Estimating Compensating Wage Differentials with Endogenous Job Mobility

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Background

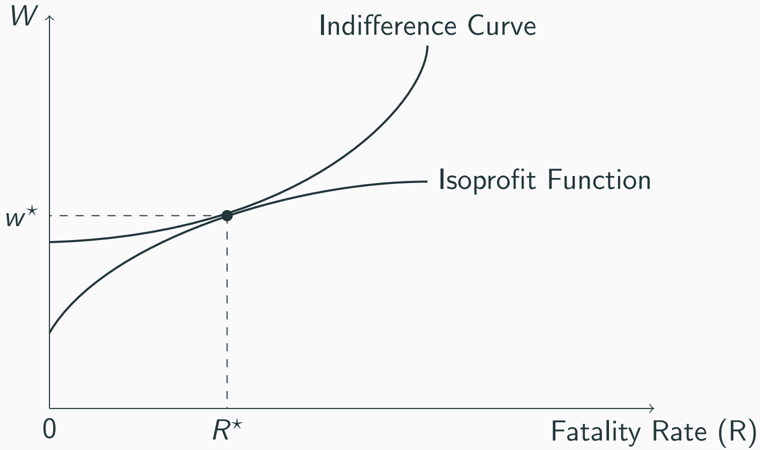
- Theory of equalizing differences: workers induced to accept less attractive jobs by compensating differences in wages
  - Implies job characteristics have implicit wage prices $(+/-)$ or 'compensating wage differentials' (CWDs)
- This theory is among the fundamental market equilibrium constructs in labor economics [Smith 1776; Rosen 1974]
- CWDs are empirically relevant:
  - Understanding structure of equilibrium wages—do measures of earnings inequality overstate/understate compensation inequality?
  - Direct public policy applications—e.g. the value of statistical life
- Empirical support for theory of equalizing differences is elusive

Background

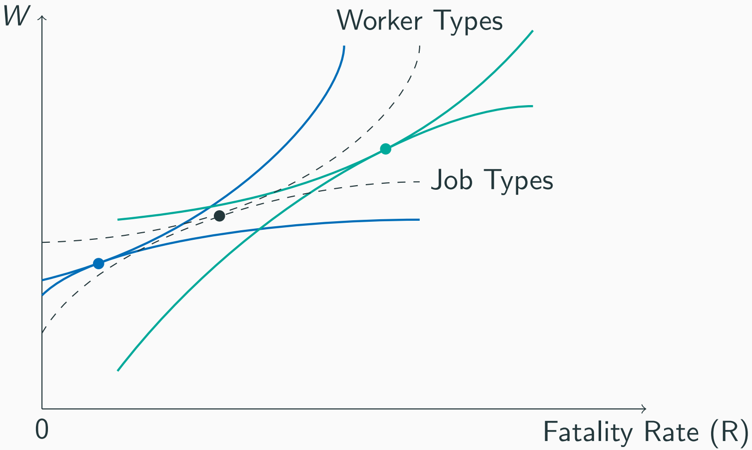
- Equilibrium wage is the sum of multiple prices: rate at which workers sell time plus implict prices of all amenities
- Extracting implicit prices from wages requires model that sufficiently captures key features of wage determination
  - Unobserved differences in worker ability [Brown 1980; Hwang et al 1992]
  - Impacts of job mobility and nonrandom job assignment [Solon 1988; Gibbons & Katz 1992; DeLeire, Khan, & Timmins 2013; Abowd, McKinney & Schmutte 2018]
- Problem is feasible if we assume perfect competition [Rosen 1974]
  - Sorting creates 'hedonic pricing function,' defines equilibrium

The Rosen hedonic pricing function

Graphical Overview: Rosen Pricing Function



Graphical Overview: Rosen Pricing Function



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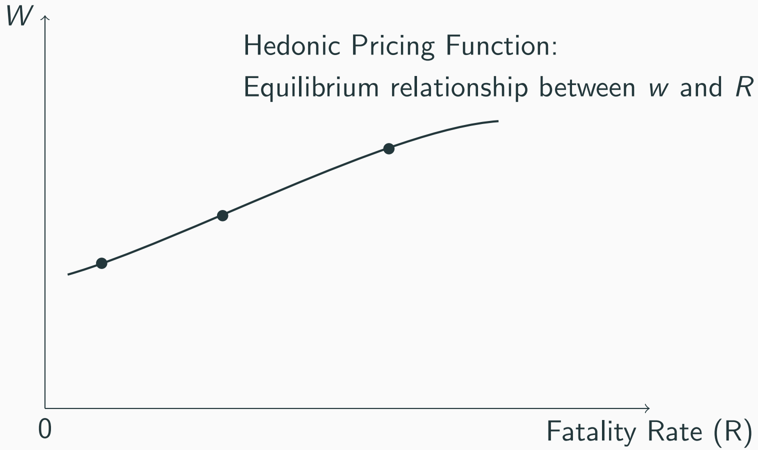

