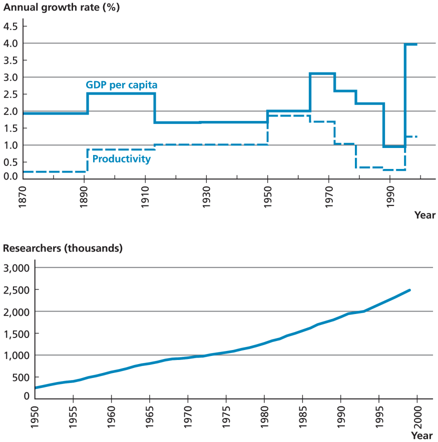
3. The Production of Technological Change I

References: Weil, Chapter 9.2.-9.3., Jones, Chapter 5.1.

Observe:

- Positive trend of resources allocated to R&D (researchers)
- No long-run positive trend of GDP growth and productivity growth
- Possibly a Productivity Slowdown.



These facts for the

- leader countries
- most advanced countries creating the leading edge technology

refute the scale effect: according to the toy model income growth should be increasing.

A First Refinement of the Model

3 fold purpose:

- more realistic R&D production function
- elimination of the scale effect
- preparation for the full model.

Ideas production function faced by a single firm:

$$\dot{A} = \bar{\delta} L_A \tag{1}$$

i.e.

- a firms takes general productivity of R&D (parameter $\bar{\delta}$) as given.
- from firm perspective: linear homogeneity in L_A

Yet, at the aggregate level R&D productivity is endogenous:

$$\bar{\delta} = \delta A^{\phi} L_A^{\lambda - 1}, \quad \phi > 0, \quad 0 < \lambda < 1. \tag{2}$$

Observe external effect on A:

- The level of existing ideas/technology matters for productivity in R&D.
- It is no longer simplified to be exactly 1 ($\phi \neq 1$).
- standing on shoulders of giants $\rightarrow$ large ϕ.
- fishing out $\rightarrow$ small ϕ.

Observe external effect on L_A:

- Duplication externality: stepping on toes.
- Many firms do the research but only one (the first) gets the patent.
- Patent races.
- The more researchers the higher is the possibility to invent things more then once.

[Note that the Notation follows Jones and differs slightly from Weil's.]

Insert (1) in (2) to get aggregate growth of ideas:

$$\dot{A} = \delta A^{\phi} L_A^{\lambda} \qquad \Rightarrow \qquad \hat{A} = \delta \frac{L_A^{\lambda}}{A^{1-\phi}} \tag{3}$$

Assume as before a constant share of workers in R&D and thus

$$y = A(1-\gamma_A) \qquad \Rightarrow \qquad \hat{y} = \hat{A} \tag{4}$$

Observe from decreasing returns in A-production:

- the higher the level A, the lower the rate $\hat{A}$
- good news: eliminations of the scale effect (for $A \to \infty$)
- bad news: there is no long-run growth.

$\rightarrow$ a seeming way out: assume there is population growth.

Steady-state where $\hat{A}$ does not change i.e. from log.-diff. of (3) w.r.t. time:

$$0 = \lambda \hat{L}_A - (1-\phi)\hat{A} \tag{5}$$

For constant γ_A: $\hat{L}_A = \hat{L} \equiv n$. Thus at the steady-state:

$$\hat{A} = \frac{\lambda}{1-\phi} \cdot n \tag{6}$$

The result of "semi-endogenous growth theory": economic growth is ultimately driven by population growth.

Note the difference:

- neoclassical growth theory: large n is bad for growth (capital dillution)
- now: large n is good for growth (larger growth rate of people who invent something).

Observe: a scale effect of 2nd order: higher growth of L leads to higher economic growth.
$\rightarrow$ Yet, is this true?

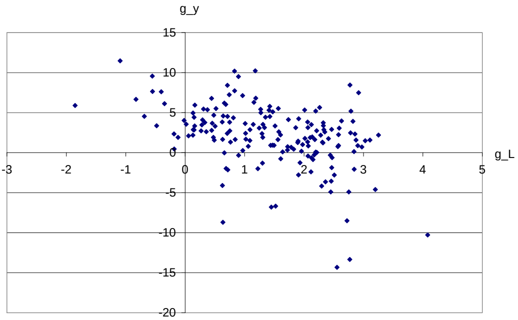
- until 1850 $\rightarrow$ next lecture
- after 1850: again, the result is refuted by empirical observations.

Today most of the advanced (leading-edge) countries

- have decreasing (or even negative!) population growth
- almost constant productivity growth.

The most backward LDC's

- have high population growth
- are not pushing the leading-edge of the world technology frontier.



