This presentation is related to material from the textbook’s Chapter 9

• This PowerPoint lecture supplements, but does not substitute for, the textbook.
• The technical parts of the lecture are thoroughly explained in the textbook.
• Additional examples are provided in Course Materials on Blackboard.

Adam Smith’s *Wealth of Nations*

The greatest improvements in the productive powers of labour, and the greater part of the skill, dexterity, and judgement with which it is any where directed, or applied, seem to have been the effects of the division of labour.


Adam Smith’s *Wealth of Nations*

... the invention of all those machines by which labour is so much facilitated and abridged, seems to have been originally owing to the division of labour. Men are much more likely to discover easier and readier methods of attaining any object, when the whole attention of their minds is directed towards the single object, than when it is dissipated among a great variety of things ....


Adam Smith’s *Wealth of Nations*

All the improvements in machinery, however, have by no means been the invention of those who had occasion to use the machines. Many improvements have been made by the ingenuity of the makers of machines, when to make them became the business of a peculiar trade; and some by that of those who are called philosophers or men of speculation, whose trade is not to do any thing, but to observe every thing; and who, upon that account, are often capable of combining together the powers of the most distant and dissimilar objects. In the progress of society, philosophy or speculation becomes, like every other employment, the principal or sole trade and occupation of a particular class of citizens... Each citizen becomes more expert in his own peculiar branch, more work is done upon the whole, and the quantity of science is considerably increased by it.


Adam Smith and the New Growth Economists

• Adam Smith and other early economists laid the groundwork for modern growth theory.
• In this lesson, we will focus on two recent models:
  – The Solow growth model
  – The Schumpeterian R&D model
• These two models can explain economic growth quite well, and they are easily adapted to incorporate the effects of international trade.

• Production function $Y = f(K, L)$ with diminishing returns.
• If labor supply is fixed, then the function can be written as $Y = f(K)$.
• Diminishing returns implies a decreasing slope; each additional unit of capital adds less to output than the previous unit.

Solow assumes that the saving rate is constant and between 0 and 1.
• The saving function is a reduced image of the production (income) function.
• The saving function depends on the production function and the saving rate.

• Depreciation is assumed to be a constant fraction $\delta$ of the stock of capital $K$.
• Thus, depreciation is a straight-line function of $K$.

• Saving and investment are equal where the depreciation line and the savings function intersect.
• In equilibrium, a capital stock of $K^*$ results in output $Y^* = f(K^*)$.
• $K^*$ and $Y^*$ are referred to as the steady state levels of capital and output/income.

• The steady state level of $K^*$ is a stable equilibrium.
• If $K < K^*$, investment exceeds depreciation and $K$ grows.
• If $K > K^*$, depreciation exceeds investment and $K$ shrinks.

• The Solow model depicts an economy with a stable equilibrium.
• Output/income depends on the rate of saving, the rate of depreciation, and the shape of the production function.
A Rise in the Rate of Saving

Implies $I = \sigma f(K) > \delta K$, and the Capital Stock Grows

And There Is a Transition to Higher Steady State Levels of Capital and Output

Transitional Growth vs. Permanent Growth

- An increase in saving cannot maintain economic growth permanently, however.
- Once the new steady state is reached, the economy again stops growing.
- A further increase in saving would generate another spurt of medium-term growth.
- But, the saving rate cannot increase forever; it cannot be greater than 1!

Transitional Growth vs. Permanent Growth

- The static gains from increased saving provide only medium-term transitional growth.
- These gains are still limited by the path to the new steady state.
- How can permanent growth be generated within the Solow model?
- Permanent growth requires continuous upward shifts in the production function.
- This requires technological progress.

Technological Progress in the Solow Model

- Technological progress is represented by a shift to a new production function.
- There is technological progress if the same capital stock, $K$, produces a higher level of $Y$. 
• Without technological progress neutralizes diminishing returns.
• Output doubles when the capital stock is doubled.
• Without technological progress, an increase in capital from 1 to 2 would only have shifted the economy to c, a 40% rise in Y.

The Solow Model and Technological Progress

• The Solow growth model shows that continued economic growth is only possible if the production function continually shifts up, which requires continued technological progress.
• Thus, the Solow model establishes the importance of technological progress, but it does not explain how to achieve it.
• Several insightful models of models of technological progress have been developed to complement the Solow growth model.

Continued Technical Progress Implies Continued Growth

If technological progress continues to shift the production function upward, capital stock and output can continue to grow without reaching a steady state with zero growth.