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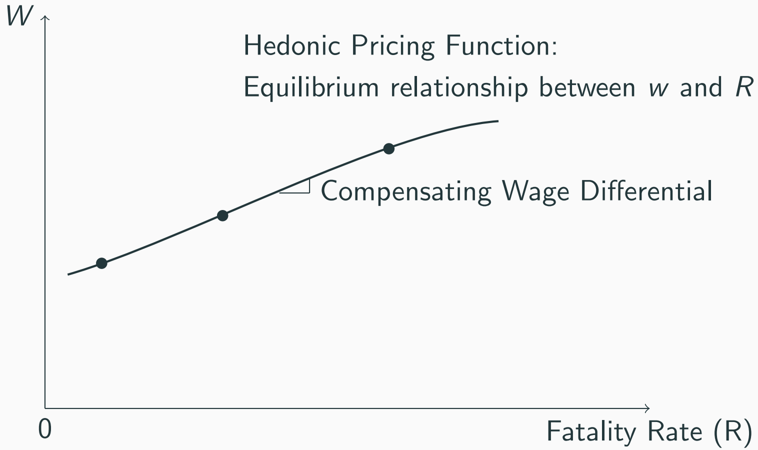


Background

- Problem: labor markets are not perfectly competitive
- Introducing search frictions causes severe (unresolved) complications [Hwang et al. 1998]
- Structural search literature moved away from Rosen framework, replaced with:
    - Stochastic offer function [Bonhomme & Jolivet 2009]
    - Bilateral bargaining [Dey & Flinn 2005]
    - Revealed preference [Sullivan & To 2009; Sorkin 2018; Taber & Vejlin 2018]

This Paper

- We show that existence of Rosen's equilibrium hedonic pricing function is compatible with imperfect competition
    - We focus on role of firms as a source of wage dispersion
    - Combine elements of Abowd et al. (1999) AKM wage model with Rosen framework
    - Allow wage process to incorporate search frictions, limited worker mobility, other imperfections
- Develop model of imperfect labor market competition in which our wage equation is the equilibrium outcome
    - Clarify conditions under which our empirical estimand can be interpreted as either:
        1. Preferences: marginal willingness to pay for amenity
        2. Equilibrium prices: treatment effect on wages of job amenity
    - Show that Rosen's hedonic equilibrium can be adapted to include forms of imperfect competition that are consistent with data

Empirical Application

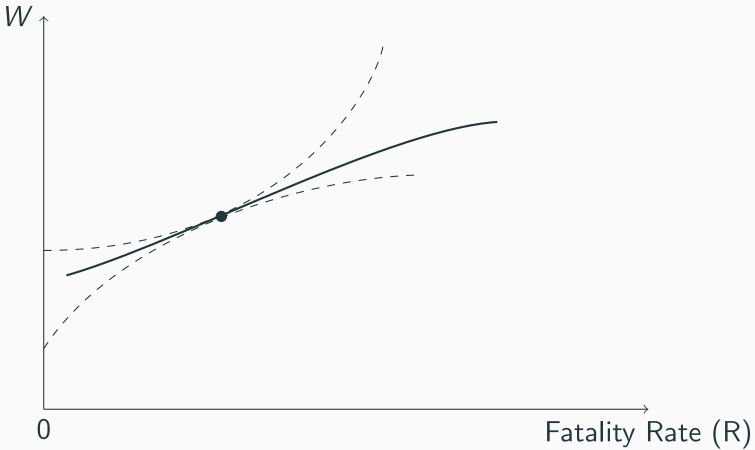
- Empirical application using 100% census of jobs in Brazil 2005-10
- Evaluate method in context of one observed amenity: occupational fatality rates
    - Method can extend to many amenities that vary within employer

Outline

1. Graphical overview of estimation challenges and model approaches
2. Synthesizing AKM wage decomposition and CWD models
3. Data and empirical setting
4. Results
5. Theory: Model of equilibrium wages and amenities in imperfectly competitive labor market
6. Empirical evaluation of exogeneity conditions
7. Conclusions

Estimation challenges:
The ability bias puzzle

Graphical Overview: Ability Bias



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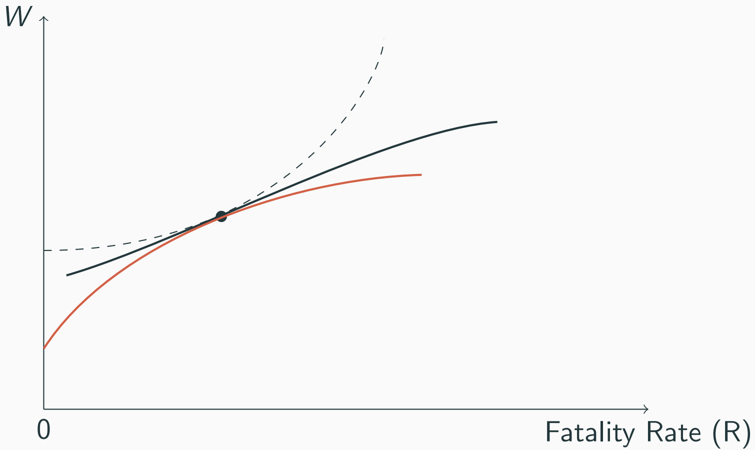

