

# Cyclical Labor Market Sorting

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# Disclaimer

Opinions expressed herein are those of the authors alone and do not necessarily reflect the views of the U.S. Census Bureau or the Federal Reserve System.

All results have been reviewed to ensure that no confidential data are disclosed.

# Motivation

- ▶ How do we rank workers in terms of productivity?
- ▶ How do we rank firms in terms of productivity?
- ▶ How does the joint distribution of workers/firms change over the business cycle?
- ▶ What does the match production function look like?
- ▶ Why should we care? Mismatch, inequality, cyclical labor reallocation rates, etc.

# Outline

- ▶ Data: Linked employer-employee microdata.
- ▶ Measurement: Rank workers by productivity, 4 ways. Rank firms by productivity, 4 ways.
- ▶ Results: Worker-firm sorting patterns. Cyclical changes. Agreement among ranking methods.
- ▶ Model: Target cyclical sorting moments. Implications for the match production function. Costs of mismatch.

# Results Summary

1. Worker-type distribution moves towards better workers in recessions (cleansing). Firm-type distribution moves towards *worse* firms (sullyng).
2. Positive assortative matching strengthens in recessions.
3. Strongest shift away from low-ranked workers at high-ranked firms.
4. Different ranking methods agree on the qualitative results.
  - ▶ Very similar composition changes, some differences on magnitude and cyclicalty of sorting.
5. Implications of cyclical sorting moments for production function:
  - ▶ More variation from worker type than firm type
  - ▶ Complementarity between workers and firms appears positive but potentially small

## Related Literature

- ▶ Cyclical Worker Composition
  - ▶ van Ours and Ridder (1995), Gautier, van den Berg, van Ours, and Ridder (2002), Devereux (2002), Modestino, Shoag, and Ballance (2014, 2016)
- ▶ Cyclical Job Ladders and the Sullyng Effect of Recessions
  - ▶ Barlevy (2002), Moscarini and Postel-Vinay (2009, 2012, 2013, 2016), Cairó, Hyatt, and Zhao (2016), Haltiwanger, Hyatt, Kahn, and McEntarfer (2017)
- ▶ Labor Market Sorting
  - ▶ Abowd, Kramarz, and Margolis (1999), Eeckhout and Kircher (2011, 2017), Bagger, Sørensen, and Vejlin (2013), Eeckhout and Sepahsafari (2015), Lopes de Melo (2015), Bartolucci, Devicienti, and Monzón (2015), Bagger and Lentz (2016), Dinlersoz, Hyatt, and Janicki (2016), Card, Cardoso, and Kline (2016), Herkenhoff, Phillips, and Cohen-Cole (2017), Hagedorn, Law, and Manovskii (2017), Lise and Robin (2017), Haltiwanger, Hyatt, and McEntarfer (2018)

## **Longitudinal Employer-Household Dynamics (LEHD)**

- ▶ Quarterly employer-employee linked dataset primarily derived from state unemployment insurance records and the Quarterly Census of Employment and Wages and covering approximately 98% of private sector employment.
- ▶ Eleven state sample: California, Colorado, Idaho, Illinois, Kansas, Maryland, Montana, North Carolina, Oregon, Washington, and Wisconsin
- ▶ All eleven states have data for the entirety of the analysis period from 1994-2014.
- ▶ Only include dominant employer jobs and transitions, see Hyatt, McEntarfer, McKinney, Tibbets, and Walton (2014).

## **Business Register and Longitudinal Business Database**

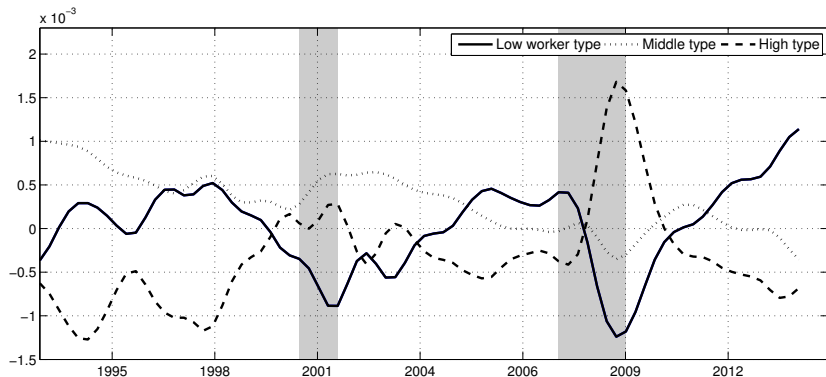
- ▶ Annual revenue and total employment at EIN level for SEINs operating in the eleven states over the 1996-2014 period, see Haltiwanger, Kulick, Jarmin, and Miranda (2017).





# Cyclical Fluctuations in Worker and Firm Composition

# Change in Employment Share by Worker Type: Additive



**Figure:** Quarter-over-quarter change in share of total employment by worker type as estimated in the additive worker-firm fixed effect model. Source: LEHD micro-data for an eleven state sample covering 1994-2015.

Reranking

Employment

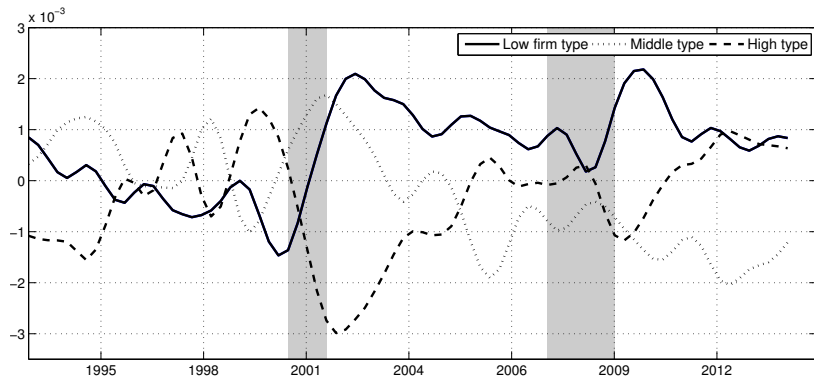
Earnings

# Worker Employment Share Change Regressions

	Additive	Reranking	Employment	Earnings
<i>First-Difference of Unemployment Rate</i>				
Workers: Low	<b>-12.6***</b> (2.71)	<b>-11.41***</b> (2.29)	<b>-44.93***</b> (5.03)	<b>-13.88***</b> (3.15)
Workers: High	<b>14.82***</b> (2.18)	<b>12.87***</b> (1.70)	<b>31.60***</b> (3.89)	<b>16.90***</b> (2.72)
<i>Deviation of Unemployment Rate from HP Trend</i>				
Workers: Low	<b>-3.17**</b> (1.20)	<b>-2.74***</b> (1.03)	<b>-11.22***</b> (2.65)	<b>-2.99**</b> (1.40)
Workers: High	<b>2.37**</b> (1.10)	<b>2.21**</b> (0.89)	<b>7.35***</b> (2.00)	<b>2.09</b> (1.35)

*Notes:* Estimates of change in share of employment on the seasonally-adjusted unemployment rate, season dummies, and a time trend. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1%, respectively. Standard errors are in parentheses.

# Change in Employment Share by Firm Type: Additive



**Figure:** Quarter-over-quarter change in share of total employment by firm type as estimated in the additive worker-firm fixed effect model. Source: LEHD micro-data for an eleven state sample covering 1994–2015.

Surplus

Poaching

Productivity

Comparing Recessions

# Firm Employment Share Change Regressions

	Additive	Surplus	Poaching	Productivity
	<i>First-Difference of Unemployment Rate</i>			
Firms: Low	<b>1.95</b> (3.87)	<b>8.99**</b> (3.62)	<b>11.96**</b> (5.51)	<b>8.18**</b> (3.36)
Firms: High	<b>-8.50*</b> (4.65)	<b>-6.63</b> (4.46)	<b>-8.90*</b> (4.66)	<b>5.45</b> (3.72)
	<i>Deviation of Unemployment Rate from HP Trend</i>			
Firms: Low	<b>5.52***</b> (1.45)	<b>5.37***</b> (1.41)	<b>6.30***</b> (2.20)	<b>5.02***</b> (1.30)
Firms: High	<b>-6.55***</b> (1.79)	<b>-7.15***</b> (1.65)	<b>-6.89***</b> (1.78)	<b>-4.11***</b> (1.46)

*Notes:* Estimates of change in share of employment on the seasonally-adjusted unemployment rate, season dummies, and a time trend. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1%, respectively. Standard errors are in parentheses.

