

# **Job Transformation, Specialization, and the Labor Market Effects of AI**

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Lukas Freund

Boston College

Lukas Mann

Arizona State University

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*Harvard*

## Motivation: job transformation through AI

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# Job transformation: the case of weavers in the 19th century

Period	Preparatory tasks		Tasks while machine running					Tasks while power loom stopped								
	Prepare warp	Dress warp	Let off warp	Pick shuttle	Beat reed	Take up cloth	Adjust warp tension	Replace empty bobbin	Monitoring	Fix smashes	Adjust temples	Back up loom	Replace empty shuttle	Fix broken weft	Fix broken warp end	Remove cloth, cleaning
<b>Handloom</b>	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
<b>Early power loom (~1820)</b>							•	•	•	•	•	•	•	•	•	•
<b>1833</b>							•	•	•	•	•	•	•	•	•	•
<b>1883</b>							○	•	•	•	•	•	•	•	•	○

Notes. • = Task performed; ○ = Reduced frequency; Empty = Task not performed.

Based on Bessen (2012), who draws on the records of the Lawrence Company, MA.

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  - example: power looms and weavers [Bessen, 2012]
  - ↓ routine intensity mostly due to within-occupation changes [e.g., Atalay et al., 2021]
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⇒ **(How) will AI affect earnings through job transformation? Winners and losers?**

- State-of-art models abstract from job transformation as **measurement** is hard
  - ① workers' portfolios of **task-specific skills**
  - ② which **tasks** will be **automated**

① **Theory:** propose task-based theory of job transformation

② **Measurement:** estimate task-specific skills

③ **Application:** project LLM-induced job transformation effects

## ① Theory: propose task-based theory of job transformation

- occupations bundle tasks, performed by workers or machines
- workers have heterogeneous portfolios of task-specific skills, choose occ. & earn wage
- automation leads to job transformation by shifting weights on labor-produced tasks  
→ characterize earnings effects of job transformation

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## ② Measurement: estimate task-specific skills

- LLMs: occupational task weights for 30+ tasks (clustering of  $\sim 20,000$  O\*NET tasks)
- NLSY: worker panel of occ. choices & wages  
→ estimate skill distribution via MLE using model structure

## ③ Application: project LLM-induced job transformation effects

# A quantitative model of AI-induced job transformation effects

Literature

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→ map tasks  
to exposure measures

## ③ Application: project LLM-induced job transformation effects

- LLMs automate information-processing tasks [Eloundou et al., 2023]

## ① Occupation-level automation exposure $\not\Rightarrow$ adverse worker-level impacts

- large shifts in occupational skill composition following AI automation
- ambiguous relationship b/w exposure & average wage change at occupational level
- winners and losers *within* occupation

## ② Even absent job *elimination*, LLM automation of information-processing tasks creates large and heterogeneous wage effects through job transformation

# Theory

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# Model environment: task-based production meets Roy

► Equilibrium definition

## Technology and firms

**Occupation:**  $o \in \mathcal{O}$  **bundles**

discrete tasks  $\mathcal{T}$  with weights

$$\{\alpha_{o,\tau}\}_{\tau \in \mathcal{T}}$$

$$Y_{i,o} = \prod_{\tau \in \mathcal{T}} x_{i,\tau}^{\alpha_{o,\tau}}$$

$$\text{where } x_{i,\tau} = x_{i,\tau}^{\text{machines}} + x_{i,\tau}^{\text{labor}}$$

**Tasks:** Assigned to labor ( $\mathcal{T}_l$ ) or machines ( $\mathcal{T}_m$ )

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## Workers

**Skills:** Heterogeneous, fixed  
**task-specific:**

$$s_i \equiv \{s_{i,\tau}\}_{\tau \in \mathcal{T}_l} \sim \mathcal{N}(\bar{s}, \Sigma_s)$$

$$\rightarrow x_{i,\tau}^{\text{labor}} = \exp(s_{i,\tau}) \cdot l_{i,\tau}$$

**Occupational choice:** Choose  $o \in \mathcal{O}$  s.t. Gumbel preference shocks

**Time:** Supplied inelastically

$$\sum_{\tau \in \mathcal{T}_l} \ell_{i,\tau,t} = 1$$

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## Markets

**Labor:** Competitive  
wages

**Capital:** Infinitely  
elastic supply of  
machines at rate  $r$

**Goods:** Fixed  
occupational prices  
 $\rightarrow$  partial equilibrium

## Firm's optimal production problem

- **Output** of firm in occ  $o$  with worker  $i$  given idiosyncratic shock  $\varepsilon_{i,t} \sim \mathcal{N}(0, \varrho)$ :

$$y_{i,o,t}(\cdot) = \underbrace{\prod_{\tau \in \mathcal{T}_l} (\exp(s_{i,\tau} + \varepsilon_{i,t}) \cdot \ell_{i,\tau,t})^{\alpha_{o,\tau}}}_{\text{worker-produced}} \underbrace{\prod_{\tau \in \mathcal{T}_m} (\exp(z_\tau) \cdot m_{i,\tau,t})^{\alpha_{o,\tau}}}_{\text{machine-produced}}$$

- **Profits:**

$$\pi_{i,o,t} = \max_{\{m_{i,\tau}\}_{\tau \in \mathcal{T}_m}, \{\ell_{i,\tau}\}_{\tau \in \mathcal{T}_l}} y_{i,o,t}(\{\ell_{i,\tau,t}\}_{\tau \in \mathcal{T}_l}, \{m_{i,\tau,t}\}_{\tau \in \mathcal{T}_m}) - \exp(w_{i,o,t}) - r \sum_{\tau \in \mathcal{T}_m} m_{i,\tau,t}$$

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- **Optimality:**

► FOC capital

$$\ell_{i,\tau,t} = \frac{\alpha_{o,\tau}}{\sum_{\tau \in \mathcal{T}_l} \alpha_{o,\tau}}$$

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- **Optimality:**

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$$\ell_{i,\tau,t} = \frac{\alpha_{o,\tau}}{\sum_{\tau \in \mathcal{T}_l} \alpha_{o,\tau}} \longrightarrow \text{matrix } A: |\mathcal{O}| \times |\mathcal{T}_l|$$

## Optimal time allocation is proportional to weight matrix $A$

$$\ell_{i,\tau,t} = \frac{\alpha_{o,\tau}}{\sum_{\tau \in \mathcal{T}_l} \alpha_{o,\tau}} = \frac{\alpha_{o,\tau}}{LS_o}$$

### Remark: Task-weight matrix.

A summarizes relative weights attached to tasks  $\tau \in \mathcal{T}_l$  across occupations  $o \in \mathcal{O}$ :

$$A = \begin{pmatrix} \frac{\alpha_{1,1}}{LS_1} & \frac{\alpha_{1,2}}{LS_1} & \cdots & \frac{\alpha_{1,n_{\text{skill}}}}{LS_1} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\alpha_{n_{\text{occ}},1}}{LS_{n_{\text{occ}}}} & \frac{\alpha_{n_{\text{occ}},2}}{LS_{n_{\text{occ}}}} & \cdots & \frac{\alpha_{n_{\text{occ}},n_{\text{skill}}}}{LS_{n_{\text{occ}}}} \end{pmatrix} \in \mathbb{R}^{|\mathcal{O}| \times |\mathcal{T}_l|}$$

where  $LS_o = \sum_{\tau \in \mathcal{T}_l} \alpha_{o,\tau}$  denotes the labor share in occupation  $o$ .

# Model yields a tractable log-linear wage equation

▶ Intercept term

$$w_{i,\cdot,t} = \mu + As_i + \varepsilon_{i,t}$$

log wage of  $i$   
if choose  $o$  in  $t$

occ.-specific  
intercept

weighted skills

idiosyncratic  
productivity shock

$$\widehat{w}_{i,o,t} = \widehat{\mu_o} + \sum_{\tau_l} \frac{\alpha_{o,\tau}}{LS_o} \cdot s_{i,\tau} + \widehat{\varepsilon}_{i,t}$$
$$= \mu_o + \underbrace{\frac{1}{n_{skill}} \sum_{\tau_l} s_{i,\tau}}_{\text{scalar absolute advantage}} + \text{Cov} \left( n_{skill} \cdot \frac{\alpha_{o,\cdot}}{LS_o}, s_{i,\cdot} - \underbrace{\frac{1}{n_{skill}} \sum_{\tau_l} s_{i,\tau}}_{\text{specialization vector}} \right) + \varepsilon_{i,t}$$

# Occupational choice is modeled as simple as possible

► Equilibrium

- Each period, worker  $i$  chooses occ. subject to preference shock  $u_{i,o,t} \sim \text{Gumbel}(0, \nu)$ :

$$\hat{o}_{i,t} = \operatorname{argmax}_o w_{i,o,t} + u_{i,o,t}$$

- **Occupational choice probabilities:**

$$P(\hat{o}_i = o | w_{i,\cdot,t}) = \frac{\exp(w_{i,o,t}/\nu)}{\sum_{o'} \exp(w_{i,o',t}/\nu)}$$

- No exogenous switching costs

## Automation in this model leads to job transformation

- **Automation:** rise in machine productivity  $z_{\tau^*}$  making it optimal to reassign  $\tau^*$

$$\mathcal{T}'_l = \mathcal{T}_l \setminus \tau^* \quad \mathcal{T}'_m = \mathcal{T}_m \cup \tau^*$$

- **Job transformation:** weight on  $\tau^* \downarrow$  & weight on all other entries  $\uparrow$  proportionally to their occupation-specific weight

$$\begin{aligned} A'_o - A_o &= \left( \frac{\alpha_{o,1}}{LS'_o} \cdot \frac{\alpha_{o,\tau^*}}{LS_o} \quad \frac{\alpha_{o,2}}{LS'_o} \cdot \frac{\alpha_{o,\tau^*}}{LS_o} \quad \dots \quad -\frac{\alpha_{o,\tau^*}}{LS_o} \quad \dots \right) \\ &= \frac{\alpha_{o,\tau^*}}{LS_o} \times \left( \frac{\alpha_{o,1}}{LS'_o} \quad \frac{\alpha_{o,2}}{LS'_o} \quad \dots \quad -1 \quad \dots \right) \end{aligned}$$

## Wages change due to canonical and job-transformation effects

- Change in expected ( $\mathbb{E}[\varepsilon_{i,t}] = 0$ ) potential log wage for  $i$  in occupation  $o$ :

$$\begin{aligned}\mathbb{E}[w_{i,o,t+1} - w_{i,o,t}] &= \Delta\mu_o + \underbrace{(A'_o - A_o)s_i}_{\text{job transformation effects}} \\ &= \Delta\mu_o + \underbrace{\frac{\alpha_{o,\tau^*}}{LS_o}}_{\text{occupational exposure}} \left( \sum_{\tau \setminus \tau^*} \underbrace{\frac{\alpha_{o,\tau}}{LS_o - \alpha_{o,\tau^*}} s_{i,\tau} - s_{i,\tau^*}}_{\text{relative specialization}} \right)\end{aligned}$$

where

$$\Delta\mu_o = \underbrace{\frac{\alpha_{o,\tau^*}}{LS_o - \alpha_{o,\tau^*}} (z_{\tau^*} - \log r + \mu_o)}_{\text{productivity & displacement effect}}$$

# Job transformation effects are tied to task bundling

## Remark: Task bundling

Occupation  $o$  features **task-bundling** if

$$|\{\tau \in \mathcal{T}_l : \alpha_{o,\tau} > 0\}| > 1.$$

The economy features a **no-bundling property** if no occupation features task bundling:

$$|\{\tau \in \mathcal{T}_l : \alpha_{o,\tau} > 0\}| = 1 \quad \forall o \in \mathcal{O}.$$

