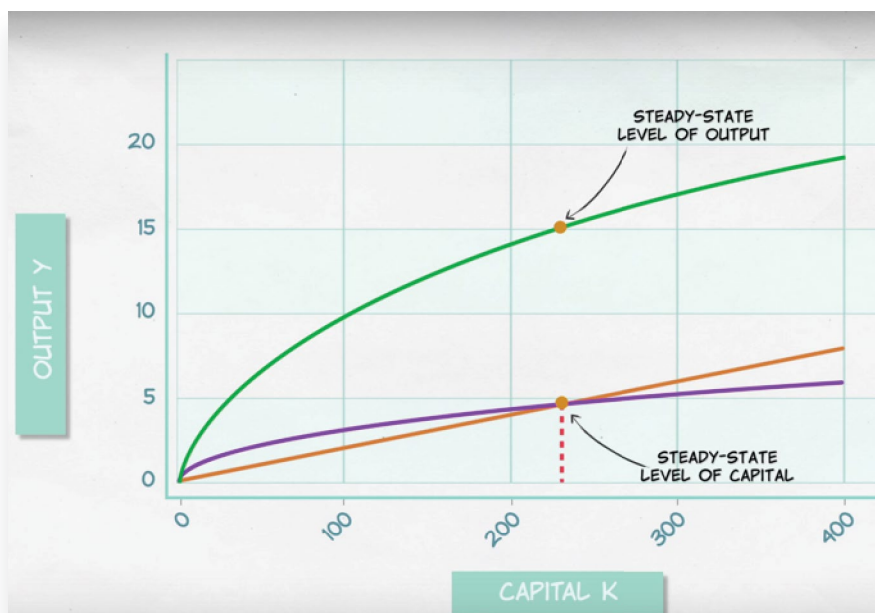
Check for Understanding: Practice Question #3

Students often forget that the Solow model includes consumption. Test and, if necessary, teach this explicitly.

The Simple Solow Model and the Steady State

1 It's helpful if students get a lot of practice with the super simple model and finding steady state: We suggest using Wolfram's interactive model of the Super Simple Solow Model. There is also an option to embed the model in your PowerPoint (Note: Wolfram model only works in IE and Firefox, NOT Chrome). Students need a laptop (or alternatively you can model it for the class).

Check for Understanding: Practice Question #4

Using the model allows you to ask a series of 'rapid-fire' questions where you provide students with an economy's conditions (i.e., savings rate, capital stock, and depreciation rate) and ask if I>D, I<D, or I=D

(steady state). While it's important for students to be able to interact with the Solow model mathematically, this exercise quickly builds intuition of the model. It also allows you to gauge your students' understanding of the model and whether you need to spend more time with the basics.

Check for Understanding: Practice Question #5

Ensure students understand that if capital is in the steady state, so too is output.

2 If needed, mathematically solve for a country's steady state with the super simple Solow model. (Set Investment=Depreciation to solve for steady state K). Though the math may not work out perfectly, we recommend asking students to help create the problem. (e.g., ask one student to pick a savings rate, etc.)

Check for Understanding: Practice Question #6

Challenge students to intuitively understand the investment/consumption tradeoff by providing students with two different countries' economic conditions and having students identify which country they'd prefer to live in. The main takeaway is for students to realize that there is a tradeoff between consumption today and consumption tomorrow and more investment is not always the right answer. This will reinforce the various parts of the graph, specifically the difference between invest- ment, consumption, and total output. Depending on students' comfort level, you can have them actually solve these problems or continue to use the Wolfram model. Discuss.