World Bank data for year 2000 and 174 countries

Estimates from Brander and Dowrick (NBER 1993, J. Pop. Econ., 1994)

TABLE 1: Per Capita Output Growth vs. Population Growth
Regression coefficients (t-statistics) [White-adjusted]

Period / Method	Whole Sample n=107	Less Developed n=40	More Developed n=67
1961-85			
OLS	-0.44 (-2.4) [-3.3]	0.61 (1.0) [1.2]	-0.19 (-1.2) [-1.4]
weight=population	-0.72 (-3.4)	-2.57 (-3.9)	-0.14 (-0.8)
weight=RGDP p.c.	-0.25 (-1.9)	0.69 (1.1)	-0.10 (-0.7)
weight=GDP	-0.25 (-1.6)	-2.70 (-4.1)	-0.09 (-0.5)
1961-65			
OLS	-0.62 (-2.0) [-2.2]	-1.15 (-1.5) [-1.7]	-0.29 (-1.0) [-1.1]
weight=population	-1.18 (-2.7)	3.38 (3.3)	-0.66 (-2.0)
weight=RGDP p.c.	-0.30 (-1.4)	-1.08 (-1.6)	-0.13 (-0.5)
weight=GDP	-0.93 (-3.0)	3.55 (3.6)	-0.39 (-1.2)
1981-85			
OLS	-0.64 (-2.2) [-2.4]	-1.29 (-1.2) [-1.3]	1.02 (-3.5) [-2.8]
weight=population	-1.39 (-3.3)	-4.43 (-6.8)	-1.24 (-4.3)
weight=RGDP p.c.	-0.68 (-3.1)	-0.96 (-1.1)	-0.94 (-3.4)
weight=GDP	-0.43 (-1.4)	-4.25 (-7.1)	-1.02 (-4.1)

We need a further qualification:

- Did Newton and Einstein become the founding fathers of traditional and modern physics by birth ? (by chance ?): No ! $\rightarrow$ read their biographies.
- Not the number of people L is crucial for $\hat{A}$ but the number of *educated people* $H = h \cdot L$

Conclude: productivity growth can be fueled for quite a while by

- a higher share of people becoming educated.
- a higher share of people becoming researchers.
- higher share of countries belonging to the group of fully advanced countries.

And in the veeeeery long-run?

- when all people are educated
- when almost all people are working in R&D
- when all people live in advanced countries

does economic growth stop?

Note:

- permanent population growth is no way out even if all people were born already as fully fledged researchers (Einsteins).
- because there cannot be population growth forever.

"[I]f the human race had sprung from a couple living in 10,000 BC and had grown since then, not at maximum biological rate but only at a modest 1 per cent per annum, the earth would now be a sphere of flesh several thousand light-years in diameter with a surface advancing into space at a rate many times faster than the rate at which light travels." (Marc Blaug)

Nevertheless there is a little hope for perpetual growth:

- Mankind might populate other galaxies.
- At least one good economic argument (who knows it?).

For the time being we take the current model (in its educated-people interpretation) as an approximative explanation for economic growth in the long-run.

General purpose technologies (GPT).

- So far we've modelled technological progress as incremental/continuous.
- Yet a handful of key innovations lead to a drastic change of economic history.
- They kind of "reset" the economy to grow in many or all of its sectors to a higher level.

Characteristics of a GPT

- pervasive (technology must spread to many sectors)
- scope for improvement over time (lowering the costs of its use)
- innovation spawning, i.e. it enables the production of new products.

Usually researchers consider as GPT

- waterwheel
- steam (railways)
- electricity (dynamo)
- motor vehicles
- IT (transistor)

And perhaps in the future: nano-technology.

(But not: the clock, movable type, gunpowder, DNA decoding. $\rightarrow$ why?)

When a new GPT arrives:

- non-monotonous adjustment process
- with an initial slump of productivity
  - replacement of old machines
  - workers are relocated from production to research.
- Some say the Productivity Slowdown can be explain by these dynamics in the wake of the IT revolution
  - Robert Solow (1987): We see the computer age everywhere but in the productivity statistics.
  - Others say it was the oil crises.

Differential technological progress.

In our aggregated model we don't see that technological progress affects sectors differently. Yet new technology may

1. replace an old technology (digital vs analog camera, record player)
2. may be complement to an old technology (IT in the car)

Observe:

- if technological progress is complementary its scope is in the end bounded by the non-growing parts/sectors
- goods of non-growing sectors become more expensive (e.g. oil, haircuts, lawyers)

More generally

- (up to now) technological progress affects mainly manufacturing (and agriculture).
- we spend more on services, the sector with low productivity growth.
- looks like there are complementarities at work.

2 Sectors with exceptionally low productivity growth (Baumol's cost disease):

- education
- government services

$\rightarrow$ Why?

A rephrasing of the crucial question: What happens when all people are employed

- in R&D
- and in the service sector?

Does growth stop?