The Option Value of Occupations

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Bank of Portugal & IZA

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BEST JOBS
U.S. News & World Report
2023

CNN Money | Companies | Markets | Tech | Media | U.S.

2017

100 Best Jobs in America

CNNMoney/PayScale.com's top 100 careers with big growth, great pay and satisfying work

Investopedia | INVESTING | SIMULATOR | ECONOMY | PERSONAL FINANCE | NEWS | REVIEWS | ACADEMY

CAREERS > SALARIES & COMPENSATION

25 Highest Paid Occupations in the US

+ *future* jobs ⟹ option value

Sources: U.S. News, CNN Money, Investopedia

What I do & find

1. **Document** diverging occupational wage trajectories
   Hungarian linked administrative data across employers and occupations

2. **Model** job mobility within and across occupations
   Wage schedules, wage offers, labor market frictions, amenities, switching costs

3. **Estimate** substantial heterogeneity in the flow vs. option value of occupations
   Low-skill occs. have high flow value / high-skill occs. have high option value

4. **Simulate** counterfactual occupational wage trajectories
   Starting in bottom-wage high-skill occs. $\gg$ top-wage low-skill occs.

Trajectories
Literature

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Trajectories
Literature

Model in words

Opportunities vs. choices

Individual works in a job (occupation a, wage i), enjoys flow utility u_{ai}

Their wage may increase/decrease from i to w at rate χ_{ai}^{aw}

They may separate from their job at rate δ_a

They may receive a job offer from occupation o at rate λ_a^o

- Wage offer $w \sim f^{o\cdot}$
- Stochastic switching cost $\tilde{c}_a^o$ $\implies$ accept offer if $V_{ow} - \tilde{c}_a^o > V_{ai}$

Model in math

Employed in occupation a earning wage i:

$$V_{ai} = \frac{\overbrace{u_{ai}}^{\text{flow value}}}{\Gamma} + \overbrace{\frac{\mathbb{E}_w\left[\chi_{ai}^{aw} V_{aw}\right]}{\Gamma} + \frac{\delta_a V_n}{\Gamma} + \underbrace{\frac{\mathbb{E}_{o,w,\tilde{c}}\left[\lambda_a^o \max\{V_{ow} - \tilde{c}_a^o, V_{ai}\}\right]}{\Gamma}}_{\text{option value}}}^{\text{continuation value}}$$

$$\Gamma = \sum_o \lambda_a^o + \sum_w \chi_{ai}^{aw} + \delta_a + \rho$$

Model in terms of CCPs

$\tilde{c}_a^o \sim \text{Logistic}(c_a^o)$ (cf. Arcidiacono, Gyetvai, Maurel, and Jardim, 2022 NBER WP)

$$\rho V_{ai} = u_{ai} + \sum_w \chi_{ai}^{aw} (V_{aw} - V_{ai}) + \delta_a (V_n - V_{ai}) - \sum_{o,w} \lambda_a^o \log\left(1 - p_{ai}^{ow}\right) f^{ow}$$

$$\text{where} \quad p_{ai}^{ow} = \frac{\exp(V_{ow} - V_{ai} - c_a^o)}{1 + \exp(V_{ow} - V_{ai} - c_a^o)}$$

Identification in a nutshell

$$\text{hazard} = \underbrace{\Pr(\text{offer arrives})}_{\text{opportunities}} \times \underbrace{\Pr(\text{offer is accepted})}_{\text{choices}}$$

Separating opportunities from choices

- Frequent offers $\Longrightarrow$ wait for a high-wage offer $\Longrightarrow \uparrow$ transitions at high wages
- Strong preferences $\Longrightarrow$ accept any wage offer $\Longrightarrow \uparrow$ transitions at all wages

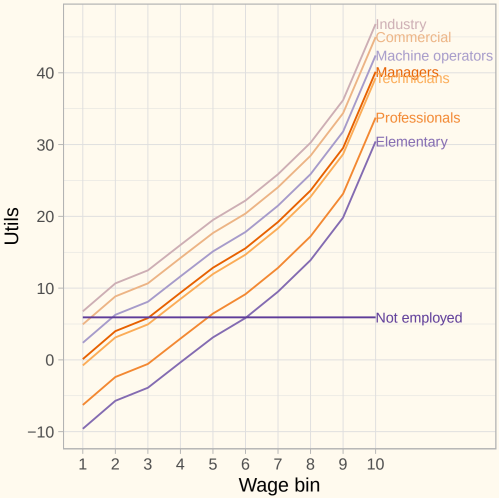
Identification

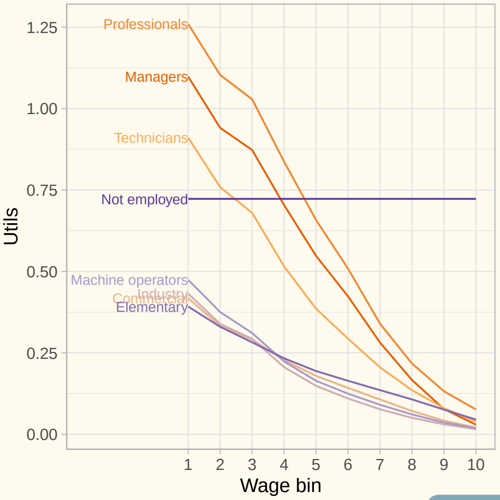
Estimation

Labor market frictions

More results

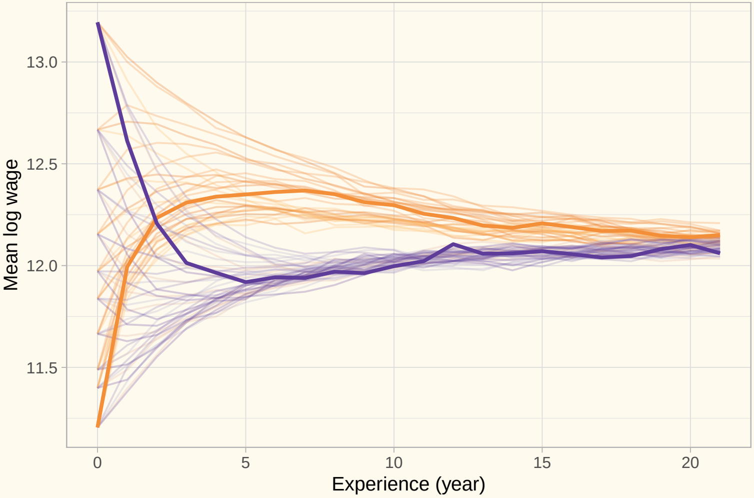
The flow vs. option value of occupations