# Evidence on Worker and Firm Composition

- ▶ Higher levels of the cyclical indicator (unemployment):
  - ▶ Shift away from low-ranked workers, toward higher-ranked workers
  - ▶ Shift away from high-ranked firms, toward low-ranked firms
- ▶ Differences in timing
  - ▶ Worker shifts more responsive to unemp. FD (NBER recessions)
  - ▶ Firm shifts more responsive to HP-detrended unemployment (times of high unemployment)
  - ▶ Local maximum in shift toward high-ranked workers often precedes local maximum for low-ranked firms Timing

# Cyclical Labor Market Sorting

## Correlation between worker and firm type

	Additive	Reranking & Surplus	Employment & Poaching	Earnings & Productivity
<i>First-Difference of Unemployment</i>				
Unemployment (FD)	<b>1.74***</b> (0.41)	<b>-0.40</b> (0.25)	<b>1.18**</b> (0.48)	<b>0.44***</b> (0.13)
<i>Difference in Unemployment from HP Trend</i>				
Unemployment (HP)	<b>0.25</b> (0.18)	<b>0.31***</b> (0.10)	<b>-0.02</b> (0.20)	<b>0.30***</b> (0.05)

Notes: Dependent Variable: Correlation of Worker and Firm Ranks within given model for each quarter. Regress on the cyclical indicator with season dummies and a linear time trend. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parentheses.

Worker-Firm Correlations



# Sorting and Increases in Unemployment (FD)

	Additive	Reranking & Surplus	Employment & Poaching	Earnings & Productivity
<i>Employed at Low-Type Firms</i>				
Workers: Low	-0.84 (2.34)	0.93 (1.66)	-8.25*** (3.04)	0.51 (2.42)
Workers: High	2.34* (1.29)	4.59*** (1.26)	9.76*** (1.94)	3.47** (1.33)
<i>Employed at High-Type Firms</i>				
Workers: Low	-9.09*** (1.58)	-6.45*** (1.65)	-18.10*** (3.05)	-4.08*** (1.30)
Workers: High	5.70** (2.31)	4.06** (1.74)	11.00*** (1.56)	10.62*** (2.17)

*Notes:* Estimates of the on the change in share of employment on the seasonally-adjusted first difference of unemployment rate, season dummies, and a time trend. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1%, respectively. Standard errors are in parentheses.

# Poaching Propensity and Increases in Unemployment (FD)

	Additive	Reranking & Surplus	Employment & Poaching	Earnings & Productivity
<i>Employed at Low-Type Firms</i>				
Workers: Low	34*** (7)	38*** (7)	46*** (8)	24*** (8)
Workers: High	32*** (9)	38*** (7)	18*** (5)	40*** (13)
<i>Employed at High-Type Firms</i>				
Workers: Low	-77*** (12)	-50*** (11)	-76*** (14)	-45*** (9)
Workers: High	-19*** (6)	-21*** (5)	-13*** (4)	-12*** (4)

*Notes:* Estimates of net poaching (share of worker-firm employment) on the seasonally-adjusted first difference of unemployment rate, season dummies, and a time trend. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1%, respectively. Standard errors are in parentheses.

# Evidence on Cyclical Labor Market Sorting

- ▶ Correlation between worker and firm types increases when unemployment increases
- ▶ Reductions in the share of low-type workers is concentrated in high-type firms
- ▶ Both low-type and high-type workers move from low-ranked to high-ranked firms, and more quickly during expansions

# Search & Matching Model

# Search & Matching Model

The *Lise and Robin (2016)* search-and-matching model

- ▶ Heterogeneous worker quality ( $x$ )
- ▶ Heterogeneous firm quality ( $y$ )
- ▶ Aggregate productivity shocks ( $z_t$ ) - follows AR(1) process
- ▶ Output of a worker-firm match is  $f(x, y, z)$
- ▶ Search from nonemployment: Firm makes TIOLI offer to worker.
- ▶ Wage of a match changes only when one party has a credible outside option.
- ▶ On-the-job search: Firms engage in Bertrand competition. Worker goes to the highest productivity match, and receives the total surplus of the losing firm.
- ▶ Total match surplus  $S(x, y, z_t)$  depends on the production function and the evolution of  $z_t$  - *no endogenous distributions*.

# Model Estimation

- ▶ *Lise and Robin (2016)*: SMM targeting 28 moments.
- ▶ We extend the *Lise and Robin (2016)* model to match 9 new moments: the change in employment shares of match types in response to a 1% change in the unemployment rate.
- ▶ Following *Lise and Robin (2016)*, we parameterize the production function as:

$$f(x, y, z_t) = z_t (p_1 + p_2x + p_3y + p_4x^2 + p_5y^2 + p_6xy)$$

- ▶ We also allow different firms to have different sensitivity to the aggregate shock:

$$f(x, y, z_t) = z_t^{1+p_7y} (p_1 + p_2x + p_3y + p_4x^2 + p_5y^2 + p_6xy)$$

# Cyclical Sorting Moments Comparison

Table: Cyclical Sorting Moments: Data & Model-Implied

Moment	Data	Untargeted Est.	LEHD Moments Est.	Excess Sensitivity Est.
$\beta_{LL}$	-1.900	-343.294	3.086	-5.084
$\beta_{ML}$	4.453	51.521	15.500	0.0691
$\beta_{HL}$	4.523	-49.866	5.210	2.908
$\beta_{LM}$	-7.211	-35.390	-9.241	-5.326
$\beta_{MM}$	2.599	-37.221	-1.814	5.54
$\beta_{HM}$	4.668	404.378	4.322	-1.049
$\beta_{LH}$	-9.180	-165.962	-9.258	18.033
$\beta_{MH}$	-1.876	258.472	-5.981	-9.422
$\beta_{HH}$	3.924	-82.638	-1.824	-5.636

Notes: Coefficient  $\beta_{ij}$  is the impact of a 1 percent change in the unemployment rate on the share of matches between type  $i$  workers and type  $j$  firms, where  $i$  and  $j$  can be low (L), medium (M), or high (H)

# Estimated Production Function

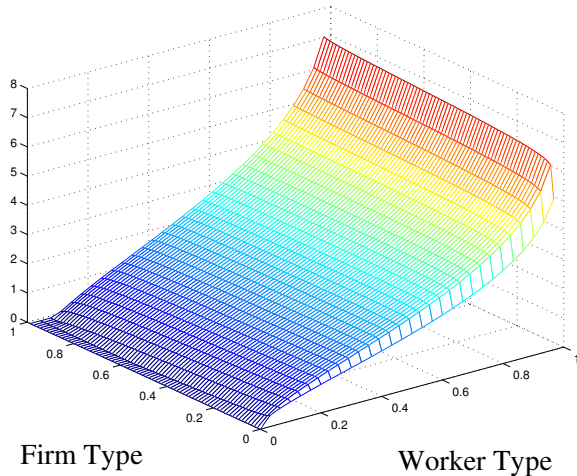
$$f(x, y, z_t) = z_t^{1+p_7y} (p_1 + p_2x + p_3y + p_4x^2 + p_5y^2 + p_6xy)$$

Table: Production Function Parameter Estimates

Parameter	Untargeted Estimates	LEHD Moments Estimates	Excess Sensitivity Estimates
$p_1$	0.003	0.001	0.004
$p_2$	2.053	2.745	2.09
$p_3$	-0.140	-0.230	-0.088
$p_4$	8.035	8.102	7.165
$p_5$	-1.907	-1.940	-2.105
$p_6$	6.596	6.577	6.121
$p_7$	-	-	-0.095



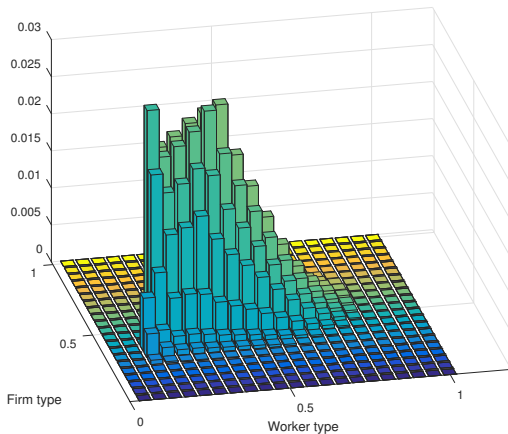
# Estimated Production Function



- ▶ Firm type does not rank firm's productivity globally:  $p_3 < 0$ ,  $p_5 < 0$ ,  $p_6 > 0$
- ▶ Most variation in match output is driven by the worker type Lise & Robin