- ⇒ In a no-bundling economy, wage changes are solely driven by  $\Delta\mu_o$
- ⇒ With task bundling, wages also change due to **job transformation**

# Decomposition of occupation-level wage changes

► Approximation

## Remark: Decomposition

$$\begin{aligned} & \mathbb{E}_i[w_{i,o'} | \hat{o}'_i = o] - \mathbb{E}_i[w_{i,o} | \hat{o}_i = o] \\ &= \underbrace{\mathbb{E}_i[w_{i,o'} | \hat{o}_i = o] - \mathbb{E}_i[w_{i,o} | \hat{o}_i = o]}_{\Delta w_o \text{ of incumbents}} + \underbrace{\mathbb{E}_i[w_{i,o'} | \hat{o}'_i = o] - \mathbb{E}_i[w_{i,o'} | \hat{o}_i = o]}_{\text{re-sorting}} \\ &= \underbrace{\Delta \mu_o}_{\text{productivity and displacement}} + \underbrace{(A'_o - A_o) \cdot \bar{s}}_{\text{task shift}} + \underbrace{(A'_o - A_o)(\bar{s}_{|o} - \bar{s})}_{\text{selection}} \\ &\quad + \underbrace{\mathbb{E}_i[w_{i,o'} | \hat{o}'_i = o] - \mathbb{E}_i[w_{i,o'} | \hat{o}_i = o]}_{\text{re-sorting}} \end{aligned}$$

where  $\hat{o}_i$  is the occupational choice of individual  $i$

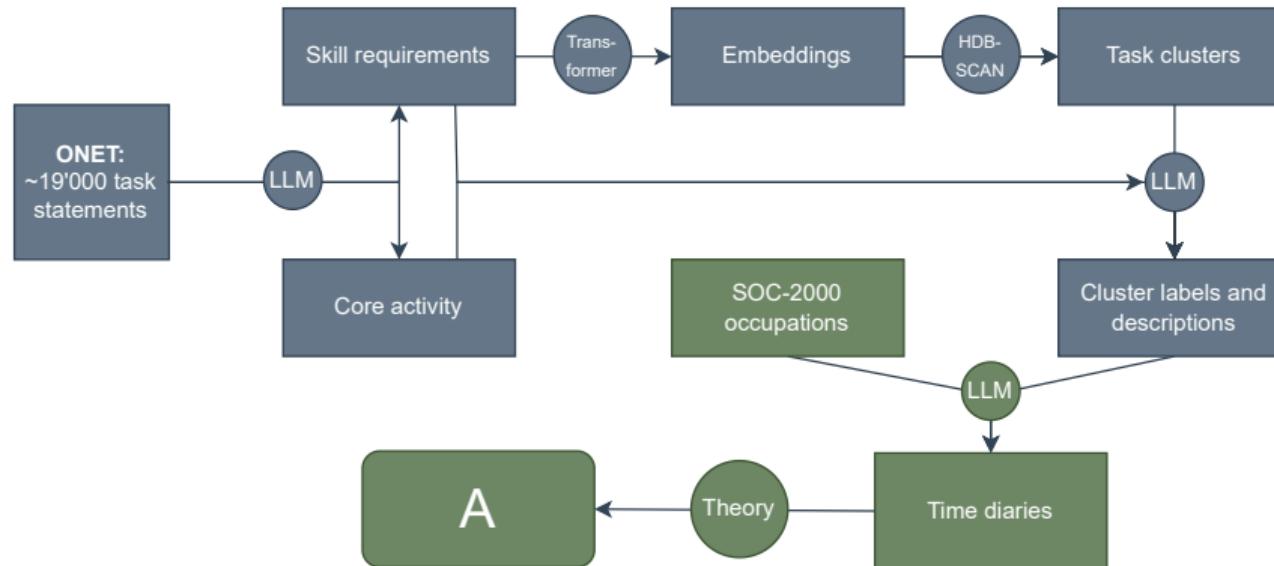
## **Measurement**

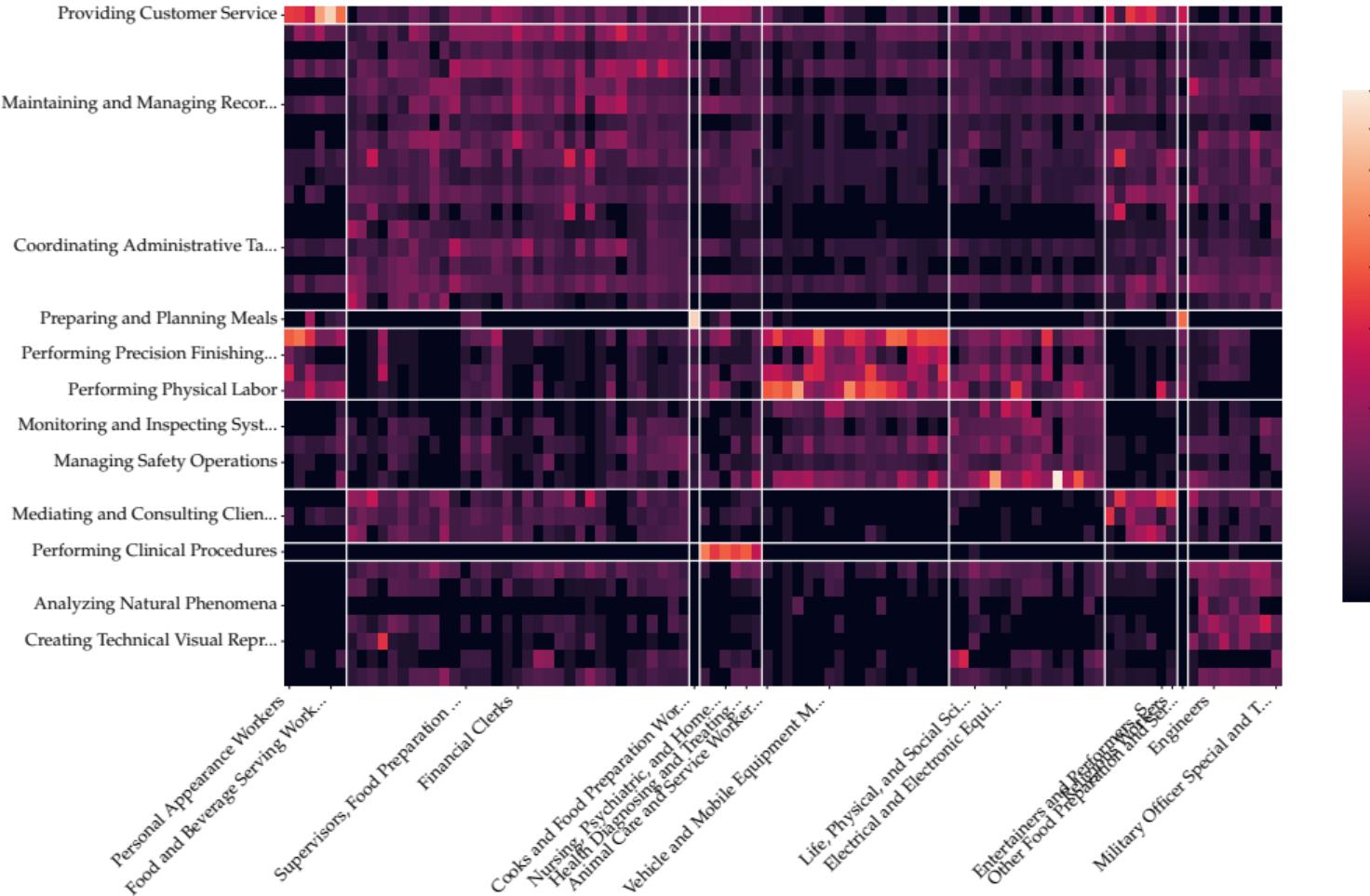
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- **Goal:** parametrize the model at same ‘resolution’ as task-exposure measures
- **Step 1:** map model tasks & occupations to data, construct A
  - O\*NET: ~ 19,000 task statements (~ most exposure measures) → cluster them
  - occupations: 90+ SOC-2000 minor groups (~ 3d)
- **Step 2:** estimate unobserved skill distribution ( $\bar{s}, \Sigma_s$ ) using MLE
  - given A + NLSY '79 + model structure

# Step 1: constructing the task-weight matrix A

[▶ Validation](#) [▶ Examples](#)





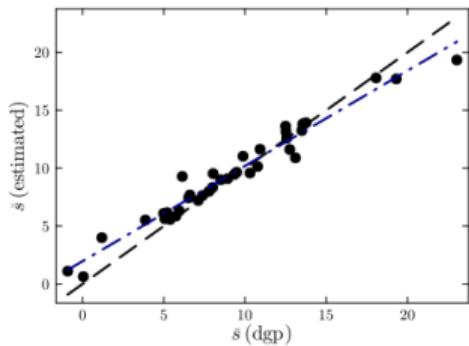
## Step 2: estimation of task-specific skills

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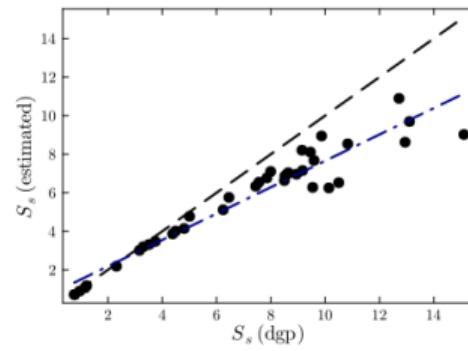
- **Measurement challenge #1:** skill distribution is unobserved
- **Solution:** use the structure of the model to estimate  $(\bar{s}, \Sigma_s)$ 
  - variation: realized wages & occupational choices
  - intuition: economist vs software engineer
- **Data:** NLSY '79 + A matrix
  - worker-level panel of occupational choices and wages
  - NLSY '97 yields v similar parameter estimates
- **Formalization:** max. likelihood
- **Implementation:** MC integration + auto-diff. + stochastic gradient descent
  - Details
- **Validation:** Monte Carlo exercise

