Macroeconomics: Economic Growth (Licence 3)
Lesson 7: Endogenous growth

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Endogenous growth

Endogenous growth theories:

- Models in which we can have positive long-run growth even without assuming exogenous technological progress
- Models in which policy interventions can permanently affect the growth rates of the economies
- Aim: explaining the **differences in income per capita across countries** and the exponential growth observed in the last two centuries, and showing how policies interventions can affect growth

Endogenous growth

Limits of the neoclassical growth theory (Solow model):

- Technological progress is exogenous
- Technological improvements arrive exogenously at a constant rate g
- Aim of Endogenous Growth Theory: model of determinants of technological improvement

Endogenous growth

What is Technology?:

- Technology is the way inputs are transformed into output in the production process
- In a general production function $Y = F(K, L, .)$ technology of production is given by the function $F(.)$
- The term "A" in the Solow model is an index of technology
- **Ideas:** improve technology of production
- **New ideas** allow a given bundle of inputs to produce more output or better output (high quality)

Endogenous growth

What is Technology?:

- **In the Solow model, the only element that produces trend/long run growth is technology (A)**, which grows at constant rate over time and it is exogenous.
- Where does "A" parameter come from?
- Think of A as ideas of how to combine inputs more efficiently
  - **Better ideas:** higher output per worker
  - **New ideas as determinant of growth** So that we need to continue to have new ideas to grow
- Note that **economics of ideas is different** from economics of goods and services

Endogenous growth

Economics of ideas

- The **economics of producing ideas is different from our standard world of perfect competition**
- First model of endogenous growth developed by Romer (1990):
- Main assumptions
  - **Ideas** $\rightarrow$ nonrivalry $\rightarrow$ High fixed cost $\rightarrow$ increasing returns
  - $\rightarrow$ **Imperfect competition**
  - Non-rivalrous goods: an unlimited number of people can jointly use a given good

Endogenous growth

Economics of ideas: Romer (1990)

- **Ideas** $\rightarrow$ nonrivalry $\rightarrow$ High fixed cost $\rightarrow$ increasing returns $\rightarrow$ **Imperfect competition**
  - **Ideas are non-rivalrous goods** (e.g., everybody can use basic calculus at the same time)
  - Once an idea has been created anyone with the knowledge of the idea can take advantage of it.
  - Example: Toyota take advantage of just-in-time inventory methods does not mean that GM can not take advantage of the same technique (idea)

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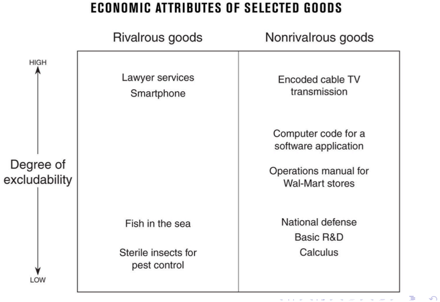
Economics of ideas: Romer (1990)

- Ideas are partially excludable
- **Degree of excludability of a given good:** it is possible to prevent people, who have not paid a fee for the use of the good, from using it
- The degree of excludability is related to the rivalry but also to the institutions (e.g., patent protection)
- **Public goods:** non-rivalrous with very low degree of excludability
- Ideas are non-rivalrous and can have either a high or a low degree of excludability.
- Copyright and Patent Systems: grant inventors to charge for the use of ideas.

Growth rates over time across countries



- Ideas are nonrivalrous goods but they vary substantially in their degree of excludability.
- Nonrivalrous goods that are unexcludable are public goods like National

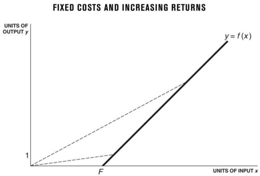
Endogenous growth

Increasing returns to scale

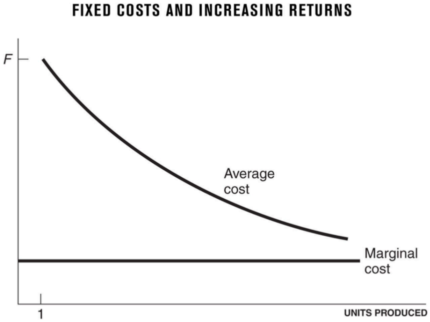
- Ideas are non-rivalrous: Produce them once, and then any one can use them
- **Ideas have high fixed costs** of a new invention e.g., it took a lot of effort to invent calculus or a new drug
- **Ideas have low (zero) marginal costs:** e.g., it costs nothing for you to use calculus now; or, it costs very little to produce one more pill,
- The combination of fixed costs and low marginal costs mean ideas have increasing returns to scale

Increasing returns to scale and imperfect competition

- **Increasing returns to scale:** implies that the average cost of the idea (or good that embodies the idea) is higher than the marginal cost of reproducing the idea (or good that embodies the idea)
- due to the existence of **fixed costs**
- E.g.: it cost a lot to produce the first unit of the latest application for your smartphone (high fixed cost) but subsequent units are produced simply by copying the soft'ware from the first unit



- Plots a production function $y = f(x) = 100 * (x - F)$, with fixed costs F and constant marginal cost
- Increasing return to scale if $f(ax) > af(x)$ and a higher than 1.
- Doubling the inputs more than double the output.


