Economic growth
Class 12
Creative destruction

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Model of Creative destruction

- Aghion and Howitt
- A model of Growth Through Creative Destruction
- Econometrica, 1992
- two elements to the growth model
  - the Schumpeterian idea of creative destruction
  - a simple version of uncertainty
- Research and development

Idea of creative destruction

- New products (inventions) frequently replace old ones
- Some inventions don't make others obsolete
  - people use both for some time (perhaps divided by income level)
  - sometimes compatible with older inventions
- Some inventions are "drastic"
  - older goods or processes disappear relatively rapidly
  - new goods dominate older ones
- Competition for producing new goods is part of the force that drives capitalism

Some examples of creative destruction

- Printing press
  - replaced hand written books
  - made books available to masses
- steam engine, internal combustion engine, electric engine
  - replace animal and water power
  - but adds much animals could not do
- computer
  - replaces typewriter, slide rule, mail, encycopedia, libraries
  - adds calculating power
- television or computer games
  - replace life (ok: reading, playing music, conversation, games)
  - adds new forms of entertainment
- Digital camera

Some examples of creative destruction

- On a more micro level
- individual products
- Frequent updates
- new characteristics added
- new design (works better, looks nicer)
- new ways of producing something similar
  - flat panel televisions
- Some goods have very short lives (computer parts)

Schumpeter

> "The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets,...[This process] incessantly revolutionizes the economic structure form within, incessantly destroying the old one, incessantly creating the new one. This process of Creative Destruction is the essential fact about capitalism.

from: Joseph Alois Schumpeter (1942) Capitalism, Socialism and Democracy, New York, Harper Brothers, p. 83.

.Creative Destruction

- Positive side
  - implies a negative relationship current and future research with results in
  - the existence of a unique steady state growth path
  - the possibility of cyclical growth patterns
- Normative side
  - current innovations have positive externalities for future research and development
  - they exhibit a negative externality on current (incumbant)producers (the business stealing effect)

.The model: general aspects

- Schumpeterian model of endogenous growth in a context of uncertainty
- Growth in generated by a random sequence of quality improving innovations that come from research and development activities
- Vertical innovations implies that new inventions make old ones obsolete
- Research is carried on by firms that, if successful, have a monopoly on the technology they produce (a patent) until it is replaced by a better technology

.The model: general aspects

.Three types of labor

- Unskilled labor used only in final good production
  - we will fix the amount at $M = 1$, all supplied
  - is combined with an intermediate good to produce the final good
- Skilled labor used in intermediate good production and in research
  - in fixed supply, all used, but divided between the 2 uses
  - more intermediate good production means less research
  - $N = L_t + n_t$ where L_t is used in intermediate good production and n_t in research
- Specialized labor (not in our version of the model) used only in research (here $R = 0$)

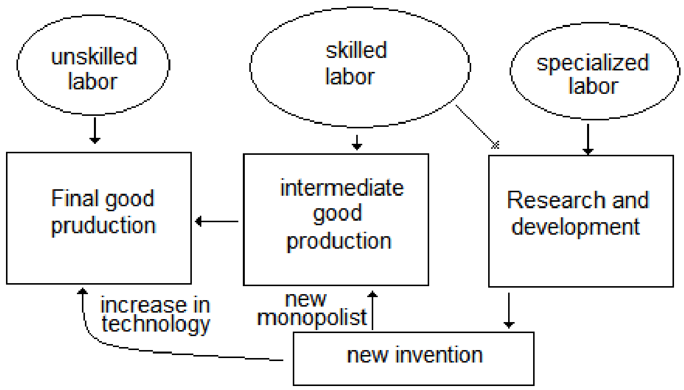

Figure 1: Drawing of the model

Idea behind research

- Invention of new goods or processes is random
- but the probability distribution depends on the labor spent on research
- More labor spent in a period, more likely the research will be successful sooner
- Probability is in terms of an arrival model
  - new inventions arrive
  - arrive faster if more labor used in research
  - alternative way of thinking: waiting time before new invention arrives
  - arrival times and waiting times are inverses of each other