Formulas
Comp. difftl’s

Simulating job trajectories



Procedure

What I do & find

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Additional Slides

Literature

Career decisions

Keane and Wolpin (1997), Neal (1999), Sullivan and To (2014), ...

Occupational choice

Miller (1984), McCall (1990), Antonovics and Golan (2012), ...

Heterogeneity in job search

Postel-Vinay and Robin (2002), Cahuc, Postel-Vinay, and Robin (2006), Taber and Vejlin (2020), ...

Option values

Rust (1987), Arcidiacono (2004), Stange (2012), ...

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Arcidiacono, P. (2004). Ability Sorting and the Returns to College Major. *Journal of Econometrics 121*(1–2), 343–375.

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Harasztosi, P. and A. Lindner (2019). Who Pays for the Minimum Wage? *American Economic Review 109*(8), 2693–2727.

Keane, M. P. and K. I. Wolpin (1997). The Career Decisions of Young Men. *Journal of Political Economy 105*(3), 473–522.

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Koren, M. and S. Tenreyro (2013). Technological Diversification. *American Economic Review 103*(1), 378–414.

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Stange, K. M. (2012). An Empirical Investigation of the Option Value of College Enrollment. *American Economic Journal: Applied Economics 4*(1), 49–84.

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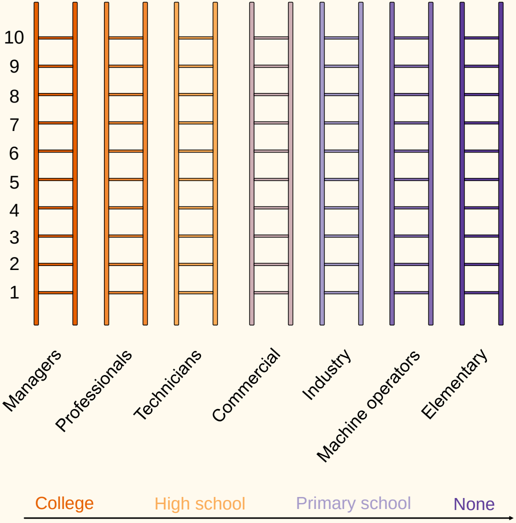
Taber, C. and R. Vejlin (2020). Estimation of a Roy/Search/Compensating Differential Model of the Labor Market. *Econometrica 88*(3), 1031–1069.

Verner, E. and G. Gyöngyösi (2020). Household Debt Revaluation and the Real Economy: Evidence from a Foreign Currency Debt Crisis. *American Economic Review 110*(9), 2667–2702.

Occupational ladders and skill levels



2-digit occs.

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Skill levels and most frequent occupations

1–Managers College+HS	Managing directors Legislators	4–Commercial Primary	Catering Services
2–Professionals College	STEM Business, legal, and soc. sci.	5–Industry Primary	Metal and electrical ind. Construction
3–Technicians High school	STEM Business	6–Machine operators Primary	Drivers Assemblers
		7–Elementary	Elementary

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Hungarian linked EE data with occupations

2003–2017, 50% sample

- 5 million individuals, 900 thousand firms per year
- Estimation sample: 22–50 males $\longrightarrow$ 5 million job spells

1. (Virtually) continuous-time data

2. Reliable occupational classification $\longrightarrow$ high vs. low-skill occupations

Various versions used in Koren and Tenreyro (2013 AER), Halpern, Koren, and Szeidl (2015 AER), DellaVigna, Lindner, Reizer, and Schmieder (2017 QJE), Harasztosi and Lindner (2019 AER), Verner and Gyöngyösi (2020 AER)

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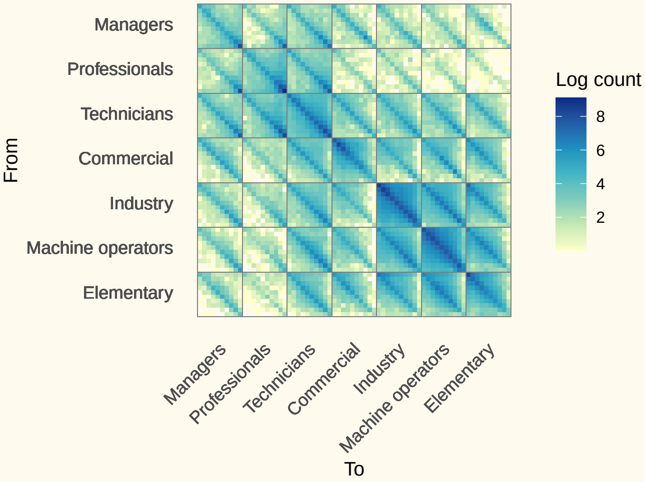
Observed EE transitions