Conditional Convergence, The Basics

1 In the Human Capital and Conditional Convergence video, students learn that human capital shares similar characteristics with physical capital, namely diminishing returns and depreciation, and that countries converge when their institutions are similar.
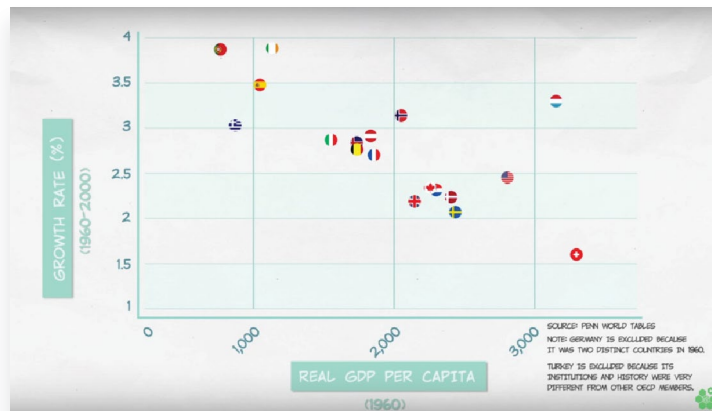
2 Briefly review the Conditional Convergence graph highlighted from the video (above) showing that wealthier OECD countries in 1960 grew less than poorer OECD countries, corroborating with Solow model predictions of conditional convergence. Highlight the importance of institutions for conditional convergence before discussing nuances and challenges.

Connect Solow Model and Conditional Convergence to Development Economics

1 There is a large literature about the importance of geography and land/natural resources in explaining a country's economic wealth. (See Marginal Revolution University video on Geography and Growth.) Does the Solow model include natural resources and geography as factors? Why or why not?

> #### Alternate Exercises
>
> Play a clip from Conversations with Tyler: Jeff Sachs, 2:36-18:36. Have students identify factors that Sachs mentioned as mattering for conditional convergence and catching-up vs cutting-edge growth. How is his view similar to and/or different from Solow's predictions of conditional convergence? Do you agree or disagree with his claims?

2 In a 2014 interview with McKinsey, Robert Solow made the following claim

"...Industries catch up, not whole economies."

Ask students to explain what the quote means and whether they agree or disagree. Is this idea compatible with the Solow model? (You may not want to mention who said the quote until after students discuss.) Ideally, this could be a peer learning exercise where students sitting next to each other would first discuss and then share out depending on size of the class.
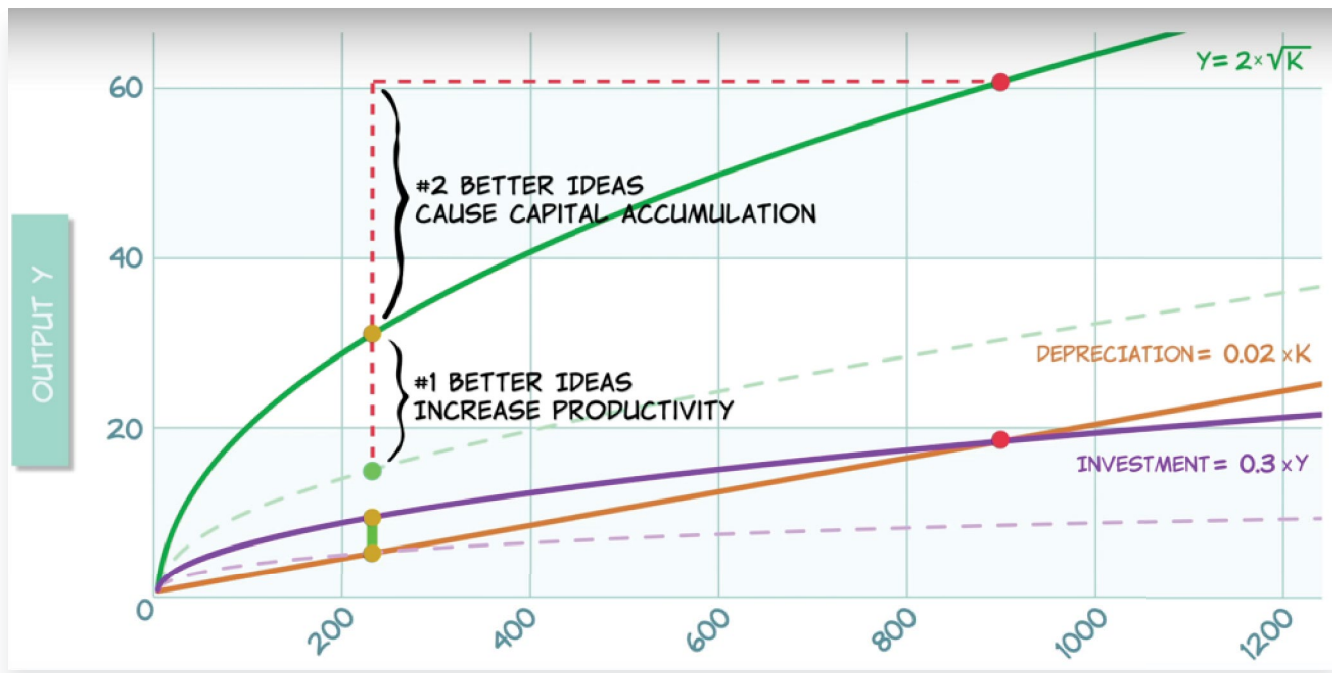
The Solow Model and Ideas, the Basics

