Skills, Tasks and Technologies: Implications for Employment and Earnings

Daron Acemoglu, David Autor
Handbook of Labor Economics (2011)

Motivation

Canonical **skill-biased** technical change model

two skill groups produce two goods, technology is factor-augmenting

Explains the long-run comovement of the college wage premium and relative college labor supply

Silent on

1. Falling real wages for low-skill men
2. Non-monotone wage-growth across quantiles
3. Job polarisation: rising employment shares at the top and bottom
4. Rapid diffusion of ICT that directly substitutes capital for routine tasks
5. Offshoring of routine tasks to low-wage countries

Re-allocation of tasks within occupations & to machines and foreign labor

task: a unit of work activity that produces output

skill: a worker's endowment of capabilities for performing various tasks

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From "What does technology do to **skills**?" to "What does technology do to **tasks**?"

Q: How does technology affect the mapping from skills to work and the distribution of earning?

A Ricardian task model of endogenous **skill-task** assignment

Allows **heterogeneity** in skills within education groups

Relates to the literature on

- Technology-driven demand for skills (Goldin and Katz (2008), Autor, Levy, Murnane (2003))
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Roadmap

- Labor market trends
- Canonical model
- New model
  - without machines
  - with machines
  - offshoring
  - endogenous technical change
- Empirical analysis

empirical facts

Race between supply and demand

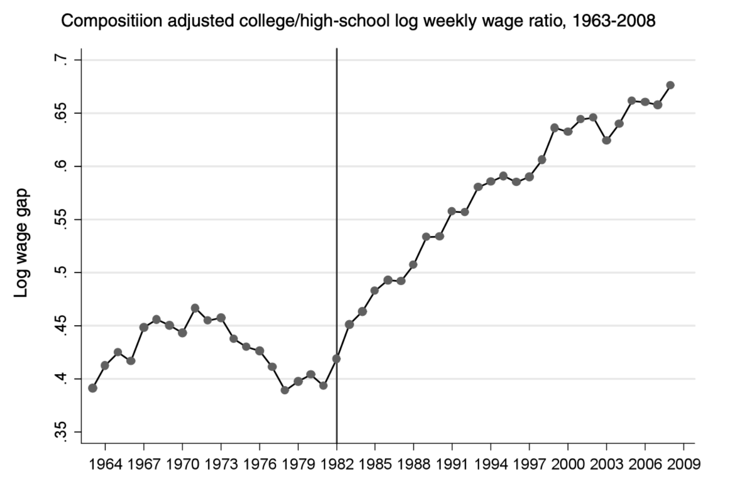

Figure 1: College/high-school wage premium, 1963-2008.
Source: the March Current Population Survey.

Race between supply and demand

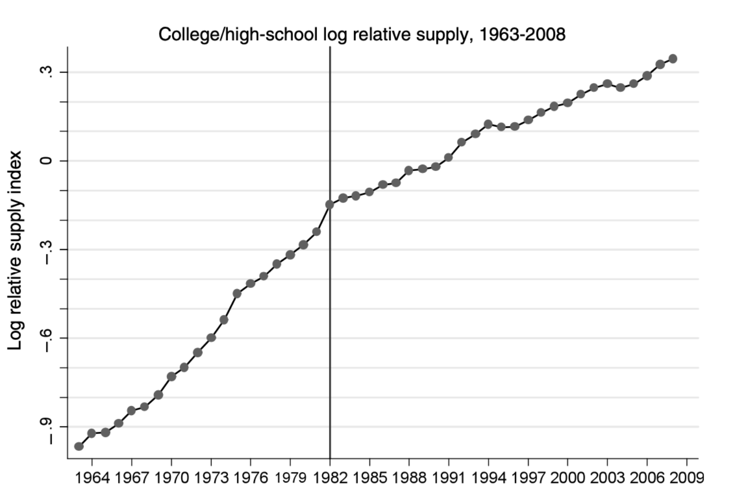

Figure 2: Relative supply of college labor.
Source: the March Current Population Survey.