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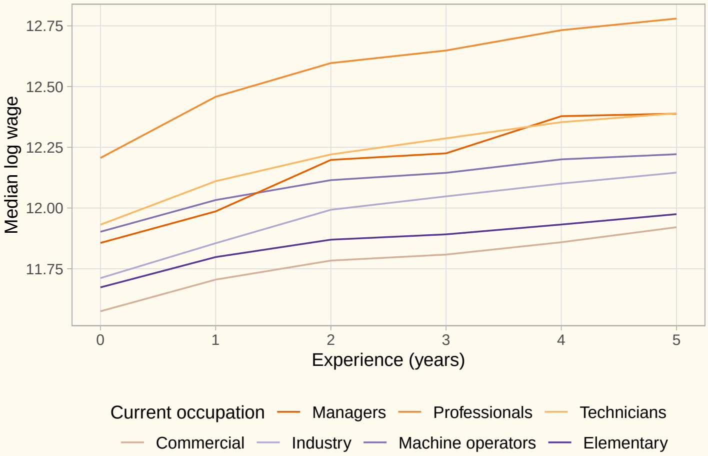
Occupations capture diverging wage trajectories

By age
By first occ.
By current occ.
Data
Job ladders
Transition matrix
Back

Occupations capture diverging wage trajectories

Back

Occupations capture diverging wage trajectories



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Occupations capture diverging wage trajectories

Back

Flow vs. continuation value—formulas

$$V_{ai} = \overbrace{\frac{u_{ai}}{\Gamma}}^{\text{flow value}} + \overbrace{\frac{\mathbb{E}_w\left[\chi_{ai}^{aw} V_{aw}\right]}{\Gamma} + \frac{\delta_a V_n}{\Gamma} + \underbrace{\frac{\mathbb{E}_{o,w,\tilde{c}}\left[\lambda_a^o \max\{V_{ow} - \tilde{c}_a^o, V_{ai}\}\right]}{\Gamma}}_{\text{option value}}}^{\text{continuation value}}$$

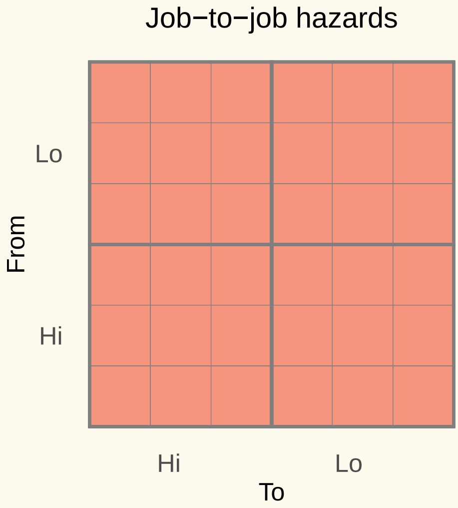
$$\Gamma = \sum_o \lambda_a^o + \sum_w \chi_{ai}^{aw} + \delta_a + \rho$$

Back

Offered wages (opportunities)

Identifying variation

Hazards across destination jobs

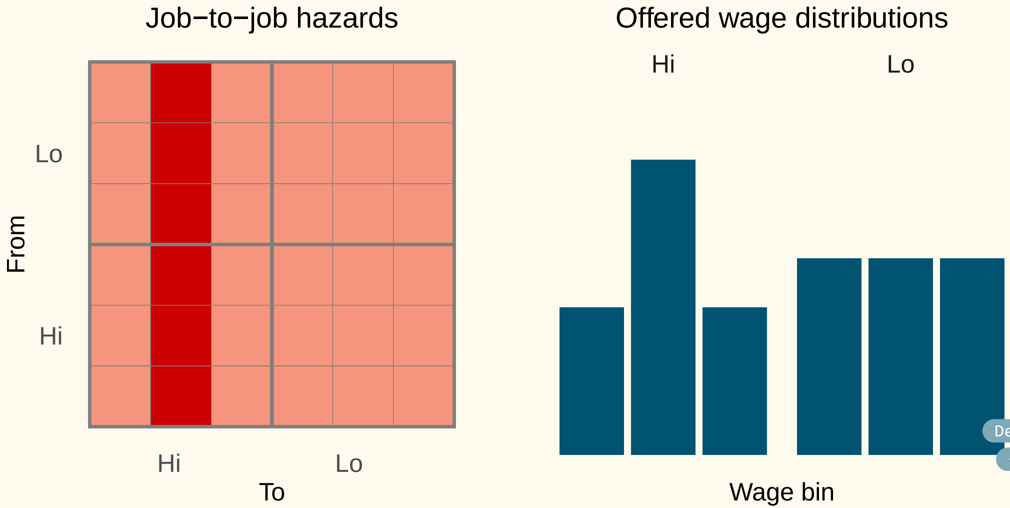


Derivation
Back

Offered wages (opportunities)

Identifying variation

Hazards across destination jobs

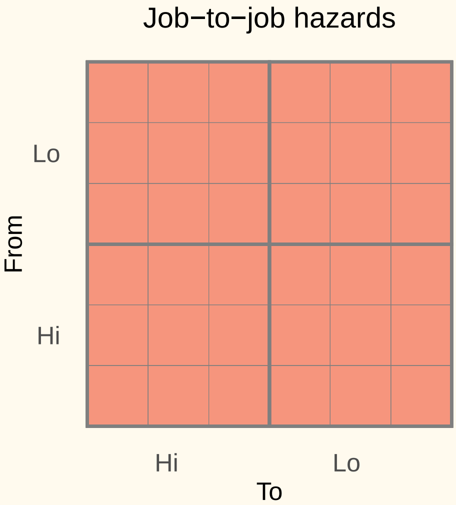


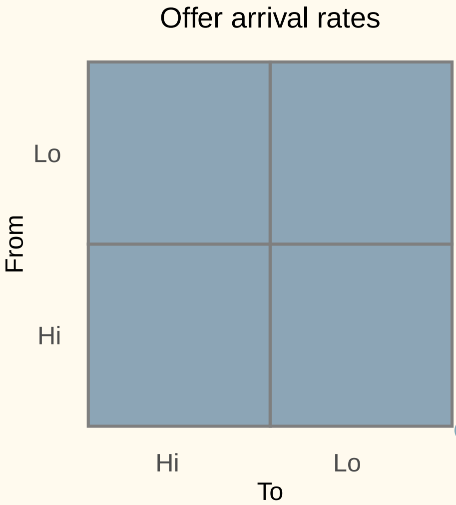
Derivation
Back

Offer arrival rates (opportunities)

