Chapter 8

Technology and Growth

The proximate causes

- ✓ Physical capital
- ✓ Population growth
  - ✓ fertility
  - ✓ mortality
- ✓ Human capital
  - ✓ Health
  - ✓ Education
- ✓ Productivity
  - ➢ Technology
  - ➢ Efficiency
- ➢ International trade

Plan

1. Define technological progress
2. TP in the Solow model
3. What determines the rate of TP
    1. Technology transfers
    2. R&D expenditures and their returns
        1. The problem of exclusion and patents
        2. Financial markets
    3. Remarks
        1. Creative destruction
        2. The fertility of research
        3. Leader or follower?
        4. Immitation or creation?
4. Barriers to the transfer of technology
    1. Appropriateness of technology
    2. Tacit knowledge

Introduction

- We have seen that productivity is important to explain economic growth.
- Productivity is partly explained by technological progress.
- In this chapter, we would like to understand what determines technological progress.
- Later on, we will try to estimate the share of technological progress in explaining productivity differences between countries.

What is technological progress?

- *Technology:* The knowledge about how to combine inputs in order to produce outputs.
- Technological innovations allow us to produce more outputs with the same inputs.

The various forms of TP

1. Better products:
   - The latest version of Android allows you to make better use of your time (labor and human capital) and phone (physical capital).
   - Today's car engines go a lot farther than 40 years ago on one liter of fuel.
   - Car safety and reliability…
2. New products:
   - New medicines allow us to live longer at lower real cost.
   - MP3 music, cloud computing, 3D printing!!!
3. More variety:
   - laptop characteristics
   - cereal choices…
4. Improved production processes
5. Better organization and coordination

It all boils down to more services per unit of input.

Technological Progress in the Solow Model

Take note

(NB Differs slightly from Weil's Appendix chap 8.)

TP in the Solow model

- TP allows to "break" the limits of decreasing returns.
- With TP, there is no S-S with constant income per capita.
- But there is possibly a S-S with constant and sustained growth.
- So how can economies benefit from TP?
- What determines TP?

Exlaining TP

1. What determines the rate of TP
    1. On rivalry and technology transfers
    2. R&D expenditures and their returns
        1. Patents and the problem of exclusion
        2. The importance of well-developed financial markets
    3. Additional considerations
        1. Creative destruction
        2. The fertility of research
        3. Leader or follower?
        4. Immitation or creation?
2. Barriers to the transfer of technology
    1. Appropriateness of technology
    2. Tacit knowledge

On rivalry and technology transfers

- Technology is made up of ideas that have no concrete physical existence. This makes it very different from other types of investments.
- Conventional production factors are characterized by rivalry in their use: K, h, L
- The use of ideas is non-rival. Important implications for economic growth:
  - A country that is poor because of lack of capital must make important sacrifices to remedy. Capital transfers from another countries require sacrifices from the latter.
  - A country that is poor because of technological backwardness can potentially adopt another country's technology without affecting the latter.

What determines technological progress?

- TP is a form of investment: Sacrifices in terms of goods and services consumed.
- Before mid 19th c., most of TP was the result of "solo inventors".
- Today, a lot of TP takes the form of official R&D activities (recent phenomenon).
- Today, governments participate a lot also:
  - USA 2009: 27% of R&D is paid for directly by government (a lot of it is military).
  - This leaves 73% for private sector.

Researchers and Research Spending, 2009

Country	Number of Researchers	Researchers as a Percentage of the Labor Force	Research Spending ($ billions)	Research Spending as a Percentage of GDP
United States	1,412,639	0.89%	398.2	2.8%
Japan	655,530	1.00%	137.9	3.4%
Germany	311,519	0.74%	82.7	2.8%
France	229,130	0.80%	48	2.2%
Korea	236,137	0.96%	43.9	3.3%
OECD Total	4,199,512	0.70%	965.6	2.4%

Source: OECD Main Science and Technology Indicators database.

Researchers and Research Spending, 2009

- In 2009, advanced countries sacrifice around 2-3% of their income "directly" to research and devote close to 1% of their workforce to it.

What determines technological progress?

- By far the main form of government help in increasing R&D is through the patent system.
- Let us investigate this…

A problem of exclusion

- Exclusion:
  - Ease with which the owner of a factor can "exclude" others from using it without his permission.
- It is relatively easy to exclude others from the use of physical capital.
- For this reason, its owner can be compensated for its use by others who must ask for permission, i.e., pay to use it.
- (What about a natural resource like a fishery or underground water? NB A natural resource is also an asset, i.e., natural capital.)

A problem of exclusion

- It is usually difficult to exclude others from using an idea.
- This is why the creator of a new idea often has difficulties in being compensated for his/her work in creating the idea.
- This sharply reduces incentives to create new ideas.
- The patent system seeks to mitigate this problem of exclusion.