Wage growth polarization

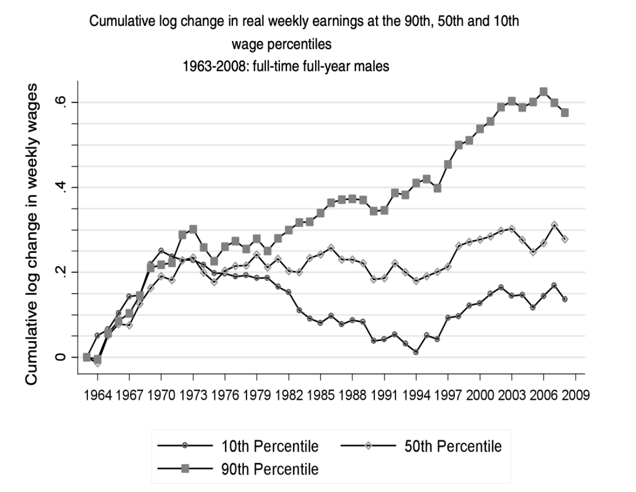

Figure 3: Real wages at 10th, 50th, 90th percentiles, males. Source: the March Current Population Survey.

Wage growth polarization

Figure 4: U-shaped growth of male hourly wages in 1988-2008.
Source: Current Population Survey May and Outgoing Rotation Group samples.

Job polarization

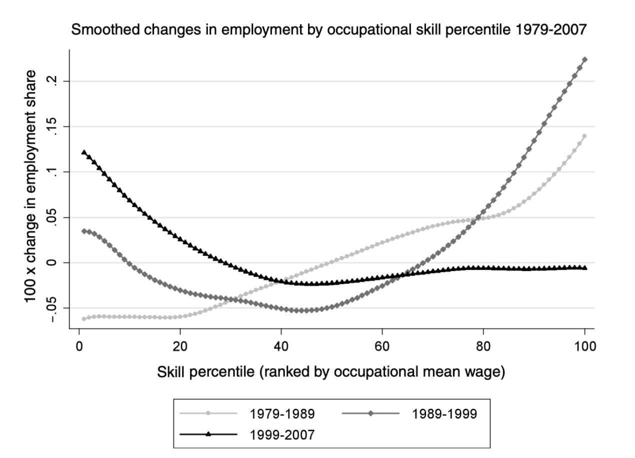

Figure 5: Change in employment by occupational skill percentile (1979-2007). Source: Census.

Job polarization

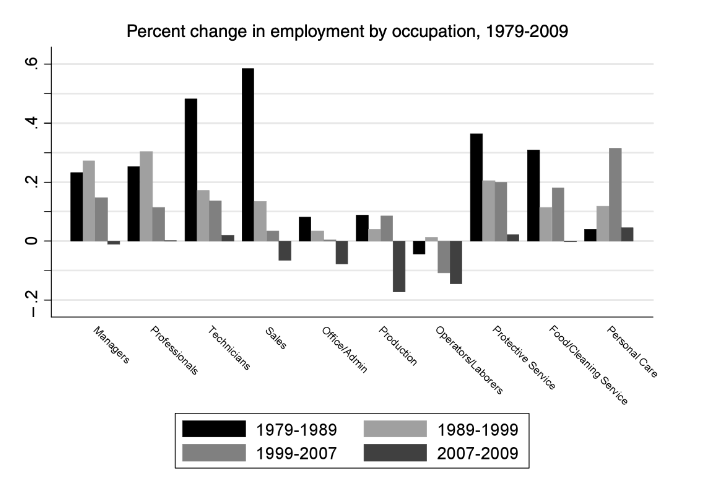

Figure 6: Decadal employment growth in 10 major US occupations.
Source: Current Population Survey May and Outgoing Rotation Group samples.

Job polarization

Category	Manag. / Profes.	Sales / Admin.	Production	Services
Task Type	Non-routine Cognitive	Routine Cognitive	Routine Manual	Non-routine Manual
Employm. Trend	$\uparrow$	$=\downarrow$	$=\downarrow$	$\uparrow$

Table 1: Specialization and employment dynamics in four broad occupational categories.

Similar trend in EU (10 countries) from 1992 through 2008

Testing for changes in **industry structure**:

$$\Delta E_{jt} = \sum \Delta E_{kt} \lambda_{jk} + \sum \Delta \lambda_{jkt} E_k \equiv \Delta E_t^B + \Delta E_t^W$$

1979-2007: employment trends are mainly **within-industry**

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The rising role of occupations/tasks in determining earnings

