Technology Usage and Life-Cycle Earnings

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Motivation

Human capital theory is a standard framework to explain life-cycle earnings.

Missing element: people of different ages use different technologies.

- technologies differ by productivity
- skill-technology complementarity Goldin and Katz 1998
- technology choice is endogenous

Research question:
How does technology usage affect life-cycle earnings and through what channels?

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What I do

Investigate technology usage patterns:

- construct an index to measure technology usage using **occupations** as a proxy.
- document empirical relationships between technology uasge and labor earnings.

Develop a life-cycle model with endogenous technology choice and human capital investments

- account for technology usage patterns over the life-cycle and across education.
- quantify the contribution of technology usage to life-cycle earnings.

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Main findings

1. Technology usage plays a key role in life-cycle earnings. It contributes
   - 25% growth in mean earnings between age 23 and 60.
   - 46% growth in life-cycle inequality (variance of log earnings).

2. Earnings growth and inequality are amplified by the interaction of technology and human capital through a **reinforcement** mechanism.

3. Policy implications: the distortionary effect of a progressive tax on earnings growth would be underestimated in a model *without* technology usage.

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Measurement of technology usage

Utilize O*NET data set to measure technology using **occupations** as proxy.

Gallipoli and Makridis 2018

Construct an index based on how intensively workers use information technology.

- draw information from the importance of programming skills, etc.

Distance to the frontier: a **time-invariant** index $n_i \in [-1, 0]$ Evidence

Examples of occupation:

$n = -0.95$ Janitors

$n = -0.58$ Sale agents

$n = -0.28$ Economists

$n = 0$ Hardware engineers **(Frontier technology)**

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Technology usage matters a lot at the occupational level

Control for occupation fixed effects in a **two-step regression**

$$\ln w_{i,t} = \beta_0 + \sum_j \lambda_j OCC_j + \sum_t \beta_{2,t}\text{year}_t + \beta_3\text{age}_{i,t} + \beta_4\text{age}^2_{i,t} + X'_{i,t}\gamma + \epsilon_{i,t} \quad (1)$$

$$\hat{\lambda}_j = \beta_{0'} + \beta_1 n_j + \epsilon_j \quad (2)$$

To what extent the variation across occupations $(\hat{\lambda}_j)$ can be explained by technology?

- β_1 is estimated to be 0.78 (standard error 0.063).
- $R^2 = 0.473$ in the second step $\rightarrow$ the technology dimension explains **almost half** of the variations across occupations.

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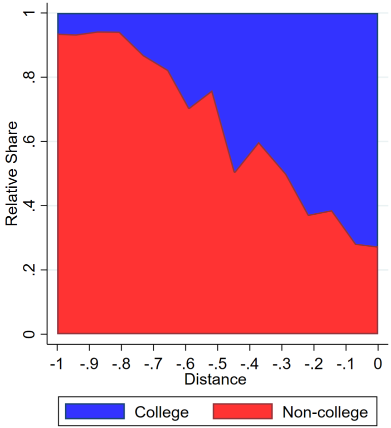
More college workers in advanced technologies



Overview of the life-cycle model

Key features:

- A college decision before the working stage
- Endogenous **technology switching**: choose $n \in [-1, 0]$
- Human capital accumulation at the working stage
- Rich interactions between these two terms
- Incomplete markets: idiosyncratic shocks

Details

Trade-offs of technology usage

Benefit:

- Earnings function is the product of technology level and human capital
  $\rightarrow$ technology-skill complementarity (**direct channel**)

Costs:

- Workers have to pay a catch-up cost (disutility) to work with any type of technology in each period
  The cost decreases with the level of human capital (**catch-up channel**)
- Workers suffer human capital loss if switching to a better technology (**switching channel**)

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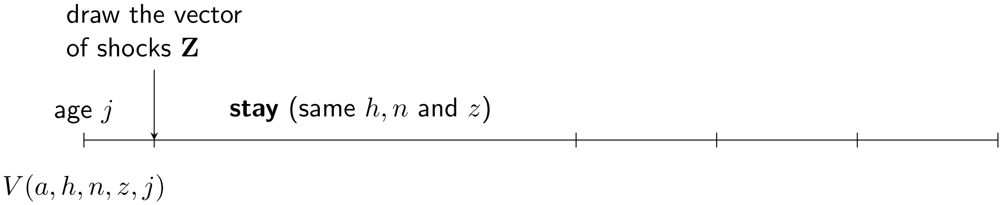
Timeline of the working stage

a : asset h : HC n : tech z : shock j : age

Value functions

Timeline of the working stage



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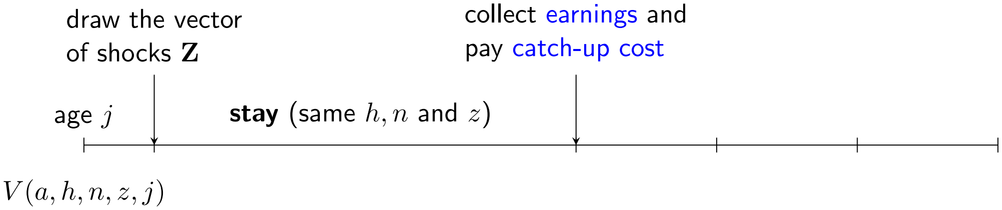