FIXED COSTS AND INCREASING RETURNS
F
Average
cost
Marginal
cost
1
UNITS PRODUCED

- Constant MC (e.g/ it costs 10 to produce an additional unit)
- The first unit costs F to produce because of **fixed cost of idea**
- **At higher levels of production the fixed cost is spread over more units so the average cost declines.**
- **The presence of fixed cost implies that setting a price equal to MC results in negative profits**
- $\rightarrow$ since the average cost is always greater than MC with increasing return to scale
- Firms will enter if they can charge a price higher than MC recovering the fixed cost.

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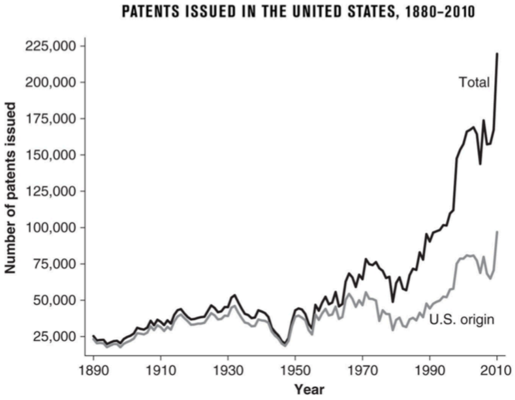
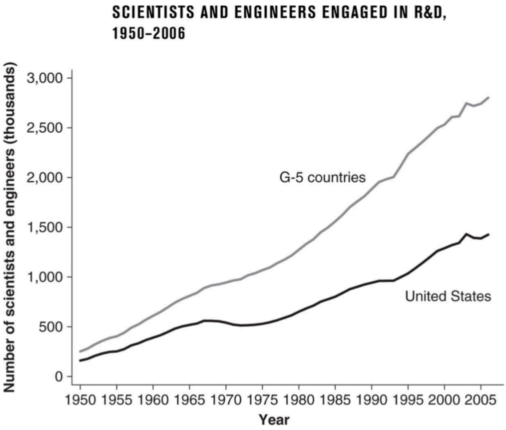
- Firms that produce ideas, or goods that embody ideas **earn positive profits** by charging a price for the good over the marginal cost
- The profits are there to make up for the large fixed cost to coming up with the idea
- **Patent protection:**
  - These firms can only sustain these profits by preventing others from using the idea (patents, branding, copyrights, etc.)
  - Without **protection for the ideas, firms will not earn profits.**
  - Without profits, firms will not undertake fixed cost of *R&D* to invent new product..
  - Incentive to innovate are linked to the **protection of the intellectual property rights**
  - According to North (1981), the creation of institutions that protect property rights is at the basis of the high growth rates of income that we observe from the 1800s

Economic Growth



- Data on ideas are (of course) imperfect; proxies for inputs: e.g., R &D expenditures, or number of researchers; proxies for output: e.g., number of patents (check http://www.oecd.org/sti/msti.htm)

Economic Growth



Population and growth

- Population is positive for ideas
  - (1) More people means more researchers, thinkers, inventors, etc..
  - (2) More people means larger markets, and so more profits for firms that use ideas.
  - More profits means more investment in R&D.
  - All together, population (or scale) will be a positive contributor to growth

- **Endogenous growth models**
- A first approach to have **increasing returns to scale at the macroeconomic level and the presence of a competitive equilibrium consists in allowing externalities**,
- i.e. accumulation of knowledge is a by-product of other activities in the economy, such as capital accumulation (Arrow 1962 "learning by doing", Romer 1986);
- in this approach there is not a clear distinction between ideas and capital.

- **Endogenous growth models**
- Later, we will study other two main approaches (imperfect competition):
  - **Product varieties models**: innovation is a specific activity motivated by profits and takes the form of creation of new varieties of products; e.g., Romer 1990 and Jones 1995;
  - **Schumpeterian models**: new and better quality intermediate products replace old products / creative destruction; e.g. Aghion and Howitt 1988.

- **Endogenous growth models**
- **AK models:**
- perfect competition and increasing returns.
- This is the "first approach" to endogenous growth which is based on AK models
- even if individuals are not compensated for accumulating knowledge, **knowledge accumulates embodied in capital accumulation** .
- i.e., knowledge accumulates because of an "externality"; Arrow, 1962: learning by doing.