<u>Identifying variation</u>

Hazards across origin and destination occupations at high wages





Derivation
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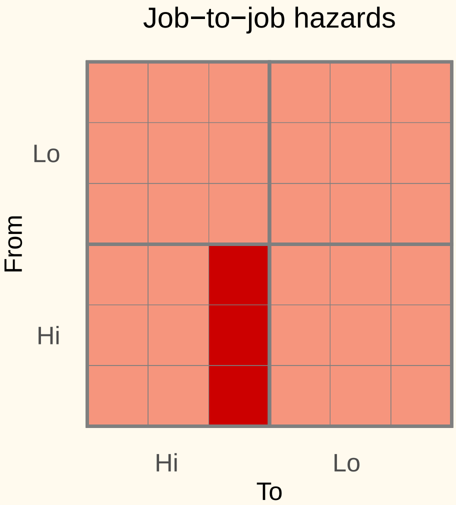


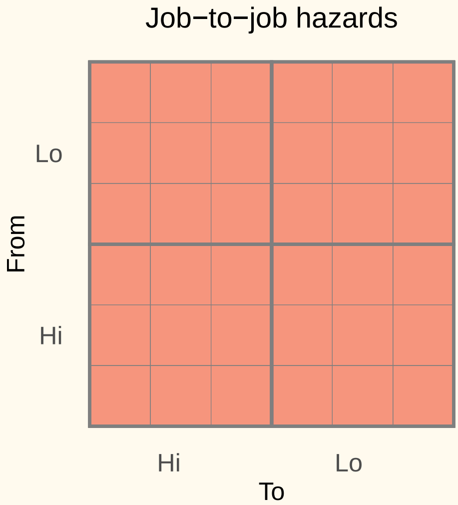
Derivation

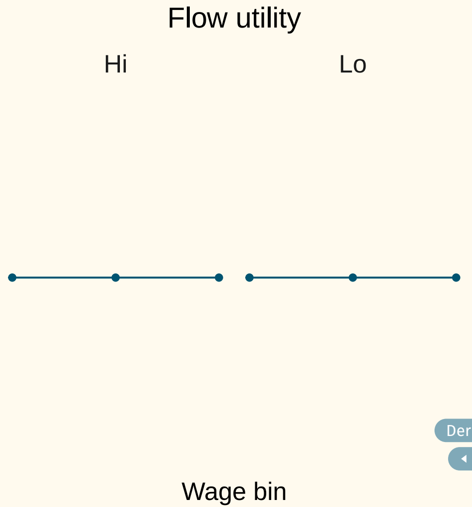
Back

Flow utilities (choices)

Identifying variation

Hazards across origin and destination jobs





Derivation

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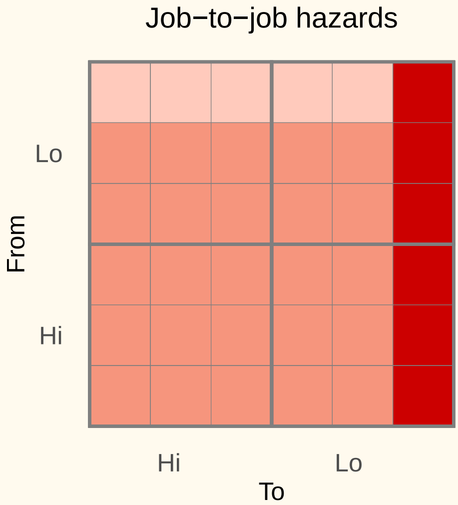
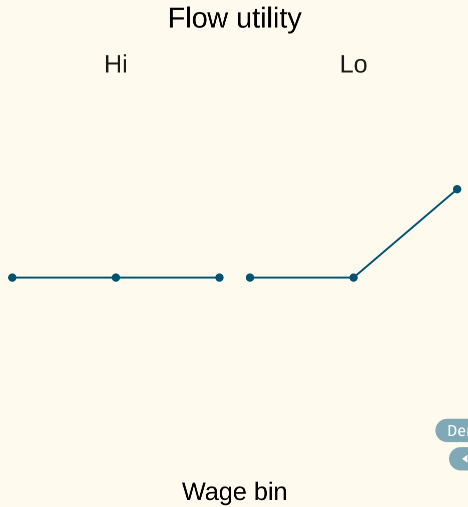


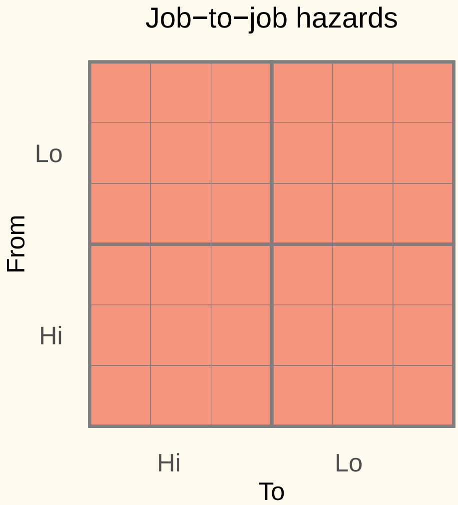


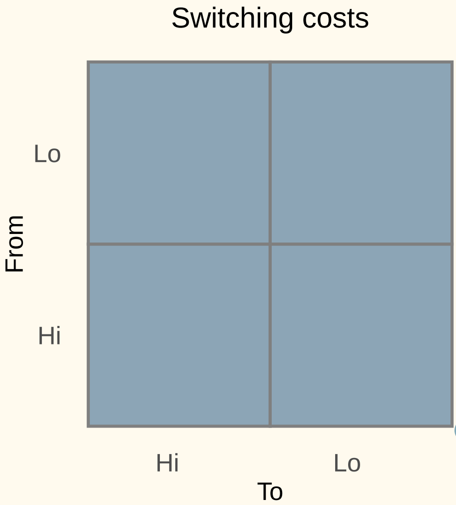
Derivation
Back

Switching costs (choices)

