Economic Growth

Lecture 8: Technological Progress and Efficiency

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Overview

- Models of endogenous growth
  - How is the level of innovation in a market economy determined?
  - Is the level of innovation in a market economy socially optimal?
  - Designed to analyze the economic growth in the advanced economies
- Role of efficiency in productivity

How is the level of innovation determined in a market economy?

The Romer Model

- Developed by Paul Romer
- Expanding-variety type of innovation
  - An innovation is an introduction of a new intermediate input in the market
  - E.g. introduction of phone, mobile phones, smart phones, foldable smart phones,...

The Schumpeterian model

- Insights of Joseph Schumpeter
  - Creative destruction: existing firms/technologies are replaced by new and better firms/technologies
- Developed by Aghion and Howitt (1992) and Grossman and Helpman (1991)
- Quality-ladder type of innovation:
  - Horse cart is replaced by Ford Model T, which is replaced by modern cars

- In both models to produce a new intermediate input, one needs to own the blueprints of production
  - Ownership of blueprints of productions brings in monopoly profits
- Blueprints are produced by researchers and sold to monopolists
  - Reason to do R&D

Determination of the fraction of labor force working in R&D

Return to innovation: expected discounted sum of future profits

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  - high discount rate means future consumption is valued less
  - the lower the value of future consumption, the lower the incentive to give up current consumption to have higher future consumption $\Rightarrow$ lower incentives to innovate

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- positively on the probability of innovation (+)
  - The higher the chance of a successful innovation, the higher the incentives to innovate
- negatively on the probability of innovation (−)
  - The higher the chance of being replaced by subsequent inventors, the lower the incentives to innovate
  - Notice that this motive is missing in the Romer model.

The fraction of labor force working in R&D and economic growth?

- Assuming the idea production is of the form: $\boxed{\dot{A} = \frac{(\gamma_A L)^\lambda}{\mu} A^\phi}$, where $0 < \phi < 1$. $\Rightarrow g_A \equiv \frac{\dot{A}}{A} = \frac{(\gamma_A L)^\lambda}{\mu} \frac{A^\phi}{A}$.
- An increase in γ_A leads higher rate of technological progress in the short-run, which leads to economic growth.
- Long-run growth rate is independent of the fraction of labor force engaging in innovation.
  - $\dot{A} = \frac{(\gamma_A L)^\lambda}{\mu} A^\phi \Rightarrow \boxed{\frac{\dot{A}}{A} = \frac{(\gamma_A L)^\lambda}{\mu} \frac{A^\phi}{A}} \Rightarrow \frac{1}{A^{1-\phi}}$
  - (+) Larger γ_A makes idea creation easier, and boosts economic growth
  - (-) Higher level A makes it harder to achieve same growth rate
  - Net effect: long-run growth rate of technology (and output per worker) is independent of the fraction of labor force engaging in innovation if $\phi < 1$
- In this regard, the analysis is similar to an increase in the investment rate in the Solow model.
- More on appendix