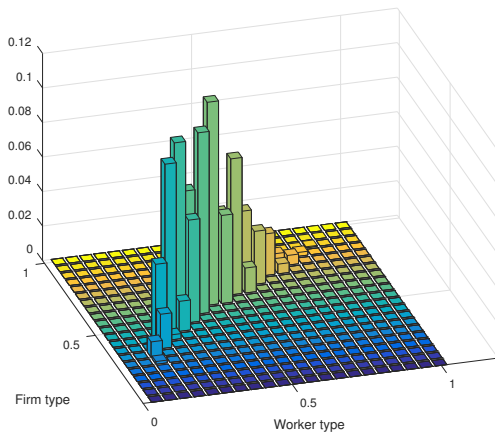
Excess Sensitivity

# Mismatch



- ▶ Given the matched populations of workers and firms, frictions keep agents from reaching their optimal match.

# Mismatch



- ▶ Moving to the optimal assignment increases output 2%.

# Evidence from model estimation

- ▶ Differences in output driven by worker type rather than firm type
- ▶ Complementarities in production between worker and firm type positive but small
- ▶ Fit of model not materially improved by allowing high-type firms to experience greater “demand shocks”
  - ▶ Effect small and suggests low-type firms experience *greater* cyclical shifts in productivity.
  - ▶ Fit of cyclical composition moments declines.
- ▶ Mismatch effect on output about 2%

Direct Estimation of Production Function

# Conclusion

1. Worker-type distribution moves towards better workers in recessions (cleansing). Firm-type distribution moves towards *worse* firms (sullyng).
2. Positive assortative matching strengthens in recessions. More mass on the diagonal.
3. Different ranking methods agree on the qualitative results.
4. Match production function appears flat w.r.t. firm type. Main variation is along worker dimension.

# Appendix

# Worker and Firm Ranking Methods

# Method 1: Additive Worker and Firm Ranking

Rank firms by their estimated fixed effects from AKM regression model<sup>1</sup>

$$w_{it} = \alpha_i + \psi_{J(i,t)} + X_{it}\beta + \epsilon_{it} \quad (1)$$

where

- ▶  $w_{it}$  = log quarterly earnings of worker  $i$  in period  $t$
- ▶  $\alpha_i$  = worker-specific fixed effect for worker  $i$
- ▶  $\psi_{J(i,t)}$  = firm-specific fixed effect for firm  $J$ , which is employing worker  $i$  in period  $t$
- ▶  $X_{it}$  = a set of distinct dummy variables for workers' age in years for each time-period  $t$ .

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<sup>1</sup>References: *Abowd, Kramarz, and Margolis (1999)*; *Card, Heining, and Kline (2013)*; *Card, Cardoso, and Kline (2014)*



# Additive Worker-Firm Identifying Assumptions

$$\epsilon_{it} = \phi_{J(i,t),t} + m_{i,J(i,t)} + \zeta_{it} \quad (2)$$

where

- ▶  $\phi_{J(i,t),t}$  = a time-varying firm-specific shock to log earnings
- ▶  $m_{i,J(i,t)}$  = an idiosyncratic worker-firm specific match component to log earnings
- ▶  $\zeta_{it}$  = a composite error term

Identifying Assumptions:

- ▶  $Cov(\alpha_i, \phi_{J(i,t),t}) = 0$
- ▶  $Cov(\alpha_i, m_{i,J(i,t)}) = 0$
- ▶  $Cov(\alpha_i, \zeta_{it}) = 0$

## Method 2: Worker Reranking from Nonemployment

Within any given firm, the earnings of *workers hired from nonemployment* should be increasing in worker productivity. But firms may *mismeasure* individual worker productivity and *no single firm* employs all workers.

1. Construct an initial ranking of workers by their residual average earnings at jobs where each worker was hired directly from nonemployment
2. For each worker and given the rank order of her coworkers, calculate the worker rank that maximizes the likelihood of observing this worker's earnings relative to her coworkers (who are also hired from nonemployment). Optimal Worker Rank
3. After calculating the optimal rank for each worker, repeat Step 2, but using the new optimal ranking for the coworkers' ranks. Iterate until convergence criteria is met.<sup>2</sup>

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<sup>2</sup>Reference: *Hagedorn, Law, and Manovskii (2016)* 

## Method 2: Worker Reranking from Nonemployment

Only consider job spells where worker  $i$  is hired directly from nonemployment. Rerank each worker  $i$  relative to her coworkers who were also hired directly from nonemployment ( $J_i$ ).

1. Assume measurement error in worker and coworkers' wages are normally distributed
2. For each pairwise comparison of worker  $i$  to coworker  $j \in J_i$ , calculate the posterior probability that  $i$  is ranked above  $j$ ,  $p(i > j)$  (and vice versa), given the observed average earnings and tenures of  $i$  and  $j$ . If there are multiple co-employers of  $i$  and  $j$ , then estimated the weighted probability across all employers. Posterior Probability
3. Conditional on the ordered ranking of the coworkers  $(r_1, \dots, r_{J_i})$ , identify the optimal rank  $r_i^*$  that maximizes

$$\sum_{\forall j \text{ s.t. } r_j < r_i^*} p(i > j) + \sum_{\forall j \text{ s.t. } r_j^* < r_j} p(j > i) \quad (3)$$

## Worker Reranking from Nonemployment

For each worker-to-coworker pair at firm  $k$ , estimate that the posterior probability that worker  $i$  is ranked above coworker  $j$ .

- ▶ Assume that the measurement error is normally distributed ( $\epsilon \sim \mathcal{N}(0, \sigma^2)$ ) and *iid* across workers and time.
- ▶ Assume that worker types  $\alpha_i$  are *iid* across workers and normally distributed  $\alpha_i \sim \mathcal{N}(\mu, \tau^2)$
- ▶ The difference of workers average wages at firm  $k$  are:

$$\bar{w}_{i,k} - \bar{w}_{j,k} = \alpha_{i,k} - \alpha_{j,k} + \frac{1}{n_{i,k}} \sum_{t=1}^{n_{i,k}} \epsilon_{i,k,t} - \frac{1}{n_{j,k}} \sum_{t=1}^{n_{j,k}} \epsilon_{j,k,t} \quad (4)$$

- ▶ Using an uninformative prior where  $\tau^2 \rightarrow \infty$ , the probability that worker  $i$  is ranked above worker  $j$  is

$$p(\alpha_{i,k} > \alpha_{j,k}) = \Phi \left( \frac{\bar{w}_{i,k} - \bar{w}_{j,k}}{\frac{\sigma^2}{n_{i,k}} - \frac{\sigma^2}{n_{j,k}}} \right) \quad (5)$$


## Method 2: Firm's Average Surplus Over Reservation Wage

Firm type is increasing in the surplus paid to workers over the workers' reservation wage.

1. Estimate the reservation wage for each worker type as the 10<sup>th</sup> percentile of firms' average residual earnings from nonemployment paid to workers of that type.
2. Calculate each firm's average surplus paid to workers of a given type. This type-specific surplus calculates the within-firm-and-type average difference between a worker's residual earnings and the reservation wage of the worker type.
3. Rank firms by the average across all worker types of the within-firm-and-type worker earnings surplus.<sup>3</sup>

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<sup>3</sup>References: *Lopes de Melo (2016)*; *Hagedorn, Law, and Manóvski (2017)* 

## Method 3 (Workers): Employment Rate Ranking

High type workers are less likely to experience nonemployment spells.

1. Construct a set of 0-1 employment indicators for every quarter that a worker is between the ages of 25-55 ("prime age"). The employment indicator equals one if the worker had positive UI earnings in that quarter.
2. Rank workers by their average prime-age employment rate after controlling for age and time-period fixed effects.

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## Method 3 (Firms): Poaching Share of Hires

Higher type firms are better able to attract workers from other employers and thus are more likely to poach a new hire from a previous employer (versus hiring from nonemployment).