Production and technology

- Production technology
$$Y_t = A_t x_t^{\alpha} L_u^{1-\alpha}$$
- where A_t is technology in stage t, x_t is the amount of the intermediate good, $L_u = 1$ is the fixed amount of unskilled labor
- changes in technology arrive with an arrival rate λn_t where n_t is the total labor used in research
- The arrival rate comes from a Poisson distribution with the density function
$$f(k|n_t\lambda) = \frac{(n_t\lambda)^k e^{-n_t\lambda}}{k!}$$

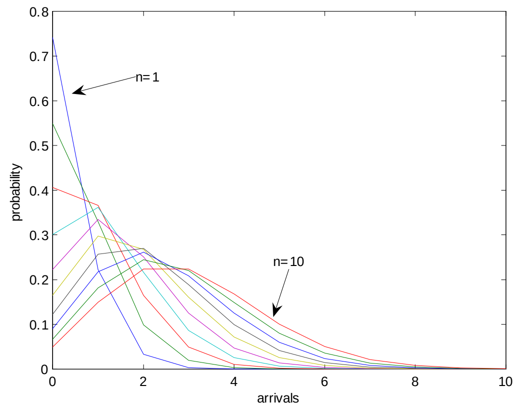

Figure 2: Poisson arrival rates

- Arrival rates are how many innovations arrive in a given period (we really haven't defined a period yet)
- the Poisson distribution tells us the probability that exactly k innovations will arrive in a period
  - some other uses of a Poisson distribution: bombs

.The Poisson distribution

- Poisson distribution for $k = 1, ..., 10$ and $\lambda = .3$

.Waiting times

- How long one waits between arrivals
- Expected waiting time is $1/\lambda n_t$
- Waiting times are a exponential distribution

$$f\left(x|\frac{1}{n_t\lambda}\right) = \frac{1}{n_t\lambda}e^{-\frac{x}{n_t\lambda}}.$$

- When a innovation arrives, it improves technology by a ratio of γ so

$$A_{t+1} = \gamma A_t$$

.Waiting times

- Higher λ imply shorter waiting times

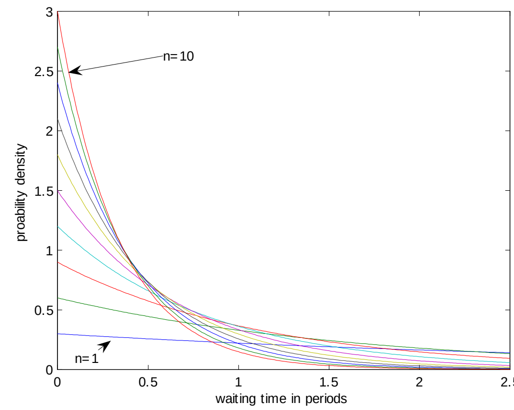

Figure 3: Waiting times from exponential distribution

.The model: households

- Households provide unskilled and skilled labor to the markets
- unskilled labor is used only in final good production
- skilled labor is used in intermediate good production and research
- both are in fixed supply: $M = 1$, $N =$ total supply of skilled
- Household maximize
$$u = \int_0^\infty e^{-rt} y_t dt,$$
  - where $r < 0$ is the constant rate of time preference,
  - and y_t is the consumption of the final good at time t
  - notice that time is continuous
  - it will later be broken up into periods of constant technology

.The model: Production

- Production of the final good takes place with the technology
$$y_t = A_t x_t^\alpha.$$
with $0 < \alpha < 1$.
- The intermediate good production is monopolistic, given that only the most advanced technology good is produced, and the production technology is
$$x_t = L_t.$$

