

## Lecture 8: Economic Growth III: Technology

### I. OVERVIEW

- In today's lecture, we will wrap up our analysis on how best to increase the economy's productive capacity, this time by focusing on technology.
- We will first define what economists call "technology". Then we discuss the special importance of technology in fostering growth and address policy issues on how to achieve faster technological progress.

### II. WHAT IS TECHNOLOGY?

- Economists define technology as ideas, or knowledge, that help us produce output from inputs. Having more technology means being able to produce more output with a given amount of inputs.
- Technology can take many shapes: it can be engineering discoveries like the invention of the airplane or the light-bulb, basic knowledge like calculus, service concepts like the all-in-one shopping of Wal-Mart or the multiplex movie theatre or production concepts like assembly line production.
- Economists categorize technology into three types:
  1. Capital-augmenting technological change: ideas that increase the amount of output that can be produced by capital. Examples include shift work: rotating workers on the machines so as to produce more output with the same number of machines.
  2. Labor-augmenting technological change: ideas that increase the amount of output that can be produced by labor. An example of labor augmenting technological change would be the assembly line: Henry Ford's introduction of mass production. Another example might even be the concept of specialization that Adam Smith described in his famous description of a pin factory.
  3. Total factor productivity: ideas that make both labor and capital more productive. An example of TFP would be the invention of a flight simulator, which can train more pilots quicker using fewer instructors and fewer planes.

### III. THE NATURE OF TECHNOLOGY

- In order to understand the special nature of technology, we need to understand the underlying economics. Typically, we classify economic goods along two dimensions: rivalry and excludability.

#### **Excludability**

- The degree of excludability of a good is the extent to which the owner can restrict access to the product to those who pay for the privilege of using the product.
- Non-excludable goods often tend to have spillovers of costs or benefits that are not captured by the producer (owner) of the good; these are also known as externalities.
- If these externalities are positive then the good is under-produced by the market; government intervention to increase production may be necessary (public goods). Alternatively, the externalities may be negative so that the good is over-produced by the market (tragedy of the commons); government intervention to restrict production may be necessary.

## Rivalry

- A rival good is a good that when used by one person, cannot be used by another person. Several people can simultaneously use a non-rival good; use by one does not preclude its use by another.
- The basic nature of non-rival goods implies that a lot of time and money must be spent to come up with the product but once it is created the good becomes relatively easy to replicate.
- A few examples are given in the table below.

	RIVAL	NON-RIVAL
EXCLUDABLE	A Discman, A pen A computer keyboard	Satellite TV Computer Software Movie Theatre.
NON-EXCLUDABLE	Fishing in the ocean. Grazing on Federal land A swing in a public park	National Defense A fireworks show Calculus

## Classifying Technology

- New technology can be thought of as new ideas that enable us to produce more output with the same amount of inputs. In the classification outlined above, ideas are non-rival: the use of an idea by one does not preclude the use of an idea by another.
- The degree of excludability varies: some ideas like calculus are non excludable. Other ideas like satellite TV broadcasts, or the process for making Coca-Cola are mostly excludable. A third category of ideas: software programs, books, etc. are only excludable if the proper legal safeguards are in place.
- This is the primary difference between technology and other inputs. While most other inputs are rival in nature, technology is non-rival in nature; many producers can use the same idea to produce more output.
- Technology is also important because regular inputs are characterized by diminishing returns: the more of an input we use, holding others constant, the less output each additional unit is able to produce.
- In the production function  $Y=F(K, L, T)$ , we can see that increases in  $Y$  can occur because of increases in the inputs: capital and labor or because of increases in technology. In the absence of technological progress, growth in output has to come through accumulation of inputs: i.e. by adding more workers and/or machines.
- However each new worker will be able to produce less unless we add more machines and each new machine will be worth less once we have utilized all the workers. Therefore, technology turns out to have a very important role to play in overcoming the limitations imposed by diminishing returns to labor and capital.
- At many points in history, prophecies of doom have been announced based on the idea that scarcities in one input or another (land, oil, people) will bring economic growth to a grinding halt. These prophecies have been disproven so far mostly because of technological progress: we have learned to produce more with less of the scarce inputs, thus reducing the dangers posed by the finiteness of available resources.

#### IV. HOW IS TECHNOLOGY “PRODUCED”

- Sometimes a new technology is a completely innocent byproduct of another activity. However, the more likely scenario is that technology is the result of a systematic search to find new and better ways of doing things. Research by Upjohn chemists to find hepatitis drugs, research by GM engineers to find more fuel-efficient electronic engines etc.
- The excludability of the good becomes important; otherwise the person doing the up front expenditure on developing the product may not be able to extract the benefits because competitors enter the cheap reproduction stage. Because some ideas are non-excludable: the owner of the good may not be able to charge people for its use.
- When we combine the non-excludability with the non-rivalry we see that people may be reluctant to invest the upfront money necessary to create an idea; they are worried about other people expropriating the idea for their own use without incurring much additional cost.
- As a result, in order to entice researchers to come up with ideas, especially ideas that are not excludable, we need to either
  - a) Subsidize fixed costs (the government)
  - b) Set up property rights (patents, copyrights)
- Without a subsidy or a system of property rights to the idea researchers will not develop the idea because after they incur the fixed cost, others can enter the market and charge much lower prices for their goods.
- The government can also play a role by setting up a good system of secondary and higher education, thus allowing companies to hire scientists and engineers who they can provide resources to generate new ideas.
- Similarly, companies may concentrate only on doing R&D for products that benefit their own industry. Yet there is a lot of basic scientific research that has benefits for a wide variety of industries; government funding of research in universities and colleges have helped produce several such ideas like the Internet.

#### V. POLICY RECOMMENDATIONS TO ENCOURAGE THE DEVELOPMENT OF TECHNOLOGY

1. Set up a system of patents and copyrights to encourage research on ideas that are inherently non-excludable.
2. Provide research grants and subsidies to firms that encourage in research that will always be non-excludable (basic scientific research in universities)
3. Better education and training of scientists and engineers.