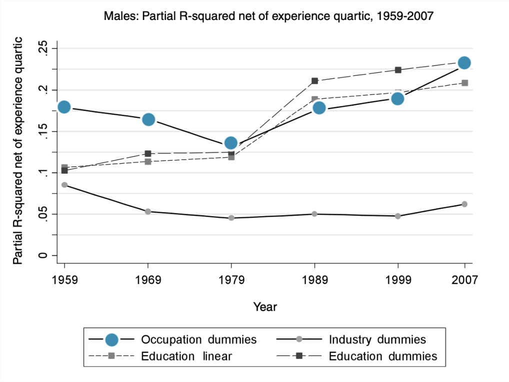

Figure 7: Partial R^2 of education vs occupation vs industry in wage regressions, 1959-2007: males

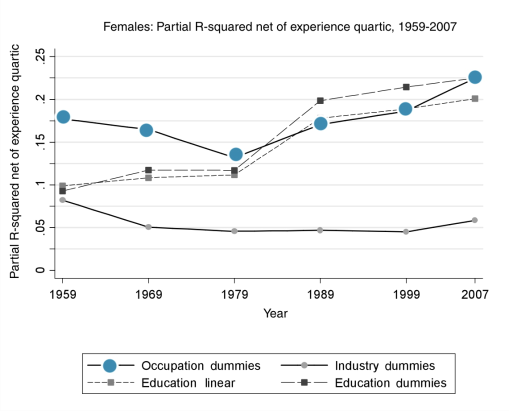

Figure 8: females

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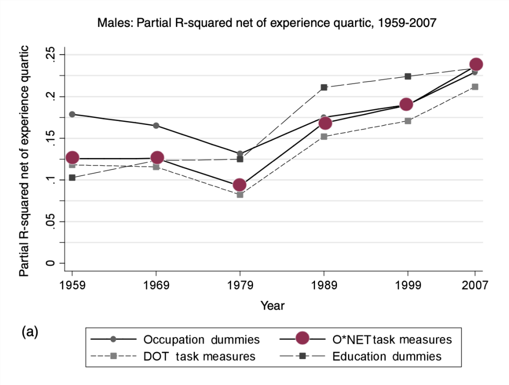

Figure 9: Partial R^2 of direct task measures (O*NET) vs occupation/education: males

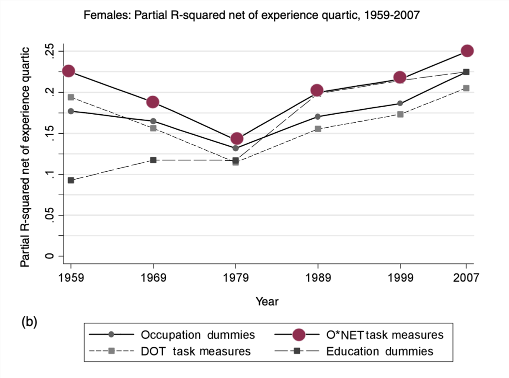

Figure 10: females

old model

Canonical model

Tinbergen's (1974, 1975) "race":

- 2 skill types: H and L, skills = education
- Imperfect substitutes in production
- Heterogeneity within skill type: l_i for $i \in \mathcal{L}$, h_i for $i \in \mathcal{H}$
- Aggregation: $L = \int_{i \in \mathcal{L}} l_i \, \mathrm{d}i$ and $H = \int_{i \in \mathcal{H}} h_i \, \mathrm{d}i$.
- Production: $Y = \left[(A_L L)^{\frac{\sigma-1}{\sigma}} + (A_H H)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$, technology is **factor-augmenting**
- Log **skill premium**:

$$\ln \omega = \ln\left(\frac{w_H}{w_L}\right) = \frac{\sigma - 1}{\sigma} \underbrace{\ln\left(\frac{A_H}{A_L}\right)}_{\text{technology skill bias}} - \frac{1}{\sigma} \underbrace{\ln\left(\frac{H}{L}\right)}_{\text{skills supply}}$$

$\frac{H}{L} \uparrow \longrightarrow \omega \downarrow$

for $\sigma > 1$ $\frac{A_H}{A_L} \uparrow \longrightarrow \omega \uparrow$

Canonical model

Assuming $\ln\left(\frac{A_{H,t}}{A_{L,t}}\right) = \gamma_0 + \gamma_1 t$

$$\ln \omega = \frac{\sigma - 1}{\sigma}\gamma_0 + \frac{\sigma - 1}{\sigma}\gamma_1 t - \frac{1}{\sigma}\ln\left(\frac{H_t}{L_t}\right)$$