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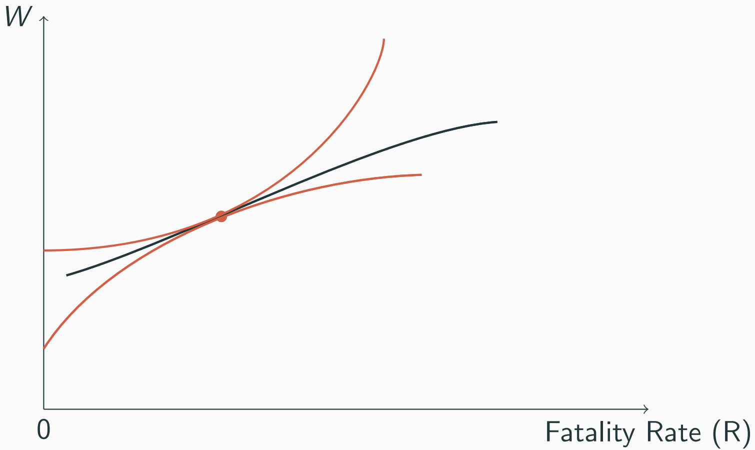

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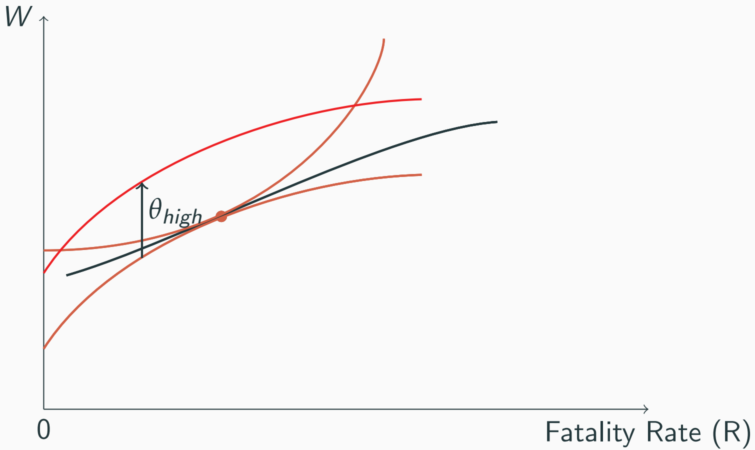
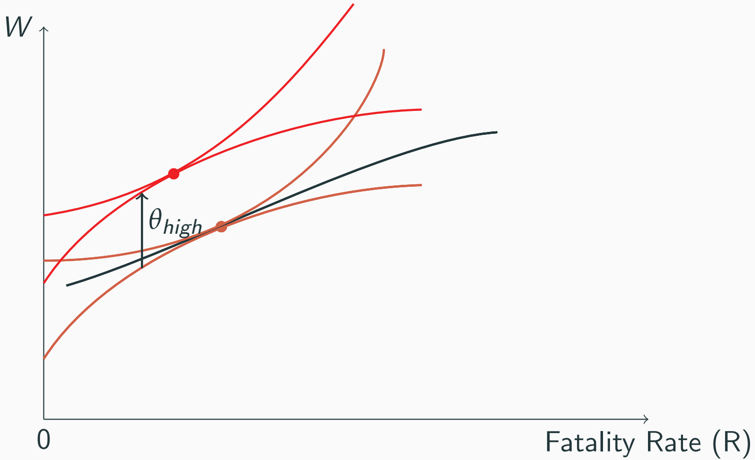
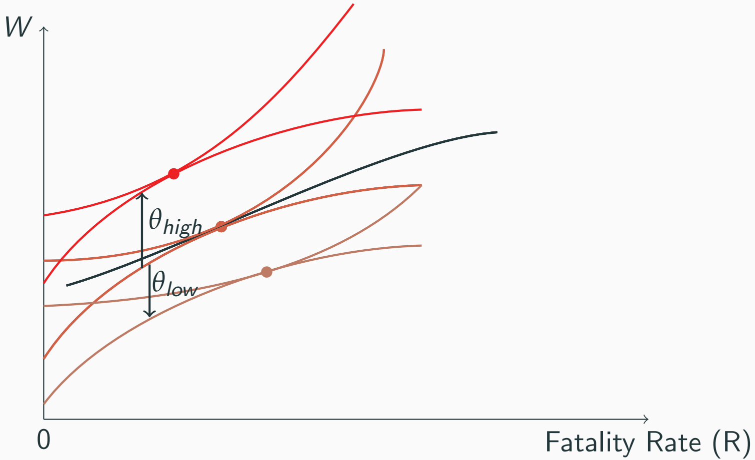


At any fatality rate, firms can pay high ability workers more while still earning $\pi = 0$