Identifying variation

Hazards across origin and destination occupations at all wages



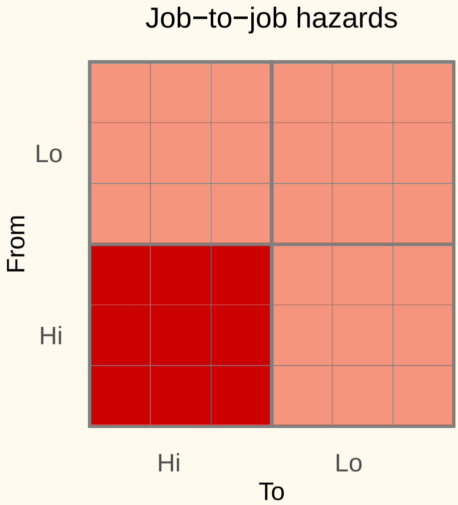


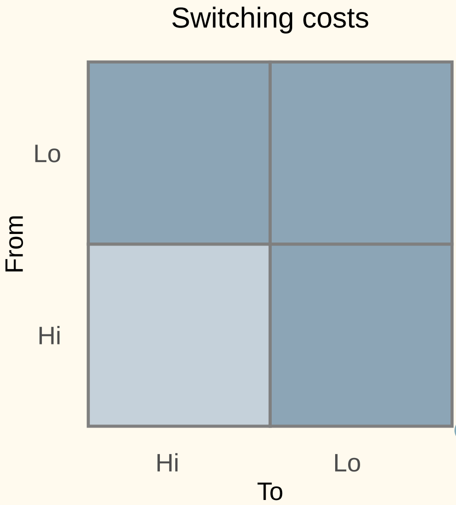
Structure
Derivation
Back

Switching costs (choices)

Identifying variation

Hazards across origin and destination occupations at all wages





Structure

Derivation

Back

Offered wages (opportunities)

Idea: compare hazards of moving to the same job as the current one. Differential rates across wages are due to differences in offer propensity.

Note that $p_{ai}^{ai} = p_{aj}^{aj}$ for all a, i, j

$$p_{ai}^{ai} = \frac{\exp(V_{ai} - V_{ai} - c_a^a)}{1 + \exp(V_{ai} - V_{ai} - c_a^a)} = \frac{\exp(-c_a^a)}{1 + \exp(-c_a^a)}$$

Therefore

$$\frac{h_{ai}^{ai}}{h_{aj}^{aj}} = \frac{\lambda_a^a p_{ai}^{ai} f^{ai}}{\lambda_a^a p_{aj}^{aj} f^{aj}} = \frac{f^{ai}}{f^{aj}}$$

$$\implies f^{ai} = \frac{h_{ai}^{ai}}{\sum_w h_{aw}^{aw}}$$

Very simple estimation is appealing to wider audience

Back

Offer arrival rates (opportunities)

Idea: the odds of accepting an offer plus its reverse needs to be equal for all wages

Log odds of accepting offers can be written in two ways:

1. Plugging in structural parameters for CCPs:

$$\varpi_{ai}^{bj} = \log\left(\frac{p_{ai}^{bj}}{1 - p_{ai}^{bj}}\right) = \log\left(\frac{h_{ai}^{bj}}{\lambda_a^b f^{bj} - h_{ai}^{bj}}\right)$$

   Only unknown is $\lambda_a^b \implies \varpi_{ai}^{bj} \equiv \varpi_{ai}^{bj}(\lambda_a^b)$

2. Plugging in value functions for CCPs:

$$\varpi_{ai}^{bj} = \log\left(\frac{p_{ai}^{bj}}{1 - p_{ai}^{bj}}\right) = V_{bj} - V_{ai} - c_a^b$$

Back

Offer arrival rates (opportunities)

First, offer arrives from same occupation:

$$\varpi_{ai}^{aj} = V_{aj} - V_{ai} - c_a^a$$

$$\implies \varpi_{ai}^{aj} + \varpi_{aj}^{ai} = \varpi_{ak}^{a\ell} + \varpi_{a\ell}^{ak} \quad \implies \quad \lambda_a^a \text{ from any } (i, j, k, \ell) \text{ 4-tuple}$$

Next, offer arrives from another occupation:

$$\varpi_{ai}^{bj} = V_{bj} - V_{ai} - c_a^b$$

$$\implies \varpi_{ai}^{bj} + \varpi_{bj}^{ai} = \varpi_{ak}^{b\ell} + \varpi_{b\ell}^{ak} \quad \implies \lambda_a^b, \lambda_b^a \text{ from any two } (i, j, k, \ell), (i', j', k', \ell') \text{ 4-tuples}$$

Back

CCPs

Idea: having identified the offered wages and arrival rates, CCPs map to hazards

By the hazard definition,

$$h_{ai}^{bj} = \lambda_a^b p_{ai}^{bj} f^{bj}$$

$$\implies p_{ai}^{bj} = \frac{h_{ai}^{bj}}{\lambda_a^b f^{bj}}$$

Back

Flow utilities and switching costs (choices)

