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Economics of Innovation

Lecture 7 –
Labor market effects of innovation

http://www.economics-of-innovation.com

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Agenda for today

1. Does technological progress create or destroy jobs?
2. Does technological progress change the type and quality of jobs?

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Innovations: Creation or destruction of jobs?

- Depends on time period
  - Long run
    - Technological progress is *very good news* for workers
    - Trend has been towards simultaneous growth in per capita income, wages, productivity, number and quality of jobs
  - Medium run
    - Technological change can be good or bad news for workers – potential for conflict in the medium run
    - Structural change within and across industry sectors
  - Short run
    - Technological progress, labor productivity, employment and wages are pro-cyclical:
      - Positive joint development during booms
      - Negative joint development during recessions

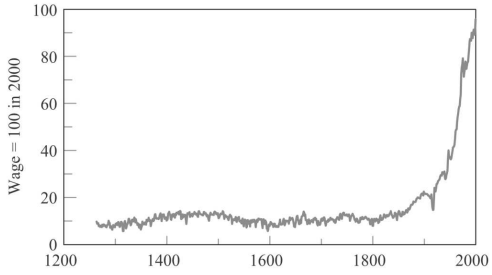
Long run – number of jobs

- Long run supply of labor is price-inelastic and restricted by number of workers
  - Population size and growth
  - Age distribution, health conditions
  - Labor force participation (e.g. women)
- Technological progress does not influence workforce size directly…
  - …but it can have an indirect influence through the factors above (e.g. medicine, contraception, nutrition)
    - Maybe positive feedback loop: population size and (modest) population growth might influence technological progress positively
      - Semi-endogenous and endogenous growth models
      - Again, good news for workers

Long run – wage development

- Growth theory:
  - Wages positively depend on technological change
    - Implies wages are highest in countries that are technologically most advanced (highest labor productivity) - strong empirical support
  - Influence of population growth on wage:
    - Negative in exogenous growth models (Solow 1957)
    - In semi- and endogenous growth models, the negative effect of a growing labor force on wages is compensated by the positive effect on technological progress (more ideas)
      - Mixed empirical evidence, depending on countries and time periods studied
- Technological progress is the single most important determinant of growing real wages in the long run!

Real wage in London, 1200-2000

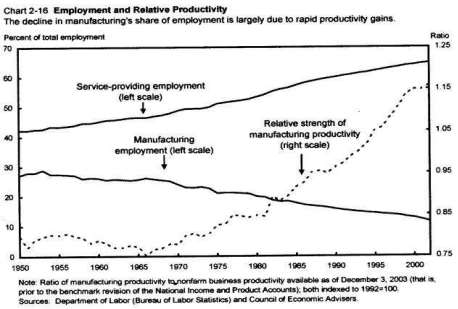


Sources: The New Palgrave Dictionary of Economics online. Data before 1914: Allen (2001).
Later wage and price indices: Phelps Brown and Hopkins (1955), Mitchell (1998), ILO (various years)

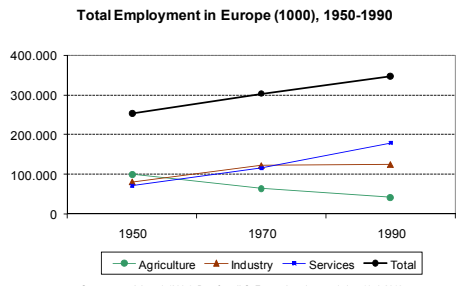
Medium run

- Structural change
  - Redistribution of economic activity
    - Decreasing shares of labor in agriculture
    - Developed countries: also decreasing share in manufacturing, increase in services
- "Creative destruction"
- Technological and frictional unemployment possible
  - Possibility of job-less productivity growth in the medium run

Medium run structural changes

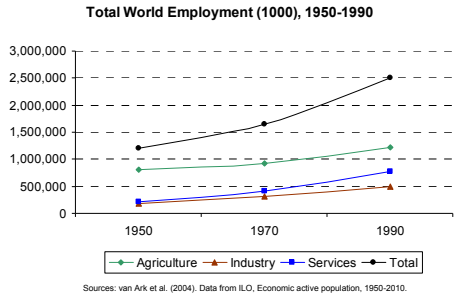


Sectoral distribution of employment in Europe



Sources: van Ark et al. (2004). Data from ILO, Economic active population, 1950-2010.

Sectoral distribution of employment in the world



Sources: van Ark et al. (2004). Data from ILO, Economic active population, 1950-2010.