Graphical Overview: Ability Bias

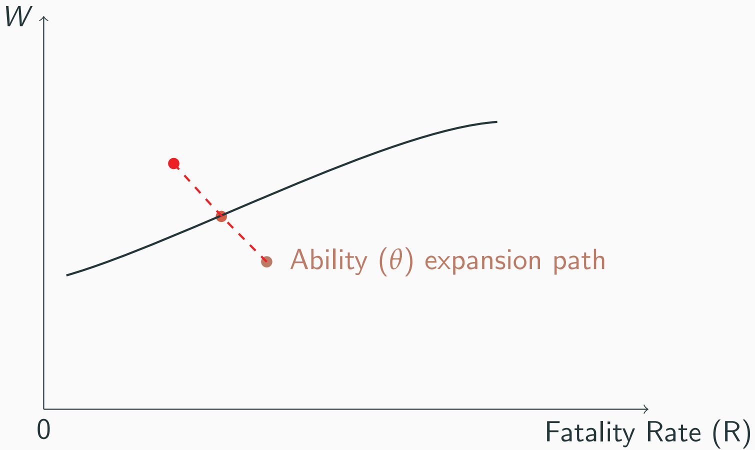


If safety is a normal good, high ability workers trade off greater earnings potential for more safety



Firms pay low ability workers less when earning $\pi = 0$

Graphical Overview: Ability Bias



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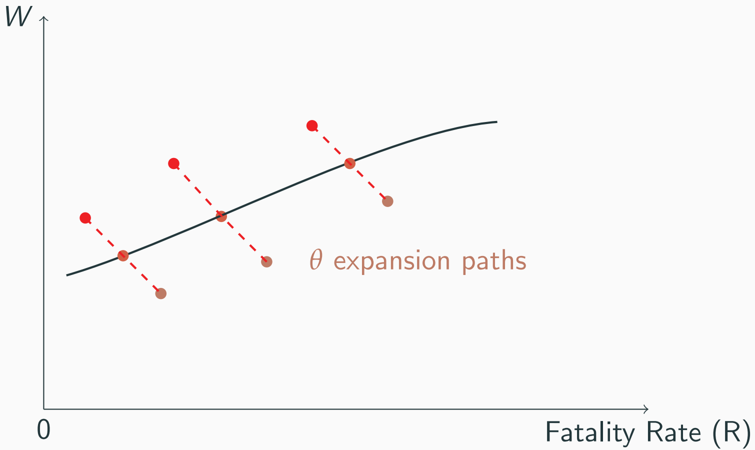
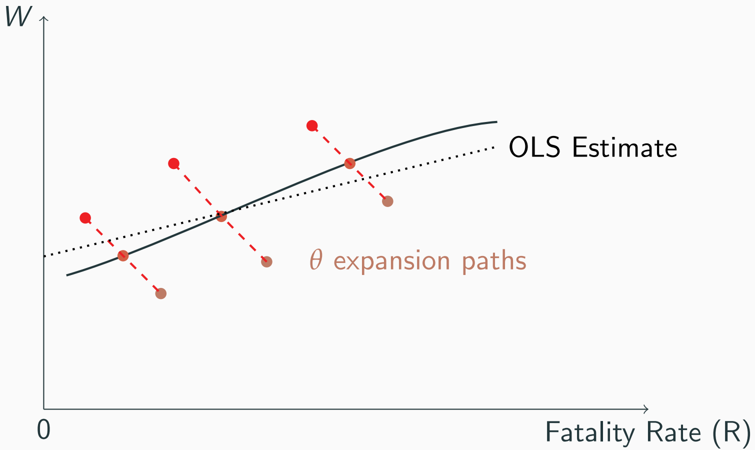


The same argument can apply to any point along the pricing function

Graphical Overview: Ability Bias



Omitting ability likely to attenuate CWD because of wrong-sided variation along expansion paths

Ability Bias

$$\ln w_{it} = X_{it}\beta + R_{it}\gamma + \theta_i + \varepsilon_{it}$$

- If amenities are normal goods, workers with $\uparrow$ earnings choose to buy $\uparrow$ amenities
    - Latent ability θ_i negatively correlated with fatality rate R
    - Bias caused by omitting θ_i likely negative
- Potential solution—estimate within-worker model using panel data
    - Brown (1980); Garen (1988); Kniesner et al 2012
- Puzzle: Virtually all within-worker estimates give $\widehat{\gamma}_{\text{Cross-Sectional}} >> \widehat{\gamma}_{\text{Within-Worker}}$

The role of firms in explaining the ability bias puzzle

Job Mobility and Wages:

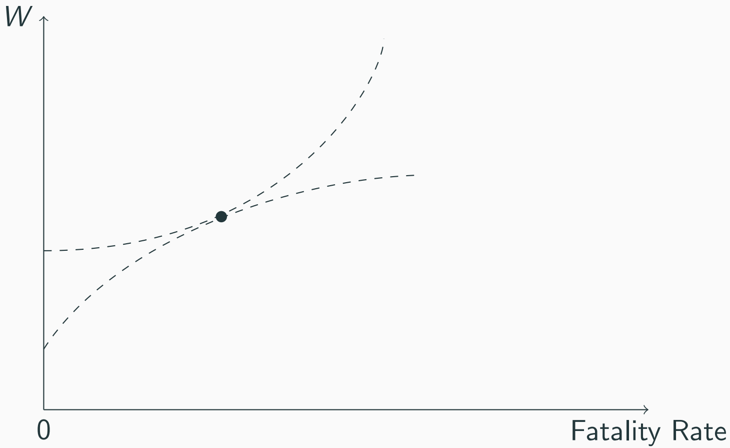
- Explanation: worker effects model cannot adequately capture within-worker wage process, largely driven by job mobility
- Why do workers move?
    1. Search frictions affect wage/amenity bundles
       [Hwang, Mortensen, Reed (1998); Lang and Majumdar (2004)]
    2. Workers get good/bad news about ability
       [Gibbons and Katz (1992)]
    3. Workers get good/bad news about match quality
       [Abowd, McKinney, Schmutte (2015)]