The noted growth economist Paul Romer broadens the definition of technology:

The word technology invokes images of manufacturing, but most economic activity takes place outside of factories. Ideas include the innumerable insights about packaging, marketing, distribution, inventory control, payments systems, information systems, transactions processing, quality control, and worker motivation that are all used in the creation of economic value in a modern economy. If one looks carefully at the details of the operations of a corporation like Frito-Lay, one sees that there are as many subtle ideas involved in supplying potato chips to a consumer as there are in making computer chips. In addition, the ideas involved in supplying potato chips are probably more important for successful development in the poorest countries.


Ranking Technological Breakthroughs

Nathan Rosenberg, a economic historian who has devoted his career to investigating technology, suggests that:

A major innovation is one that provides a framework for a large number of subsequent innovations, each of which is dependent upon, or complementary to, the original one.

Finally, the idea spreads slowly. Then it begins to be applied more often, followed by widespread acceptance and adoption. Finally, the idea reaches 100 percent diffusion as the last potential users are finally won over.

The S-Curve of Technology

A Factory With a Central Power Drive

Case Study: Electricity and Manufacturing

- Early factories had most often been powered by central sources of power, a water wheel or a steam engine, which were usually linked to factory machines by large shafts.
- All machines on the factory floor turned when the shaft turned, whether they were being used or not.
- Electric motors would revolutionize the way factories powered their equipment.
- The impact of electric motors on the efficiency of factories occurred only gradually, however.

Case Study: Electricity and Manufacturing

- The first electric motors were relatively large and were designed to simply replace water wheels or steam engines.
- This example is typical of technological progress: it comes in steps.
- Only after the turn of the century did industrial engineers realize that machines driven by their own motors permitted much more flexibility than centralized power systems.

Case Study: Electricity and Manufacturing

- Ford introduced electrically-powered conveyors that moved partially-assembled automobiles from machine to machine along an assembly line.
- By 1920, still fewer than one-third of U.S. factories had converted to individually-controlled electric machines.
- By 1929, over half of all factories had converted as competition forced manufacturers to match the gains in efficiency of their competitors.
- It takes decades for powerful innovations to boost an economy, but the delayed payoff can be immense.

Important characteristics of technological progress:

- Technology is a complex set of knowledge, ideas, and methods and is likely to be the result of a variety of different activities, both intentional and accidental.
- Technological progress is a sequence of small increments lying along a continuous path.
- While the growth path of technology is continuous, it does not generally exhibit a constant slope or growth rate.
- Technology is at least partially nonrival in nature.
- Technology is often not excludable.
Most goods are rival, in that if one person uses them, others are necessarily excluded from using them. But, technology is nonrival. If one person uses an idea or method, that does not prevent another from using it.

Technology Is a Nonrival Good

- The creation of new technology is different from the production of ordinary products that economists have been modeling for years.
- Most goods are rival, in that if one person uses them, others are necessarily excluded from using them.
- But, technology is nonrival.
- If one person uses an idea or method, that does not prevent another from using it.

If it cannot be profitably marketed, how can the creator of technology recoup the costs of creating technology?

A Model of Technological Progress

- The Solow model and the discussion of technological progress points to the need for a model of technological progress.
- How can a society continually generate the new ideas and knowledge that will permit an economy to continue growing?
- How can a society speed up its technological progress so that it can raise standards of living more rapidly?
- What policies can influence the rate of technological progress?

Technology Is a Nonrival Good

- But, if the marginal cost of using a particular form of technology is zero, competitive market forces will tend to drive the price of existing technology toward zero.
- At such a low price, why would anyone create new knowledge?
- If it cannot be profitably marketed, how can the creator of technology recoup the costs of creating technology?

Technology Is a Nonrival Good

- Even though they may be nonrival in nature, new ideas may still be excludable.
- That is, the creator of a new idea may be able to prevent people from using it, thus giving the creator the power to limit supply and charge for the use of her ideas.
- Patent laws of course seek to do exactly that, giving the creator of an idea, product, or process exclusive use for a given number of years.

All other things equal, the excludability of ideas will increase the rate at which ideas are produced.

However, excludability can also dampen the rate of technological progress.

New knowledge builds on old knowledge.

There is evidence, however, that patents and copyrights do not restrict the dissemination of ideas nearly as much as some writers have suggested.

Technology Is a Nonrival Good

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Excludable