Lecture notes 6: The Role of Technology in Growth and Development

Growth in LS is wrapped up with technological progress, often two seem indistinguishable:

- We consume goods that did not even exist 50 years ago.
- Modern inventions ranging from the obviously important (automobile) to minor (zipper) have changed the way in which goods are produced,
- Have enabled workers to produce more than they did a few generations ago.

Changes in productivity have played an important role in economic Development:

- Productivity improvements is linked to improved technology:
- E.X. invention of a new production process.
- What explains technological progress?
- Do differences in technology are the explanation for
- differences in the levels of productivity among countries
- Today?

The Nature of Technological Progress (TP)

TP is captured as a change in the parameter *A* in the Cobb-Douglas production function,

$$y = Ak^{\alpha}h^{1-\alpha}$$

To produce more output than was previously possible.

A crucial aspect of Technical Change:

- it allows to transcend the limitations imposed by diminishing returns.
- Growth of income per capita due solely to factor accumulation must eventually cease, because economy eventually reaches a steady state in which growth ceases.
- As TP increases A, growth of income per capita can continue.

Technology Creation

- Creating new technologies requires investment.
- Nature of investment in T varied across different places and times.
- In a modern economy, vast resources are devoted to (R&D), to create new products or processes.

Table 1: Scientists and Engineers Engaged in R&D in the G-7 Countries, 1993

United States	962,700
Japan	526,500
Germany	229,800
France	145,900
United Kingdom	140,000
Canada	76,600
Italy	74,400

Research and Development:

1. A fairly recent phenomenon. Before the mid-nineteenth century technological advance was primarily the product of “tinkerers” rather than formally trained scientists.
2. Even today, formal R&D of big corporations is often overshadowed by hackers working in their spare time out of a garage.
3. Most R&D conducted by private firms seeking to maximize profits.
4. Unique nature of technology led governments to play a role in research.
5. For example, in 1714 the British government offered a prize of £20,000 for the creation of a seagoing clock accurate enough to measure longitude.
6. In the US in 1997, 30.5% of R&D was sponsored by the government, although a good deal of this was aimed at military rather than productive applications.
7. The Internet was created and nurtured under government auspices.
8. Providing inventors with legal protection against the copying of their work, patents.

Transfer of Technology

Technology is **non-rival**: one person's use of a piece of technology in no way prevents others from using it just as effectively.

Non-rivalry of technology means we should focus on transfers between firms or countries.

Easy transferability means that the incentives for creating technology are diminished.

The Determinants of R&D Spending

Obviously, firms engage in R&D in the hope of inventing something: a new product, or a new, more efficient, way of producing some existing product.

If is successful, it will be able to raise its profits.

In the best case, its invention will give it a monopoly on some product, or produce at lower price.

The extra profits that arise from this competitive advantage are the incentive that makes the firm do R&D:

1. An invention that can be patented and thus protected from imitation.
2. Size of the market in which it can sell its product.
3. How long the advantage conferred by a new invention will last?
4. Uncertainty surrounding the research process.

Patents, Trade Secrets, and the Terminator Gene

- Transferability reduces incentive to create new technologies.
- Venice patent law of 1474
- US Constitution authorizes Congress to enact laws “to promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries.”
- Patents generally lasts for 20 years, chemical compounds, ornamental designs, and even new varieties of plants.
- An invention must be both novel and non-obvious.
- In US, 176,000 patents in 2000.
- Patenting an invention requires a detailed public description. Makes it easier to come up with a close substitute – and once the patent has expired others will be able to copy it exactly.
- Coca-Cola was never patented, and has remained secret for more than a century.

Patents are also useful only if the legal sanctions against copying can be enforced.

Creative destruction, Joseph Schumpeter, the dislocations suffered by firms and workers who are displaced by new technologies.