AKM and the Components of Earnings Structures

$$\ln w_{ijt} = X_{ijt}\beta + \theta_i + \psi_{J(i,t)} + \varepsilon_{ijt}$$

- Separate literature has studied the components of earnings
  [Abowd et al. (AKM 1999); Woodcock (2004); Card et al. (2013)]
- Across many countries worldwide, surprisingly similar wage patterns:
  - $\approx$ 40% of earnings variance explained by θ_i
  - $\approx$ 20-25% of earnings variance explained by $\psi_{J(i,t)}$
- Firm earnings effects $\psi_{J(i,t)}$ potentially consistent with search frictions, imperfect competition, efficiency wages, or unobserved firm-level amenities
- Woodcock (2004) estimates 60% of variation in wages from voluntary job changes explained by firm effects

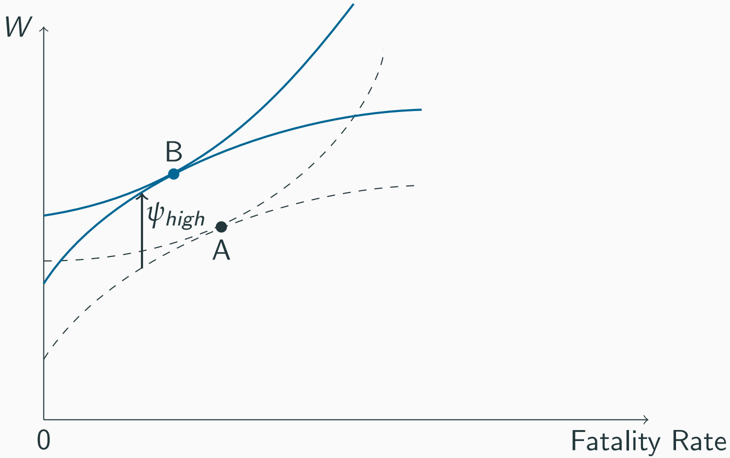
Explaining the Ability Bias Puzzle



$\ln w_{ijt} = X_{ijt}\beta + \theta_i + \psi_{J(i,t)} + \varepsilon_{ijt}$

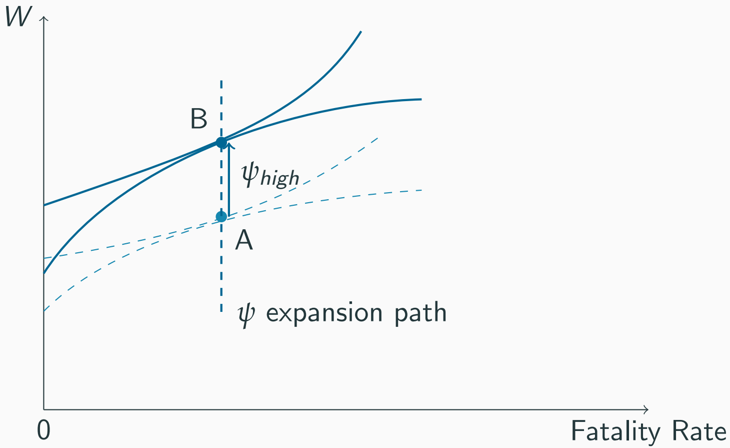
Reinterpret the wage process in the context of the AKM wage model

Explaining the Ability Bias Puzzle



Worker enters the labor market and takes job A. After searching, they learn about job B and switch.