Idea: remaining parameters come from changes across wages vs. occupations

Plug the structural parameters in the values in the log odds:

$$
\begin{aligned}
\varpi_{ai}^{bj} &= V_{bj} - V_{ai} - c_a^b \\
&= \frac{1}{\delta_b + \rho}\left(u_{bj} + \sum_w \chi_{bj}^{bw}(\varpi_{bj}^{bw} + c_b^b) - \sum_{o,w} \lambda_b^o \log(1 - p_{bj}^{ow}) f^{ow}\right) \\
&\quad - \frac{1}{\delta_a + \rho}\left(u_{ai} + \sum_w \chi_{ai}^{aw}(\varpi_{ai}^{aw} + c_a^a) - \sum_{o,w} \lambda_a^o \log(1 - p_{ai}^{ow}) f^{ow}\right) \\
&\quad + \frac{\delta_b - \delta_a}{(\delta_b + \rho)(\delta_a + \rho)}\left(u_n - \sum_{o,w} \lambda_n^o \log(1 - p_n^{ow}) f^{ow}\right) - c_a^b
\end{aligned}
$$

This expression is linear in u_{bj}, u_{ai}, u_n, and c_a^b

We can write this in matrix form as

$$\kappa = A\theta \qquad \Longrightarrow \qquad \theta = A^+\kappa$$

◂ Back

Additional structure: relative symmetry along skill content

Skill content of origin occupation (rows) / Skill content of destination occupation (columns)

	Managers (5)	Professionals (4)	Technicians (3)	Office clerks (2)	Commercial (2)	Industry (2)	Machine operators (2)	Elementary (1)
Elementary (1)	α_1^5	α_1^4	α_1^3	α_1^2	α_1^2	α_1^2	α_1^2	
Machine operators (2)	α_2^5	α_2^4	α_2^3	α_2^2	α_2^2	α_2^2		
Industry (2)	α_2^5	α_2^4	α_2^3	α_2^2	α_2^2			
Commercial (2)	α_2^5	α_2^4	α_2^3	α_2^2				
Office clerks (2)	α_2^5	α_2^4	α_2^3					
Technicians (3)	α_3^5	α_3^4						
Professionals (4)	α_4^5							
Managers (5)								

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Estimation procedure

Two-stage MLE, competing risks with exponential hazards and two-sided censoring

1. Estimate wage change rates χ and separation rates δ Formulas
2. Estimate hazards, imposing structure Likelihood

$$L(h) = L\left(\underbrace{\lambda f}_{\text{Pr(offer arrives)}} \times \underbrace{p(\lambda, f, u, c, \hat{\chi}, \hat{\delta})}_{\text{Pr(offer is accepted)}} \right)$$

CCPs come from iterating the value function to a fixed point VFI

Additional structure on offered wages, switching costs, flow utilities f c u

I allow for two unobserved heterogeneity types Reduced EM algorithm

Global optim

Back

Estimating wage change rates χ and separation rates δ

$$\left(\hat{\chi}_{ai}^{aw}\right)_r = \frac{\sum_\iota q_{\iota r} \sum_s \mathbb{1}(a_s = a, i_s = i, d_s = WW, j_s = w)}{\sum_\iota q_{\iota r} \sum_s \mathbb{1}(a_s = a, i_s = i)\, t_s}$$

$$\left(\hat{\delta}_a\right)_r = \frac{\sum_\iota q_{\iota r} \sum_s \mathbb{1}(a_s = a, d_s = EN)}{\sum_\iota q_{\iota r} \sum_s \mathbb{1}(a_s = a)\, t_s}$$

◂ Back

Likelihood

Likelihood contribution of a single spell s:

$$L_s(h) = \prod_{a,i} \prod_{b,j} \left[\left(h_{ai}^{bj} \right)^{\mathbb{1}(b_s=b,\, j_s=j)} \exp\left(-h_{ai}^{bj} t_s \right) \right]^{\mathbb{1}(a_s=a,\, i_s=i)}$$

Full likelihood:

$$L(h) = \sum_{\iota=1}^{I} \sum_{s=1}^{S_\iota} \log L_s(h)$$

Imposing structure:

$$L(\lambda, f, u, c) = \sum_{\iota=1}^{I} \sum_{s=1}^{S_\iota} \log L_s(\lambda f p(\lambda, f, u, c, \hat{\chi}, \hat{\delta}))$$

Back

Value function iteration

mth iteration:

$$\left(\sum_o \lambda_a^o + \sum_w \chi_{ai}^{aw} + \delta_a + \rho\right) V_{ai}^{(m)} = u_{ai} + \sum_o \lambda_a^o V_{ai}^{(m-1)} + \sum_w \chi_{ai}^{aw} V_{aw}^{(m-1)} + \delta_a V_n^{(m-1)}$$
$$+ \sum_{o,w} \lambda_a^o \log\left(1 + \exp\left(V_{ow}^{(m-1)} - V_{ai}^{(m-1)} - c_a^b\right)\right) f^{ow}$$

I calculate the CCPs as

$$p_{ai}^{bj} = \frac{\exp\left(V_{bj}^* - V_{ai}^* - c_a^b\right)}{1 + \exp\left(V_{bj}^* - V_{ai}^* - c_a^b\right)}$$

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Reduced EM algorithm

1. Estimate posterior type distribution using reduced-form full loglikelihood:

$$\max \sum_{\iota} \log \left[\sum_r \pi_r \left(\underline{L}_{\iota r} \prod_s \tilde{L}_{sr} \right) \right] \quad \rightsquigarrow q_{\iota r}$$