# Validation: Monte-Carlo study

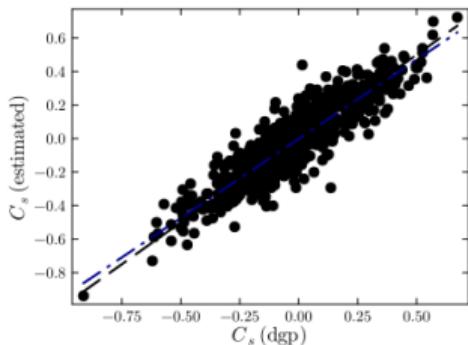
(a) Means



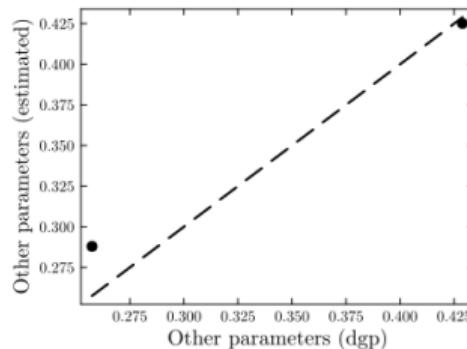
(b) Standard deviation



(c) Correlation

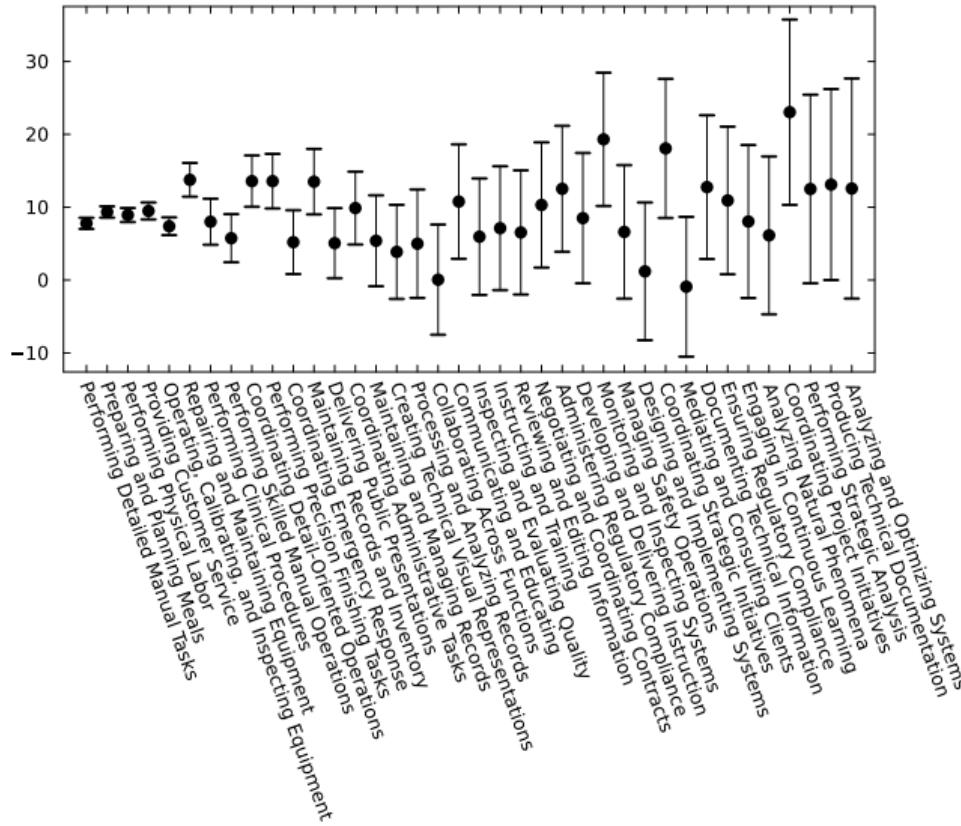


(d) Other parameters



# Skills in cognitive tasks tend to be more dispersed

▶ Other parameters

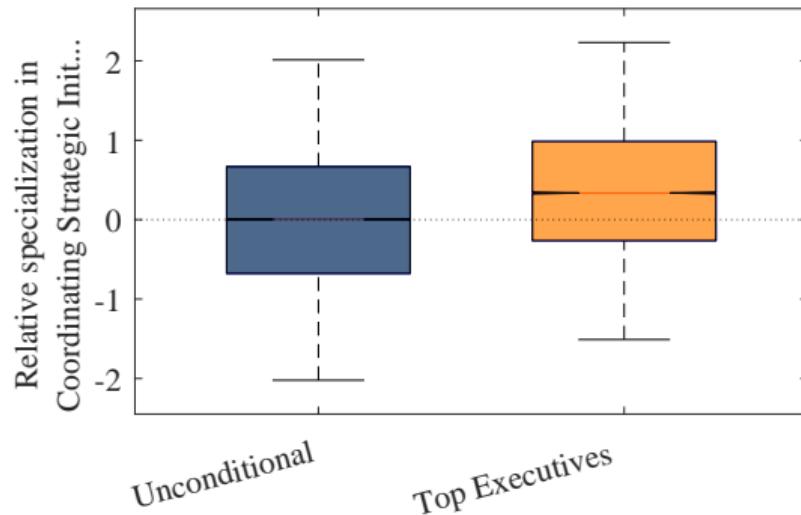


# Conditional skill distribution is shaped by selection

- Workers tend to select into occupations which load heavily on tasks they are relatively skilled at

relative specialization:

$$s_{i,\cdot} - \frac{1}{n_{\text{skill}}} \sum_{\tau_l} s_{i,\tau}$$



# Model properties & validation

## ① Wage variance decomposition

- data: std. dev. 0.60, 28% between-occ. share
- model: std. dev 0.70, 19% between-occ. share

## ② Staying and switching probabilities

▶ Jump

## ③ Direction of moves driven by task requirements

▶ Jump

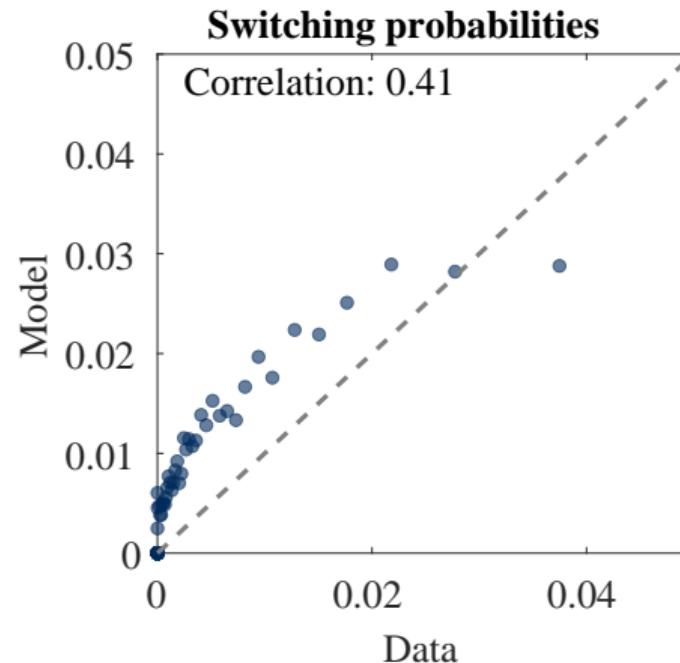
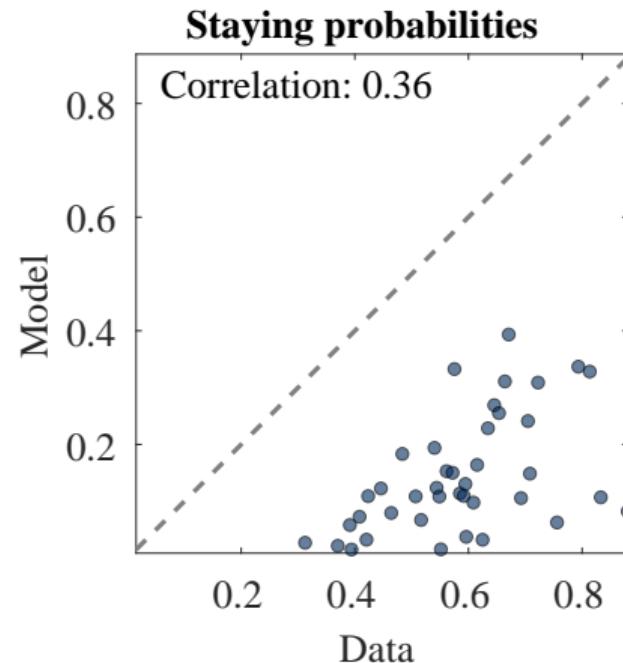
## ④ Frequency of moves shaped by specialization

▶ Jump

# Model properties: occupational transition probabilities

▶ Learning extension

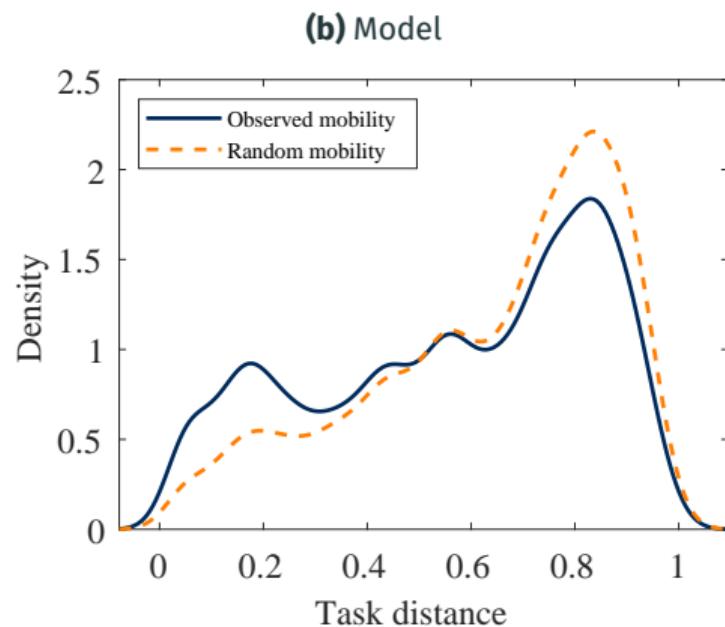
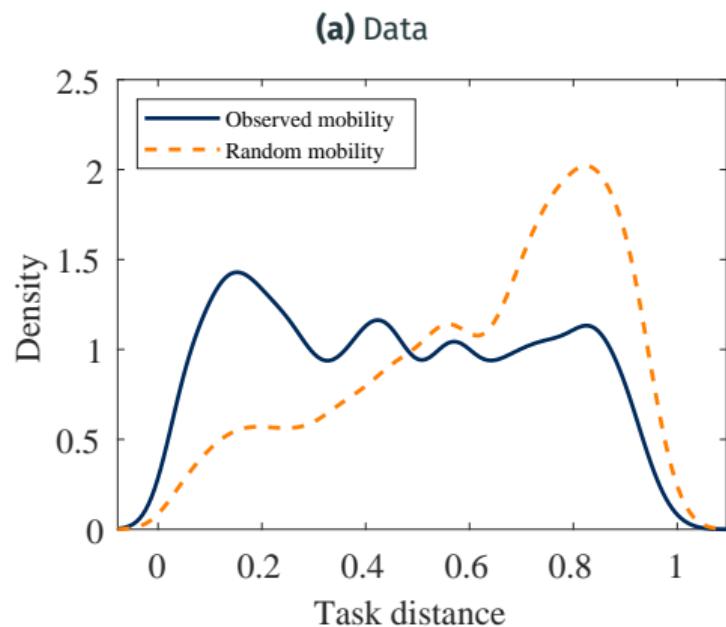
- Some persistence (but not quite enough) – directionally tracks switching patterns



# Model properties: task requirements and switching

- Workers are more likely to move to occupations with similar task requirements

[cf. Gathmann-Schoenberg, 2010]



## **LLM automation**

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## We use the model to project the wage effects due to LLM automation