R&D expenditures

- Private R&D takes the form of
  - Formal laboratory research
  - Daily innovations in higher product quality, lower production costs or better organization.
- Firms engage in such activities because they expect to profit from their inventions through
  - Monopoly over new product
  - Lower production costs
- Firms react to incentives: The higher the expected profits from R&D, the more R&D they will do.
- Upshot:

To understand the pace of R&D, one must look at what affects firms' expected profits from R&D..

Expected returns from R&D

- The harder it is to copy an idea without permission, the higher the expected return from innovation:

Patents help creators of ideas exclude others from using them without their permission.

- Patents aim to grant a monopoly of usage leading to above normal profits.
- Note that this is not just about products. Patents on improved production processes are also immensely important.

Expected returns from R&D

- Even with patent system, exclusion may be so difficult that firms prefer not to register their patents, lest someone uses the idea without permission.
- Market size is important: A patent may cover a large market (USA and EU have gigantic market sizes).
- For this reason, world integration likely contributes to more R&D.

Expected returns from R&D

- The anticipated duration of monopoly is important too. It depends crucially on
  1. Time to introduction of new competing product
  2. Patent duration (17-20 years)
- High risk from R&D activities
  - R&D projects are very risky by definition.
  - Financial markets play a crucial role to help diversify that risk.

Remark
Creative destruction: The process

- Very often, a new invention replaces an old one. The innovating firm "seeks" the profits of an existing one. That is the purpose of the innovation.
- Later on, this innovating firm is replaced by another one in turn.
- Endless dynamic process of *creative destruction.* (Also referred to as *Schumpeterian Growth*.)
- People benefit greatly from such continuous innovations.

There are many who believe that the most fundamental explanation for long run growth is all here.

Creative destruction: A challenge

- Difficulty with the process of creative destruction:
  - The gain of one firm is the loss of another (zero-sum game).
  - For incumbent firms, owners and workers lose.
- Dominant firms will try to block entry from competitors. If successful, incentives to innovate are low. This can greatly slow down TP. (Classical case of entrenched interests.)
- Ex: In the late 1990's Microsoft tried to block entry of competitors on web browser's market. It was partly successful.
- This destructive potential of the creation process makes it difficult to adopt a good industrial policy with incentives to innovate.
- In Canada, the Competition Bureau is constantly on the watch for firms that try to block entry from competitors.

A note on the fertility of research

- Argument that "easy" discoveries have already been made.
- A diminishing returns to technology argument.
- TP must therefore slow down eventually.
- No hard evidence on this.

A note on the fertility of research

- Others think that the more we know, the easier the new discoveries: Increasing returns
- One inescapable story:
  - Research derives from "brain power".
  - Brain power is determined by the number of people doing research, the quality of their education and their incentives to innovate.
  - Ideas know no frontier: TP of any country depends on the whole world's stock of brain power.
  - The recent integration of China, India, Russia, etc., into the world economic system has potentially doubled the stock of brain power, or more. TP is probably not about to slow down.
  - Provided incentives are there…

A note on the fertility of research

- There are many reasons to believe that the fertility of the research process depends on the possibility of thinking freely.
- People will not express their original ideas unless their environment is "receptive" to new ideas and change.
  - A lot of new ideas on the production process occur daily on the shop floor.
- Interactions between TP and
  - Freedom
  - Culture of entrepreneurship (read What exactly is an entrepreneur? (The economist 2014))
  - Incentives to innovate
  - …
- Note the link with creative destruction.
- Age of Enlightenment?

A note on innovation versus imitation

- Technology in a country can increase for two different reasons:
  1. Through innovation (creation of new ideas)
  2. Through imitation
- Imitation is much cheaper.
- This suggests the presence of technological leaders and followers.

To lead or to follow?

- Being a leader is not always desirable
  - Sacrifice in R&D investments may be too high.
- The evidence indicates that many countries are simultaneously at the technological frontier, but usually in different sectors.

  There is no overall leader
- This suggests that technology constantly diffuses across the world.
- The efforts of one country always end-up benefitting all other countries.
- But some countries appear to be slower than others at adopting the new technologies. Why?