- Research generates new technologies at an poisson arrival rate equal to

$$\lambda n_t.$$

- When a technological innovation arrives, its use causes the technology parameter in the final good production to increase by

$$A_{t+1} = \gamma A_t$$

Decision of the monopolist (intermediate good producer)

- The monopolist knows that the final good production function is

$$y_t = A_t x_t^{\alpha}$$

- uses that to determine what price it should charge the final good producer for the intermediate good.
- The final good producer maximizes the flow of profits as

$$\pi_t^{final} = y_y - p_t x_t = A_t x_t^{\alpha} - p_t x_t$$

- chosing the amount of intermediate good it wants to use.
- First order conditions are

$$\frac{\partial \pi_t^{final}}{\partial x_t} = \alpha A_t x_t^{\alpha-1} - p_t = 0,$$

- so the (inverse) demand for intermediate goods is

$$p_t = \alpha A_t x_t^{\alpha-1}$$

Decision of the monopolist (intermediate good producer)

- the intermediate good producer maximizes

$$\begin{aligned} \pi_t^{int} &= p_t x_t - w_t L_t = p_t x_t - w_t x_t \\ &= \alpha A_t x_t^{\alpha-1} x_t - w_t x_t \\ &= \alpha A_t x_t^{\alpha} - w_t x_t. \end{aligned}$$

- First order conditions are

$$\frac{\partial \pi_t^{int}}{\partial x_t} = \alpha^2 A_t x_t^{\alpha-1} - w_t = 0$$

- or

$$x_t = \left(\frac{\alpha^2}{\frac{w_t}{A_t}} \right)^{\frac{1}{1-\alpha}}.$$

Decision of the monopolist (intermediate good producer)

- To be able to talk about stationary states with increasing technology we will need a technology adjusted wage
- $\varpi_t = w_t/A_t$ as the technology-adjusted wage, x_t is a decreasing function of ϖ_t of the form
$$x_t = \left(\frac{\alpha^2}{\varpi_t}\right)^{\frac{1}{1-\alpha}}.$$

Monopolist profits

- The intermediate good producer's profits are

$$\begin{aligned}
\pi_t &= \alpha A_t x_t^{\alpha} - w_t x_t \\
&= \alpha A_t \left(\frac{\alpha^2}{\varpi_t}\right)^{\frac{\alpha}{1-\alpha}} - A_t \varpi_t \left(\frac{\alpha^2}{\varpi_t}\right)^{\frac{1}{1-\alpha}} \\
&= \alpha A_t \left(\frac{\alpha^2}{\varpi_t}\right)^{\frac{\alpha}{1-\alpha}} - \alpha^2 A_t \left(\frac{\alpha^2}{\varpi_t}\right)^{\frac{\alpha}{1-\alpha}} \\
\pi_t &= (1-\alpha)\,\alpha A_t \left(\frac{\alpha^2}{\varpi_t}\right)^{\frac{\alpha}{1-\alpha}} \\
\pi_t &= A_t \widetilde{\pi}\left(\varpi_t\right)
\end{aligned}$$

How profits respond to wages

- taking the derivative of profits with respect to wages, gives

$$\begin{aligned}
\frac{\partial \pi_t}{\partial \varpi_t} &= \frac{\alpha}{1-\alpha}(1-\alpha)\,\alpha A_t \left(\frac{\alpha^2}{\varpi_t}\right)^{\frac{\alpha}{1-\alpha}-1} \left(-\frac{\alpha^2}{\varpi_t^2}\right) \\
&= -\alpha^2 A_t \left(\frac{\alpha^2}{\varpi_t}\right)^{\frac{\alpha}{1-\alpha}} \left(\frac{1}{\varpi_t}\right) < 0,
\end{aligned}$$

- profits decline as risk adjusted wages increase
- Higher expected future demand for research will drive up wages and reduce the profits from doing research
- This tends to reduce current research

Research

- Inventions occur with Poisson arrival rate λ per worker in research (or with average waiting time $1/\lambda$)
- With n_t workers, arrival rate is $n_t\lambda$