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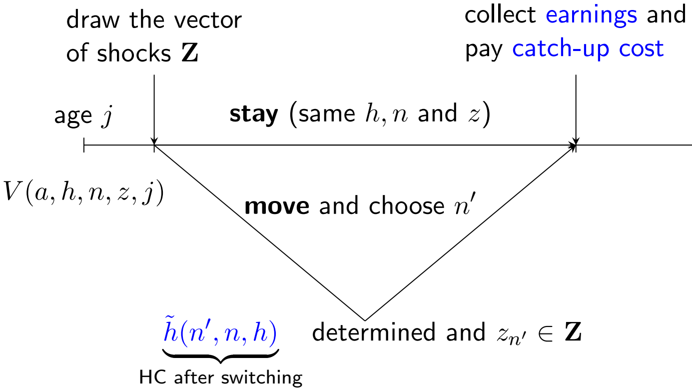

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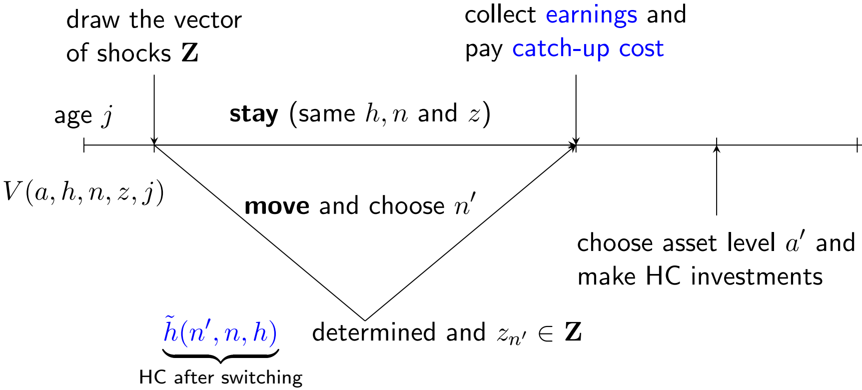

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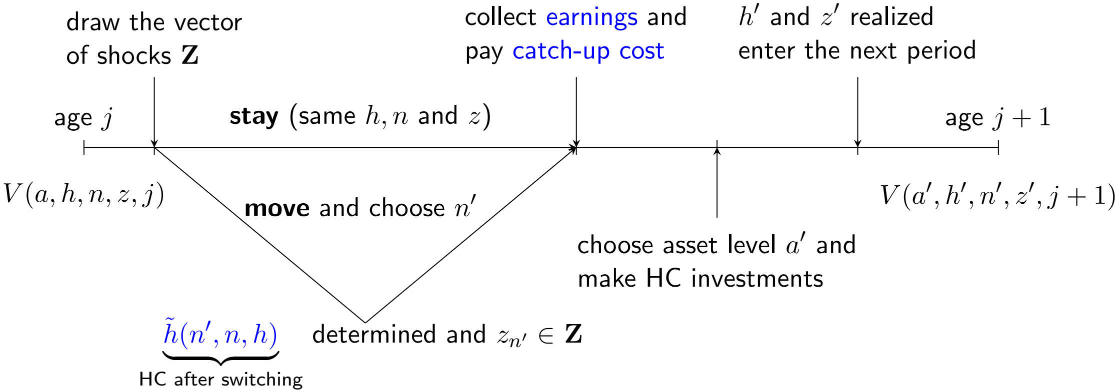

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Value functions

Parameterization

Targeted moments:

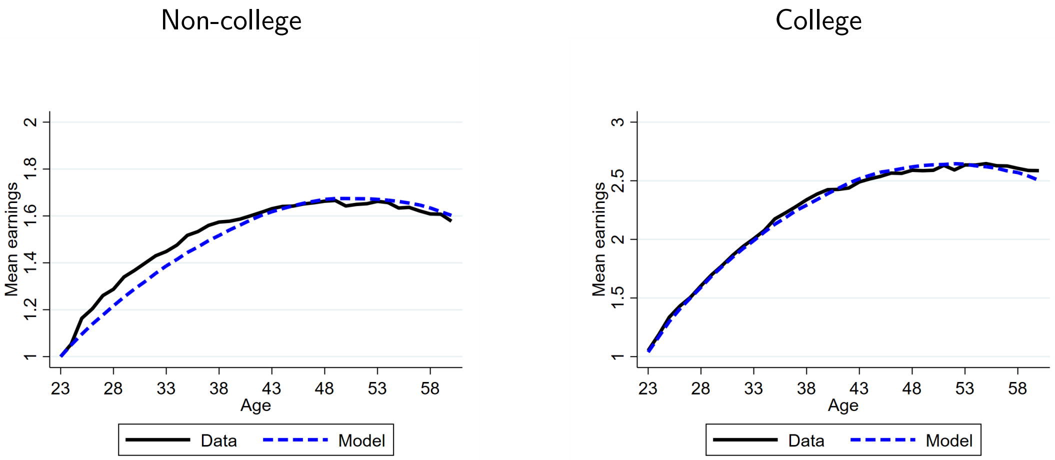
- Life-cycle technology usage profiles: mean distance
- Life-cycle earnings profiles: mean and dispersion (variance of log earnings)
- College attainment rate

8 parameters chosen externally: demographic and technology-related

24 parameters chosen internally

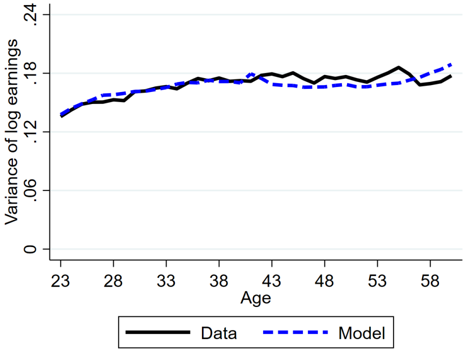
- catch-up cost: technology gap across education
- human capital and shocks: earnings profiles

Model fit: earnings growth profiles

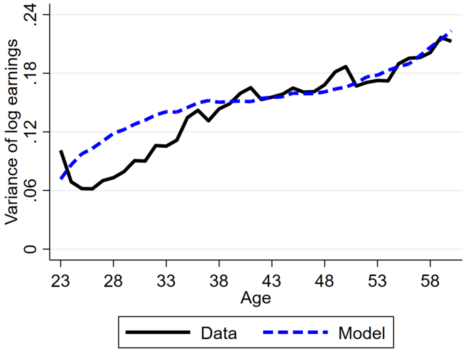


Model fit: earnings inequality profiles

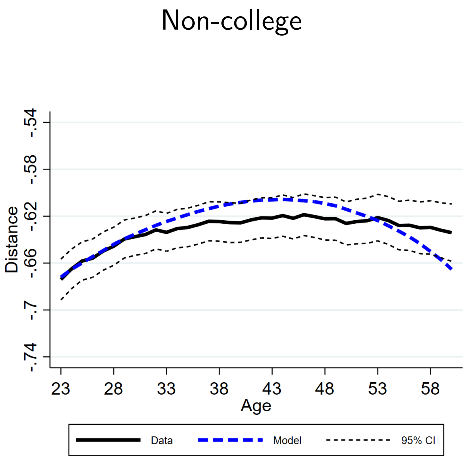
Non-college

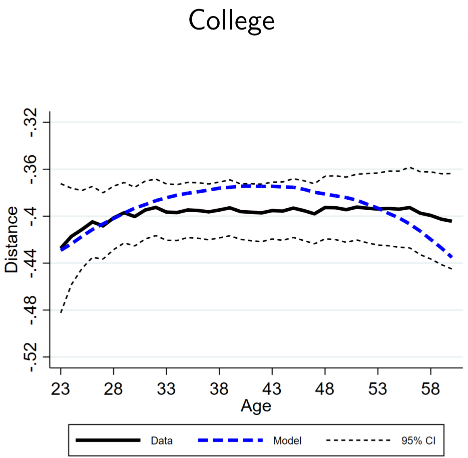


College



Model fit: technology usage profiles





Quantifying the role of technology usage

Remove technology usage from the model

- Everyone is assigned to the same technology over the life-cycle
- No catch-up cost (no disutility term associated with technology usage)

$\rightarrow$ boils down to a risky human capital investments model

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	% of college workers	Mean earnings growth (log)	Δ in life-cycle inequality (log)
Benchmark	29.8	59.4	12.3
Remove technology usage	18.2	44.6	6.6