Medium run sources of structural change

- Innovations can have two effects on labor demand:
  - Compensation effect: Increase in production leads to increasing demand for labor
  - Substitution effect: Production becomes more capital intensive, substituting for labor; or – replacement of other products
  - Most innovations have more or less both effects
- Net-effect depends on type of technology / innovation and demand conditions
  - Some technologies are labor-substituting (e.g. machine production), others are labor-augmenting (e.g. statisticians and computers)
  - Growing consumer demand for end product favors compensation effect

Medium run employment effect of different innovation types

- Product innovation:
  - Creation of new markets, new demand
  - Compensation effect usually stronger than substitution effect, resulting often in net employment gains at firm & industry level
- Process innovation:
  - More (of the same) output can be produced with less inputs
  - Substitution effect usually stronger than compensation effect, often resulting in net employment losses at firm & industry level
- Investment products can be product innovation in one sector, but process innovation in others
  - Net employment effect at the aggregate level depends on the effect across all sectors (e.g. machinery, ICT)

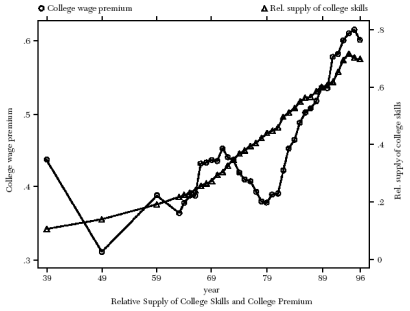
Medium run structural change

- Firms and sectors with rapid product innovations tend to grow fast and generate employment
  - R&D intensive manufacturing, e.g. pharma, electronics, ICT production, biotechnology
  - Knowledge intensive service sectors, e.g. consulting, telecommunications, media, Internet-content and -services
- Firms and sectors that focus on process innovations tend to stagnate or grow slowly and reduce employment
  - Agriculture
  - Low technology manufacturing, e.g. food processing, paper, basic metals, tobacco
- Over time, employment shifts toward growth sectors & firms

Does technological progress change the type and quality of jobs?

- Majority of empirical evidence suggests – yes, it does!
- Recent findings suggest that technical change, in particular ICT:
  - favors more skilled workers
  - replaces tasks previously performed by the unskilled
  - increases income inequality
- This pattern can be found within and across countries, industries and firms (in varying degrees)
- ICT is complementary to skilled labor & innovation
  - Interactions of the three increase firm productivity
  - As ICT gets cheaper and more powerful, it induces more and more complementary investments into skilled labor and innovation (Bresnahan, Brynjolfsson and Hitt 2002)

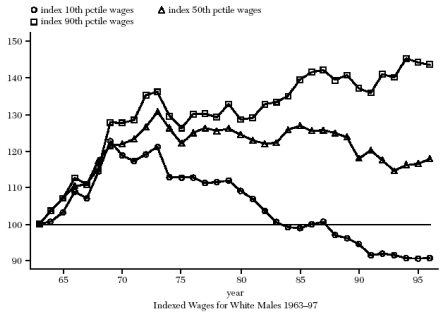
Supply and wage premium of high skill workers, USA 1939-1996



Relative Supply of College Skills and College Premium

Source: Acemoglu (2002). The Behavior of the (log) College Premium and Relative Supply of College Skills (weeks worked by college equivalents divided by weeks of noncollege equivalents).

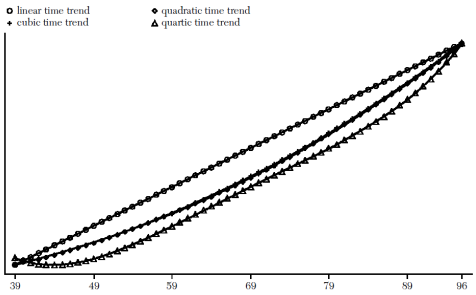
Growing wage gap, USA 1963-1996



Indexed Wages for White Males 1963-97

Source: Acemoglu (2002). Changes in the Indexed Value of the 90th, 50th, and 10th Percentiles of the Wage Distribution for White Males (1963 values normalized to 100).

Increasing relative demand for skills



Alternative Time Trends for the Relative Demand for Skills

Source: Acemoglu (2002). Estimates of Time Trends from Regressions of ln ω on ln (*H/L*), *year*, *year*^{2}, *year*^{3} and *year*^{4} between 1939 and 1996 in the US. Data from censuses and March CPSs.

