Chapter 8: The impact of technology on growth

Reconsider the Cobb-Douglas production function:

$$Y = AK^{\alpha}L^{1-\alpha}$$ with Output as a function of Capital and Labour

As we found before, an economy might reach a steady-state, because capital has the nature of diminishing returns and labour is only limited available. Therefore the only factor which can lift an economy out of the steady-state is A, as long as it can grow. (With K and L at the limit, so they cannot increase further to increase output) Please recall that A is a measurement for productivity, thus technology.

Attributes of technology

- Investment is needed in order to finance new technology (through the investment in R&D-Research and Development)
- Technologies are *non-tangible*, unlike the other factors of production, labour and capital. Thus unlike L and K, technologies are non-rival. **Non-rivalry** implies that an unlimited amount of people can use that factor at the same time.
- Because of its non-rivalry inventors might not be able to protect their technologies, with free transfer of ideas damaging the profitability of the technology for the inventor. **Excludability** is said to be low, which means that it is hard to protect own technology from free transfusion.

The largest fraction of R&D activity is done by the private sector, e.g. independent firms. The incentives for companies to invest in R&D are mainly profit considerations, in order to maximise profits. With new technologies a firm might be able to build up a comparative advantage or even create a monopoly. To evaluate the profitability of new technology the company takes the potential market size for the new technology, the degree of excludability (protection ability) and the upfront investment sum into account. A crucial threat of the majority of private investment into new technologies is that new technologies have to fulfil the criteria of profitability and not welfare enhancing for the whole society.

Joseph Schumpeter formulated with his theory of "**creative destruction**" a potential threat starting from new technologies. A new technology implemented by one firm can lead to destruction of old technologies used by its competitors. Take for example the implementation of telephones and their influence on the telegraph. Therefore new technology can lead to destruction of former knowledge.

A patent is a grant made by a government that confers on the creator of an invention the sole right to make, use and sell that invention for a set period of time, generally 20 years. To receive a patent, an inventor must produce something that is both novel(not something that was already known) an nonobvious. Generally an inventor must file for a patent separately in each country where they want to protect their invention.

Sometimes patents are not the best solution to protect innovations because patenting an invention requires a detailed public description. It is easy for competitors to come up with a product that is almost the same and bring it out directly when the patent has expired. They are also only useful if the legal sanctions against copying an invention can be enforced.

The impact of technology on growth

1. In the One-country world model

First we only consider one country for our analysis of R&D's impact on growth. That excludes technology transfer between countries and implies that all technology used must have been created in that economy. Therefore, we will regard two models; first the influence on output per worker and after that the productivity growth change.

For the influence on the worker's output we will regard the production function, but disregard physical and human capital and only take the labour into account. With γ representing the fraction of the labour force which is engaged in R&D the production function for the output per worker is:

$$Y = A^*(1-\gamma_A)$$

Therefore, the output per worker is higher, the smaller γ (the share of R&D workforce) is, (or the bigger A is). That finding seems a paradox, but becomes clear when considering that less people doing R&D means more workers producing more output (in the short run).

On the other hand, regarding the growth rate of technology, which is the change in A and thus ΔY (see productivity function) is equal to:

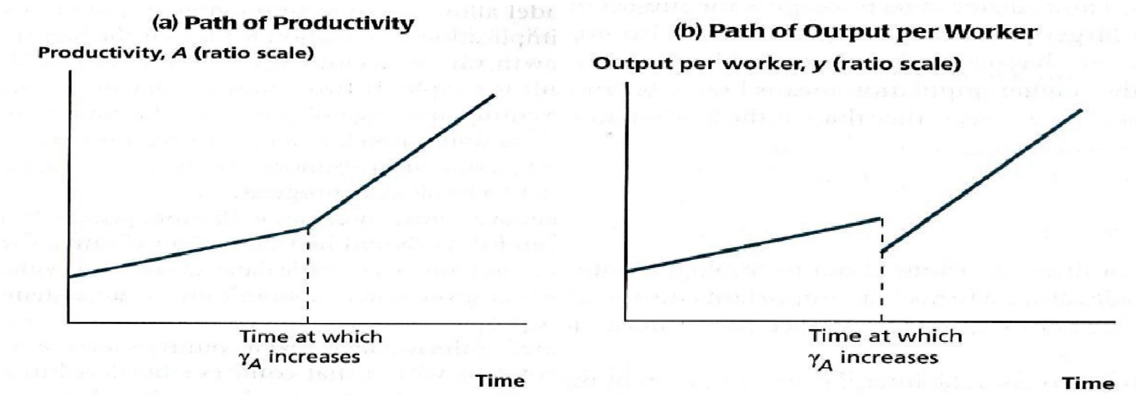
$$\hat{A} = Y_g = (\gamma_A/\mu)^*L$$

Whereas μ is the cost of creating new technologies and "γ_A" still the fraction of workers engaged in R&D. $\hat{A}$ is the productivity growth rate. Therefore with this model, increasing the number of "γ_A", e.g. more R&D personnel will increase output.

The two ways of analysing the influence of R&D brought us to two different findings; are they not combinable? Yes, the first finding, that increasing the R&D labour force will decrease the output, because of less persons working today will decrease output today, holds only for the short run.

In the long run, that is what the second equation states; an increase in the R&D labour force will enhance output. Also the bigger the population (equal to L in the second equation) the larger the growth rate of technology.

The two effects of a shift of labor into R&D can be shown graphically in the following graphs:



Of course, this model is rather limited, because it does not consider cross-border technology acquaintance.

2. Two-country model

For the two-country approach we have to incorporate the possibility of technological transition from one country to the other. Consequently, we have to add

- **Imitation**: coping an existing technology
- **Innovation:** the new invention of technology.

The two countries are divided in a technological "leader", which uses innovation for own technology. The second country is a technological "follower", coping already invented technologies by using imitation. Country 1 is the leader and country 2 is the follower.

We assume that both countries account for the same population size, hence $L1=L2=L$, but

according to the "leader-follower" system, the technological level (A) differs. Leader has a higher level of A and also higher costs of creating new innovations.

For the "leader", that uses innovation, the formula for one country approach is applicable since the leader will not copy knowledge and is therefore reliant on own innovation for its economy. Therefore, the growth rate of technology is also:

$$\hat{A} = (\gamma/\mu)\, L_i$$

The only difference recognisable is that country “leader” is facing the costs μ_i, the costs of

inventing technologies from the scratch.

The “follow” country only applies the imitation approach, thus not creating own technology but coping the knowledge from the leader country. We assume that the bigger the technological gap between leader and follower, the lower is the cost of acquiring the new technology. If the difference is infinitely large, the cost of copying the technology falls to “0”. Therefore, the country “follower” has a similar equation for the growth rate of technology as country “leader”:

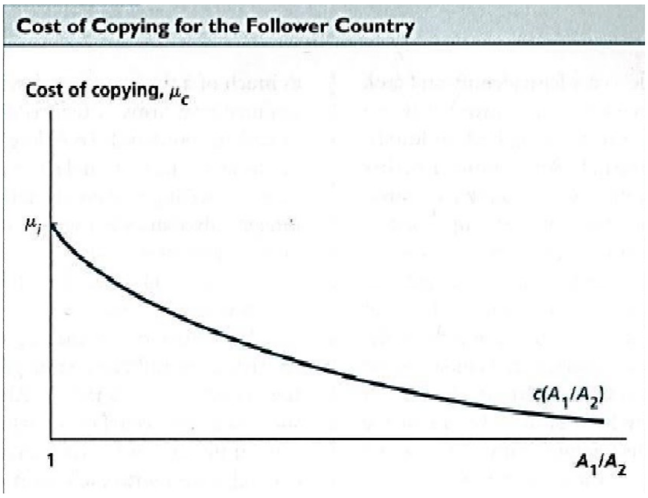
$$\hat{A} = (\gamma/\mu_c)\, L$$

The only difference is that country “follower” is facing costs “μ_c”.

$$\mu_c = \gamma_F / \gamma_L \times \mu_i$$

This formula can also be written in terms of the technology gap between the leader and the follower country.