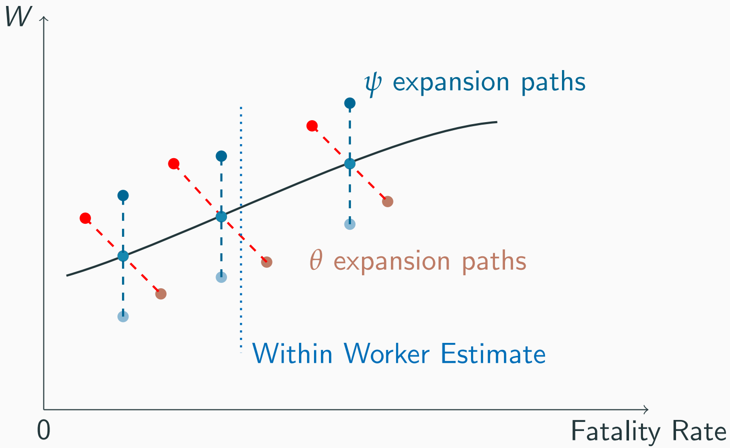
Explaining the Ability Bias Puzzle



Even if safety is normal, slope of expansion path ambiguous

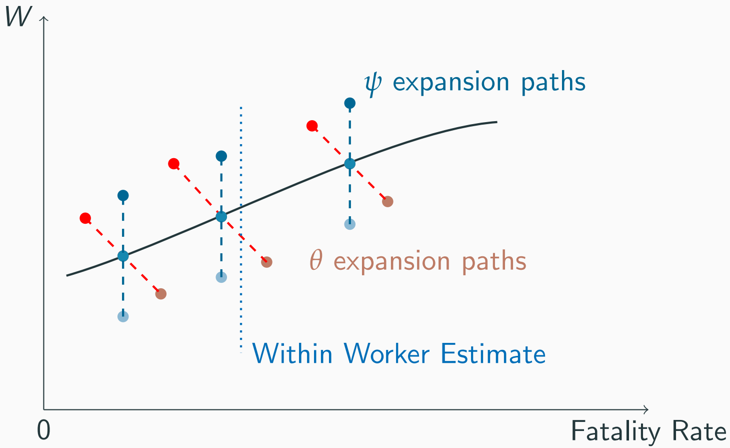
ψ may be correlated with marginal cost of safety

Explaining the Ability Bias Puzzle



Adding worker effects may control for ability, but leaves only variation along ψ expansion path, *increasing* total bias

Explaining the Ability Bias Puzzle



Our approach: condition on both θ and ψ to account for ability while also modeling within-worker wage process

Data and Empirical Setting

Data

- Longitudinal employer-employee data from Brazil: 2003-2010
  - Covers all formal-sector jobs (50 million per year, 430 million job-years)
  - Purpose of the data is to administer the *Abono Salarial*, a constitutionally-mandated annual bonus equal to one month's earnings
- Job characteristics: contracted wage, hours, occupation, date of hire, date of separation, cause of separation (including death on the job)
- Worker characteristics: age, education, race, gender
- Establishment characteristics: industry, number of workers, location

- Why Brazil? US LEHD excludes occupation, hours, education, detailed fatality rates

Fatality Rates

- We calculate fatality rates using the cause of separation data
- Preferred measure is three-year moving average fatality rate by 2-digit industry by 3-digit occupation cell
    - 11,440 industry-occupation cells compared to 720 in BLS data
    - 2003-04 data used only to construct 3-year MA
- Scale measure to equal deaths per 1,000 full-time equivalent job-years (ie deaths per 2,000,000 hours)

Analysis Sample

- Men ages 23-65
  - Extension of this paper in Lavetti & Schmutte JoE 2023 focuses on gender differences in labor market sorting patterns gradient
- Full-time (30 hrs) dominant job in each calendar year
- Exclude singleton firms, government, and temporary jobs
- Exclude industry-occupation cells with fewer than 10,000 full-time full-year equivalent workers
- Winsorize wage distribution at 1st and 99th percentiles

Summary Statistics

	Population	Analysis Sample
Age	36.98	36.23
Race *branco* (White)	0.56	0.58
Elementary or Less	0.40	0.40
Some High School	0.09	0.10
High School	0.36	0.39
Some College	0.04	0.04
College or More	0.11	0.07
Contracted Weekly Hours	42.19	43.34
Hourly Wage	6.10	5.10
Log Hourly Wage	1.47	1.37
Total Experience (Years)	20.58	19.86
Job Tenure (Months)	58.70	44.28
Fatality Rate (per 1,000)	0.071	0.083
Zero Fatality Rate (Percent)	0.14	0.09
Number of Observations	158,254,802	83,418,032

Empirical Model and Estimates

Baseline Estimates

- We begin with the worker effects model

$$\ln w_{it} = x_{it}\beta + \gamma R_{c(i,t),t} + \theta_i + \nu_{it}$$

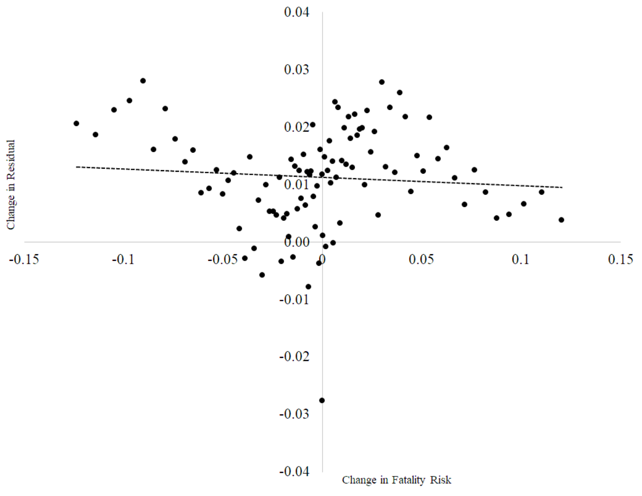
  where c(i,t) is the ind-occ cell of worker i in year t
- X includes years of experience effects, establishment size effects, tenure, state effects, year effects, 1-digit industry effects, and 1-digit occupation effects

Estimates

Table 1: Compensating Wage Differentials for Full-Time Prime-Age Men

	Dependent Variable: ln(*Wage*)	
	Pooled	Worker Effects
Fatality Rate (3-Yr MA)	0.279	0.037
	(0.001)	(0.001)
Zero Fatality Rate	0.073	0.008
	(0.000)	(0.000)
N	83,411,371	83,418,032
R^2	0.458	0.913
VSL (millions of reais)	2.84	0.37
95% CI	[2.83, 2.86]	[0.35, 0.39]