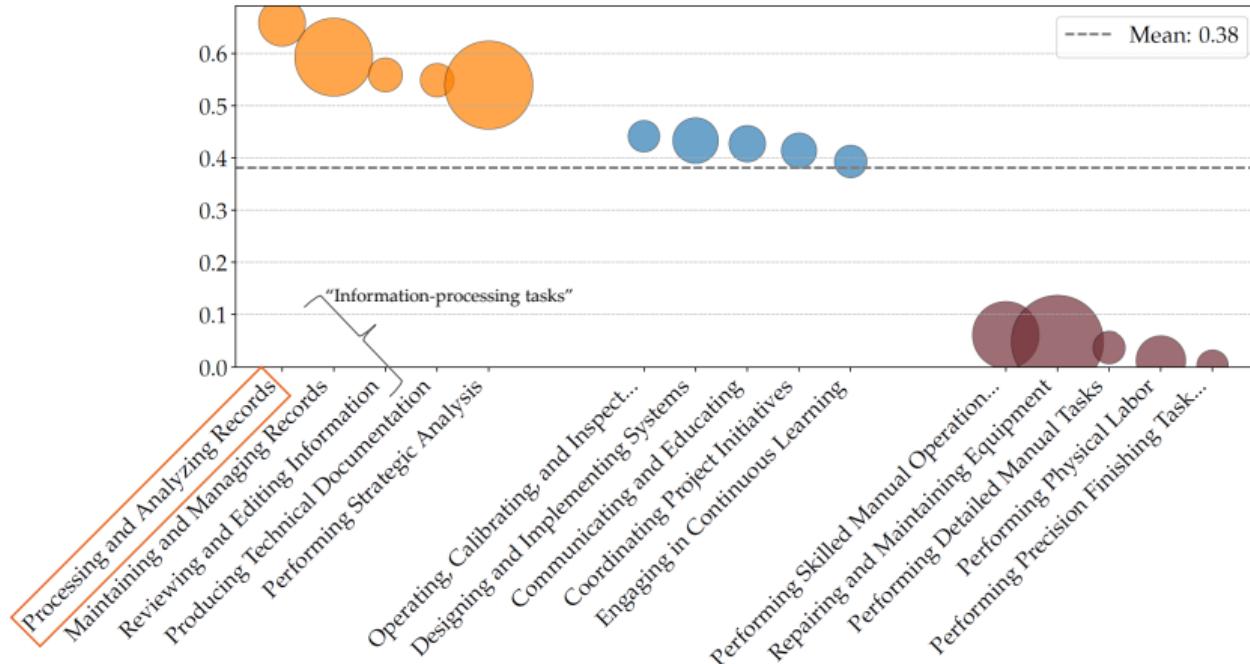
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- **Scenario:** What happens if LLMs automate certain tasks?
- **Measurement challenge:** which specific tasks will be/are being automated?
  - forward-looking analysis
  - labor share  $\neq$  sufficient statistic when considering job transformation effects
- **Solution:** exploit mapping of model tasks to LLM task exposure measures
  - exposure measures from Eloundou et al. (2024)
  - framework is flexible enough to map to many other exposure measures from literature  
[Webb, 2019; Eloundou et al., 2024; Anthropic/Handa et al., 2024; ...]
  - scenario where  $z_{\tau^*}$  is just high enough for task to be fully automated in all occ.'s

# Scenario: LLMs automate information-processing task(s)

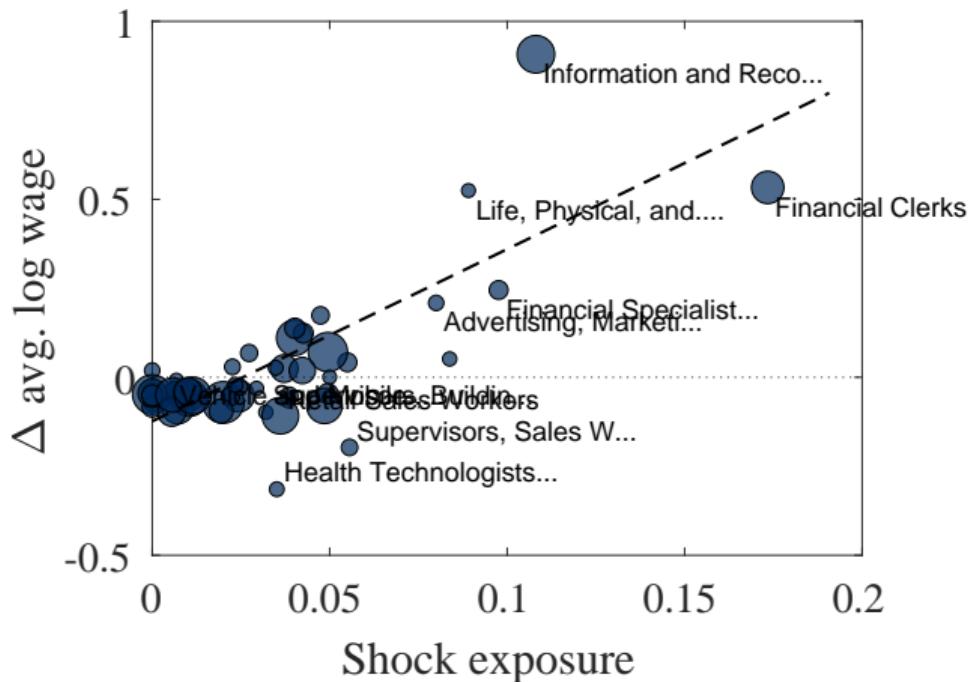
▶ Webb (2020)

Task exposure measures from Eloundou et al. (2024) aggregated to our task clusters:



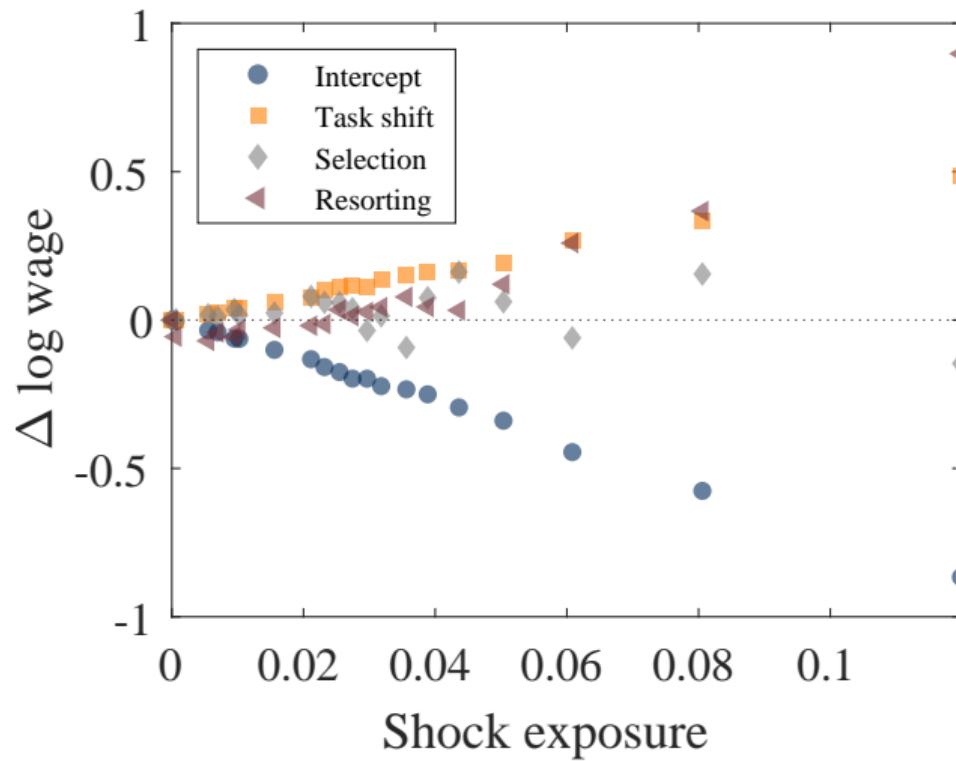
## Occupation-level effects: positive relation with exposure

⇒ More exposed occupations experience *larger* wage gains on average...



## Decomposition: positive slope driven by task upgrading and resorting

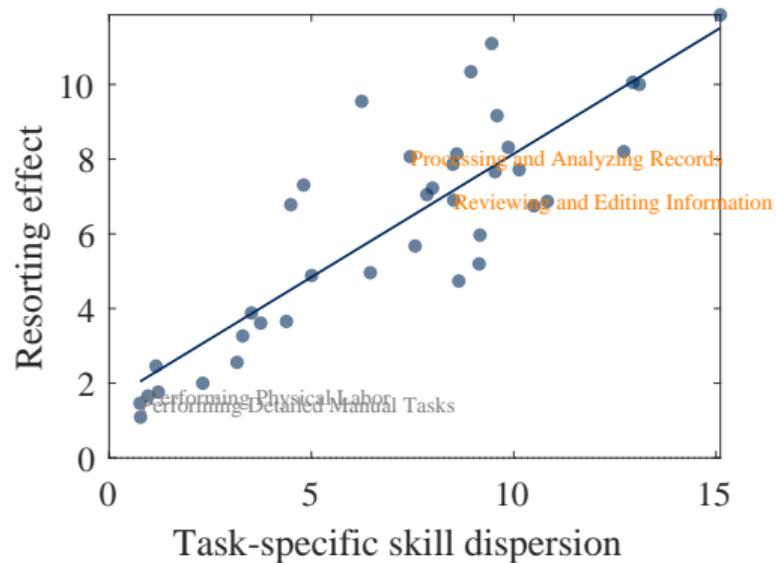
⇒ ... as  $\Delta\mu_0 < 0$  is offset by positive task-shift & resorting effects



# The resorting effect is stronger when AI-exposed tasks are automated

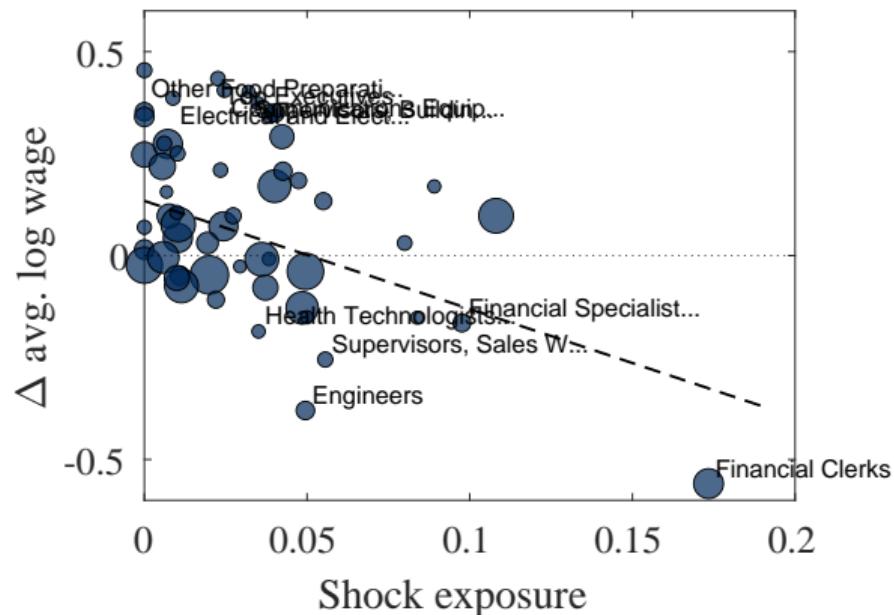
▶ Task-shift effect

- ⇒ AI-exposed tasks associated with larger skills dispersion → larger re-sorting effects
- occupational averages provide worse guidance to worker-level outcomes



## Average individual-level effects are negatively related to exposure

⇒ Incumbent workers' wages in highly exposed origin occupations decline on average