Race between technolog. development and college expansion

Katz and Murphy (1992), relative college/high school wages and supply 1963-1987:

$$\ln \omega_t = \text{ constant } + \underset{(0.005)}{0.027} \cdot t - \underset{(0.128)}{0.612} \cdot \ln\left(\frac{H_t}{L_t}\right).$$

$\Rightarrow$ the elast. of subst. b/w college/non-college 1.6

an annual increase of 2.7% in the relative demand for college labor

Canonical model

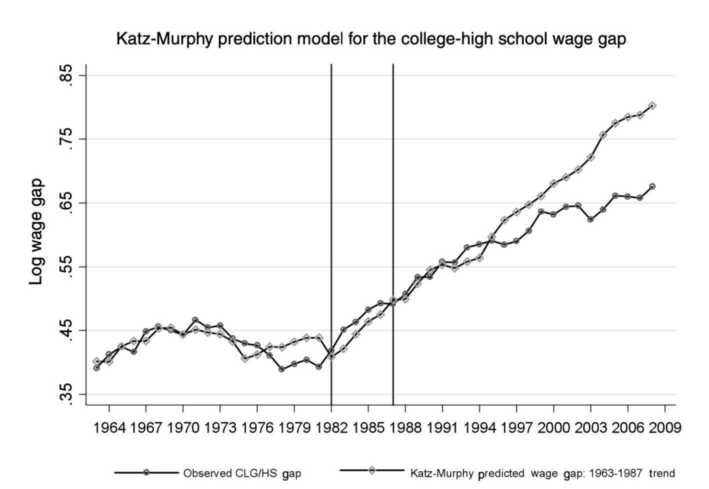

Figure 11: Out-of-sample performance of the Katz–Murphy canonical model.
Source: the March Current Population Survey.

Canonical model

Shortcomings:

- doesn't generate time-varying within-group inequality
- doesn't generate real wage decreases
- skill biased technical change is not a steady process
- doesn't allow for skill replacing technologies
- exog. technology

new model

A Ricardian task-based model

A generalization of Acemoglu and Zilibotti (2001).

Environment:

Tasks $\sim [0,1]$

Final good production function: $Y = \exp\left[\int_0^1 \ln y(i) \mathrm{d}i\right]$

All markets are perfectly competitive

3 factors of production: H, M, L–skilled workers in fixed inelastic supply

Task production function:

$$y(i) = A_L \alpha_L(i) l(i) + A_M \alpha_M(i) m(i) + A_H \alpha_H(i) h(i)$$

where A_j is a skill j biased technology,

$\alpha_j(i)$ is a skill type j productivity for task i,

l, m, h are the number of workers of each type

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A Ricardian task-based model

Equilibrium:

Assump.: $\alpha_L(i)/\alpha_M(i)$ and $\alpha_M(i)/\alpha_H(i)$ are continuously differentiable and **strictly decreasing**

Any eqm is **separating**: $\exists I_L, I_H$, $0 < I_L < I_H < 1$, s.t. $\forall i < I_L$ are performed by L-skilled workers, $I_L < i < I_H$ by M–skilled workers, $i > I_H$ by H–skilled workers.

The **law of one price** for skills:

$$\begin{aligned}
w_L &= p(i)A_L\alpha_L(i) \quad \forall i < I_L & \qquad p(i)\alpha_L(i) = p(i')\alpha_L(i') \equiv P_L \\
w_M &= p(i)A_M\alpha_M(i) \quad \forall I_L < i < I_H & \qquad p(i)\alpha_M(i) = p(i')\alpha_M(i') \equiv P_M \\
w_H &= p(i)A_H\alpha_H(i) \quad \forall i > I_H & \qquad p(i)\alpha_H(i) = p(i')\alpha_H(i') \equiv P_H
\end{aligned}$$

From final good cost minim.: $p(i)y(i) = p(i')y(i') \; \forall i, i'$

For $i, i' \in [0, I_L)$, $p(i)\cancel{A_L}\alpha_L(i)l(i) = p(i')\cancel{A_L}\alpha_L(i')l(i') \; \forall i, i' \;\Rightarrow\; l(i) = l(i') = \dfrac{L}{I_L}$

for $i \in (I_L, I_H)$, $l(i) = \dfrac{M}{I_H - I_L}$; for $i \in (I_H, 1]$, $l(i) = \dfrac{H}{1 - I_H}$

A Ricardian task-based model

Equilibrium (cont.):