Modeling Technology Creation
One-Country Model

Ly – Labor, only input, number of workers producing output.
L - A - number of workers creating new technologies.
L – total labor force

$$L = L_Y + L_A \tag{1}$$

$$\gamma_A = \frac{L_A}{L} \tag{2}$$

$$L_Y = (1 - \gamma_A) L \tag{3}$$

The production function is very simple:

$$Y = AL_Y \tag{4}$$

Combining the previous two equations:

$$Y = A(1 - \gamma_A) L \tag{5}$$

$$y = A(1 - \gamma_A) \tag{6}$$

Assume that the rate of technological progress is a function of the number of workers who are devoting their time to R&D.

(7) $$\dot{A} = \frac{L_A}{\mu}$$

(8) $$\hat{y} = \frac{\gamma_A}{\mu} L$$

Combining this equation with the equation for the growth rate of technology, equation (7), we Get

(9) $$\hat{y} = \hat{A} = \frac{\gamma_A}{\mu} L$$

If A suddenly increases for some reason: two effects, A will increase the growth rate of both output, y, and productivity, A. But moving workers into the R&D sector will mean that fewer workers are involved in producing output.

Figure 1:

Spending more on R&D lowers output in the short run but raises it in the long run Similarity to increasing investment in physical capital but a crucial difference:

An increase in R&D leads to a *permanent* increase in the rate of growth of output.

The model predicts countries with more people should have higher levels of technology, and should be richer, than countries with fewer people.

This prediction does not hold true in the data.

Explanation: level of technology in a country depends also on R&D done abroad. Technologies cross borders.

International Technology Transfer

In 1950, Eiji Toyoda, an engineer whose family's firm had built trucks for the Japanese army during World War II, was invited to visit the Ford Motor Company's River Rouge automobile plant, among the most technologically advanced automobile factories:

- Toyoda spent two months there carefully observing its workings.
- Why Ford was willing to let Toyoda observe its plant?
- Presumably felt that there was no threat of competition from a small company.
- A decision Ford would probably regret when Toyoda's firm, renamed Toyota, rose to become a world automotive superpower.

Transfer of technology across international borders was part of a long history:
Europe benefited from technologies that it imported from the rest of the world: for example, paper and gunpowder from China, and the decimal numeral system (Arabic numerals) from India, food crops (potatoes, corn (maize), tomatoes, and chili peppers).

Technological advantage viewed as precious: in 18th-19th Britain banned the emigration of skilled craftsmen as well as the export of some kinds of machines, in an effort to keep technology from spreading.

Not an effective policy: 1789, Samuel Slater slipped out of England in disguise, memorized cutting-edge technology in textile manufacture. He built first water-powered textile mill in US, RI, became known as father of the American Industrial Revolution.

Effort to import technologies from more advanced countries:
In 1697, Czar Peter the Great under a false identity took a job at a Dutch shipyard in order to learn advanced technologies to bring back to Russia.
During the Industrial Revolution, Britain’s European rivals attempted to copy technologies by: encouraging migration of skilled workers, setting up gov research projects, industrial spies.
Following the restoration of the Meiji emperor in the 1860's, Japan embarked on an ambitious program to bring the best of foreign technology from abroad.
In one of the oddest stories of technology transfer, the Soviet Union was greatly aided in its attempt to develop its own hydrogen bomb by analyzing the airborne fallout from the United States’ tests, which circulated around the whole planet.

Today no attempts to restrict transfer of technology for economic reasons, perhaps for national security.
R&D firms view domestic competitors as a threat just as foreign rivals.

Multinational firms further reduces the relevance of national borders.

DEVC have embarked on ambitious strategies to encourage the transfer of technology:

Taiwan, encouraged foreign investment through tariff protections and subsidies with the conditions that foreign firms help in the creation of local technological capability, for example by buying components locally.

Two Country Model:

Innovation – technology can be invented

Imitation - copying of a technology from elsewhere.

A1 and A2 .

$$(1) \quad y_1 = A_1\left(1-\gamma_{A,1}\right)$$

$$y_2 = A_2\left(1-\gamma_{A,2}\right)$$

Imitation - open only to the country that is “technology follower.”