1. Calculate the total number of hires at a firm and the total number of same-quarter or adjacent-quarter dominant-employer EE hires at a firm.
2. Rank firms by each firm's share of hires from EE transitions relative to the total number of hires at the firm.<sup>4</sup>

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<sup>4</sup>Reference: *Bagger and Lentz (2016)*

## Method 4, Workers: Earnings Ranking

High type workers may exhibit higher average earnings.

1. Rank workers by the average of their residual earnings after controlling for age and time-period fixed effects.
2. This is the initial guess of a worker's type in Method 1 (AKM) and Method 2 (HLM).

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## Method 4, Firms: Firm Value-Added-Per-Worker and Labor Productivity

Firm type is increasing in value added per worker.

1. In every year, calculate the firm's (EIN-level) deviation from the industry average log revenue per worker. Annual firm revenue data from Haltiwanger, Kulick, Jarmin, and Miranda.
2. Estimate the firm-specific "value-added-per-worker" as the sum of the BEA annual estimate of industry-specific value-added-per-worker and the exponential of the firm's deviation from the previous step.
3. Estimate each firm's average residual log value-added-per-worker after controlling for firm age interacted with calendar year indicators.
4. Rank firms by their average residual log value-added-per-worker. <sup>5</sup>

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<sup>5</sup>References: *Cairó, Hyatt, and Zhao (2016)*; *Haltiwanger, Hyatt, and McEntarfer (2016, 2017)*; *Bartolucci, Devicienti, and Monzón (2017)*

# Worker and Firm Ranking Correlations

# Worker-Firm Rank Correlations

**Table:** Correlation of Worker and Firm Ranks Across Models

	Firm Rankings				Worker Rankings		
	Additive Firm	Surplus	Poaching Share	Productivity	Additive Worker	Reranking	Employment
<b>Firm Rankings:</b>							
Additive							
Surplus							
Poaching							
Productivity							
<b>Worker Rankings:</b>							
Additive	0.33						
Reranking		0.24					
Employment			0.22				
Earnings				0.35			

*Notes:* All correlations are statistically distinct from zero at the 0.0001 significance level.

# Worker-Firm Rank Correlations

Table: Correlation of Worker and Firm Ranks Across Models

	Firm Rankings				Worker Rankings		
	Additive Firm	Surplus	Poaching Share	Productivity	Additive Worker	Reranking	Employment
<b>Firm Rankings:</b>							
Additive							
Surplus							
Employment							
Productivity							
<b>Worker Rankings:</b>							
Additive	<b>0.33</b>	0.49	0.23	0.33			
Reranking	0.16	<b>0.24</b>	0.13	0.18			
Employment	0.16	0.18	<b>0.22</b>	0.14			
Earnings	0.38	0.52	0.24	<b>0.35</b>			

Notes: All correlations are statistically distinct from zero at the 0.0001 significance level.

# Worker-Firm Rank Correlations

**Table:** Correlation of Worker and Firm Ranks Across Models

	Firm Rankings				Worker Rankings		
	Additive Firm	Surplus	Poaching Share	Productivity	Additive Worker	Reranking	Employment
<b>Firm Rankings:</b>							
Additive	1.00						
Surplus	0.77	1.00					
Employment	0.43	0.44	1.00				
Productivity	0.45	0.55	0.32	1.00			
<b>Worker Rankings:</b>							
Additive	<b>0.33</b>	0.49	0.23	0.33	1.00		
Reranking	0.16	<b>0.24</b>	0.13	0.18	0.31	1.00	
Employment	0.16	0.18	<b>0.22</b>	0.14	0.31	0.24	1.00
Earnings	0.38	0.52	0.24	<b>0.35</b>	0.98	0.79	0.29

*Notes:* All correlations are statistically distinct from zero at the 0.0001 significance level.

# Sample Selection and AKM Correlations

**Table:** Correlation of Worker and Firm Ranks Across AKM Models

<b>Correlation</b>	0.312	0.326	0.165	0.159	0.176
Control Variables					
Age Quadratic and Time FE	-	Y	Y	Y	Y
Birth Year * Time FE	Y	-	-	-	-
Random Sample					
10%	-	-	-	Y	Y
100%	Y	Y	Y	-	-
Outliers					
20+ Quarters	-	Y	-	-	-
Time Range					
1994-2003	-	-	Y	Y	-
2004-2013	-	-	-	-	Y
1994-2013	Y	Y	-	-	-

*Notes:* All correlations are statistically distinct from zero at the 0.0001 significance level.

# Additional Regression Slides

# Employment Share-Unemployment Rate Regressions

$$\Delta \frac{E_t^{type}}{E_t} = \beta_1 \Delta U_t + \beta_2 t + d_q + \epsilon_t$$

where

- ▶  $E_t^{type}$  = total number of employed workers of given type in period  $t$
- ▶  $E_t$  = total employment in period  $t$
- ▶  $U_t$  = cyclical indicator
  1. first-difference in unemployment rate (NBER recessions)
  2. difference in unemployment rate from HP trend (times of high vs. low unemployment)
- ▶  $t$  = linear time trend
- ▶  $d_q$  = calendar quarter fixed effect

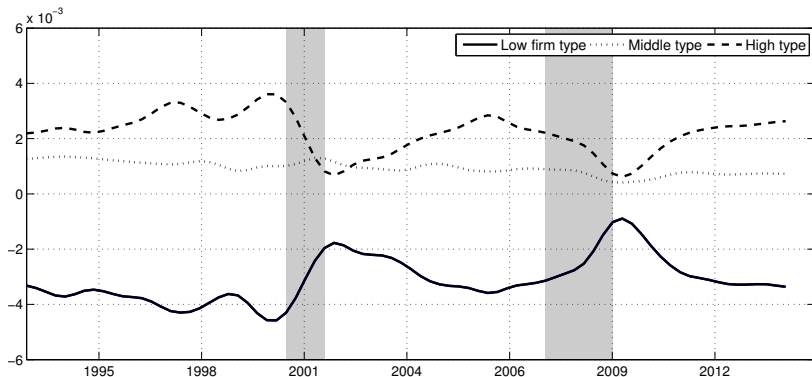


# Sorting and Times of High Unemployment (HP)

	Additive Earnings &	Reranking & Surplus	Employment & Poaching	Earnings & Productivity
<i>Employed at Low-Type Firms</i>				
Workers: Low	0.89 (0.95)	0.90 (1.02)	-3.45** (1.55)	-0.34 (1.48)
Workers: High	1.98*** (0.49)	1.76*** (0.53)	2.26** (1.02)	0.23 (0.44)
<i>Employed at High-Type Firms</i>				
Workers: Low	-2.69*** (0.71)	-2.19*** (0.63)	-5.58*** (1.32)	-0.32 (0.67)
Workers: High	-1.20 (0.97)	-0.78 (0.73)	2.50*** (0.87)	0.70 (0.92)

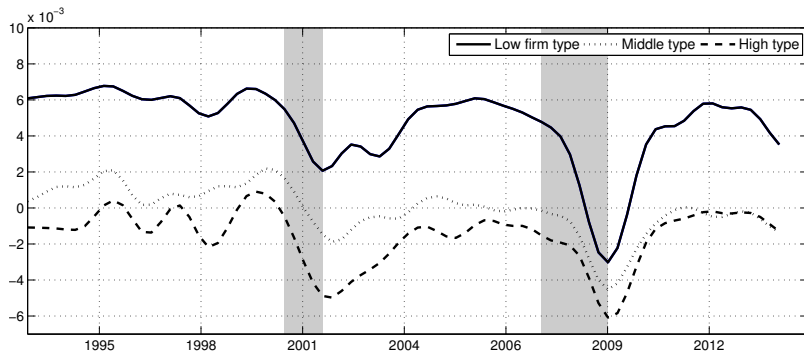
*Notes:* Estimates of the seasonally-adjusted first difference of unemployment rate, season dummies, and a time trend on the change in net hires from nonemployment or poaching. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1%, respectively. Standard errors are in parentheses.