$100 + 2 \Rightarrow 2\%$

$200 + 4 \Rightarrow 2\%$

$1000 + 20 \Rightarrow 2\%$

Insights from the Romer model and the Schumpeterian model

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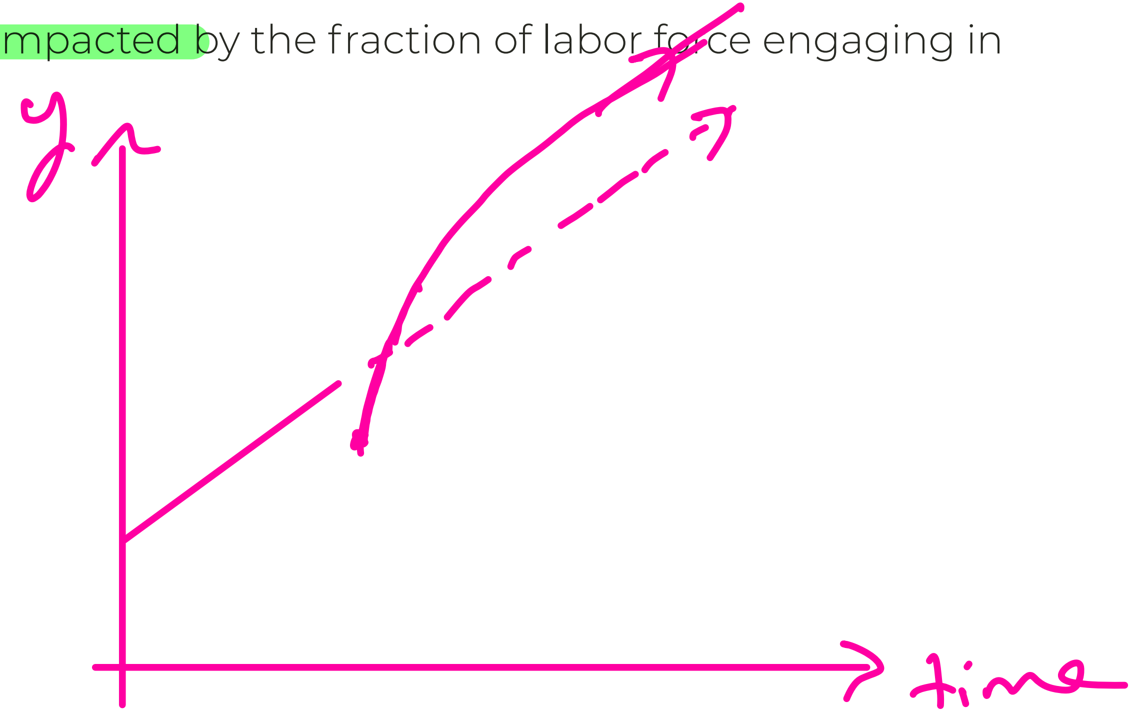

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  - Consistent with the empirical evidence.
- The level of income per capita in the long run is impacted by the fraction of labor force engaging in research
- A larger population size leads to higher levels of income per capita in the long-run. Due to non-rivalrous nature of ideas
  - Larger population, more inventors, higher levels of technology
  - Larger population, larger market for inventions, more inventors, higher levels of technology

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- Long-run economic growth rate is positively related to population growth rate
    - Higher population growth rate generates steady increase in the number of researchers
    - Higher rates of economic growth

Insights, cont'd

- Long-run economic growth rate is positively related to knowledge spillovers, ϕ
  - If current research benefits future researchers more, the economy can achieve higher economic growth rates
- If the discount rate applied to monopoly profits is large, the Schumpeterian model imply a larger fraction of labor force engaging in innovation
  - because relative importance of being replaced by others is small
- If the discount rate is relatively small, the Schumpeterian model imply a smaller fraction of labor force engaging in research
  - because people are sensitive to the future destruction of profits

Socially optimal R&D

Because of the externalities in the innovation process, competitive equilibrium R&D level is not socially optimal. Remember that $\dot{A} = \frac{L_A^\lambda}{\mu} A^\phi$

- if $\phi > 0$: "standing on shoulders"
  - Current researchers do not financially benefit from the positive impact of their inventions on the subsequent inventors
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- Consumer surplus effect
  - Private gain of an innovation = profit < Consumer surplus = Social gain
  - leads to under-invesment in R&D in the market economy

Socially optimal R&D, cont'd

- Also, specific to the Schumpeterian model:
  - Inventors steal markets from existing producers
  - *Business stealing effect:* Innovators do not internalize the cost they impose on incumbent producers
  - Leads to over-investment in innovation
- Overall,
  - markets under-invests in innovation
  - Lucking, Bloom, and Van Reenen (2018) estimate that, in the US
    -social returns to R&D in the United States are about 60 percent
    -private returns are about 15 percent
- Ground for government interference to correct for the externalities
- Anti-trust policy should take into account the contrasting effects of market power on the economu:
  - in standard markets, monopolies involve deadweight losses, hence inefficient
  - to provide incentive to innovate, markets need to be imperfect

Do interactions with other inventors boost innovation?

Watch this short video by Stefanie Stantcheva: Where does innovation come from?