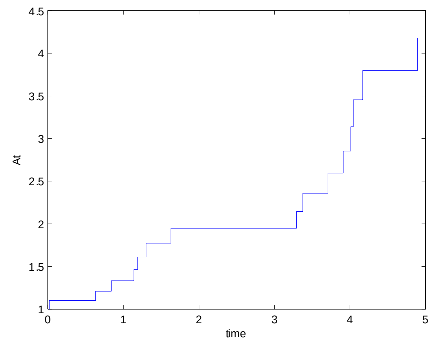

Figure 4: Innovations path

- for $\lambda = .3$ and $n_t = 8$, a path of innovations looks like

Research

- All inventions are drastic and give inventor patent with infinite life
- Patent becomes useless when next invention occurs
- Inventor only can use (or sell) monopoly rights until the next invention arrives
- expected life of a patent is $1/(\lambda n_t)$
- Since new technology is known to all: new research starts there
- New invention raises technology by $\gamma > 1$, so

$$A_{t+1} = \gamma A_t$$

Research

- Research firms have a flow of expected profits equal to

$$\lambda n_t V_{t+1} - w_t n_t,$$

  where V_{t+1} is the value of the next $(t+1)$ innovation.

- Maximizing profits with respect to the number of resarchers gives that

$$\lambda V_{t+1} - w_t.$$

- The intermediate good firm that own the time t technology will not engage in research.

- By doing so it will
  - shorten the expected time it has a monopoly on the technology and
  - if it is successful will have a gain from research equal to $V_{t+1} - V_t$
  - other research firms will have a gain equal to V_{t+1}.

.Research and profits

- The value of the new technology is the expected discounted flow of profits it will produce.
- Notice that the flow of profits is constant over the time that the firm has the lead technology (since production of the final and intermediate goods are constant).
- Call these expected profits π_{t+1}.
- Then the value of the firm is

$$V_{t+1} = \frac{\pi_{t+1}}{r + \lambda n_{t+1}}.$$

.Creative destruction

- rewrite the value of the firm as

$$rV_{t+1} = \pi_{t+1} - \lambda n_{t+1} V_{t+1}.$$

- this says that the flow of expected profits genereated by the firm equals the flow of profits minus the expected loss from being replaced by a new innovation

.Capital markets

- Need to finance research
- number of ways of doing this
- notice that utility is linear
- this implies that individuals are risk neutral
- reseachers can be paid off when their firm invents a new good by getting shares in the monopoly profits

.Equilibrium

- Only one decision for the economy to make: how many skilled worker in research: choose n_t in

$$N = x_t + n_t.$$

- Combine this equation with the rest of the equations of the model

$$w_t = \lambda V_{t+1},$$

$$V_{t+1} = \frac{\pi_{t+1}}{r + \lambda n_{t+1}},$$

and

$$\begin{aligned} \pi_t &= A_t \widetilde{\pi}(\varpi_t) \\ &= (1-\alpha)\alpha A_t \left(\frac{\alpha^2}{\varpi_t}\right)^{\frac{\alpha}{1-\alpha}} \end{aligned}$$

.

- This gives

$$\begin{aligned} w_t &= \lambda V_{t+1}, \\ \frac{w_t}{A_t} &= \lambda \frac{\pi_{t+1}}{r + \lambda n_{t+1}} \frac{1}{A_t}, \\ \frac{w_t}{A_t} &= \lambda \frac{A_{t+1} \widetilde{\pi}(\varpi_{t+1})}{r + \lambda n_{t+1}} \frac{1}{A_t}, \end{aligned}$$

- or

$$\varpi_t = \lambda \gamma \frac{\widetilde{\pi}(\varpi_{t+1})}{r + \lambda n_{t+1}},$$

- where

$$\widetilde{\pi}(\varpi_{t+1}) = (1-\alpha)\alpha A_{t+1} \left(\frac{\alpha^2}{\varpi_{t+1}}\right)^{\frac{\alpha}{1-\alpha}}$$

.