Mechanism

Implication on non-linear taxation

Recalibrate the model without technology usage and compare policy implications of a progressive tax with the benchmark model

progressivity

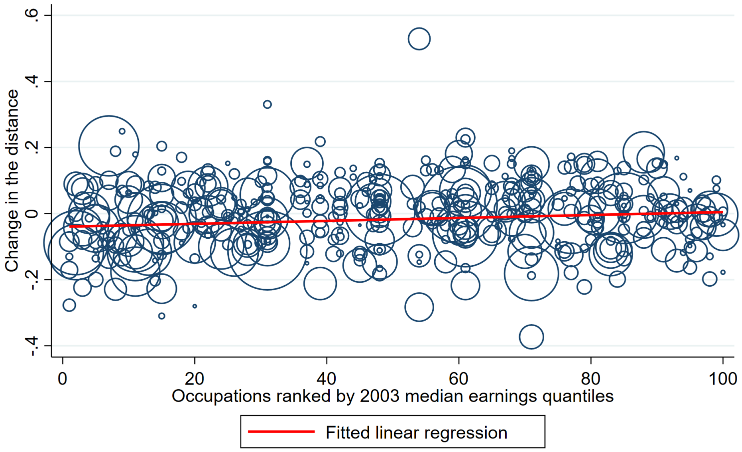
	% of college workers	Mean earnings growth (log)	Δ in life-cycle inequality (log)
Benchmark (proportional tax)	29.8	59.4	12.3
Progressive tax (European level)			
Without technology	19.8	50.2	10.4
With technology	18.9	45.9	10.2

- Progressive taxes distorts HC investments and hence lowers earnings growth.
- This distortionary effect is larger when considering technology usage.

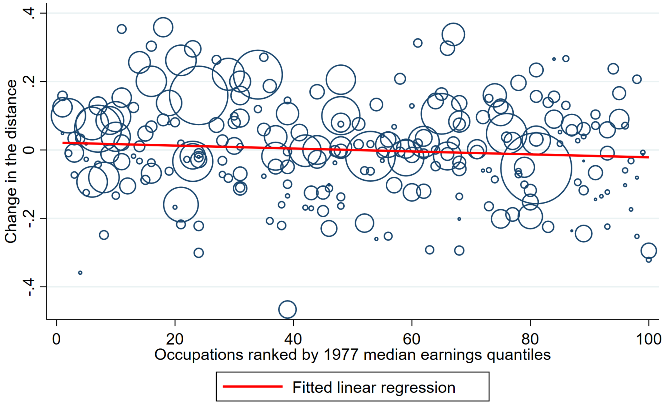
Main takeaways

- Technology usage contributes almost half of the growth in life-cycle inequality and one-third of the growth in mean earnings through the interaction with human capital.
- Technology usage also provides additional incentives for college education.
- Important implications of non-linear taxation on labor earnings.

Relative positions are stable between 2003 and 2021 back



Relative positions are also stable between 1977 and 2003



Construct a similar index in 1977 using 4th edition of the Dictionary of Occupational Titles

Tradeoffs: college education back

Individuals are heterogeneous in initial human capital h_0 and psychic cost q

Benefits:

- Additional human capital accumulation in college by choosing x

$$h_c(h_0, x) = (h_0 \cdot x)^{\alpha_h} + h_0$$

- Faster HC accumulation at the working stage.
- **Initial advantage**: better access to advanced technologies after graduation.

Costs:

- Time cost: four years of earnings
- Psychic cost of college education (disutility): $c_h(x, q) = q(x + \mathbb{1}\{x > 0\})$

Timing of the working stage back

The value function of a worker of education s at age j:

$$V_s(a,h,n,z,j) = \int \max\{V_s^{stay}(a,h,n,z,j), V_s^{move}(a,h,n,\mathbf{Z},j)\} dF(\mathbf{Z})$$

1. Workers first draw a vector of shocks $\mathbf{Z}$ over the technology distribution.
   - Shocks for each technology are independently drawn from the same lognormal distribution.
   - V is evaluated before drawing $\mathbf{Z}$.
2. Decide to stay with the current technology or switch to new technologies?
3. If switch, how far to switch?
4. Collect earnings, make HC investment and smooth consumption.