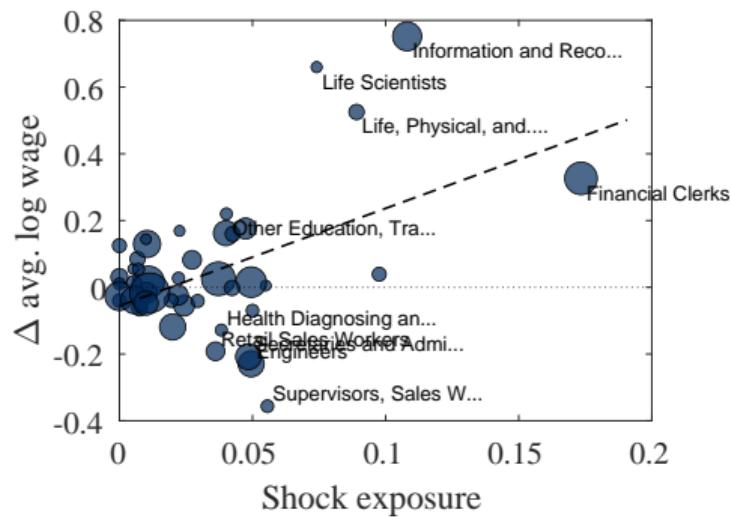
# Leavers lose, but stayers win

► Relative specialization

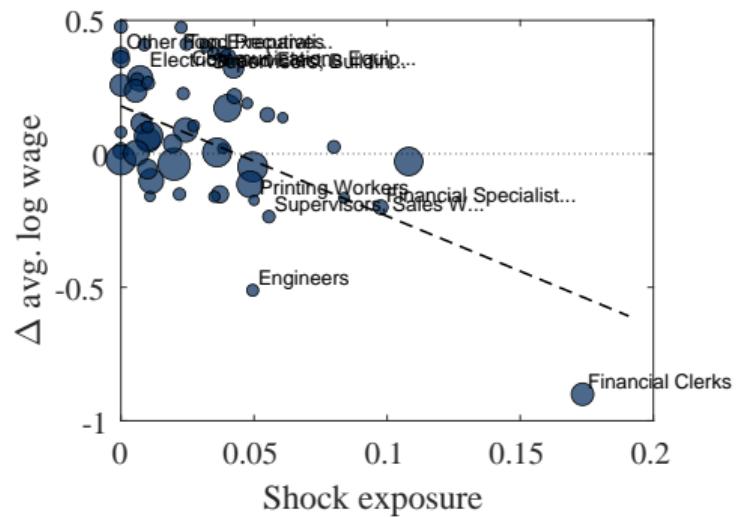
⇒ Stayers win, leavers lose

- consistent with evidence on *task upgrading* for stayers [Bartel et al., 2007; Dauth et al., 2021] and losses for occupation switchers [e.g. Huckfeldt, 2022]

(a) Incumbent stayers

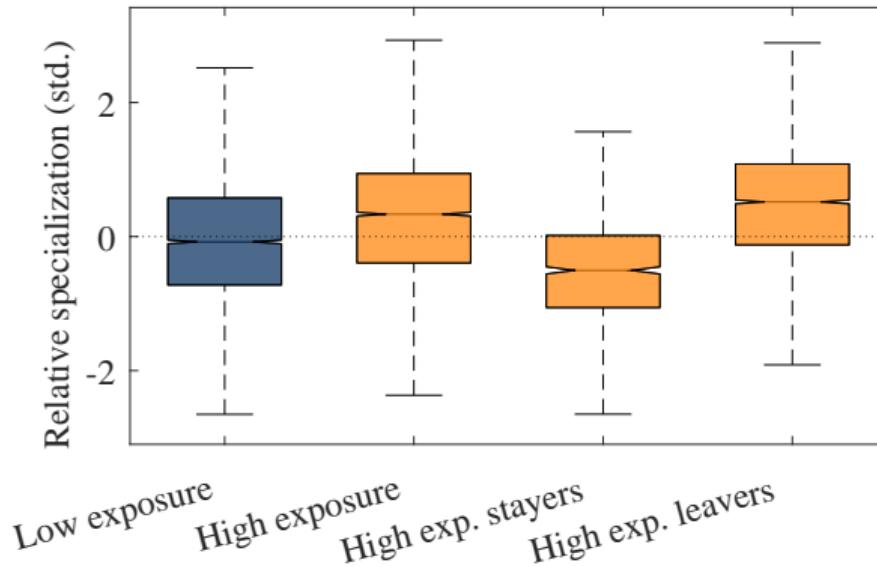


(b) Incumbent leavers



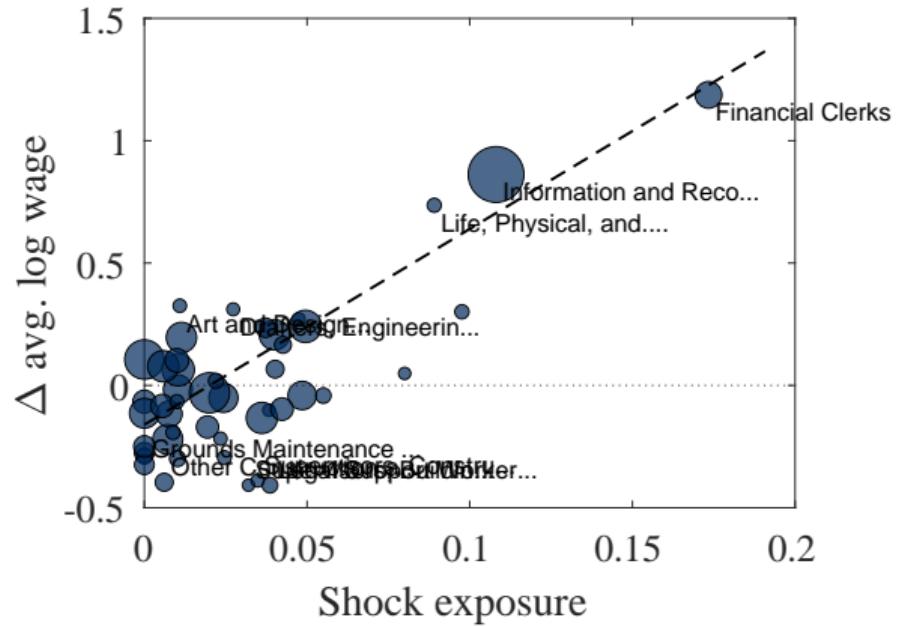
# This systematic heterogeneity reflects selection

- ⇒ Leavers: *specialists* in now-automated task
- ⇒ Stayers: *generalists*



# In-switchers experience large wage gains

⇒ Workers previously deterred by skill barriers in automated task experience gains



## Recap of results: LLM-driven automation of information-processing tasks

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- LLM-driven automation generates more occupational reallocation than in past
  - occupation-level averages offer limited guidance for worker-level outcomes
- **Selection** on specialization generates neg. link b/w exposure & incumbent wages
  - incumbent leavers specialized in information-processing tasks
- + Automation **benefits** those reallocating time to tasks in which they're more skilled
  - incumbent stayers who excel in customer-facing and coordination tasks
- + Or enabled to access better occupations by **reducing skill-based entry barriers**
  - in-switchers (think of “vibe coding”)

## Conclusion

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## The model's predictions align with anecdotal evidence

- **NYT** (May 14. '25): “**Your A.I. Radiologist Will Not Be With You Soon**”
  - “*Radiologists do far more than study images. They advise other doctors and surgeons, talk to patients, write reports and analyze medical records.*”
  - G. Hinton in '25: “[*In a few years, most medical image interpretation will be done by] a combination of A.I. and a radiologist, and it will make radiologists a whole lot more efficient in addition to improving accuracy.*”
- **FT** (Jun. 08 '25): “**Disrupted or displaced? How AI is shaking up jobs**”  
*“According to PwC, the mix of capabilities sought by employers is changing 66 per cent faster in occupations most exposed to AI, such as financial analysts, than in those least exposed, such as physical therapists.”*
- **CNN** (Oct. 11 '25): “**Your plumber has a new favorite tool: ChatGPT**”  
*“People go into the trades because they like doing the hands-on work itself, and if some of the administrative tasks can be automated, then that should help those workers lean into the parts of the job they like and do smarter work.”*

- **Main contribution:** a tractable framework to quantify the labor market consequences of AI-induced job transformation
- **Find** AI-induced job transformation leads to large and heterogeneous wage effects, even conditional on occupation
- **Big picture takeaways:**
  - ① occupational exposure  $\neq$  adverse individual wage effects
  - ② absence of AI-induced job destruction  $\neq$  absence of large labor market effects
- **Follow-up work:**
  - historical analysis: industrial robots, job transformation, and changing skill rewards
  - tracking changing task content due to AI (novel surveys)
  - junior vs. senior roles

Thank You!

## Extra Slides

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# What's new?

▶ Intro ▶ Conclusion

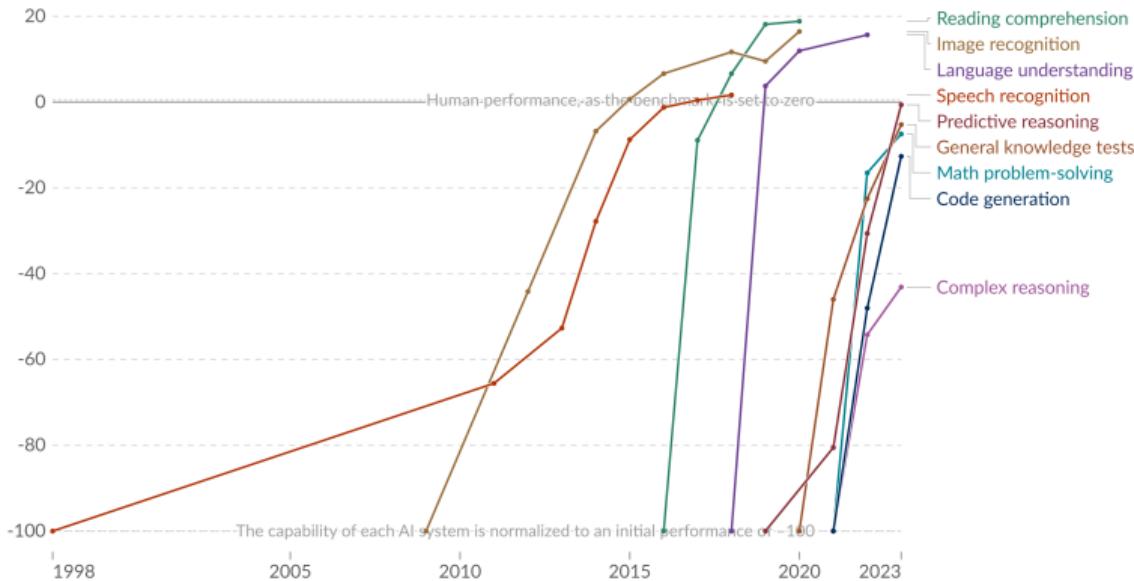
- **Measurement of job exposure to technologies** [Brynjolfsson et al., 2018; Webb, 2019; Felten et al., 2021; Eloundou et al., 2023; Gathmann et al., 2024; Kogan et al., 2024]  
⇒ map to **structural** model → individual **earnings effects** as a function of skills
- **Model-based analysis of AI** [Hampole et al., 2025; Fan, 2025]  
⇒ model with **bundling & skill heterogeneity** → quantify how job transformation affects heterogeneous worker's earnings
- **Task-based theory** [Acemoglu-Autor, 2011; Acemoglu-Restrepo, 2018; Acemoglu-Restrepo, 2022; Freund, 2023; Autor-Thompson, 2025]  
⇒ introduce task bundling → highlight automation effects due to  $\Delta$  task content
- **Empirical literature on job transformation** [Autor et al., 2003; Autor and Handel, 2013; Spitz-Oener, 2006; Atalay et al., 2020; Autor et al., 2024]  
⇒ **link tasks with skills** → quantify **earnings effects**
- **Multi-dimensional skills** [Lindenlaub, 2017; Lise-PostelVinay, 2021; Deming, 2023; Grigsby, 2023]  
⇒ **estimate** distribution of high-dim. task-specific skills → **measure specialization**

# AI capabilities are rapidly improving relative to humans

## Test scores of AI systems on various capabilities relative to human performance

Our World  
in Data

Within each domain, the initial performance of the AI is set to -100. Human performance is used as a baseline, set to zero. When the AI's performance crosses the zero line, it scored more points than humans.