2. Calculate wage change rates, job separation rates:

$$\left(\hat{\chi}_{ai}^{aw}\right)_r = \frac{\sum_\iota q_{\iota r} \sum_s \mathbb{1}(a_s = a, i_s = i, d_s = WW, j_s = w)}{\sum_\iota q_{\iota r} \sum_s \mathbb{1}(a_s = a, i_s = i)\, t_s}, \quad \left(\hat{\delta}_a\right)_r = \frac{\sum_\iota q_{\iota r} \sum_s \mathbb{1}(a_s = a, d_s = EN)}{\sum_\iota q_{\iota r} \sum_s \mathbb{1}(a_s = a)\, t_s}$$

3. Estimate remaining structural parameters using expected complete loglikelihood:

$$\max \sum_\iota \sum_r q_{\iota r} \sum_s \log L_{sr}(\lambda f\, p(\lambda, f, u, c, \hat{\chi}, \hat{\delta})$$

Back

Structure on offered wages

Cutoffs:

$$\phi_w = \begin{cases} \theta_1^{\phi} & \text{for } w = 1 \\ \phi_{w-1} + \exp(\theta_2^{\phi} + \theta_3^{\phi} \log \mathrm{w}_w + \theta_4^{\phi} \log \mathrm{w}_w^2) & \text{for } w > 1 \end{cases}$$

Logit structure:

$$f^{ow} = \begin{cases} \Lambda(\phi_w + \theta^o) & \text{for } w = 1 \\ \Lambda(\phi_w + \theta^o) - \Lambda(\phi_{w-1} + \theta^o) & \text{for } 1 < w < W \\ 1 - \Lambda(\phi_{W-1} + \theta^o) & \text{for } w = W \end{cases}$$

Back

Global optimization routine

1. Optimize from “reasonable” starting values ($R = 1$)

2. Evaluate objective function in a Sobol sequence near local optimum
   - 1,000 points, ±50% vicinity

3. If higher value found, optimize using corresponding arg max as starting values
   If not, global optimum found

Iterate steps 2-3 until convergence

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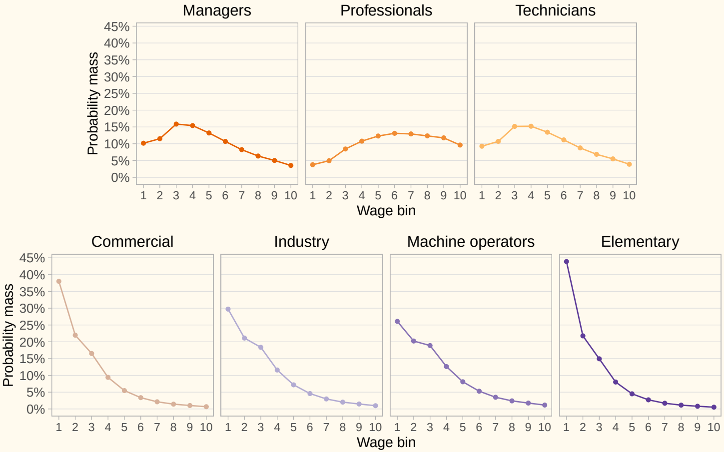
Offered wages



Structure
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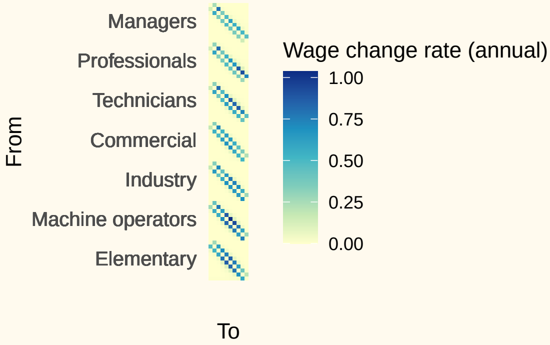
Wage change rates



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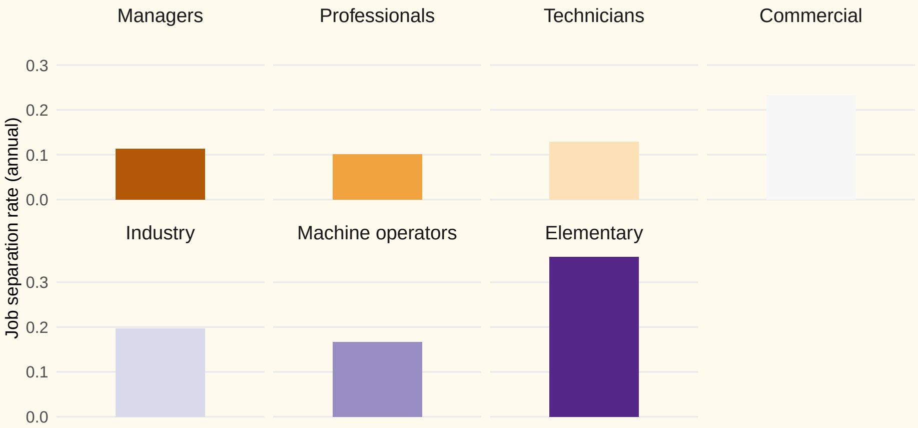
Job separation rates



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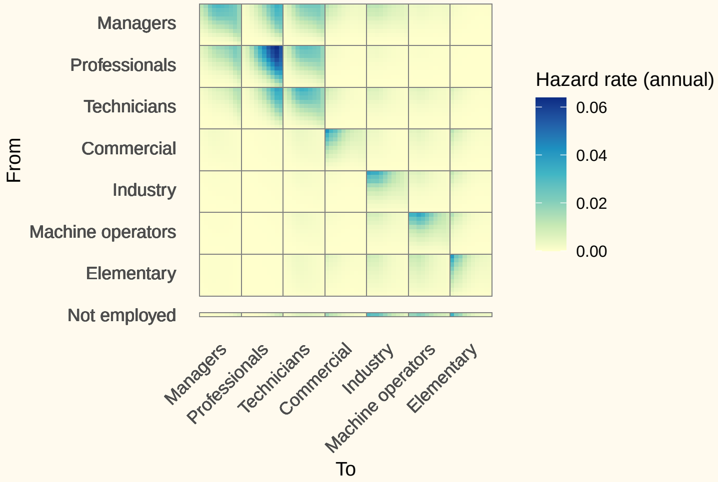
Hazards