Theory of skill premia – 1

- Acemoglu (2002): compulsory reading
  - There are two types of workers, *high skill* and *low skill*
    - Types are imperfect substitutes
  - Production function for the aggregate economy is
    $$Y(t) = \left[\left(A_l(t) L(t) \right)^{\rho} + \left(A_h(t) H(t) \right)^{\rho} \right]^{1/\rho}$$
    - $L(t)$ – low skill workers
    - $H(t)$ – high skill workers
    - $A_l(t)$ and $A_h(t)$ are factor augmenting technology terms
    - Elasticity of substitution between workers is $\sigma \equiv 1/(1-\rho)$
    - $\sigma > 1$ implies gross substitutes (empirical evidence for this!)
    - $\sigma < 1$ implies gross complements
    - $\sigma \to 0$ implies perfect complements (Leontief)
  - Labor markets are assumed to be perfectly competitive

Theory of skill premia – 2

- Unskilled wages: $w_L = \frac{\partial Y}{\partial L} = A_l^{\rho}\left[A_l^{\rho} + A_h^{\rho}(H/L)^{\rho}\right]^{(1-\rho)/\rho}$
- Skilled wages: $w_H = \frac{\partial Y}{\partial H} = A_h^{\rho}\left[A_l^{\rho}(H/L)^{-\rho} + A_h^{\rho}\right]^{(1-\rho)/\rho}$
- Wage premium: $\omega = \frac{w_H}{w_L} = \left(\frac{A_h}{A_l}\right)^{\rho}\left(\frac{H}{L}\right)^{-(1-\rho)} = \left(\frac{A_h}{A_l}\right)^{(\sigma-1)/\sigma}\left(\frac{H}{L}\right)^{-1/\sigma}$
- Premium in logs: $\ln\omega = \frac{\sigma-1}{\sigma}\ln\left(\frac{A_h}{A_l}\right) - \frac{1}{\sigma}\ln\left(\frac{H}{L}\right)$
- Skill premium increases when skilled workers get scarce:

$$\frac{\partial \ln\omega}{\partial \ln H/L} = -\frac{1}{\sigma} < 0 \mid \sigma > 0$$

Theory of skill premia – 3

- Changes of the skill premium in response to exogenous skill-biased technological change:

$$\frac{\partial \ln\omega}{\partial \ln(A_h/A_l)} = \frac{\sigma-1}{\sigma}$$

- Therefore, if $\sigma > 1$ (i.e. $\rho \in (0,1]$), improvements in the skill-complementary technology increase the skill premium
  - Corresponds to outward shift of relative demand function

The relative demand for skills with *exogenous* technological change

 Source: Acemoglu (2002).

Historical perspective

- Has technology *always* favored high skill workers? – No!
  - In the early periods of the Industrial Revolution, machines were replacing skilled workers.
  - "Deskilling" was a major purpose of technical change, by dividing and simplifying tasks that could be performed by more abundant low-skilled labor
    - In England: Increasing supply of unskilled labor in cities resulting from migration from rural areas and Ireland, similar patterns in other countries
    - Highly skilled artisans lost their businesses and were replaced by factories employing cheap, unskilled labor (e.g. weaving, spinning)
    - One result: Luddite movement, machine breaking and riots throughout Europe

Towards endogenous technological change

- Why was demand for skills rapidly decreasing in the 19th century, but rapidly increasing in the 20th?
  - Randomly shifting directions in technological development?
- Endogenous technological change:
  - Innovation incentives to develop new production technologies depend on market size (i.e. relative supply of labor skills)
  - Schmookler's (1966) demand pull hypothesis
    - Increase in relative supply of low skill workers makes development of skill-replacing technologies more attractive (19th century)
    - Increase in relative supply of high skill workers has opposite effect, leading to skill-biased technological change (20th century)
  - Innovation takes time – new technologies arrive only after a significant time lag

Theory of skill premia with endogenous technological change – 1

- We can think of the aggregate production function as representing an economy that produces two goods; one using only high skill, the other using only low skill labor
- Consumers have utility: $Y = \left[Y_l^{\rho} + Y_h^{\rho}\right]^{1/\rho}$
- Production is given by: $Y_h = N_h H$ and $Y_l = N_l L$
  - N_h number of specialized machines used by high skill workers
  - N_l number of specialized machines used by low skill workers
- A relative increase in machines for high skill workers will (as above) correspond to higher skill premia as long as $\sigma = 1/(1-\rho) > 1$