## Net Hires from Poaching by Firm Type: Additive



**Figure:** Quarter-over-quarter net hires from poaching by firm type as estimated in the additive worker-firm fixed effect model, as a percent of total employment. Source: LEHD micro-data for an eleven state sample covering 1994-2015. [Back: Emp Share](#)

# Net Hires from Nonemployment by Firm Type: Additive



**Figure:** Quarter-over-quarter net hires from nonemployment by firm type as estimated in the additive worker-firm fixed effect model, as a percent of total employment. Source: LEHD micro-data for an eleven state sample covering 1994-2015. [Back: Emp Share](#)

# Net Differentials: High Minus Low

	Additive	Surplus	Poaching	Productivity
<i>First-Difference of Unemployment Rate</i>				
Net Poaching:	<b>-11.41**</b>	<b>-11.43***</b>	<b>-10.95***</b>	<b>-9.47***</b>
High Minus Low	(1.16)	( 1.06)	(1.05)	(0.99)
Net Nonemp.	<b>4.08***</b>	<b>3.00**</b>	3.28	<b>5.77***</b>
High Minus Low	(1.33)	(1.27)	(2.10)	(1.09)
<i>Deviation of Unemployment Rate from HP Trend</i>				
Net Poaching:	<b>-13.02***</b>	<b>-12.40***</b>	<b>-12.51***</b>	<b>-11.11***</b>
High Minus Low	(1.86)	(1.81)	(1.72)	(1.54)
Net Nonemp:	0.93	1.15	1.14	<b>2.85*</b>
High Minus Low	(1.92)	(1.79)	(2.91)	(1.71)

*Notes:* Estimates of change in share of employment on the seasonally-adjusted unemployment rate, season dummies, and a time trend. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1%, respectively. Standard errors are in parentheses.

# Net Hires and Increasing Unemployment (FD)

	Additive	Rerank Surplus	Poaching Nonemp.	Revenue Productivity
<i>Net Hires from Nonemployment</i>				
Firms: Low	<b>-17.43***</b> ( 1.51)	<b>-17.33***</b> ( 1.38)	<b>-15.89***</b> ( 1.87)	<b>-15.67***</b> ( 1.80)
Firms: High	<b>-13.34***</b> ( 1.64)	<b>-11.97***</b> ( 1.55)	<b>-11.35***</b> ( 1.05)	<b>-11.58***</b> ( 1.23)
<i>Net Hires from Poaching</i>				
Firms: Low	<b>6.07***</b> ( 0.58)	<b>5.53***</b> ( 0.59)	<b>6.21***</b> ( 0.54)	<b>3.02***</b> ( 0.62)
Firms: High	<b>-5.35***</b> ( 0.61)	<b>-4.91***</b> ( 0.59)	<b>-6.07***</b> ( 0.60)	<b>-2.58***</b> ( 0.61)

Notes: Estimates of the seasonally-adjusted first difference of unemployment rate, season dummies, and a time trend on the change in net hires from nonemployment or poaching. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1%, respectively. Standard errors are in parentheses. [Back: Emp Share](#)

# Net Hires and Times of High Unemployment (HP)

	Additive	Rerank Surplus	Poaching Nonemp.	Revenue Productivity
<i>Net Hires from Nonemployment</i>				
Firms: Low	<b>-11.85***</b> (3.15)	<b>-10.99***</b> (3.06)	<b>-12.58***</b> (3.27)	<b>-12.60***</b> (3.17)
Firms: High	<b>-10.93***</b> (2.80)	<b>-10.23***</b> (2.58)	<b>-9.12***</b> (2.03)	<b>-8.78***</b> (2.26)
<i>Net Hires from Poaching</i>				
Firms: Low	<b>6.82***</b> (0.96)	<b>5.54***</b> (1.00)	<b>5.05***</b> (1.08)	<b>3.60***</b> (0.87)
Firms: High	<b>-6.20***</b> (0.94)	<b>-5.35***</b> (0.93)	<b>-6.35***</b> (1.02)	<b>-2.55***</b> (0.88)

Notes: Estimates of the seasonally-adjusted first difference of unemployment rate, season dummies, and a time trend on the change in net hires from nonemployment or poaching. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1%, respectively. Standard errors are in parentheses. [Back: Emp Share](#)

# Worker Employment Share Change Time Trend

	Additive	Reranking	Employment	Earnings
<i>First-Difference of Unemployment Rate</i>				
Workers: Low	0.0005 ( 0.0004)	0.0000 ( 0.0003)	0.0039*** ( 0.0007)	-0.0006 ( 0.0004)
Workers: High	0.0007** ( 0.0003)	0.0018*** ( 0.0002)	-0.001** ( 0.0005)	0.0017*** ( 0.0004)
<i>Deviation of Unemployment Rate from HP Trend</i>				
Workers: Low	0.0005 ( 0.0004)	0.0000 ( 0.0003)	0.0039*** ( 0.0009)	-0.0006 ( 0.0005)
Workers: High	0.0008** ( 0.0004)	0.0019*** ( 0.0003)	-0.001 ( 0.0006)	0.0017*** ( 0.0004)

*Notes:* Estimates of change in share of employment on the seasonally-adjusted unemployment rate, season dummies, and a time trend. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1%, respectively. Standard errors are in parentheses.

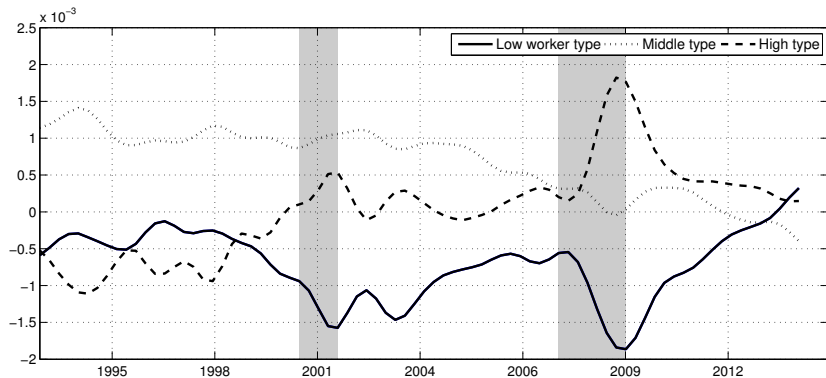
# Firm Employment Share Change Time Trend

	Additive	Reranking	Employment	Earnings
<i>First-Difference of Unemployment Rate</i>				
Firms: Low	<b>0.0020<sup>***</sup></b> ( 0.0005)	<b>-0.0006</b> ( 0.0005)	<b>0.0009</b> ( 0.0007)	<b>-0.0012<sup>***</sup></b> ( 0.0004)
Firms: High	<b>0.0014<sup>**</sup></b> ( 0.0006)	<b>0.0013<sup>**</sup></b> ( 0.0006)	<b>0.0001</b> ( 0.0006)	<b>0.0007</b> ( 0.0005)
<i>Deviation of Unemployment Rate from HP Trend</i>				
Firms: Low	<b>0.0017<sup>***</sup></b> ( 0.0005)	<b>-0.0007</b> ( 0.0005)	<b>0.0007</b> ( 0.0007)	<b>-0.0014<sup>***</sup></b> ( 0.0004)
Firms: High	<b>0.0016<sup>***</sup></b> ( 0.0006)	<b>0.0015<sup>***</sup></b> ( 0.0005)	<b>0.0003</b> ( 0.0006)	<b>0.001<sup>**</sup></b> ( 0.0005)

*Notes:* Estimates of change in share of employment on the seasonally-adjusted unemployment rate, season dummies, and a time trend. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1%, respectively. Standard errors are in parentheses.