Figure 1: Worker Effects Model: Average Job-to-Job $\Delta\epsilon_{it}$ by $\Delta R_{c(i,t)}$



Orthogonal Match Effects (OME) Model

- Two-step variation of the AKM model

$$\ln w_{it} = x_{it}\beta + \tilde{\gamma} R_{c(i,t),t} + \Phi_{i,Jk(i,t)} + \epsilon_{it}$$

$$\ln w_{it} - x_{it}\widehat{\beta} = \pi_{k(i,t)} + \gamma R_{c(i,t),t} + \tau_t + \theta_i + \Psi_{J(i,t)} + \xi_{it}$$

- Step 1: $\Phi_{i,Jk(i,t)}$ is a worker-establishment-occupation match effect
- Why not stop at step 1 and use $\widehat{\tilde{\gamma}}$?
    - In principle, this is possible (Lavetti, 2020) requires within-job variation in R
    - In practice, only 3% of variance in R occurs within jobs, may not be salient, wages may not adjust on this margin

Orthogonal Match Effects (OME) Model

- Two-step variation of the AKM model

$$\ln w_{it} = x_{it}\beta + \tilde{\gamma} R_{c(i,t),t} + \Phi_{i,Jk(i,t)} + \epsilon_{it}$$

$$\ln w_{it} - x_{it}\widehat{\beta} = \pi_{k(i,t)} + \gamma R_{c(i,t),t} + \tau_t + \theta_i + \Psi_{J(i,t)} + \xi_{it}$$

- Step 2: use within job variation to estimate $\widehat{\beta}$ and remove $x_{it}\widehat{\beta}$ component from $\ln w_{it}$
- Then regress $\ln w_{it} - x_{it}\widehat{\beta}$ on occupation effects ($\pi_{k(i,t)}$), worker effects θ_i, and establishment effects $\Psi_{J(i,t)}$
- Objective is to use across-job variation in R, while correcting for potential endogeneity associated with job changes
  - Allows job mobility decisions to be arbitrarily related to θ_i & $\Psi_{J(i,t)}$

Orthogonal Match Effects (OME) Model

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$$\ln w_{it} = x_{it}\beta + \tilde{\gamma} R_{c(i,t),t} + \Phi_{i,Jk(i,t)} + \epsilon_{it}$$

$$\ln w_{it} - x_{it}\widehat{\beta} = \pi_{k(i,t)} + \gamma R_{c(i,t),t} + \tau_t + \theta_i + \Psi_{J(i,t)} + \xi_{it}$$

- Model assumptions: suppose error term has structure $\xi_{it} = \phi_{i,J(i,t)} + \varepsilon_{it}$
  - $\phi_{i,J(i,t)}$ reflects idiosyncratic productive complementarity of each potential match [Mortensen & Pissarides 1994]
  - $\phi_{i,J(i,t)}$ assumed mean 0 for each i and j
- Key orthogonality conditions are $\mathbb{E}\left[R\phi_{i,J(i,t)}\right] = 0$ & $\mathbb{E}\left[\Psi_{J(i,t)}\phi_{i,J(i,t)}\right] = 0$

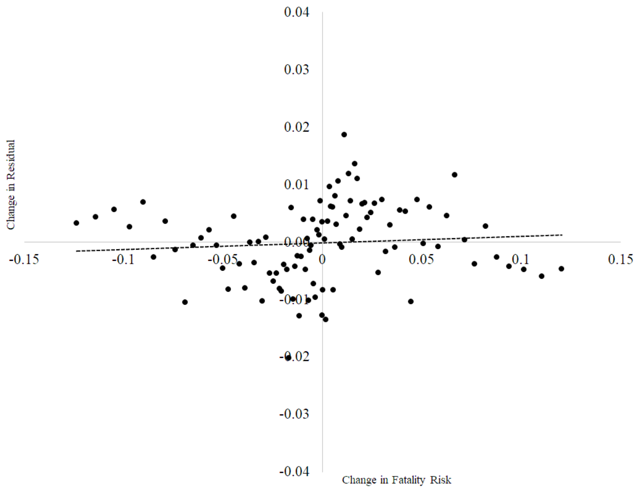
Estimates

Table 2: Compensating Wage Differentials for Full-Time Prime-Age Men

	Dependent Variable: ln(*Wage*)			
	(1)	(2)	(3)	(4)
	Pooled	Worker Effects	Match Effects	OME
Fatality Rate (3-Yr MA)	0.279*	0.037*	–0.006*	0.170*
	(0.001)	(0.001)	(0.001)	(0.001)
Zero Fatality Rate	0.073*	0.008*	–0.006*	0.014*
	(0.000)	(0.000)	(0.000)	(0.000)
N	83,411,371	83,418,032	83,418,032	83,418,032
R-Sq	0.458	0.913	0.978	0.930
VSL (millions of reais)	2.84	0.37	-0.06	1.73
95% CI	[2.83, 2.86]	[0.35, 0.39]	[-0.09, -0.03]	[1.72, 1.75]