- The other condition for an equilibrium is

$$n_{t+1} = N - x_{t+1}$$

- and

$$x_{t+1} = \left(\frac{\alpha^2}{\varpi_{t+1}}\right)^{\frac{1}{1-\alpha}},$$

- so the wage equation can be written as

$$\varpi_t = \lambda \gamma \frac{\widetilde{\pi}(\varpi_{t+1})}{r + \lambda \left(N - \left(\frac{\alpha^2}{\varpi_{t+1}}\right)^{\frac{1}{1-\alpha}}\right)}$$

- This is an equation of the form

$$\varpi_t = g(\varpi_{t+1})$$

Equilibrium

- If one prefers, the model can be thought of in terms of a wage equation,

$$\varpi_t = \lambda\gamma \frac{\widetilde{\pi}\left(\varpi_{t+1}\right)}{r + \lambda n_{t+1}},$$

- and a labor market equilibrium equation,

$$n_t = N - \left(\frac{\alpha^2}{\varpi_t}\right)^{\frac{1}{1-\alpha}},$$

- that can be written as

$$\varpi_t = \frac{\alpha^2}{\left(N - n_t\right)^{1-\alpha}},$$

Perfect foresight equilibrium

- A perfect foresight equilibrium is a sequence of $\{n_s\}_{s=t}^{\infty}$ where all agents are maximizing their utility or profits and the equilibrium conditions (the wage equation and the labor market equilibrium equation) hold in every period s.
- Individuals in period t make their decisions knowing the value of n_{t+1} and other relevant variables

Perfect foresight equilibrium

- Take the wage equation (with the function for profits put in)

$$\frac{\varpi_t}{\lambda} = \gamma \frac{\left(1-\alpha\right)\alpha A_{t+1}\left(\frac{\alpha^2}{\varpi_{t+1}}\right)^{\frac{\alpha}{1-\alpha}}}{r + \lambda n_{t+1}},$$

- substitute in the labor market equilibrium equation for both time t and time $t+1$,
- one gets

$$\frac{\alpha^2}{\lambda\left(N - n_t\right)^{1-\alpha}} = \gamma \frac{\left(1-\alpha\right)\alpha A_{t+1}\left(N - n_{t+1}\right)^{\alpha}}{r + \lambda n_{t+1}}$$

- the left hand side gives the marginal costs of research
- the right hand side gives the marginal benefits of research
- The only variables are n_t and n_{t+1}

Perfect foresight equilibrium

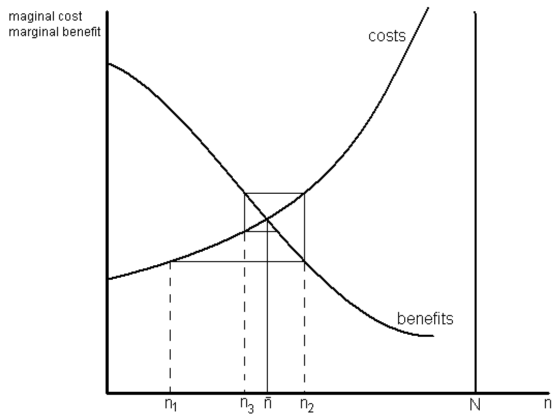

Figure 5: Costs and benefits of research: time path

- How to analyze stationary state ($n_t = n_{t+1} = \overline{n}$) or time paths

Some results for stationary perfect foresight equilibria

- Aghion and Howitt give this proposition.

> The amount of research employment $\overline{n}$ in a stationary perfect foresight equilibrium increases with: a) a decrease in the rate of interest, b) an increase in the size γ of each innovation, c) an increase in the total endowment N of skilled labor, or d) an increase in the arrival rate λ.