Data source: Kiela et al. (2023)

OurWorldinData.org/artificial-intelligence | CC BY

Note: For each capability, the first year always shows a baseline of -100, even if better performance was recorded later that year.

# GE: plan

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- Missing important model feature: heterogeneous, endogenous occupation prices
  - steady-state: high-wage occ's involve scarce skills hence high  $\mu_o$  price
  - counterfactual: occupational price response as a function of demand elasticities
- Identification challenge:  $\mu_o$  becomes endogenous and the following equation is satisfied by more than one pair  $(\mu_o, \bar{s})$ :

$$\text{mean potential wage}_o = \mu_o + A'_{o,\cdot} \circ \bar{s}$$

where  $\bar{s}$  is vector of average skills

- Options we're exploring:
  - ① time variation in task shares
  - ② dynamic skill accumulation
  - ③ identifying restriction  $A \perp \mu_o$

# FOCs

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- FOC for machines  $m := \sum_{\tau \in \mathcal{T}_m} m_\tau$ :

$$\left( \sum_{\tau \in \mathcal{T}_m} \alpha_{o,\tau} \right) \frac{y}{r} = m$$

and

$$m_\tau = \frac{\alpha_{o,\tau}}{\sum_{\tau \in \mathcal{T}_m} \alpha_{o,\tau}} m$$

- Given

$$\log y_o = \left[ \sum_{\tau \in \mathcal{T}_l} \frac{\alpha_{o,\tau}}{\sum_{\tau \in \mathcal{T}_l} \alpha_{o,\tau}} s_{i,\tau} \right] + \varepsilon_{i,o}$$

$$+ \left[ \sum_{\tau \in \mathcal{T}} \frac{\alpha_{o,\tau}}{\sum_{\tau \in \mathcal{T}_l} \alpha_{o,\tau}} \log(\alpha_{o,\tau}) \right] - \log \left( \sum_{\tau \in \mathcal{T}_l} \alpha_{o,\tau} \right) + \left[ \sum_{\tau \in \mathcal{T}_m} \frac{\alpha_{o,\tau}}{\sum_{\tau \in \mathcal{T}_l} \alpha_{o,\tau}} (z_\tau - \log r) \right],$$

# Wage equation: details

- Intercept

$$\mu_o = \sum_{\tau \in \mathcal{T}} \frac{\alpha_{o,\tau}}{\sum_{\tau \in \mathcal{T}_l} \alpha_{o,\tau}} \log(\alpha_{o,\tau}) + \left( \sum_{\tau \in \mathcal{T}_m} \frac{\alpha_{o,\tau}}{\sum_{\tau \in \mathcal{T}_l} \alpha_{o,\tau}} (z_\tau - \log r) \right)$$

- We assume that in the initial steady state there is only one composite machine task with productivity normalized to  $\log r$ , which implies that  $\mu_o$  is known for all occupations.

# Occupation-level decomposition: approximation

$$\begin{aligned}
 & \mathbb{E}[w'_o | \hat{o}'_i = o] - \mathbb{E}[w_o | \hat{o}_i = o] \\
 &= \underbrace{\Delta\mu_o}_{\text{productivity and displacement}} + \underbrace{(A'_o - A_o) \cdot \bar{s}}_{\text{task shift}} + \underbrace{\nu^{-1}(A'_o - A_o)\Sigma \left( A_o^T - \sum_{o''} h_{o''}(\bar{s}|_o) A_{o''}^T \right)}_{\text{selection}} \\
 &\quad + \underbrace{\nu^{-1}A'_o\Sigma \left( \left( (A'_o - A_o)^T - \sum_{o''} \left( h'_{o''}(\bar{s}'|_o)(A'_{o''})^T - h_{o''}(\bar{s}|_o)A_{o''}^T \right) \right) \right)}_{\text{re-sorting}}. \tag{1}
 \end{aligned}$$

where

$$\bar{s}|_o = \bar{s} + \nu^{-1}\Sigma \overbrace{\left( A_o^T - \sum_{o''} h_{o''}(\bar{s}|_o) A_{o''}^T \right)}^{\text{relative task intensity of occupation } o} \tag{2}$$

$$h_o(s) = \frac{\exp(\nu^{-1}\mu_{o'} + \nu^{-1}A_{o'} \cdot s)}{\sum_{o''} \exp(\nu^{-1}\mu_{o''} + \nu^{-1}A_{o''} \cdot s)} \tag{3}$$

# Equilibrium

## Remark: Equilibrium

An equilibrium is defined as a joint distribution  $\Gamma$  of occupation choices, log wages  $w$ , log skills  $s$  and idiosyncratic productivity shocks  $\varepsilon$ ., such that:

- ① firms make zero profits, i.e., at any point in the distribution:

$$w_{i,o,t} = \mu_o + \sum_{\tau_l} \frac{\alpha_{o,\tau}}{LS_o} \cdot s_{i,\tau} + \varepsilon_{i,t}$$

- ② workers optimize, i.e., the marginal distribution of occupations conditional on wages follows

$$P(\hat{o} = o | w_{i,.}) = \frac{\exp(w_{i,o}/\nu)}{\sum_{o'} \exp(w_{i,o'}/\nu)}$$

- ③ the unconditional marginal distributions of skills  $s$  and occupational shocks  $\varepsilon$  follow  $\mathcal{N}(\bar{s}, \Sigma_s)$  and  $\mathcal{N}(0, \varsigma^2 I)$ , respectively.

# Brief summary of NLSY '79 data

◀ Back

- 6,033 workers, 1979-2018, 110,618 total observations
  - drop individuals in the military sample and the minority oversample
- Construct annual panel comprising each individual's primary job (if any)
  - in the case of multiple jobs, the "primary job" is selected based on weekly hours worked
- Harmonized occupational classification at SOC-2000 "minor groups" level (# 93)
- Average st. dev. of log wages: 0.60
- Average annual moving probability ~ 37%

# Summary statistics NLSY '79

[◀ Back](#)

	Hispanic			Black			Non-Black, Non-Hispanic			Total		
	N	Row %	Col %	N	Row %	Col %	N	Row %	Col %	N	Row %	Col %
Male	218	7.3	49.1	346	11.5	46.1	2,439	81.2	49.6	3,003	100.0	49.1
Female	226	7.3	50.9	405	13.0	53.9	2,477	79.7	50.4	3,108	100.0	50.9
Total	444	7.3	100.0	751	12.3	100.0	4,916	80.4	100.0	6,111	100.0	100.0

# Task clustering: example tasks, extraction, assignment

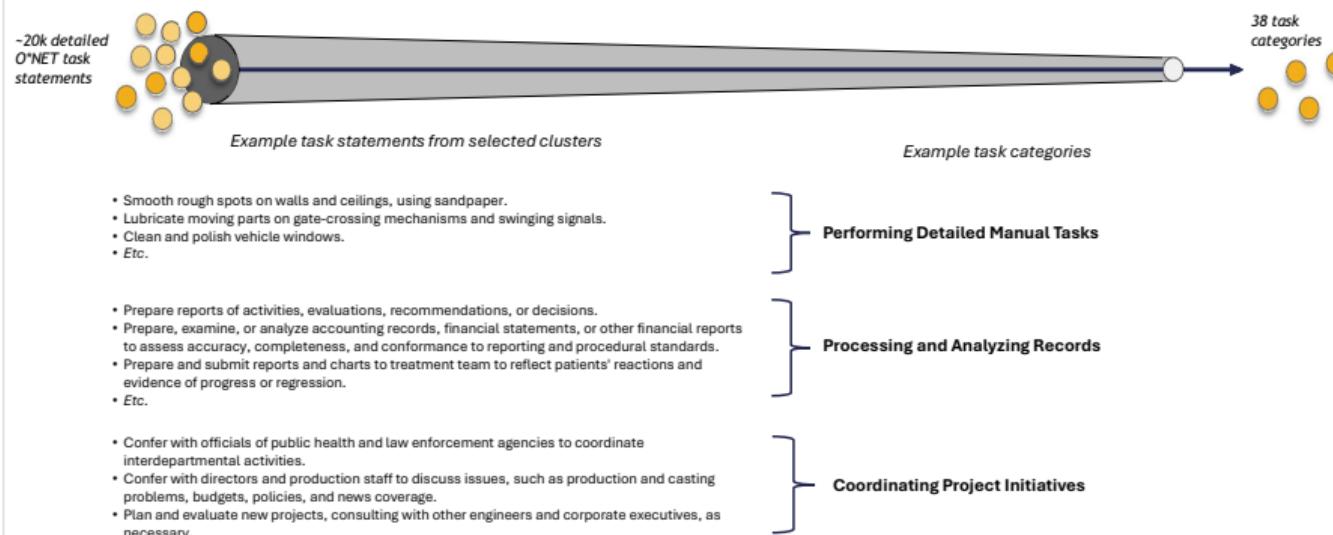
[Back](#)

Task	Activity	Skills	Cluster
Smooth rough spots on walls and ceilings, using sandpaper	smooth surfaces	manual dexterity (basic), attention to detail (basic)	Performing Detailed Manual Tasks
Lubricate moving parts on gate-crossing mechanisms and swinging signals	lubricate moving parts	manual dexterity (basic), attention to detail (basic)	Performing Detailed Manual Tasks
Perform physically demanding tasks, such as digging trenches to lay conduit or moving or lifting heavy objects	perform physical labor	physical endurance (advanced), manual dexterity (intermediate)	Performing Physical Labor
Prepare reports of activities, evaluations, recommendations, or decisions	prepare reports	report writing (advanced), analytical reasoning (intermediate), attention to detail (intermediate)	Processing and Analyzing Records
Confer with officials of public health and law enforcement agencies to coordinate interdepartmental activities.	coordinate interdepartmental activities	collaboration (advanced), project management (advanced), communication skills (intermediate)	Coordinating Project Initiatives

# Examples of mapping from detailed tasks to clusters

[Back](#)

We cluster ~20k unstructured, detailed task statements into 38 task categories based on similarity of skill requirements



For each task, we extract skill requirements, create semantic vector embeddings for these requirements using a transformer model, and perform HDBSCAN-clustering on these embeddings to create broad task categories.