Efficiency

Efficiency

Productivity = Technology × Efficiency

- Technology: Knowledge about how factors of production can be combined to produce output
- Efficiency: How effectively given technology and factors of production actually used
- Productivity is much lower in poor countries than in rich countries
  - Not obvious the only reason is a gap of technology
  - Many of the most advanced technologies are being used in poor countries

Types of Inefficiency

- Poor management practices
- Unproductive activities
- Idle resources
- Misallocation among sectors
- Misallocation among firms
- Technology blocking

Management practices

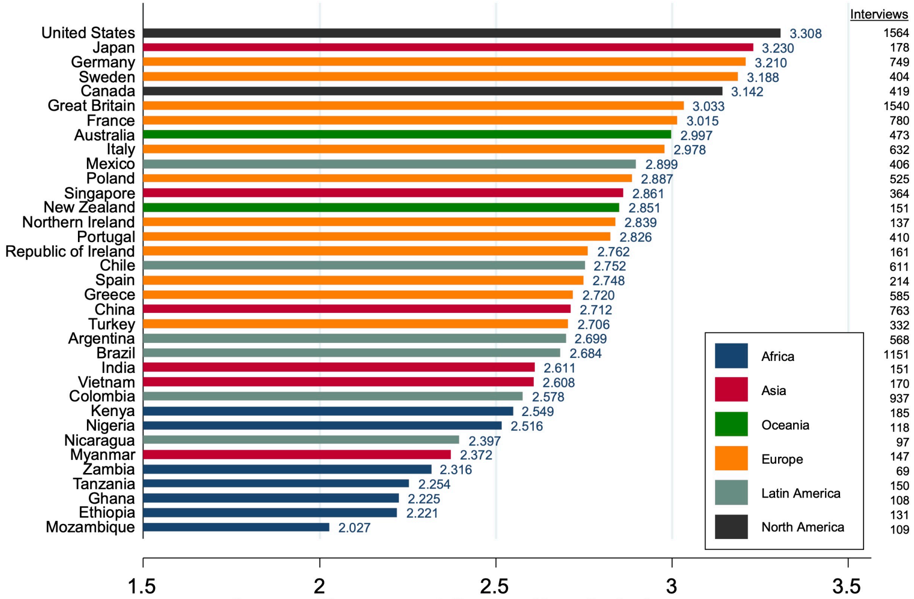
- World Management Survery (Bloom, Sadun, and Van Reenen (2017))
- Survey of thousands of managers across 40 countries
- Core management practices:
    - setting sensible targets
    - providing proper incentives
    - credibly monitoring performance
- Read the op-ed on the article
- Bloom, Lemos, Sadun, Scur, Van Reenen (2014):

> 'about a quarter of cross-country and within-country TFP gaps can be accounted for by management practices.'

Management quality and productivity

- Average management quality differs enormously across countries

Figure 1: Average Management Scores by Country

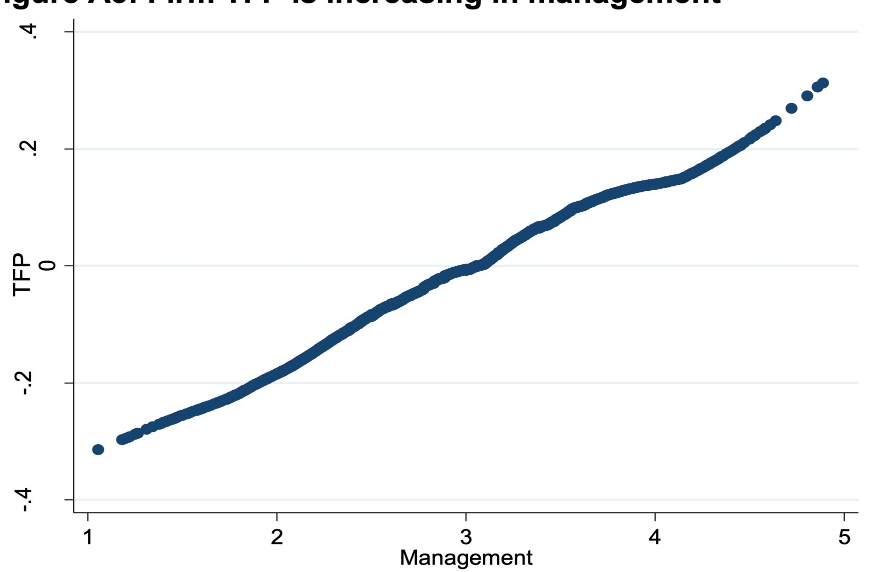


Average Management Scores, Manufacturing

Note: Unweighted average management scores; # interviews in right column (total = 15,489); all waves pooled (2004-2014)

- Firm level productivity and management quality are positively correlated

Figure A3: Firm TFP is increasing in management



Notes: This plots the lowess predicted valued of TFP against management (bandwidth=0.5). TFP calculated as residual of regression of ln(sales) on ln(capital) and ln(labor) plus a full set of 3 digit industry, country and year dummies controls. N = 10,900.