Invention – by the “technology leader” , have a higher value of *A*

Assume A is unchanging over time in each country, A,1 > A,2

This assumption and assumption of equal labor forces guarantee that Country 1 will be the technology leader and Country 2 the technology follower in the steady state of the model.

For the technology leader:

$$(2) \quad \hat{A}_1 = \frac{\gamma_{A,1}}{\mu_i} L_1$$

c the cost of acquiring a new technology via imitation

Key assumption: c goes down the further the follower is behind the leading country.

c is a function of the ratio of technology in country 1 to technology in country 2:

$$(3) \quad \mu_c = c\left[\frac{A_1}{A_2}\right]$$

Other assumptions:

1. The cost of copying is lower the larger is the technology gap between the two countries (i.e. the higher is the ratio of technology in country 1 to technology in country 2.)
2. As A1 /A2 goes to infinity, the cost of copying goes to zero. That is, if the gap in technology were infinitely large, then imitation would be costless.
3. A A1 /A2 approaches one, the cost of copying approaches the cost of invention. In other words, if the following country is very near the technology leader, it gets very little benefit from copying technology rather than inventing its own.

Figure 2

$$(4)\quad \hat{A}_2 = \frac{\gamma_{A,2}}{\underset{c}{\mu}} L_2$$

The key insight is that, in the steady state, the two countries will grow at the same rate.

Figure 3:

A stable steady state: if A1 /A2 starts off above the steady state, A2 will grow faster than A1 , and the ratio will fall. If starts off below the steady state, the opposite will be true.

Given that the two countries will grow at the same rate, we can easily solve for their relative levels of technology. Setting the two growth rates equal, we get the equation of these terms, the only one that can adjust is : c , the cost of imitation.

I SS, the two countries must grow at the same rate because if they didn’t either:

A) C2 would grow faster than C1, in which case C2 would become the technology leader, which is impossible given that C2 spends less on R&D than C1;

B) C1 would grow faster than C2, in which case the technological gap between them would grow infinitely large, and the cost of copying for c two would be zero.

Given that the two c grow at the same rate, and given that C2 devotes less effort to R&D than C1, it must be the case that C2 has a lower cost of technology creation than C1;

$$\frac{\gamma_{A,1}}{\mu_i} L_1 = \hat{A}_1 = \hat{A}_2 = \frac{\gamma_{A,2}}{\mu_c} L_2 \tag{5}$$

$$\mu_c = \frac{\gamma_{A,2}}{\gamma_{A,1}} \mu_i \tag{6}$$

the specific cost can be determined by looking at how the levels of R&D effort in the two c compare. For example, if country 2 devotes half as much effort to R&D as country 1 $(i.e.: \gamma_{A,2}/\gamma_{A,1} = 1/2)$, then it must be the case that the cost of technology creation in country 2 is half as large as in country 1 $(i.e.: \mu_c/\mu_i = 1/2)$

Once we know the value of : c in SS, we can use the function that determines : c to figure out the value of A1 /A2 in SS, and this tells us the relative level of technology in the two countries.

An interesting question: is the technology-leading c necessarily better off than the follower? The answer is: no.

Although the technology leader has a higher value of the productivity parameter, A, it also devotes a higher fraction of L to R&D and thus has fewer workers producing output.

Whether it is possible for the follower to have a higher level of income than the leader will depend on the costs of imitation relative to innovation:

- If imitation is very inexpensive, then a follower c will have a level of productivity near that of the leader while at the same time devoting a much smaller share of its labor force to R&D. In this case, it will be possible for the follower to have higher income than the leader.
- If imitation is expensive, then the follower c either will have to devote almost as much of its labor force to R&D as does the leader, in which case its level of technology will be close to that of the leader, or else will have a level of technology that is far behind that of the leader, if it devotes only a small part of its labor force to R&D.