Barriers to the transfer of technology

- Two reasons why some LDCs may take more time to adopt new technologies:
  1. Appropriateness of technology
  2. Tacit knowledge

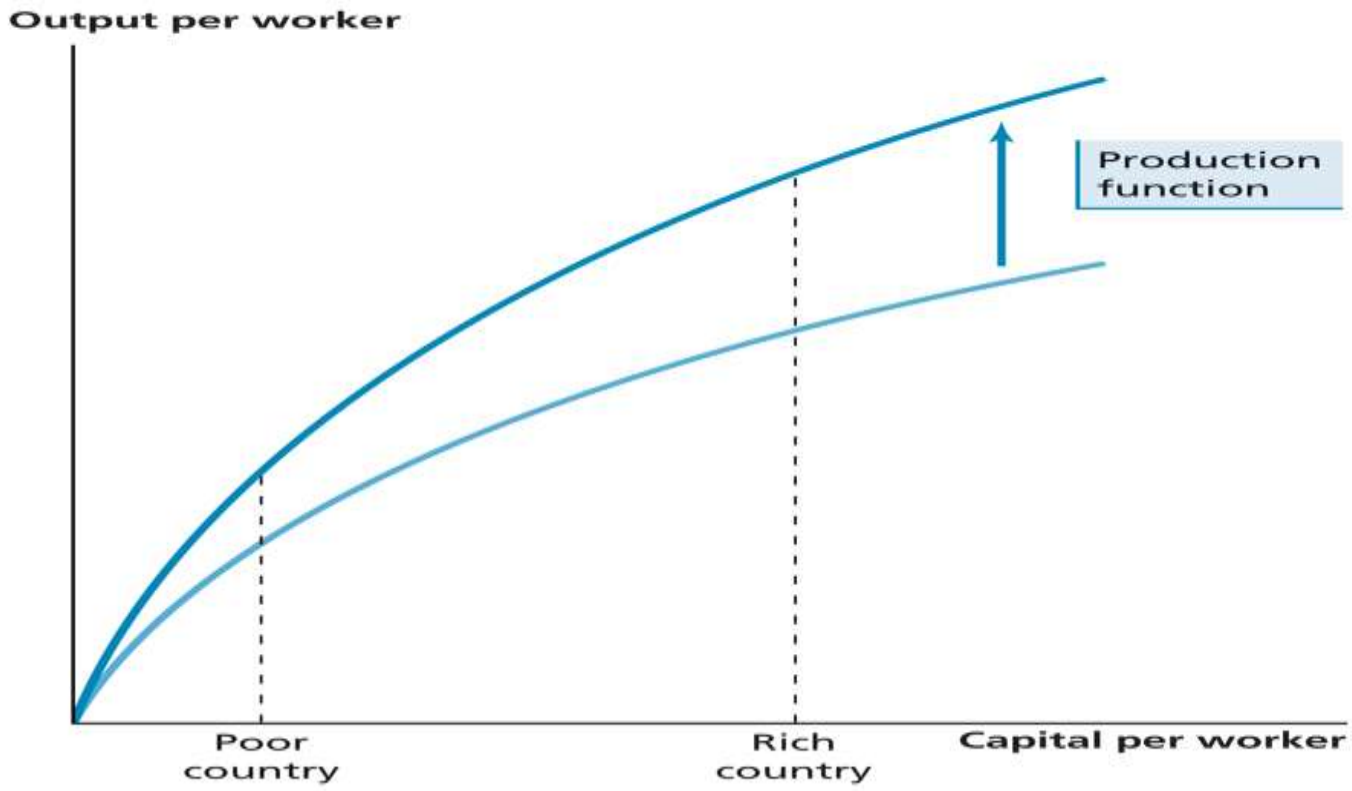
1. The problem of appropriate technology

A technology that is useful for a rich country may be of little use to a poor country.

- Since rich countries typically use a lot of physical and human capital, new technology tends to increase the productivity of capital-intensive production. Such knowledge is not so useful for LDCs that use much less capital per worker.
- Agricultural advances are typically useful only for temperate climates, not tropical. Not so useful for most LDCs.