1 Intro: The Solow Model and Ideas introduces the final input in the Solow model, ideas, and highlights its importance in driving cutting-edge economic growth.

Check for Understanding: Practice Question #7
Revisit the concept of which country would students choose to live in. This time, the two countries differ not only in their savings rate but also in ideas/productivity. One has more ideas and the other has a higher savings rate. The main point is that both savings and ideas matter for economic growth, but ideas are arguably more important. Ensure students understand where the Solow model captures ideas $Y=A\sqrt{K}$.

2 Review the following graph, if necessary, highlighting the two benefits from an increase in productivity/ideas: 1. There is an increase in productivity with the same level of capital which increases GDP in the short-run, AND 2. There is an increase in capital accumulation and further increases in GDP over the long-run because the country is able to save more in absolute terms without an increase in the savings rate.

The graph shows:
- Output Y (y-axis) vs K (x-axis from 200 to 1200)
- $Y = 2 \times \sqrt{K}$ (green curve)
- #2 BETTER IDEAS CAUSE CAPITAL ACCUMULATION
- #1 BETTER IDEAS INCREASE PRODUCTIVITY
- DEPRECIATION $= 0.02 \times K$
- INVESTMENT $= 0.3 \times Y$

Check for Understanding: Practice Question #8

Ensure students understand how a change in a country's ideas affects the investment function.

Deep Dive into Different Types of Ideas

1 It's also important to emphasize that 'ideas' mean a lot of different things. Discuss the unsexy, but critical inventions that spring up to simplify the miraculous, global coordination process (e.g., shipping container, pallet, etc.). Watch MRU's short video on the shipping container or listen to NPR's Planet Money podcast on shipping containers (start at 3:24).

2 Still other improvements are much smaller but still important factors to increasing productivity. This can also lead to a longer discussion about how ideas/productivity may not display a smooth economic growth rate over time because there are major and minor innovations (Solow comments on EconTalk about this phenomenon at 19:20-21:24).

3 **Assignment:** Students select a common object like the flat-bottom paper bag and explain how it increased productivity. The point is that we can all contribute to increasing productivity and ideas even if we aren't explicitly in R&D or the tech sector.

4 Post-Class Assignments

Student Exercises:

Option 1: Watch the next set of Solow model videos that focus on idea production.