The effects of " policy" changes:

C 2 raises its value of (A , but it is still below the value in C 1.

Figure 4: The curve representing A ^ 2 shifts up. This means that for any given value of A1/A2 (and thus for any given cost of copying), country 2 will be growing faster than it would have been before the increase in (A,2 .

The new SS will be at a lower value of A1/A2 , that is, a smaller gap in technology between the two.

Figure 5 shows how the levels of A2 and y2 will behave over time.

Growth in country 2 will return to its rate prior to the change.

Thus, an increase in R&D in the follower C causes a temporary increase in the growth rate of output is in stark contrast to the result of the one-country model that an increase in R&D produced a *permanent* increase in growth.

The leader C does not have the option to imitate technology from abroad, and thus it is effectively in the same situation described in the one-country model: a change R&D will lead to a permanent change in its growth rate of output.

The scenario of one C leading the world in every technology, with everyone else playing catch-up, might have been nearly correct at some points in history: for the UK in the early 19 century, and for the US soon after World War II.

But today, technological superiority is much more diffuse, with many C crowding the “technological frontier” and different c leading in different industries.

This does not mean that the model does not serve a useful purpose. Rather, it suggests that we should take from the model a general lesson, rather than focusing on the particular results.

The general lesson is that R&D spending within a given country will have two effects:

1. It will lead to a change in that country’s relative position in the world technological hierarchy and thus to a period of transitory growth in both technology and income within the country.
2. Increased R&D spending in a given country will lead to faster growth in technology for the world as a whole.

Barriers to International Technology Transfer

While technologies move fairly freely among the most DC, many technological advances that are made in the rich C seem to have little impact on the poorest countries. Two reasons why technological transfer from the DC to DEVC may not always flow so easily.

Appropriate Technology

Technologies developed in the richest C may not be "appropriate" to the poorer C, since technologies may require use of inputs that are not present in a poor C:

Differ in climate zones, in the mix of factors used in production,

Figure 5: Technological change, "neutral,"

Figure 6:

Figure 7: "capital-biased" technological change.

Among DC, annual R&D spending averages $218 per capita; among middle income C $6 per capita, among poorest C $1.

.of world R&D is done in DC %96

Why R&D in DC don't develop technology that could be used in DEVC? property rights,

Tacit Knowledge

Poor countries are *unable* to use technology developed in rich countries: barriers to the transfer of technologies among C:

In addition to the codified knowledge represented by a set of blueprints, there also exists **tacit knowledge** in the minds of engineers – thousands of small details about the workings of a technology, learned over years of experience and transferred from
person to person not in written form but in informal training.

Often the users of a technology will be unaware themselves of the extent of this tacit knowledge, and so the transfer of blueprints alone, without this tacit knowledge, can lead to expensive failures.

The successful transfer of a single technology to a DEVC will potentially have a large externality effect, because in the process the stock of tacit knowledge will be built up, allowing further technologies to be transferred more easily.

This is potentially an explanation for how C like South Korea and Taiwan were able, in the space of a few decades, to advance through a series of technological stages and to quickly catch up to cutting edge technologies.

Embodiment and Leapfrogging

Embodied technological progress: New technology built in to capital goods > technology is not upgraded until the capital good is replaced.

Therefore not so easy to separate factor accumulation from technological progress: a C with high investment will be technologically more advanced than one with low investment.

This effect of embodied technology can be seen in the adoption of the basic oxygen furnace, one of the most important innovations in the steel industry, which was invented in the early 1950s:
In the US, where the steel industry expanded only slowly in the period after World War II, the diffusion of this new technology was slow. In Japan, by contrast, the steel industry was growing much more quickly over this period, and thus adopted the new technology much more quickly: by 1968, 75% of Japanese steel was being produced using the basic oxygen furnace, compared to only 40% in the US.

Technological **leapfrogging:** users with the most antiquated technology jump ahead to be the most cutting-edge.
Leapfrogging can occur at the level of countries.