Theory of skill premia with endogenous technological change – 2

- From consumer maximization, the relative price of skill-intensive goods is:

$$p \equiv \frac{p_h}{p_l} = \left[\frac{N_h H}{N_l L}\right]^{\rho-1}$$

- Suppose machines are created and sold by profit-maximizing monopolies
  - Innovation of machines is costly, but once created, marginal production costs are assumed to be zero
  - Marginal willingness to pay for additional machine in the two sectors is given by:

$$\frac{\partial(p_h Y_h)}{\partial N_h} = p_h H \quad \text{and} \quad \frac{\partial(p_l Y_l)}{\partial N_l} = p_l L$$

Theory of skill premia with endogenous technological change – 3

- Hence, there are two effects:
  1. Price effect: technologies producing the more expensive goods will be improved faster. Since goods using the scarce factor will command a higher price, more innovation will be directed at the scarce factor (e.g. low-skilled workers during 1970's)
  2. Market size effect: a larger clientele for a technology leads to more innovation. Since the clientele for a technology is the number of workers who use it, the market size effect encourages innovation for the more abundant factor (e.g. high-skilled workers during 1970's)
- Creation of new machines will stop when the marginal increase in profits is equal to marginal cost of innovation in both sectors. In equilibrium: $\frac{p_h H}{p_l L} = 1$

Theory of skill premia with endogenous technological change – 4

- In equilibrium, the market size and price effects have to be balanced: $\frac{p_h H}{p_l L} = 1$
- This can only happen if N_h / N_l and $p = p_h / p_l$ adjust
- Combining terms we get: $\frac{N_h}{N_l} = \frac{A_h}{A_l} = \left(\frac{H}{L}\right)^{\rho/(1-\rho)}$
- Hence, when $\rho > 0$, the market size effect will dominate the price effect, and a greater relative supply of skilled workers will lead to more skill-biased technologies, higher N_h / N_l

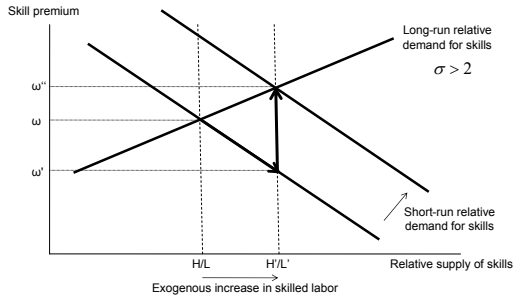
Theory of skill premia with endogenous technological change – 5

- Finally, the skill premium in the economy is (by substituting equations):

$$\omega = \frac{p_h N_h}{p_l N_l} = \left(\frac{H}{L}\right)^{(2\rho-1)/(1-\rho)} = \left(\frac{H}{L}\right)^{\sigma-2}$$

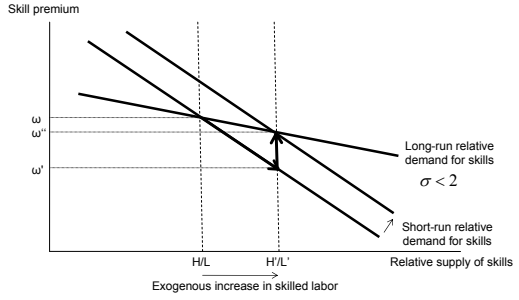
- Hence, as long as $\rho > 1/2$ (i.e. $\sigma > 2$), the skill premium will be an *increasing* function of the relative supply of skills

The relative demand for skills with *endogenous* technological change



 Source: Acemoglu (2002).

The relative demand for skills with *limited endogenous* technological change



 Source: Acemoglu (2002).

Additional factors leading to growing skill premium

- Organizational change
  - If productivity of high-skilled workers increases, it becomes more profitable for them to work in a separate organization rather than together with low-skilled workers
- Deunionization
  - Unions tend to suppress the skill premium
  - Skill-biased technical change makes wage compression more costly for skilled workers, eventually destroying the coalition with unskilled workers
- Trade with LDC
  - Can induce skill-biased technical change in DC
- All factors can reinforce each other

Summary

- Technological progress causes increases in real wages in the long run
- In the medium run, there can be adverse effects
  - Jobless productivity growth
  - Frictional unemployment due to structural change
- In the last decades, we have witnessed skill-biased technological change
  - Increasing supply and, with a lag, also increasing demand for skills
  - Increasing wage gap between skilled and unskilled workers, leading to higher inequality