▶ **Video:** The Economics of Ideas | Marginal Revolution University | Principles of Macroeconomics course

▶ **Video:** Patents, Prizes, and Subsidies | Marginal Revolution University | Principles of Macroeconomics course

▶ **Video:** TED Talk: How Ideas Trump Crises (with Alex Tabarrok)

▶ **Video:** The Idea Equation | Marginal Revolution University | Principles of Macroeconomics course

Option 2: Given everything discussed about the Solow model and ideas and convergence, have students evaluate the following quote from former USAID director, Raj Shah:

"Solow is absolutely right. Institutions are very important. I keep referencing the Solow growth model, which defines the core driver of economic growth as technological innovation. We try to make science, technology and innovation a bigger part of what USAID does around the world." (H/T: Chris Blattman post)

▷◀ **Teacher Reflection:** Reflect on the class discussion and student exercises. When were students most engaged? Confused? Bored? What could you do to change/improve the discussion? Are there any concepts to revisit?

5 Supplemental Resources

📖 **Textbook:**

The videos are based on "Growth, Capital Accumulation, and the Economics of Ideas: Catching up vs. the Cutting Edge" in *Modern Principles of Economics* by Tyler Cowen and Alex Tabarrok but are appropriate for use by any teacher using any textbook.

▶ **Additional Videos:**

• Solow Model: Comparative Statics | Marginal Revolution University | Development Economics course
• Geography and Growth | Marginal Revolution University | Principles of Macroeconomics course
• Solow Model: Solow Model and Steady State | Marginal Revolution University | Office Hours
• The Shipping Container | Marginal Revolution University | International Trade course

Podcast

- Conversations with Tyler: Jeff Sachs (also available on Medium)
- EconTalk interview with Robert Solow
- Planet Money Episode 500: The Humble Innovation at the Heart of the Global Economy

Articles/books/blogs:

- McKinsey Interview with Robert Solow (September 2014)
- What Raj Shah is reading (Chris Blattman's blog) (June 2011)

Data Sources/additional resources:

- Angus Maddison
- UNESCO data on R&D and researcher spending
- Penn World Tables
- World Bank GDP growth rates
- Wolfram's Interactive Super Simple Solow Model

6 Practice Questions

We've included a lot of questions throughout the lecture (and below) to quickly gauge student understanding. We recommend using a specific polling site such as Poll Everywhere so that you can easily tabulate student participation and understanding, but having students raise their hands also works. As a general rule, if >70% of students miss the problem, review the concept. If roughly 40-70% of students miss a specific problem, we suggest using peer learning. Ask students to convince their neighbor that they have the right answer. After a few minutes of discussion, retest the class. Teach the concept if students continue to persist in misunderstanding. For more on the benefits of peer learning, google "Eric Mazur peer learning."
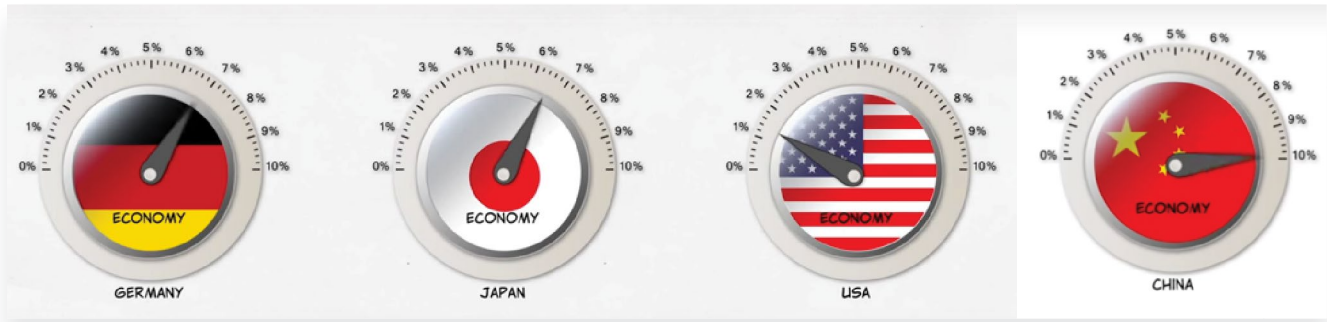
Question 1:

Show students the following figure of Germany's, Japan's, and US' economic growth rates after WWII, and China's growth rate in the 1990s. If these countries continued to grow at this rate indefi- nitely, how long would it take for the countries' GDP to double using the Rule of 70?