$\mu_c = c\,(A_1 / A_2)$

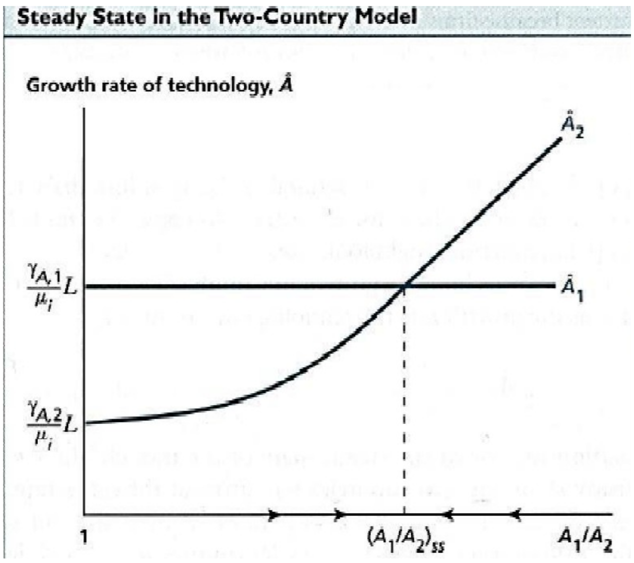


Thus, the two countries are facing different level of costs and are confronted with different levels of γ, i.e. the share of R&D labour force out of the total labour force, because the leading country needs to invent everything, for which it needs more R&D workforce.

Because both countries are interacting, due to technology transfers, we have to think about their relationship. In addition we assume that both countries have the same growth rate, i.e.

$\gamma_F = \gamma_L$. This is because if not, for example as country "follower" would have a higher growth rate than country "leader", it would become the new "leader", which is impossible since they spend less on R&D (in form of R&D staff, recall that γ is smaller for "follower" than for "leader").

If, on the other hand the original "leading" country would gain in the growth rate, the technological gap would widen and country "follower" could benefit more from the imitation. The bigger the gap the more benefit.



Consequently both countries are facing the same growth rate, when deviating from that equilibrium, both countries will always move back to the original equilibrium (as long as factors are held constant) because of the above described mechanism. The countries are in a steady-state.

Remember from the one country analysis that an increase in γ increased the growth rate in

the long-run. Contrary, if γF (i.e. R&D in “follower” country),increased only to a point at which

it still holds: $\gamma L > \gamma F$, country “follower” will be able to increase the growth rate but end up at

the same growth rate as before.

In the two-country model, an increase in γF therefore leas only to a *temporary* boost in the

growth rate, unlike in the one-country model where it leads to a *permanent* increase. That is due to the steady state equilibrium.

The transfer of technologies

The transfusion of knowledge from developed (e.g. leading countries) to developing countries can be subject to some barriers. The barriers we will examine are the “appropriate/ adoption of technology” and the influence of tacit knowledge.

- *Appropriate/ adoption* of technology includes the possibility that new technologies are not useful for the following country, since they cannot be adopted. Take for example, a technology influence which requires a high level of the input factors capital or labour, if they are not given, the technology cannot be incorporated. Furthermore new technologies might be lacking the capability of the new invention, e.g. importing a TV without having electricity. Because the poor country is lacking capital, it does not benefit as the rich country does.

- The concept of **tacit knowledge**, which is knowledge learned over years of experience transferred from person to person that is not in written form, complicates the knowledge transfer. This is because it implies that in order to implement a new technology, background knowledge, which is not teachable, hence rather informal training (practical experience) is needed.

Embodied technological progress is a new technology which requires new equipment to be used with. Therefore, technological change is also dependent on the replacement of the surrounded equipment, which leads to infrequent replacements. Take for example the introduction of 3 D movie technology, which also required the theatres to implement new projectors. A typical **disembodied technology** is software, since it can be updated, without purchasing a new computer.

That can lead to the fact that firms replace the equipment seldom and replace the old capital goods with the newest technology. The replacement occurs in jumps and is therefore called **leapfrogging**.