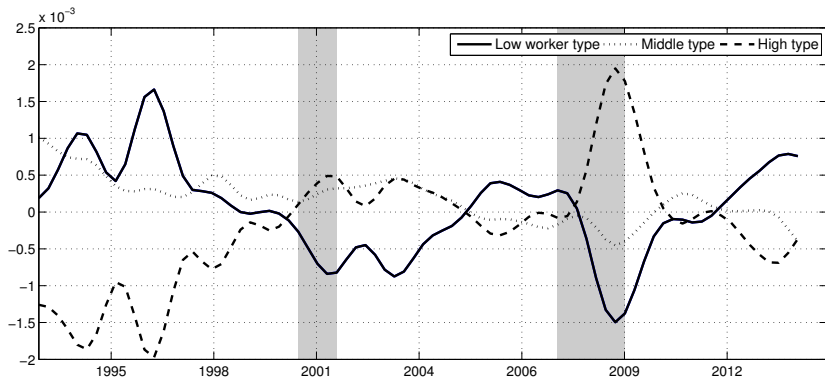


# Change in Employment Share by Worker Type: Reranking



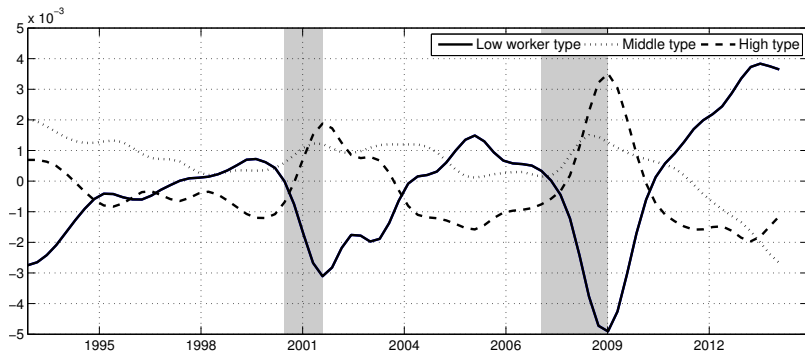
**Figure:** Quarter-over-quarter change in share of total employment by worker type as estimated using the iterative reranking of workers average earnings when hired from nonemployment relative the coworkers hired from nonemployment. Source: LEHD micro-data for an eleven state sample covering 1994-2015. [Back](#)

# Change in Employment Share by Worker Type: Average Earnings



**Figure:** Quarter-over-quarter change in share of total employment by worker type as estimated using the residual value-added of the worker's employer. Source: LEHD micro-data for an eleven state sample covering 1994-2015. [Back](#)

# Change in Employment Share by Worker Type: Employment Rate



**Figure:** Quarter-over-quarter change in share of total employment by worker type as estimated using the worker's deviation from the mean prime age employment rate.

Source: LEHD micro-data for an eleven state sample covering 1994-2015.

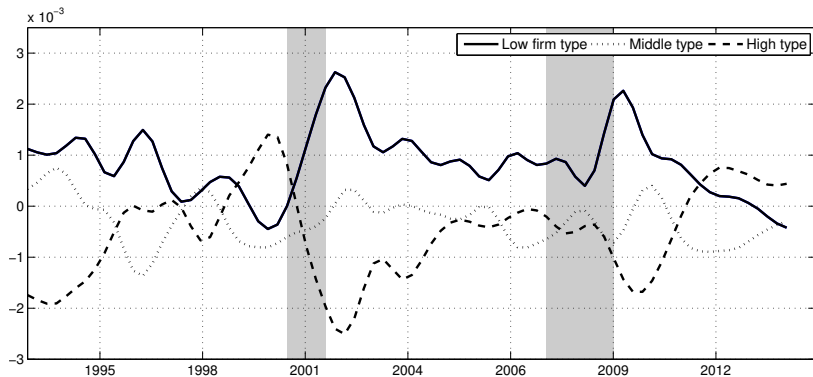
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## Change in Employment Share

	Additive	Reranking & Surplus	Poaching & Employment	Revenue Productivity
<i>Difference in Unemployment from HP Trend</i>				
Workers: Low	-3.17** ( 1.20)	-2.78** ( 1.07)	-12.10*** ( 3.09)	-0.85 ( 1.06)
Workers: High	2.37** ( 1.10)	2.06** ( 1.03)	8.21*** ( 2.24)	0.52 ( 0.81)
Firms: Low	5.52*** ( 1.45)	5.32*** ( 1.51)	2.81 ( 2.63)	1.06 ( 1.81)
Firms: High	-6.55*** ( 1.79)	-5.06*** ( 1.46)	-5.21*** ( 1.81)	-0.20 ( 1.62)

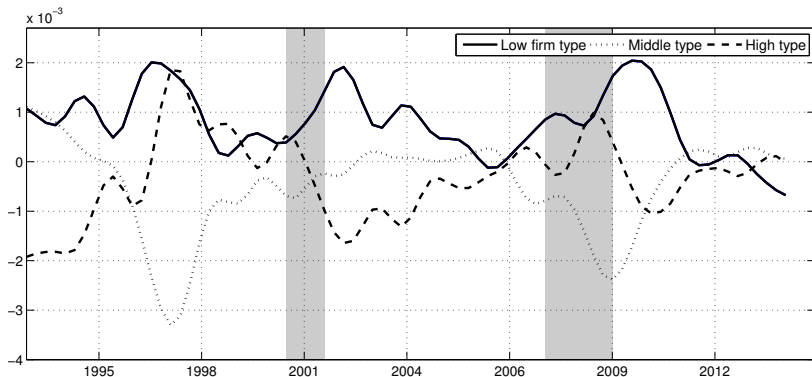
*Notes:* Estimates of change in share of employment on the seasonally-adjusted unemployment rate, season dummies, and a time trend. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1%, respectively. Standard errors are in parentheses.

## Change in Employment Share by Firm Type: Surplus



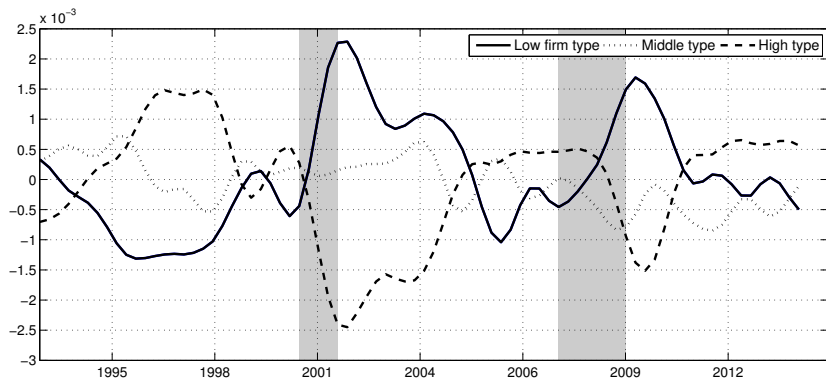
**Figure:** Quarter-over-quarter change in share of total employment by firm type as estimated using average surplus paid by a firm relative to each worker type's reservation earnings. Source: LEHD micro-data for an eleven state sample covering 1994-2015. [Back](#)

# Change in Employment Share by Firm Type: Productivity



**Figure:** Quarter-over-quarter change in share of total employment by firm type as estimated using the firm's residual value-added. Source: LEHD micro-data for an eleven state sample covering 1994-2015. [Back](#)

# Change in Employment Share by Firm Type: Poaching



**Figure:** Quarter-over-quarter change in share of total employment by firm type as estimated using share of total hires who are poached from other employers. Source: LEHD micro-data for an eleven state sample covering 1994-2015. [Back](#)





# Change in Worker-Firm Employment Share (HP)

	Additive	Reranking & Surplus	Employment & Poaching	Earnings & Productivity
<i>Employed at Low-Type Firms</i>				
Workers: Low	0.89 (0.95)	1.11 (0.67)	-0.66 (1.30)	0.36 (0.99)
Workers: High	<b>1.98***</b> (0.49)	<b>1.82***</b> (0.52)	<b>2.55***</b> (0.87)	<b>1.76***</b> (0.53)
<i>Employed at High-Type Firms</i>				
Workers: Low	<b>-2.69***</b> (0.71)	<b>-3.03***</b> (0.65)	<b>-6.62***</b> (1.30)	<b>-1.98***</b> (0.52)
Workers: High	<b>-1.20</b> (0.97)	<b>-1.28*</b> (0.72)	<b>1.89**</b> (0.79)	<b>-0.48</b> (1.02)

*Notes:* Estimates of net poaching on the seasonally-adjusted first difference of unemployment rate, season dummies, and a time trend. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1%, respectively. Standard errors are in parentheses.

# Nonemp. Propensity and Increases in Unemployment (FD)

	Additive	Reranking & Surplus	Employment & Poaching	Earnings & Productivity
<i>Employed at Low-Type Firms</i>				
Workers: Low	<b>-155***</b> (17)	<b>-149***</b> (17)	<b>-219***</b> (35)	<b>-163***</b> (20)
Workers: High	<b>-114***</b> (24)	<b>-99***</b> (20)	<b>-3</b> (26)	<b>-126***</b> (28)
<i>Employed at High-Type Firms</i>				
Workers: Low	<b>-201***</b> (23)	<b>-158***</b> (21)	<b>-251***</b> (31)	<b>-151***</b> (20)
Workers: High	<b>-62***</b> (21)	<b>-68***</b> (19)	<b>-5</b> (7)	<b>-56***</b> (20)

*Notes:* Estimates of net poaching on the seasonally-adjusted first difference of unemployment rate, season dummies, and a time trend. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1%, respectively. Standard errors are in parentheses.