Cost-minim. for H and M skills:

$$p(i)A_M\alpha_M(i)m(i) = p(i')A_H\alpha_H(i')h(i') \;\Rightarrow\; \frac{P_M A_M M}{I_H - I_L} = \frac{P_H A_H H}{1 - I_H}$$

Cutoff indiff. condit:

$$\text{b/w } L \text{ and } M: \quad A_L\alpha_L(I_L)l(I_L) = A_M\alpha_M(I_L)m(I_L) \;\Rightarrow\; \frac{A_L\alpha_L(I_L)L}{I_L} = \frac{A_M\alpha_M(I_L)M}{I_H - I_L}$$

$$\text{b/w } M \text{ and } H: \quad \frac{A_M\alpha_M(I_H)M}{I_H - I_L} = \frac{A_H\alpha_H(I_H)H}{1 - I_H}$$

$$\Rightarrow \; I_L, I_H$$

Eqm. wages:

$$\frac{w_H}{w_M} = \frac{P_H A_H}{P_M A_M} = \frac{M}{H}\frac{1 - I_H}{I_H - I_L} \qquad \frac{w_M}{w_L} = \frac{L}{M}\frac{I_H - I_L}{I_L}$$

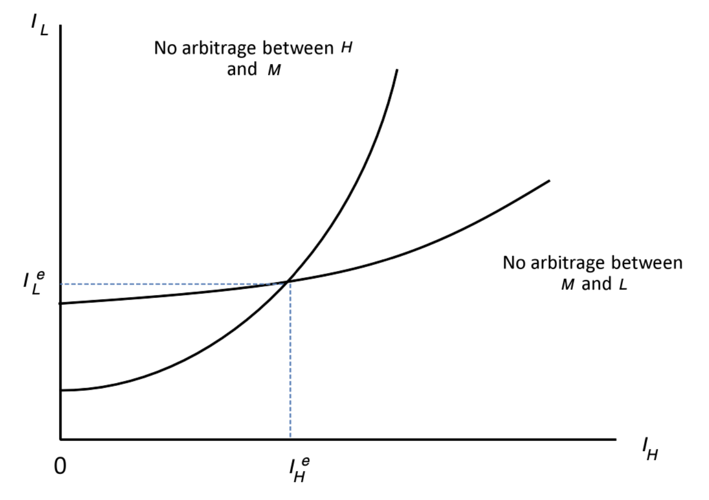

Figure 12: Equilibrium threshold tasks.

Comparative statics

The response of **task allocation** to technology and skill supplies:

$$A_H \uparrow \to \; I_L, I_H \downarrow$$

$$H \uparrow \to \; I_L, I_H \downarrow$$

indirect effect on L-skilled workers

the **substitution** of skills across tasks

The response of **relative wages** to skill supplies:

$$H \uparrow \to \; \frac{w_H}{w_L} \downarrow, \frac{w_H}{w_M} \downarrow, \qquad \text{sim. for } L, \qquad M \uparrow \to \; \frac{w_H}{w_L} \uparrow\downarrow \text{ (depends on comp. advant.)}$$

The response of **relative wages** to technology:

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empirical analysis

Wage-occupation regression

Evolution of (mean log) wages w of demographic groups (gender s, education e, age j, region k) during decade τ:

$$\Delta w_{sejk\tau} = \sum_t \beta_t^A \cdot \gamma_{sejk}^A \cdot 1[\tau = t] + \sum_t \beta_t^S \cdot \gamma_{sejk}^S \cdot 1[\tau = t]$$

$$+ \delta_\tau + \phi_e + \lambda_j + \pi_k + e_{sejk\tau}$$

where δ, ϕ, λ. π are vectors of time, education, age and region dummies, γ_{sejk}^A, γ_{sejk}^R, γ_{sejk}^S are employment shares of a demographic group in abstract, routine and service occupations in 1959.

β_A and β_S are the decade specific slopes on the initial occupation shares (= **comparative advantage**)

Model predict.: if $p(i) \downarrow$ for $i \in$ comp. adv., the relative wage of that skill group $\downarrow$

H0: wages of workers with comp. adv. in A or $S \uparrow$ over time, in $R \downarrow \equiv \beta_A, \beta_S \uparrow$, $\delta_\tau \downarrow$

Results: consistent with H0 starting from the 1980s.

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conclusion

Summary

1. Task-based framework

    Comparative advantage determines which skill group performs which tasks

2. Explains job polarization

    Technol. change displaces middle-skill routine jobs

3. Generates wage inequality dynamics