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Offer arrival rates

From \ To	Managers	Professionals	Technicians	Commercial	Industry	Machine operators	Elementary	Total
Managers	0.54	0.40	0.62	0.72	0.71	0.44	0.62	4.05
Professionals	0.66	0.63	0.53	0.06	0.08	0.08	0.13	2.19
Technicians	0.57	0.47	0.49	0.12	0.11	0.18	0.57	2.51
Commercial	0.02	0.01	0.04	0.96	0.04	0.10	0.65	1.81
Industry	0.01	0.01	0.03	0.16	0.73	0.11	0.53	1.58
Machine operators	0.00	0.00	0.03	0.09	0.17	0.83	0.29	1.42
Elementary	0.00	0.00	0.03	0.18	0.10	0.14	0.94	1.39
Not employed	0.36	0.24	0.12	0.31	0.57	0.70	1.01	3.31

(annual rates)

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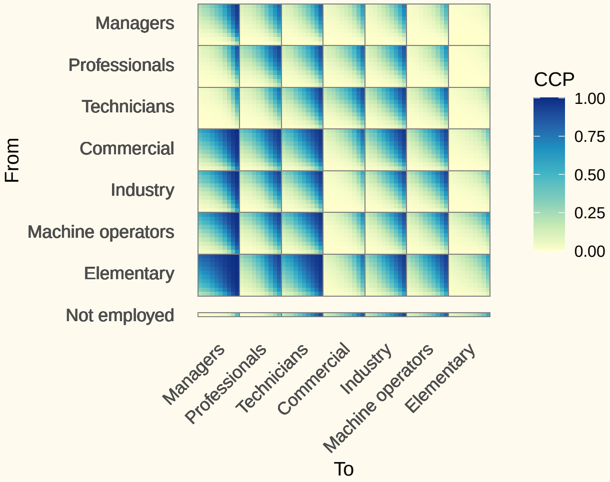
CCPs


Managers
Professionals
Technicians
Commercial
Industry
Machine operators
Elementary
Not employed
From
To
CCP
1.00
0.75
0.50
0.25
0.00

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Mean switching costs

From \ To	Managers	Professionals	Technicians	Commercial	Industry	Machine operators	Elementary
Managers	1.21	1.28	1.01	1.20	1.28	1.45	1.20
Professionals	3.18	1.16	1.24	1.01	1.26	1.64	2.06
Technicians	4.50	2.71	1.15	0.73	1.01	1.21	1.29
Commercial	1.60	1.46	0.83	2.05	1.00	1.01	1.43
Industry	1.71	1.82	1.15	3.05	1.56	0.75	1.01
Machine operators	1.94	2.36	1.38	3.07	2.28	1.73	0.80
Elementary	2.10	3.59	1.95	3.97	2.82	2.22	2.24
Not employed	5.42	4.21	1.33	1.01	1.01	1.01	0.00

(utils)

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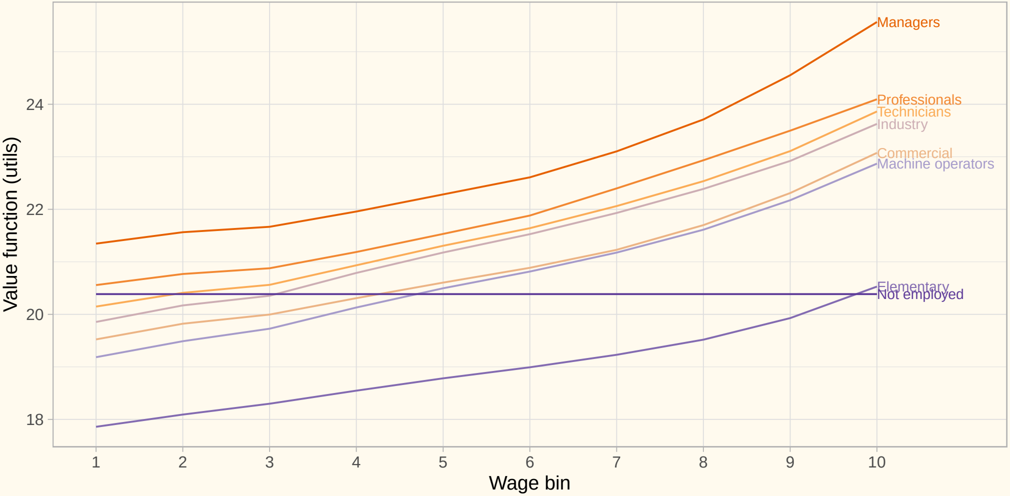
Value functions



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Compensating differentials

How much would a median-wage worker in occupation a have to be compensated to accept a machine operator job?

$$\psi_a + \beta \log \bar{w}_a = \psi_{MO} + \beta \log w_a^{MO}$$

Occupation	β	ψ_a	Comp. diff.
Managers	1.01	-0.20	0.89
Professionals		-0.52	0.65
Technicians		-0.24	0.85
Commercial		0.04	1.14
Industry		0.13	1.24
Machine operators		-0.09	–
Elementary		-0.69	0.55

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Simulation procedure

0. Initialize G number of individuals in each occupation and wage bin $G = 1,000$

1. Draw exponential durations using hazards h, wage change ratesχ, and job separation rates δ

2. Take minimum duration (competing hazards), record new job

Repeat steps 1-2 until sufficient years of cumulative durations are drawn (45 years)

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