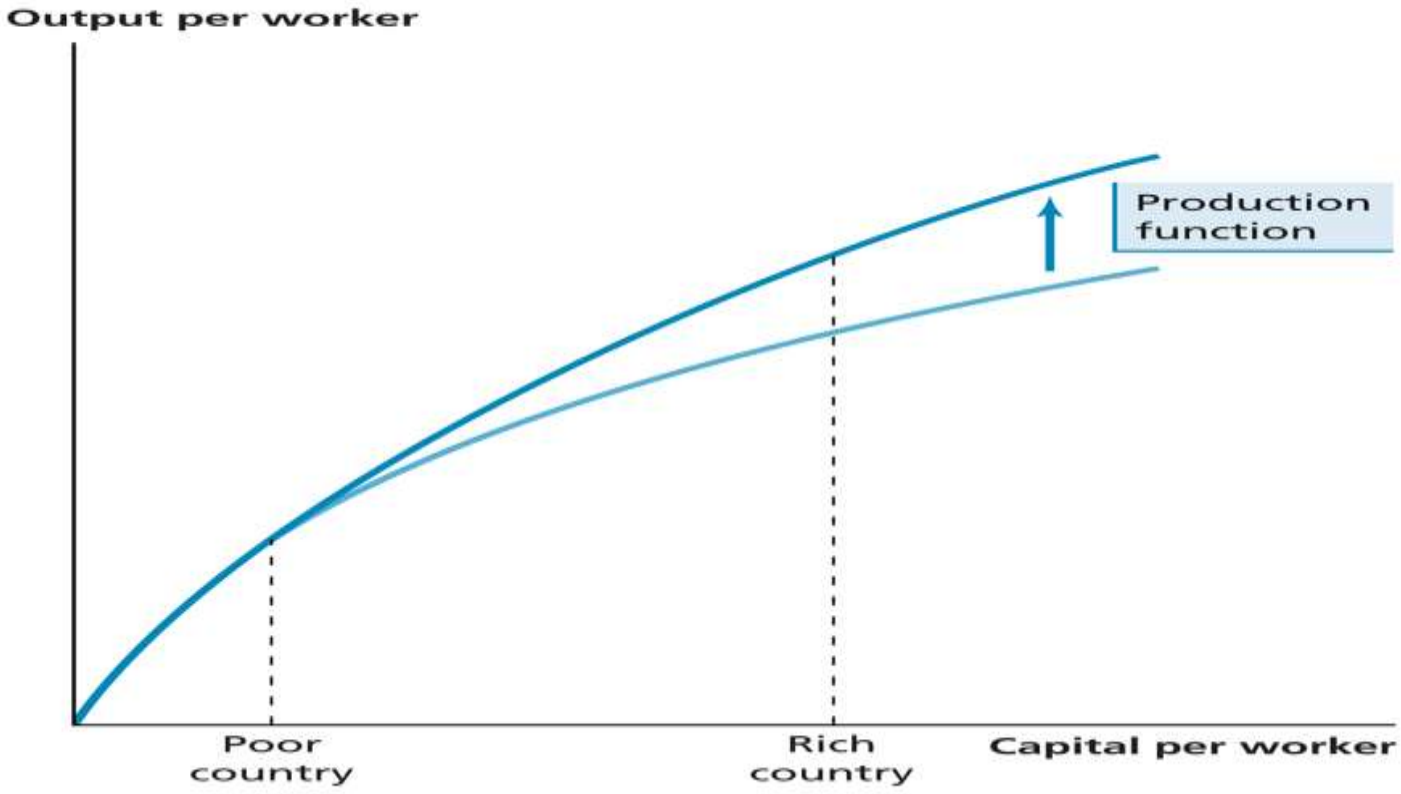
Neutral technological progress

FIGURE 8.6
Neutral Technological Change



Capital-intensive TP

FIGURE 8.7
Capital-Biased Technological Change



Biased TP

- R&D expenditures across the world:
  - ICs: $218 per capita
  - Middle-income countries: $6 per capita
  - Low-income countries: $1 per capita
- Because it mostly comes from ICs, most of today's TP aims to increase the productivity of workers who use a lot of capital.

Why so little R&D in LDCs?

1. They don’t have the means.
2. Intellectual property is usually not well protected.

2. Tacit knowledge

Neutral technology should be easy to transfer

- Patents last only 20 years and secrets cannot be kept forever as employees move between firms.
- LDCs should not be more than 20 years behind in neutral technology.
- Many are, nonetheless. Why?

Tacit knowledge

The adoption of new technology requires more than just information passed on a piece of paper.

- Through practice, technicians and engineers acquire knowledge about the use of technology that is not written anywhere.
- This knowledge gets transmitted from person to person on the "shop floor".
- People often do not even realize that they possess this knowledge.

Tacit knowledge: A case study 1960s

- A US firm builds two similar truck engine plants in Japan and India.
- Within one year, the Japanese firm was producing at similar cost and quality than its US counterpart.
- In India, costs were three times higher and quality was lower.
- The study concluded that the difference resides in the "practical" know-how of engineers and managers.

Tacit knowledge: Implications

- Technology flows more easily between two ICs than from an IC to a LDC.
- A lot of tacit knowledge is general in scope, i.e. it can be applied to different contexts. Hence the possibility of important positive externalities from the introduction of one new technology, even if in a very specific context.
- The successes of Taiwan and South Korea are partly explained in those terms.
- This is why governments are often ready to subsidize high-tech firms.

Conclusion

With TP, we can break the limits imposed by diminishing returns to capital.

- Sustained growth over the past 200 years is largely explained this way.

Conclusion

We have discussed what may affect the rate of production of new ideas. It relies on a subtle (still misunderstood) combination of

- patent system for monopoly profits
- society receptive to new ideas (freedom? Enlightenment?)
- culture of entrepreneurship (incentives)
- size of brain power *worldwide*
- Well-developed financial system