Germany: (assume 7% growth rate) approx. 10 years
Japan: (assume 6.5% growth rate): approx. 11 years

US: (assume 1.4% growth rate): approx. 50 years

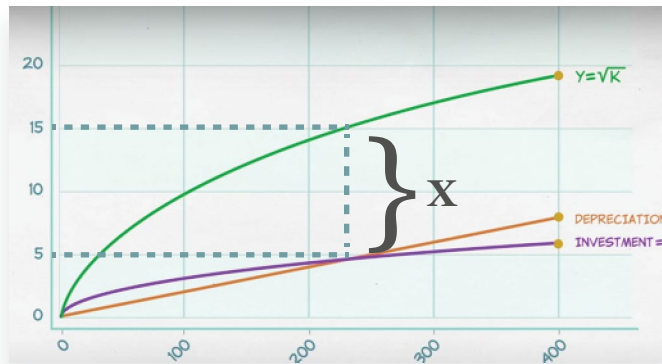**China:** (assume 10% growth rate): approx. 7 years

Question 2:

Based on growth rates in the above question, which of the following countries are likely experiencing catching-up growth?   China, Japan and Germany (after WWII)

Question 3:

The 'X' on the graph represents

        a. GDP

        b. Investment

        c. Consumption

        d. Depreciation

        e. Output per worker

Question 4:

For the following countries, use Wolfram interactive Solow Model to identify whether this country's investment is greater than, less than, or equal to capital depreciation.

Country 1: savings rate= .3, depreciation= .02, technology/ideas=1, K=225 (I=D)

Country 2: savings rate= .5, depreciation= .05, technology/ideas=1, K=300 (I<D)

Country 3: savings rate= .3, depreciation= .015, technology/ideas=1, K=400 (I=D)

Country 4: savings rate= .4, depreciation= .02, technology/ideas=1, K=250 (I>D)

Question 5:

Suppose a country has reached its steady state level of capital. This country's level of output is

a. Increasing.

b. Decreasing.

c. in steady state.

d. uncertain, depends on savings rate.

Question 6:

Two countries, country A and country B, have a production function of Y=√K, a capital stock of 100 and depreciation rate of .5% (.005). Country A saves 90% of all output and the other Country B saves 50% of all output. Where would you prefer to live?

a. Country A

b. Country B

Answer: Country B. In the steady state, citizens consume 5 in country B and 1.34 in country A.

Question 7:

For the next three questions, consider the following two countries: Thrifty and Inventive. In Thrifty, people devote 50% of GDP (Y) to making new investment goods, so γ=.5, and their production function is Y=√K. In Inventive, people devote 25% of GDP to making new investment goods, so γ =.25, and their production function is Y=2√K. Both countries begin with K=100.

What is the amount of investment in Inventive?

a. .5

b. 2.5

c. 5

d. 10

e. 25

What is the amount of consumption in Thrifty? (Hint: Anything that is not invested of GDP is consumed)

a. .5

b. 2.5

c. 5

d. 10

e. 25

In which country would you rather live?

     a. Thrifty

     b. Inventive

     c. Indifferent between the two countries

     d. Cannot be determined from the given information.

Question 8:

A country's economic growth is given by the following equation: $Y=\sqrt{K}$ and the country invests 25% to making investment goods. Suddenly, through some invention, the country's new production function becomes $Y=4\sqrt{K}$. Which of the following equations represents the country's new investment function?

     a. $I=.25\sqrt{K}$

     b. $I=.5\sqrt{K}$

     c. $I=\sqrt{K}$

     d. $I=2\sqrt{K}$

     e. Can not be determined with the given information.

· ·

⇄ Have Feedback?