- **Basic AK model**
- One implication of the Solow model is that policy changes (e.g. in saving rate s) have ONLY **level effects but no long run growth effects**
- because of diminishing returns to capital, the economy will eventually grow at its **long-run (exogenous) rate**
- In endogenous growth, policies can influence the long run growth rate
- and models are explicit theories of technological progress that allow to answer:
- **Where does technological progress come from?**

- **Basic AK model**
- Assume $\alpha = 1$, so the production function can be

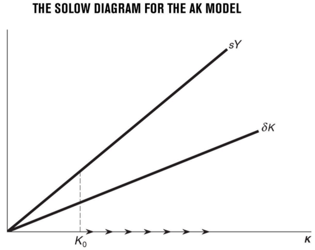
$$Y = AK \tag{1}$$

- Assumptions:
- where A is some positive constant and it is assumed that $\frac{\dot{A}}{A} = 0 \rightarrow$ i.e. no technological progress
- There is no population growth
- Notice the linearity between K and Y

- **Basic AK model**
- Accumulation of capital is like in the Solow model:

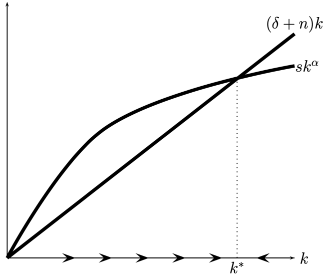
$$\dot{K} = sY - \delta K \tag{2}$$

- where s is the investment rate and δ the depreciation rate, both assumed constant



- sY line represents total investment as a function of capital stock $\rightarrow$ **since Y is linear in K sY curve is a line since $\alpha = 1$**
- δK line represents amount of investment to replace the depreciation of capital
- **Assumption: total investment is larger than depreciation: $sY > \delta K$**
- Capital stock is always growing: Increase in capital accumulation drives economic growth than never stops

The basic Solow diagram



- Plot output per worker against capital per worker
- First curve: is the amount of investment per person $sy = sk^{\alpha}$
- Diminishing returns to capital since $\alpha < 1$ each new unit of capital added was less productive $\rightarrow$ **total I fall to the level of depreciation ending capital accumulation**
- Second curve is the line $(\delta + n)k$: the amount of investment per person required to keep the amount of capital per worker constant.
- The difference between both curves is: the change in the amount of capital per worker. When $sk^{\alpha} = (\delta + n)k$ then $\dot{k} = 0$

- **Basic AK model**
- Accumulation of capital is like in the Solow model:

$$\dot{K} = sY - \delta K \tag{3}$$

- The growth rate of capital is given by diving both sides by K:

$$\frac{\dot{K}}{K} = s\frac{Y}{K} - \delta = sA - \delta \tag{4}$$

- notice that A is the marginal product of capital.

- **Basic AK model**

- The growth rate of the economy's income is equal to the growth rate of capital given by:

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \frac{\dot{K}}{K} \quad (5)$$

$$\frac{\dot{Y}}{Y} = sA - \delta \quad (6)$$

- **The growth rate of the economy is an increasing function of the investment rate** s $\rightarrow$ policy implication

- In per capita terms: production is $y = Ak$ and the growth rate of capital is given by $\frac{\dot{k}}{k} = sA - (\delta)$, which is constant and positive (if s and A are sufficiently large)

- **Basic AK model**
- In this model, growth never stops (perpetual growth)
- We have **perpetual growth** because here we have constant returns to capital accumulation since $\alpha = 1$
- **Recall in the Solow model we had diminishing return** because of $\alpha < 1$
- In the AK model the **marginal product of each unit of capital is constant and equal to A:**
- Since $Y = AK \rightarrow dY/dK = A$.

- **Basic AK model**

- Note that in the Solow model, the parameter α measures the curvature of the curve $sy = sk^{\alpha}$ in transition dynamics:

  - If α is large, then the further away the steady state value of k_* **the transition to the steady state is longer**, relative to low value of α.

  - **If $\alpha = 1$ is a limiting case in which the transition dynamics never ends**

- **Differences between Solow and AK model**
  - **In AK model:** $\alpha = 1$, thus $\frac{\dot{k}}{k} = sA - \delta$ and
  - the growth rate of capital and income depends on s and perpetual growth, thus policy changes in s can lead to changes in the long run growth rates;
  - $\rightarrow$ AK model generates endogenous growth because it involves a linearity in the capital accumulation equation from the linear production function

Economic Growth

- **Economics of ideas: Summary**
- Ideas are non-rivalrous goods and this characteristic can create externalities
- **Problem: the social benefits can be larger than the private benefits**
- The presence of ideas in the production function means that the production function is characterized by **increasing returns to scale**
- Increasing returns require imperfect competition