# Details on the estimation strategy I

- Exact likelihood:

$$\prod_i \int_s \left[ \left( \int_{w_{i,\cdot,-\omega}} \prod_t P(\hat{o}_{i,t} = \omega_{i,t} | w_{i,\cdot,\cdot}, \nu) \cdot f(w_{i,t,-\omega_t} | s, w_{i,\cdot,\omega}, \varsigma) \right) \cdot f(s | w_{i,\cdot,\omega}, \varsigma, \bar{s}, \Sigma_s) \right] \cdot f(w_{i,\cdot,\omega} | \varsigma, \bar{s}, \Sigma_s)$$

- Strategy:** Monte Carlo integration - for all  $i$  generate  $n_o$  draws from

$$f(w_{i,\cdot,-\omega} | w_{i,\cdot,\omega}, \varsigma, \bar{s}, \Sigma_s) = \int_s f(w_{i,\cdot,-\omega} | s, w_{i,\cdot,\omega}, \varsigma) f(s | w_{i,\cdot,\omega}, \varsigma, \bar{s}, \Sigma_s)$$

and evaluate the mean of  $P(\hat{o}_{i,t} = \omega_{i,t} | w_{i,\cdot,t}, \nu)$  to obtain an estimator for  $\hat{\mathcal{L}}_i(\theta)$ :

$$\hat{\mathcal{L}}_i(w_{i,t,\omega}, \nu, \varsigma, \bar{s}, \Sigma_s) = \left( \frac{1}{n_o} \sum_j \prod_t P(\hat{o}_{i,t} = \omega_{i,t} | w_{j,t,\cdot}, \nu) \right) \cdot f(w_{i,\cdot,\omega} | \varsigma, \bar{s}, \Sigma_s)$$

## Details on the estimation strategy II

- Two numerical techniques help speed up the maximum likelihood computation
- **Auto-differentiation:** efficiently compute the gradient of this function
- **Stochastic gradient descent:**
  - basic technique: gradient descent

$$\theta_{t+1} = \theta_t - \eta \cdot \nabla (-\mathcal{L}(\theta_t))$$

- randomly partition individuals into  $n$  groups:

$$\{1, 2, \dots, I\} = B_1 \cup B_2 \cup \dots \cup B_n, \quad B_i \cap B_j = \emptyset$$

- calculate the likelihood based on batch  $B_1, \dots, B_n$  only
- when done, draw a new partition

# Parameter estimates

▶ Back

- For the scalar parameters, we estimate  $\nu = 0.26$  and  $\varrho = 0.43$
- The estimate of  $\nu$  implies that reducing prospective wages in a given occupation by 1% lowers the odds of choosing this occupation by about 3.8%
- $\varrho = 0.43$  indicates that a one-standard-deviation occupation-specific random productivity shock can raise or lower wages by about 43% in a given year

# Why not use O\*NET GWAs and importance weights

◀ Back

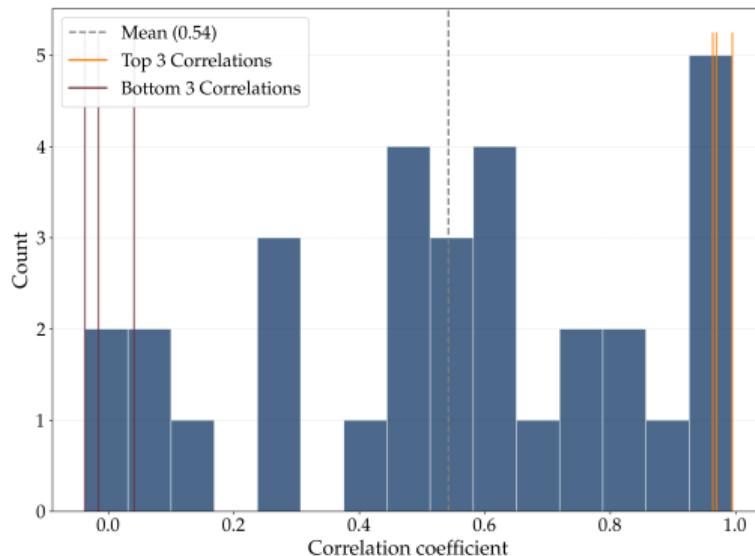
- Potential alternative to our approach: use O\*NET "General Work Activities" (GWAs) and occupational importance weights
- Reasons we prefer our approach:
  - ➊ GWAs themselves are not mutually exclusive (e.g. "Analyzing Data or Information" vs "Processing Information") nor exhaustive (esp. regarding activities differentiating high-wage occupations, e.g. complex quantitative analyses), and some seem ambiguous ("Getting Information")
  - ➋ Weights available (importance/level/frequency) don't correspond to time shares, as required to map onto the theory
  - ➌ GWAs + LLM-generated time shares: resulting  $A$  matrix is low-rank ( $\rightarrow$  poor model fit)
  - ➍ Flexibility: our approach is consistent with different occupational classifications (e.g. SOC-2000, which can be x-walked to NLSY) and time periods

## Validation of LLM-generated time shares: overview

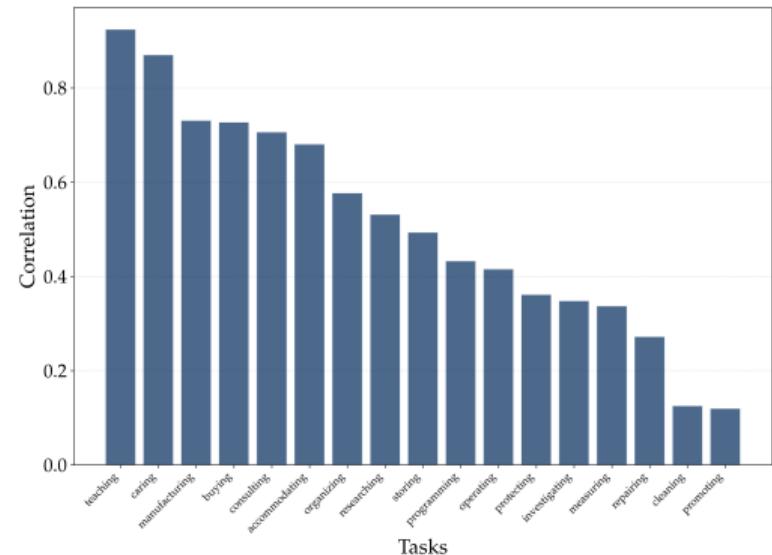
- ① LLM-generated task weights at the occupation-cluster level highly correlated with the average importance rating that O\*NET assigns to detailed tasks within each cluster ✓
- ② Comparison of time share measurement: LLM vs BIBB survey ✓
- ③ Comparison of LLM-generated time shares for GWAs to O\*NET importance weights ✓
- ④ Internal consistency: do measurements for detailed occupations aggregate up? ✓