Source: Bloom, Sadun, and Van Reenen (2017)

Unproductive Activities

- Illegal activities: theft, smuggling, kidnapping for ransom, ..
- Rent seeking: involve the use of laws or government institutions to bring private benefits
  - Economic rent: payment to a factor of production in excess of what is required to elicit the supply of that factor
  - E.g.: quotas to limit the imports of some goods, lobbying, …
  - Costs: a good deal of effort, bright people work in unproductive activities

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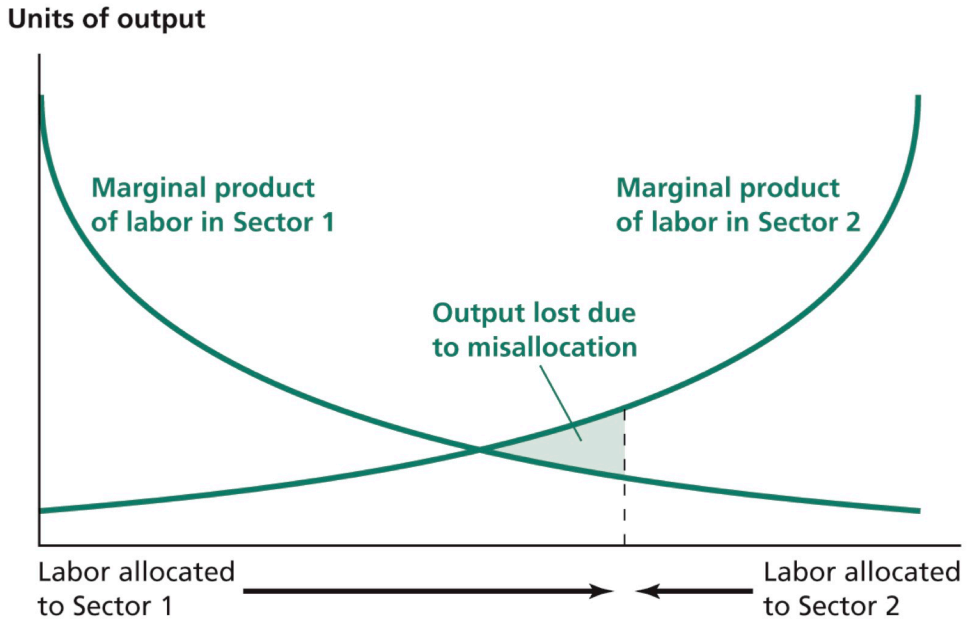
Idle Resources

- Factors of production not used at all
- Unemployment, underemployment
- Factory that sits unused
- Factory running at less than full capacity
- Example: In 2001,
  - Air Afrique: 500 employees per airplane,
  - EasyJet: 66 employees per airplane
- Example: *Firemen* employed in diesel engines of the United States and Canada railroads during the middle of the 20th century

Misallocation Among Sectors

Misallocation among sectors: marginal product of inputs are not equal across sectors

- barriers to mobility
    - geographical isolation
    - wage policy: e.g. sectoral minimum wage
    - market segmentation: potentially productive people are unable to work in certain sectors (due to licensing requirements for example)
    - tax rate differences across industries
- wages $\neq$ marginal product of labor



Graphic from: Weil (2013)

Efficiency Gains from Sectoral Reallocation

Reallocation from agriculture to manufacturing

- Taiwan: 0.7% of 5.4% annual growth over 1966-1991
- Korea: 0.7% of 5.7% annual growth over 1960-1990
- US: fraction of agricultural labor decreased from 50% to 3% over 1880-1980
- China: fraction of agricultural labor decreased from 69% to 40% over 1980-2009

Misallocation Among Firms

Misallocation among firms: marginal product of inputs are not equal across firms

- government-owned firms over-employ: political power
- monopolies under-employ: monopolistic profit
- financial frictions prevent efficient allocation of capital
- discrimination
    - preventing many talented women, ethnic minorities, and others from working on jobs that better suits their talents.

Technology Blocking

Agents deliberately prevent the use of technology

- Gutenberg's printing press (1453): scribes
- automated weaving loom (19th century): Luddites
- margarine (late 19th century): dairy farmers
- Netscape browser: Microsoft

Isn't technological progress beneficial to the economy?