# Poaching and High Unemployment (HP)

	Additive	Reranking & Surplus	Employment & Poaching	Earnings & Productivity
<i>Employed at Low-Type Firms</i>				
Workers: Low	17*** (3)	17*** (3)	22*** (3)	17*** (3)
Workers: High	21*** (3)	17*** (3)	9*** (2)	29*** (4)
<i>Employed at High-Type Firms</i>				
Workers: Low	-29*** (5)	-24*** (4)	-38*** (5)	-17*** (4)
Workers: High	-12*** (2)	-10*** (2)	-7*** (1)	-6*** (2)

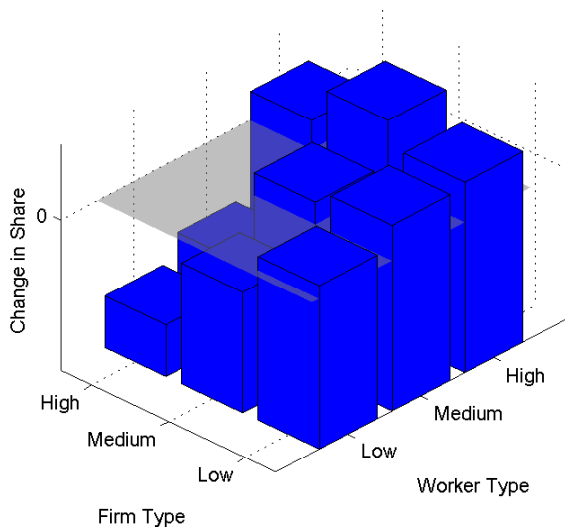
*Notes:* Estimates of net poaching on the seasonally-adjusted first difference of unemployment rate, season dummies, and a time trend. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1%, respectively. Standard errors are in parentheses.

# Nonemployment and High Unemployment (HP)

	Additive	Reranking & Surplus	Employment & Poaching	Earnings & Productivity
<i>Employed at Low-Type Firms</i>				
Workers: Low	<b>-42***</b> (9)	<b>-41***</b> (9)	<b>-57***</b> (16)	<b>-43***</b> (10)
Workers: High	<b>-25**</b> (11)	<b>-28***</b> (9)	<b>-7</b> (11)	<b>-27**</b> (13)
<i>Employed at High-Type Firms</i>				
Workers: Low	<b>-46***</b> (12)	<b>-46***</b> (10)	<b>-70***</b> (15)	<b>-40***</b> (10)
Workers: High	<b>-29***</b> (8)	<b>-28***</b> (8)	<b>-5*</b> (3)	<b>-23***</b> (8)

*Notes:* Estimates of net poaching on the seasonally-adjusted first difference of unemployment rate, season dummies, and a time trend. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1%, respectively. Standard errors are in parentheses.

# Change in Match Shares w.r.t. Unemployment Rate (OLD)



# Change in Worker-Firm Employment Share (OLD)

Table: First-Difference of Unemployment Rate on Additive Model  
Worker-Firm Employment Share

	Firm type		
	Low	Medium	High
Workers: Low	0.43 (0.70)	-0.99** (0.40)	-3.28*** (0.42)
Workers: Medium	1.16*** (0.43)	0.72* (0.41)	-2.45*** (0.43)
Workers: High	1.31*** (0.36)	2.15*** (0.50)	0.95 (0.71)

Notes: Estimates of change in share of employment on the seasonally-adjusted unemployment rate, season dummies, and a time trend. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1%, respectively. Standard errors are in parentheses.

# Interpretation

$$f(x, y, z_t) = z_t (p_1 + p_2x + p_3y + p_4x^2 + p_5y^2 + p_6xy)$$

- ▶  $p_3 < 0, p_5 < 0, p_6 > 0$ : firm productivity does not rank firms globally. Firm  $y_1$  may dominate  $y_2$  when considering worker  $x$  ( $f(x, y_1, z) < f(x, y_2, z)$ ), but we might have  $f(x', y_1, z) > f(x', y_2, z)$  too.
- ▶ “High type” firms are not high  $y$  firms. Rely on average vacancy stocks to reveal equilibrium type.

# Production Function



# Production Function Estimation

- ▶ Firms of type  $q$  have a Cobb-Douglas production technology:

$$Y_{jt} = A_t^{q(j)} K_{jt}^{\alpha_K^{q(j)}} (L_{jt} E_{jt})^{\alpha_L^{q(j)}}$$

- ▶  $E_{jt} = \prod_{r=1}^{10} e_{r,q(j)}^{L_{rjt}/L_{jt}}$  is effective labor,  $L_{rjt}$  is the number of type  $r$  workers
- ▶ Taking logs and substituting:

$$\ln(Y_{jt}) = \ln(A_t^{q(j)}) + \alpha_K^{q(j)} \ln(K_{jt}) + \alpha_L^{q(j)} \ln(L_{jt}) + \alpha_L^{q(j)} \sum_{r=1}^{10} \frac{L_{rjt}}{L_{jt}} \ln(e_{r,q(j)})$$

We estimate this using firm and year fixed effects:

$$\ln(Y_{jt}) = \alpha_L^{q(j)} \ln(L_{jt}) + \sum_{r=1}^{10} \beta_r^{q(j)} \frac{L_{rjt}}{L_{jt}} + d_t + d_j + \epsilon_{jt}$$

where  $\beta_r^{q(j)} = \alpha_L^{q(j)} \ln(e_{r,q(j)})$ .

# Estimated Shape of the Production Function (Additive)

Table: Estimated Shape of the Production Function (Additive)

	Firm type		
	Low-Type	Medium-Type	High-Type
Workers: Low	0.30	0.41	0.44
Workers: Medium	0.39	0.55	0.57
Workers: High	0.43	0.54	0.56

Notes: Estimated production function from additive model.

Reranking & Surplus

Employment & Poaching

Earnings & Productivity

Back

# Net Time Dummy Point Estimate Differential

	Additive	Reranking & Surplus	Poaching & Employment	Revenue Productivity
<i>First Difference in Unemployment Rate</i>				
TD FD:	-0.19	<b>-0.81**</b>	0.19	<b>-1.22***</b>
H - L	(0.24)	(0.31)	(0.12)	(0.36)
<i>Deviation of Unemployment Level from HP Trend</i>				
TD Level:	0.00	<b>-0.61*</b>	<b>0.25*</b>	<b>-1.10***</b>
H - L	(0.31)	(0.29)	(0.13)	(0.31)

*Notes:* Estimates of change in production function time dummies on a cyclical indicator and a time trend. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1%, respectively. Standard errors are in parentheses.

# Evidence from production function estimation

- ▶ Match output increasing in firm type for each worker type
- ▶ Contribution of firm effect seems larger than model implications
- ▶ Mixed evidence on excess cyclical “demand shocks” to higher ranked firms

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# Estimated Shape of the Production Function (Reranking & Surplus)

**Table:** Estimated Shape of the Production Function (Reranking & Surplus)

	<b>Firm type</b>		
	<b>Low-Type</b>	<b>Medium-Type</b>	<b>High-Type</b>
Workers: Low	0.27	0.40	0.45
Workers: Medium	0.32	0.48	0.57
Workers: High	0.32	0.45	0.50

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*Notes:* Estimated production function from reranking & surplus model.

# Estimated Shape of the Production Function (Employment & Poaching)

**Table:** Estimated Shape of the Production Function (Employment & Poaching)

	<b>Firm type</b>		
	<b>Low-Type</b>	<b>Medium-Type</b>	<b>High-Type</b>
Workers: Low	0.29	0.40	0.41
Workers: Medium	0.28	0.40	0.42
Workers: High	0.23	0.31	0.35

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*Notes:* Estimated production function from employment & poaching share method.

# Estimated Shape of the Production Function (Earnings & Productivity)

**Table:** Estimated Shape of the Production Function (Earnings & Productivity)

	<b>Firm type</b>		
	<b>Low-Type</b>	<b>Medium-Type</b>	<b>High-Type</b>
Workers: Low	0.31	0.36	0.38
Workers: Medium	0.39	0.47	0.49
Workers: High	0.39	0.47	0.50

*Notes:* Estimated production function from earnings & productivity method.