# Validation: LLM-generated task shares vs. BIBB

(a) Occupation-level correlations

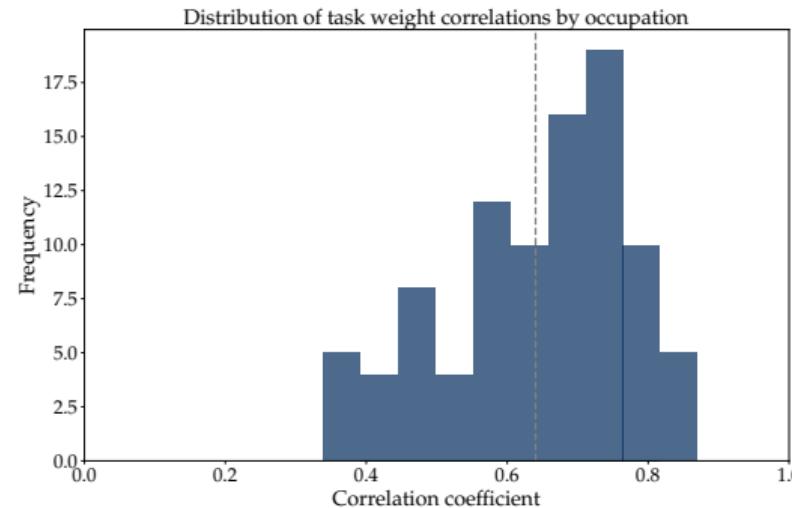


(b) Task-level correlations

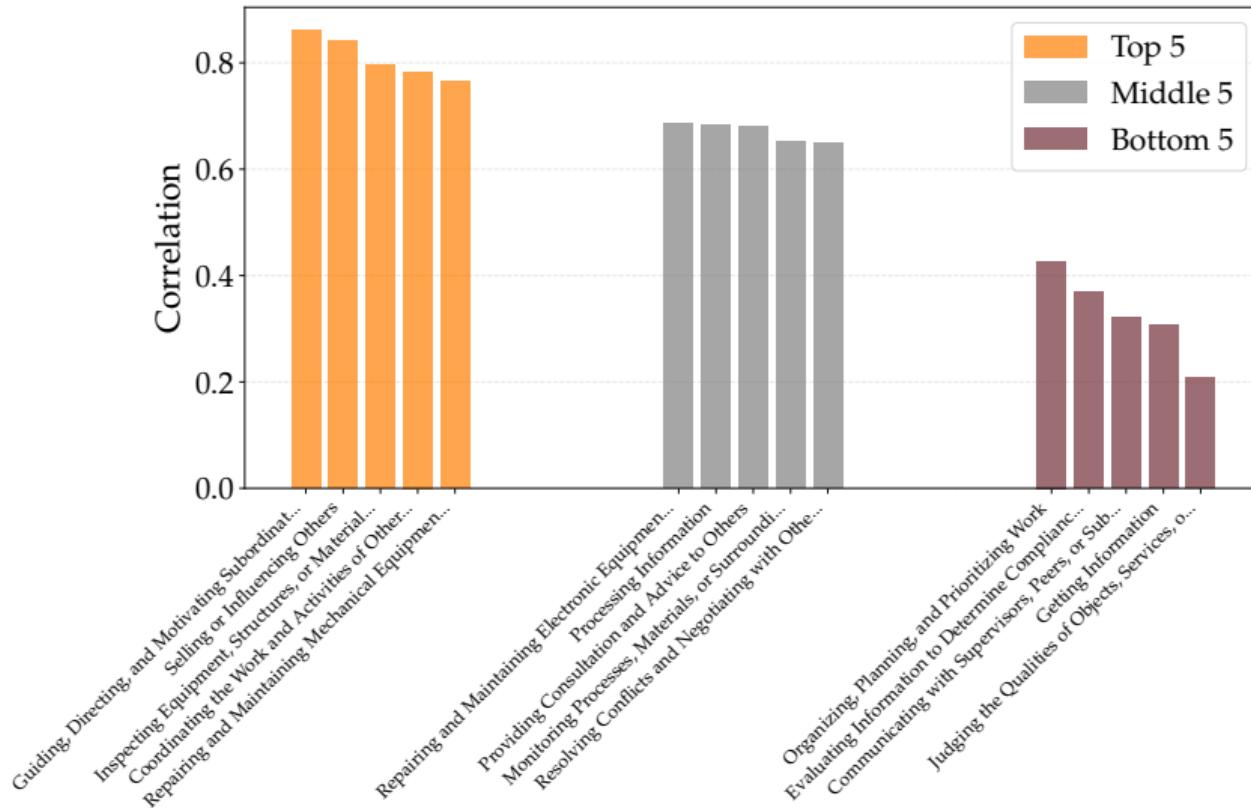


## Validation: O\*NET GWAs (1)

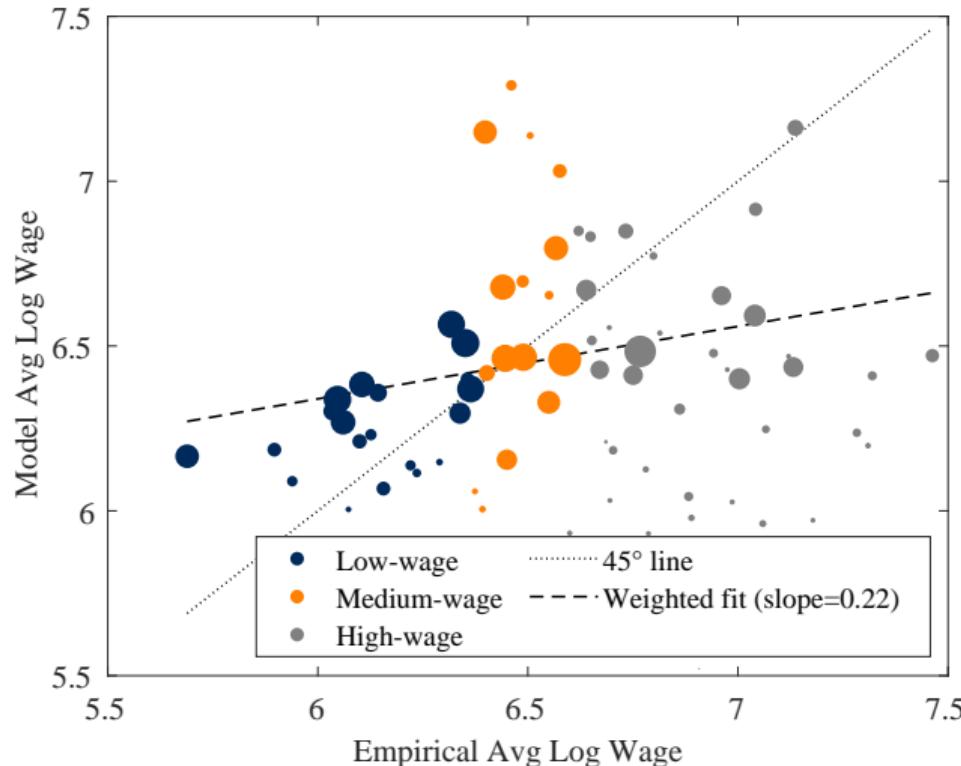
- Take O\*NET GWAs (O\*NET 5.0, consistent with SOC-2000), construct relative importance for each GWA by occupation, aggregate to SOC-2000-3d
- Let LLM generate *time shares* for the GWAs for each SOC-2000-3d occ
- How do LLM-time shares correlate with vector of O\*NET importance weights?



## Validation: O\*NET GWAs (2): correlation across occupations by task



# Model fit: occupational wages and employment shares

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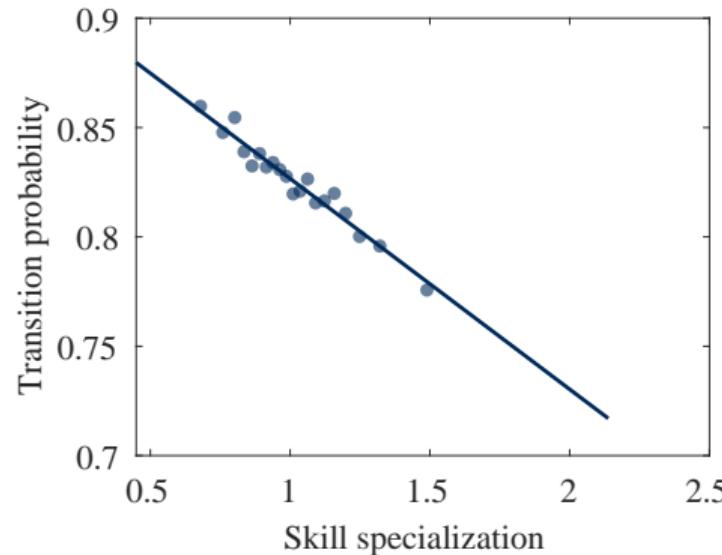
# A matrix: example tasks - extracted skills - tasks

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Task	Activity	Skills	Cluster
Direct or coordinate an organization's financial or budget activities to fund operations, maximize investments, or increase efficiency	Direct financial operations	Financial management (expert), strategic planning (advanced), budgeting (advanced), analytical thinking (advanced)	Evaluating and Strategizing
Clean and sterilize vats and factory processing areas	Clean and sterilize processing areas	Manual dexterity (basic)	Performing Material Handling Tasks
Press switches and turn knobs to start, adjust, and regulate equipment, such as beaters, extruders, discharge pipes, and salt pumps	Operate equipment controls	Technical knowledge (intermediate), manual dexterity (basic)	Performing Precision Technical Tasks
Conduct research, data analysis, systems design, or support for software such as Geographic Information Systems (GIS) or Global Positioning Systems (GPS) mapping software	Conduct research and data analysis for GIS software	Research skills (advanced), data analysis (advanced), systems design (advanced)	Analyzing Complex Data

## Model properties: specialization shapes switching frequency

- Evidence: skill specialization tends to generate persistence in occupational choice  
*[Kambourov and Manovskii, 2008; Geel et al., 2011]*



# Webb measure: selection criteria

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Table A1: Patent selection criteria.

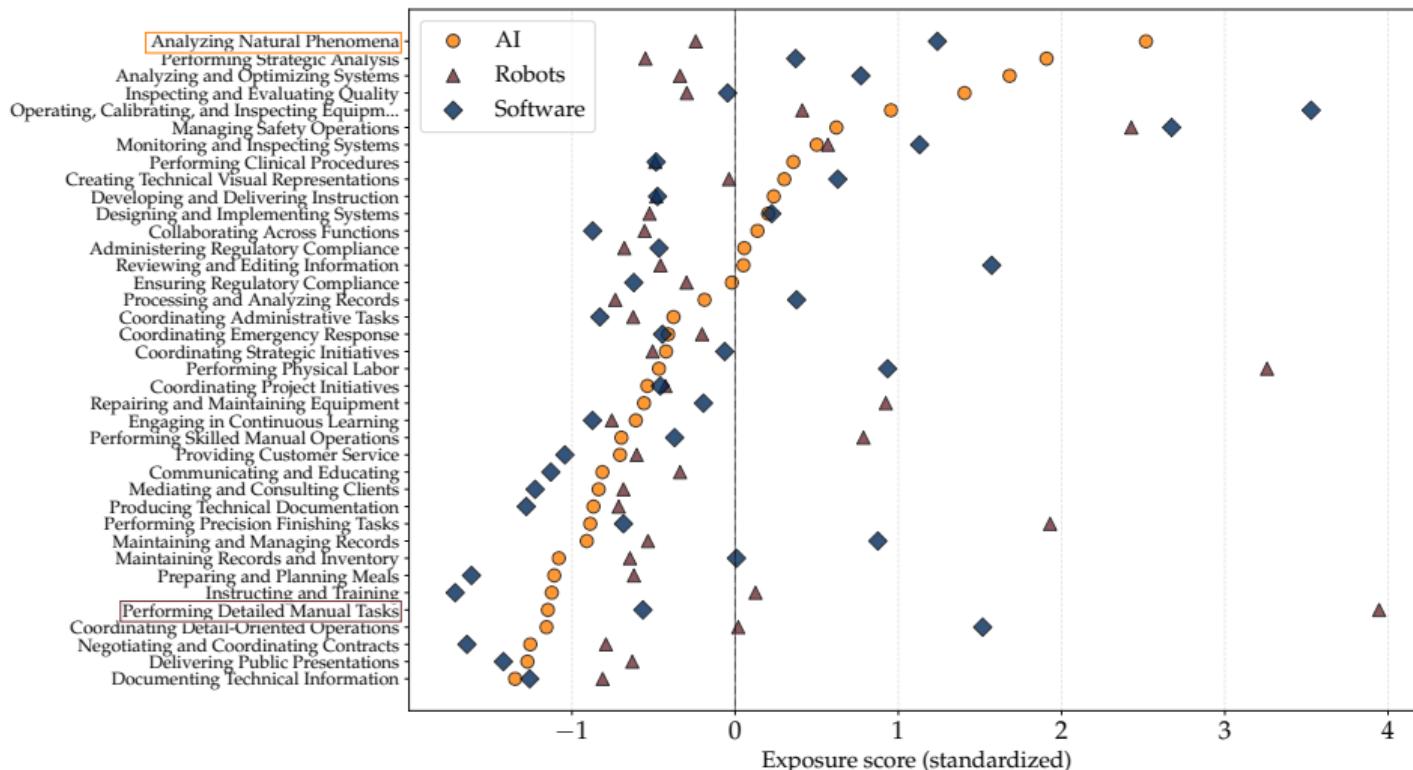
Technology	Definition
AI	Title/abstract include “neural network”, “deep learning”, “reinforcement learning”, “supervised learning”, “unsupervised learning”, or “generative model”
Software	Title/abstract include “software”, “computer”, or “program” AND title/abstract exclude “chip”, “semiconductor”, “bus”, “circuit”, or “circuitry”
Robots	Title/abstract include “robot”

*Notes:* Patents corresponding to each technology are selected using these keyword inclusion/exclusion criteria.

# Webb's (2020) exposure measures

▶ Patent criteria

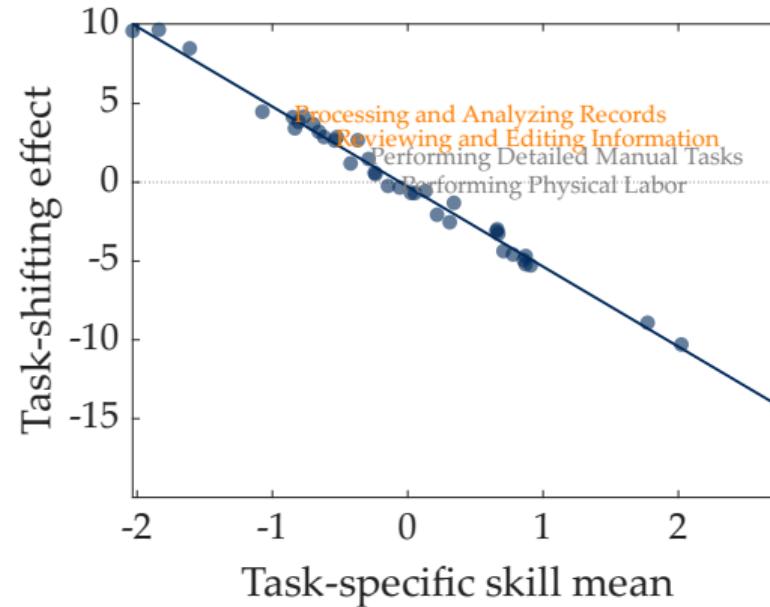
▶ Eloundou et al. (2023)



# Task-shift effect: comparison across tasks

► Resorting effect

⇒ Task-shifting effects tend to be more positive for tasks exposed to AI than for those most exposed to industrial robots



# Returns to occupational experience

- **Limitation** of baseline: lower occupational persistence than in data
- **Simple learning amendment:** if a worker picks  $o$  in  $t$ , if they didn't work in  $o$  in  $t - 1$ , their productivity is 1; if they did work in  $o$  in  $t - 1$ , their productivity is  $\exp(\Delta)$  with  $\Delta \geq o$ . Let the expected wages of a worker with skills  $s_i$  be

$$w_{i,o}^e(o) = \mu_o + A \cdot s_i$$

$$w_{i,o}^e(1) = \mu_o + \Delta + A \cdot s_i$$

⇒ Worker's (expected) value function satisfies:

$$V_o(o) = w_{i,o}^e(o) + \beta\nu \log \left[ \exp\left(\frac{V_o(1)}{\nu}\right) + \sum_{o' \neq o} \exp\left(\frac{V_{o'}(o)}{\nu}\right) \right]$$

$$V_o(1) = w_{i,o}^e(1) + \beta\nu \log \left[ \exp\left(\frac{V_o(1)}{\nu}\right) + \sum_{o' \neq o} \exp\left(\frac{V_{o'}(1)}{\nu}\right) \right]$$

and so  $V_o(1) = V_o(o) + \Delta$

- **Paper:** higher persistence but similar counterfactual results

# Estimated parameters using the NLSY97 vs. baseline