- creative destruction and technology blocking
  - the success of technology blocking depends on the relative power of the opposer/supporter

"Not everyone benefits from technological advances."

Source: Kaamran Hafeez, the New Yorker

Summary

- Analyzed the motives of innovation
- Analyzed externalities in the innovation process, and justified the role of government intervention
- Looked at the role of efficiency in productivity

To review our lectures (lectures 7 and 8) on technology and efficiency

Read

- Chapters 4 and 5 of Introduction to Economic Growth by Jones and Vollrath
- Mathematical appendix to Chapter 9 of Economic Growth by David Weil
- Chapter 10 of Economic Growth by David Weil

Appendix

Long-run growth rate

- How do we calculate long-run economic growth if $\dot{A} = \frac{L_A^\lambda}{\mu} A^\phi$?
- Growth rate of A, $g_A \equiv \frac{\dot{A}}{A} = \frac{(\gamma_A L)^\lambda}{\mu} A^{\phi-1} = \frac{(\gamma_A L)^\lambda}{\mu A^{1-\phi}}$
- For g_A to be constant in the long run, $(\gamma_A L)^\lambda$ and $\mu A^{1-\phi}$ should grow at the same rate.
- Growth rate of $(\gamma_A L)^\lambda$ is λn, where n is the population growth rate.
- Growth rate of $\mu A^{1-\phi}$ is equal to $(1-\phi) g_A$
- $(1-\phi) g_A = \lambda n$
- Growth rate of technology: $g_A = \frac{\lambda n}{(1-\phi)}$ if $\phi < 1$.
- g_A is positively correlated with λ, n, and ϕ

$g(D^x) = x g_D$

Determinants of productivity growth in the long run

In the long-run: $g_A = \frac{\lambda n}{(1-\phi)}$

To understand the intuition, suppose $\lambda = 1$ and $\phi = 0$

Then $g_A = \frac{(\gamma_A L)}{\mu} \frac{1}{A}$ all the time, $g_A = n$ in the long run

- If population does not grow, g_A will converge to 0
  - Recall $\dot{A} = \frac{\gamma_A L}{\mu}$ if $\lambda = 1$ and $\phi = 0$

$$\frac{2}{100}$$

- Hence the only source of growth is from population growth
- $g_A = n$ if $\lambda = 1$ and $\phi = 0$
- Larger population generates more ideas
- Since ideas are non-rivalrous, everyone benefits

Determinants of productivity growth in the long run, cont'd

$$\frac{\dot{A}}{A} = \frac{(\gamma_A L)}{\mu} \frac{A}{A}$$

- Now suppose $\lambda = 1$ and $\phi = 1$
- Then, $g_A = \frac{(\gamma_A L)}{\mu} \frac{A}{A} = \frac{(\gamma_A L)}{\mu}$ all the time
- Notice that this formulation is equivalent to our assumption in the last lecture
- We see sustained growth even if research effor is contant, i.e. even if $\gamma_A L$ is constant.
- Rejected by the data

$\phi < 1$

Determinants of productivity growth in the long run, cont'd (2)

$100 + 2 \Rightarrow 2\%$

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If $\phi > 0$ but $\phi < 1$:

- still positive spillovers from research

$g_A = \frac{(\gamma_A L)^\lambda}{\mu} \frac{A^\phi}{A}$ all the time

g_A at the steady state (or balanced growth path): $g_A = \frac{\lambda n}{(1-\phi)}$

- Unaffected by the fraction of population engaging in R&D
  - Intuitively, higher γ_A leads to higher $\hat{A}$ in the short run
  - In the long-run, because of diminishing marginal product of idea stock in idea creation, γ_A does not affect the long-run economic growth.

However, short-run growth rate of productivity is a still function of fraction of labor force engaging in R&D.

Income per capita in the long run

- Fraction of labor force engaging in R&D impacts income per capita
  - Positively: high level of productivity in the long run
  - Negatively: smaller fraction of workers in the production
- Size of labor force, $L(t)$, impacts income per capita positively (**scale effect**):
  - **demand effect:** $L \uparrow \Rightarrow$ larger market for an idea $\Rightarrow \uparrow$ return to research
  - **supply effect:** $L \uparrow \Rightarrow$ more potential creators of ideas