# Parameter Estimates [Back](#)

<b>Parameter</b>	<b>Lise &amp; Robin Estimates</b>	<b>LEHD Moments Estimates</b>	<b>Excess Sensitivity Estimates</b>
$\alpha$	0.497	0.769	0.665
$s$	0.027	0.010	0.005
$c_0$	0.028	0.028	0.020
$c_1$	0.084	0.213	0.132
$\delta$	0.013	0.029	0.022
$\sigma$	0.071	0.074	0.046
$\rho$	0.9997	0.9997	0.9997
$\beta_1$	2.148	3.300	4.1
$\beta_2$	12.001	6.021	15.16
$p_1$	0.003	0.001	0.004
$p_2$	2.053	2.745	2.09
$p_3$	-0.140	-0.230	-0.088
$p_4$	8.035	8.102	7.165
$p_5$	-1.907	-1.940	-2.105
$p_6$	6.596	6.577	6.121
$p_7$	-	-	-0.095



# Moment Estimates (1) Back

Parameter	Data	Lise & Robin Estimates	Excess Sensitivity Estimates
$E[U]$	0.058	0.059	0.062
$E[U^{5p}]$	0.035	0.032	0.034
$E[U^{15p}]$	0.018	0.018	0.031
$E[U^{27p}]$	0.01	0.011	0.03
$E[UE]$	0.421	0.468	0.444
$E[EU]$	0.025	0.028	0.03
$E[EE]$	0.025	0.025	0.045
$E[\text{sd labor prod}]$	0.494	0.505	0.181
$E[V/U]$	0.634	0.744	0.708
$\text{corr}[V, U]$	-0.846	-0.975	0.293
$\text{corr}[U, VA]$	-0.86	-0.983	-0.968
$\text{corr}[V, VA]$	0.721	0.996	-0.29
$\text{corr}[UE, VA]$	0.878	0.978	-0.646
$\text{corr}[EU, VA]$	-0.716	-0.91	-0.957
$\text{corr}[UE, EE]$	0.695	0.977	-0.878
$\text{corr}[\text{sd labor prod}, VA]$	-0.366	-0.361	-0.525

## Moment Estimates (2) Back

Parameter	Data	Lise & Robin Estimates	Excess Sensitivity Estimates
sd [ $U$ ]	0.191	0.203	0.144
sd [ $U^{5p}$ ]	0.281	0.315	0.112
sd [ $U^{15p}$ ]	0.395	0.413	0.07
sd [ $U^{27p}$ ]	0.478	0.439	0.082
sd [ $UE$ ]	0.127	0.127	0.054
sd [ $EU$ ]	0.1	0.095	0.195
sd [ $EE$ ]	0.095	0.112	0.316
sd [sd labor prod]	0.039	0.038	0.007
sd [ $V$ ]	0.206	0.105	0.081
sd [ $V/U$ ]	0.381	0.306	0.143
sd [ $VA$ ]	0.033	0.034	0.028
autocorr [ $VA$ ]	0.932	0.991	0.993

# Lise & Robin Production Function

- ▶ A type  $x$  worker matched with a type  $y$  firm produces

$$p(x, y, z_t)$$

- ▶  $z_t$  is the exogenous aggregate shock.
- ▶  $p_{12} > 0$ : Complementarities.
- ▶ Value of home production:  $b(x, z_t)$ .
- ▶ Flow match surplus:  $p(x, y, z_t) - b(x, z_t)$ .

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# Lise & Robin Flows

- ▶ Workers meet vacancies through a matching function (random search).
- ▶ If surplus is positive, agree to form a match.
- ▶ Matches dissolve three ways:
  - ▶ Exogenous job destruction  $\delta$ .
  - ▶ An aggregate shock  $z_t$  renders the match unprofitable.
  - ▶ The worker meets a better job through on-the-job-search.

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# Lise & Robin Wage Setting

- ▶ Hires from unemployment: Firm makes a TIOLI wage offer to the worker. Firm extracts all the expected surplus, worker gets their reservation value.
- ▶ Once a wage is negotiated, it remains constant until one party can credibly threaten to end the match.
  - ▶ Outside offers: Firms engage in Bertrand competition. Worker moves to the highest surplus firm, receives utility equal to the surplus of the losing firm (2nd highest bid).

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# Match Value

Value of a match:

$$\begin{aligned} P_t(x, y) = & p(x, y, z_t) \\ & + \mathbb{E}_t [(1 - (1 - \delta) \mathbf{1}\{P_{t+1}(x, y) \geq B_{t+1}(x)\}) B_{t+1}(x)] \\ & + (1 - \delta) \mathbf{1}\{P_{t+1}(x, y) \geq B_{t+1}(x)\} (1 - s\lambda_{t+1}) P_{t+1}(x, y) \\ & + (1 - \delta) \mathbf{1}\{P_{t+1}(x, y) \geq B_{t+1}(x)\} s\lambda_{t+1} \mathbb{E}_t [P_{t+1}(x, y)] \end{aligned}$$

Sum of:

- ▶ Flow output
- ▶ Value when the worker becomes unemployed
- ▶ Continuation value with no outside offer
- ▶ Continuation value with an outside offer

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## Lise & Robin Wage Setting

- ▶ Result: Match surplus is independent of the endogenous distributions. Depends only on the technology shock and the production function.

$$S(x, y, z_t) = p(x, y, z_t) - b(x, z_t) + \frac{1 - \delta}{1 + r} \mathbb{E}_t [S(x, y, z_{t+1})^+]$$

- ▶  $S$  is the basis of all decisions in the economy: which matches are profitable ( $S > 0$ ), which firm wins a bidding war ( $S(x, y, z_t) > S(x, y', z_t)$ ).
- ▶ The shares of  $S$  going to the worker and firm depend on endogenous distributions, even though  $S$  does not.

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# Lise & Robin Vacancy Posting

- ▶ Type  $y$  vacancies are posted at a convex cost  $c(v_t(y))$ .
- ▶ Optimality:

$$c'(v_t(y)) = q_t J_t(y)$$

- ▶  $q_t$  is the worker meeting rate.
- ▶  $J_t$  is the expected surplus accruing to the firm from meeting a random worker.
- ▶  $J_t$  depends on the shares of workers employed and unemployed. But given initial conditions and  $S$ , it is easy to simulate.

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# Estimated Production Function - Lise & Robin

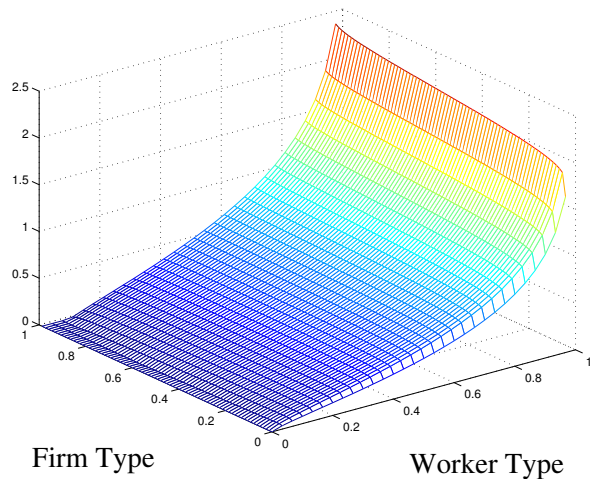


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# Estimated Production Function - Excess Sensitivity

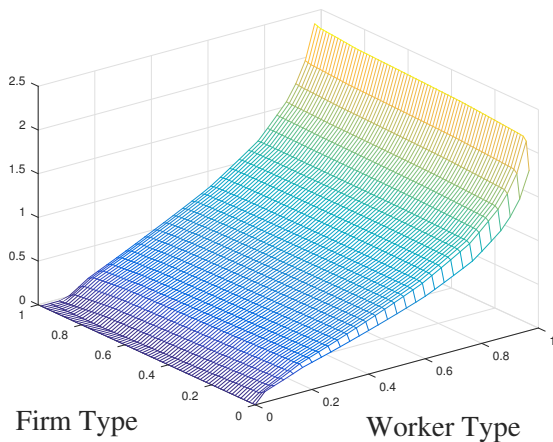


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