Value of staying with the same technology

$$V_s^{stay}(a,h,n,z,j) = \max_{c,a',e} \quad \log(c) - \underbrace{\zeta e^2}_{\text{HC investment}} - \underbrace{\boldsymbol{\phi_s(n,h,j)}}_{\text{catch-up cost}}$$

$$+ \beta \int \sum_{h_{min}}^{h_{max}} V_s(a',h',n,z',j+1) P_s(h'|h,e,j) dF_s(z'|z)$$

$$\text{s.t.} \quad a' + c = (1+r)a + w(h,n,z,j) - T(w,a)$$

j: age a: asset h: HC n: technology z: shock $s \in \{C, NC\}$ $T(\cdot)$: linear tax

Value of switching (productivity shocks $\mathbf{Z}$ known)

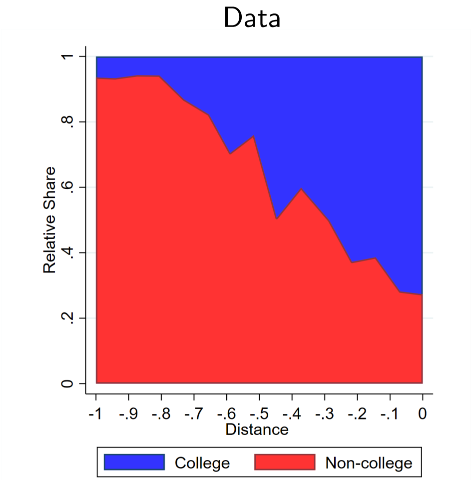
Choose the new technology n' and go back to the "stay" scenario

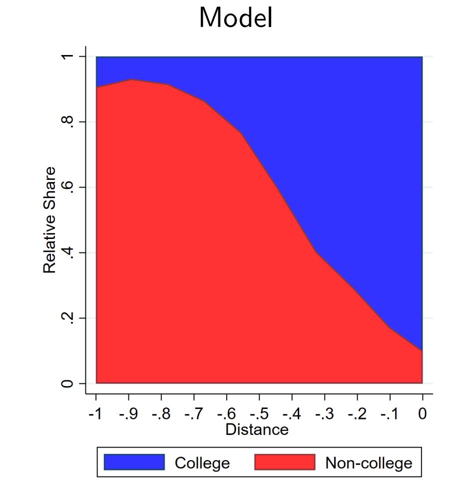
$$V_s^{move}(a, h, n, \mathbf{Z}, j) = \max_{n' \in [-1,0]} \quad V_s^{stay}(a, \underbrace{\tilde{h}(n', n, h)}_{\text{HC after switching}}, n', z_{n'}, j)$$

$\mathbf{Z}$: vector of productivity shocks over the technology distribution $n' \in [-1, 0]$

- Workers still need to pay the catch-up if they choose to switch.
- One might switch to a worse technology if he draws a really good shock z.

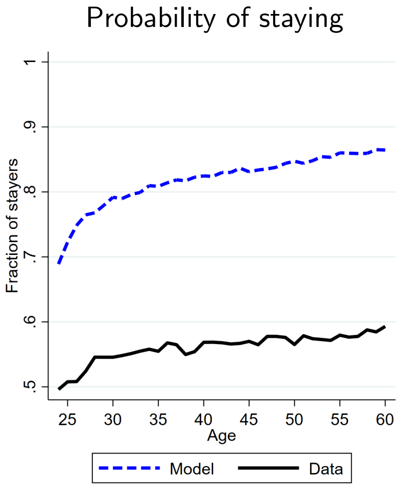
Joint distribution of technology and education (untargeted) back

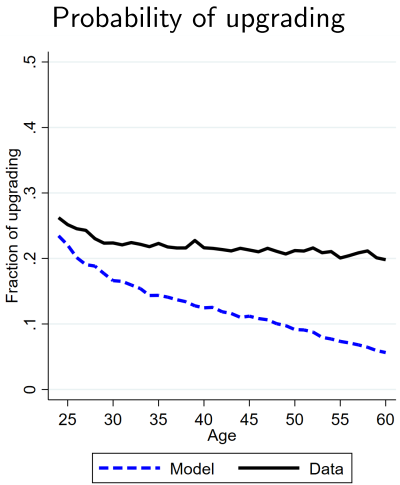




Age profiles of switching probabilities (untargeted)

back





Understanding the mechanism back

Shut down interaction channels separately

- Catch-up channel: zero catch-up cost of technology usage
- Direct channel: technology has no effects on earnings

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	% of college workers	Mean earnings growth	Δ in life-cycle inequality (log)	corr(tech,HC) at age 55
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Taxation on labor earnings back

Tax on labor earnings w Benabou 2002

$$T(w) = \tau(w) \cdot w$$

where the average tax rate is

$$\tau(w) = 1 - \lambda(w/\bar{w})^{-\tau_p}$$

- λ governs the level of tax rate
- τ_p governs the progressivity.
- $\bar{w}$ is the mean labor earnings in the economy

$\tau_p = 0 \rightarrow$ proportional tax with flat rate $1 - \lambda$.