Residual Diagnostics

Figure 2: OME Model: Average Job-to-Job $\Delta\xi_{it}$ by $\Delta R_{c(i,t)}$



OME Variance Decomposition

	Component	Share of Variance
Std. Dev. of Log Wage w_{it}	0.650	100%
Std. Dev. of P_{it}	0.648	99%
Std. Dev. of θ_i (Worker Effect)	0.456	49%
Std. Dev. of $\Psi_{J(i,t)}$ (Estab. Effect)	0.298	21%
Std. Dev. of $\gamma R_{c(i,t)}$	0.014	0%
Correlation between $(\theta_i, \Psi_{J(i,t)})$	0.280	19%
Correlation between $(R_{c(i,t)}, \theta_i)$	-0.091	2%
Correlation between $(R_{c(i,t)}, \Psi_{J(i,t)})$	-0.108	3%
Std. Dev. of Residual	0.172	7%
Std. Dev. of $\phi_{i,J(i,t)}$ (Match Effect)	0.133	4%
Average Establishment Size	17.4	
Number of Workers in Mover Sample	19,646,048	
Average Number of Jobs per Worker	1.9	

Bias Decomposition Relative to OME Estimate

$$\hat{\gamma}^{raw} = \underbrace{\hat{\gamma}^{OME}}_{\text{OME estimate}} + \underbrace{\frac{\mathrm{Cov}(\theta, R)}{\mathrm{Var}(R)}}_{\text{bias from worker eff.}} + \underbrace{\frac{\mathrm{Cov}(\psi, R)}{\mathrm{Var}(R)}}_{\text{bias from estab. eff.}} + \underbrace{\sum_k \frac{\mathrm{Cov}(x_k, R)}{\mathrm{Var}\, R}}_{\text{bias from controls}}$$

$$-0.181 = 0.170 \quad -0.212 \quad -0.272 \quad +0.134$$

Takeaways:

- High wage workers sort into safer jobs
- Firms that pay systematically higher wages offer jobs in safer occ-ind pairs
- Failing to account for either of these latent wage components introduces substantial bias

Isolating components of the variation in R

Fatality Rate	0.178*
	(0.001)
Fatality Rate*Within Occupation	-0.006*
	(0.001)
Fatality Rate*Within Establishment	-0.013*
	(0.001)
N	83,418,032
R-Sq	0.930

Theoretical Model (Brief Overview)

Theoretical Model

- Purpose: write down model of imperfect competition with endogenous amenity-wage choices that clarifies interpretation of $\widehat{\gamma}_{OME}$ relative to model primitives
- Framework: extend frictional hedonic search framework (Hwang et al. 1998) by introducing differentiated firms (Card et al. 2018) and endogenizing amenity choices
- Takeaways:
  1. OME wage model is equivalent to profit-maximizing equilibrium wage equation under assumptions we will clarify
  2. Interpretation of $\widehat{\gamma}_{OME}$ depends on testable empirical conditions related to residual match quality
  3. The canonical Rosen (1974) model of hedonic prices in implicit markets can be extended to accommodate imperfect competition

Model Setup: Workers

- Workers supply unit labor inelastically, infinite time
- Differentiated by fixed skill levels
- Choose jobs each period to maximize utility, which has common component $f(w, R) = \ln w + h(R)$ and idiosyncratic EV1 component

Model Setup: Firms and Jobs

- Firms differentiated by industry
- Exogenously endowed with firm-specific amenity and productivity
- Firms can offer employment across set of occupations
- Occupations have exogenous amenity and endogenous risk of death chosen by each firm

Model Setup: Labor Market and Timing

- In each period four events occur:
  1. Firms choose wage-risk offers to attract workers and maximize expected steady-state profits
  2. Offers delivered to all incumbent workers, and with probability λ to each outside worker
  3. Workers obtain preference shock from EV1 distribution
  4. Workers accept available offer that maximizes utility

Steady State Employment

- Steady-state firm size H depends on firm's choice of utility $\bar{u}$:

$$H(\bar{u}) = \frac{\lambda K \exp(\bar{u}) N}{[1 - (1-\lambda) K \exp(\bar{u})]} \tag{1}$$

  - If $\lambda = 1$ (offer posting), simplifies to $H(\bar{u}) = \exp(\bar{u}) KN$ where K is like a logit share (prob of acceptance) and N is # of workers
  - If $\lambda < 1$ (frictional search), firms have relative advantage in retaining incumbent workers, firm faces two different upward-sloping labor supply curves
  - $\Omega(\bar{u}) \equiv 1 - (1-\lambda) K \exp(\bar{u})$ term is firm's relative advantage in retaining incumbent workers

Equilibrium Wages

- Imposing function form assumptions on utility and firm costs, and solving for profit maximizing choice of wage and R gives:

$$\ln w^{\star} = \ln T_j + \ln \theta_s + \ln \pi_k + y_{bk}(R^{\star}) + \ln\left(\frac{1}{1+\Omega(\bar{u})}\right)$$

- Firm's profit maximizing (w, R) equates worker MWTP for safety with MC of providing it
  - Differentiating wrt R:

$$\frac{d \ln w}{dR} = h'(R)\left[1 - \left(\frac{1-\Omega(\bar{u})}{1+\Omega(\bar{u})}\right)\right]$$

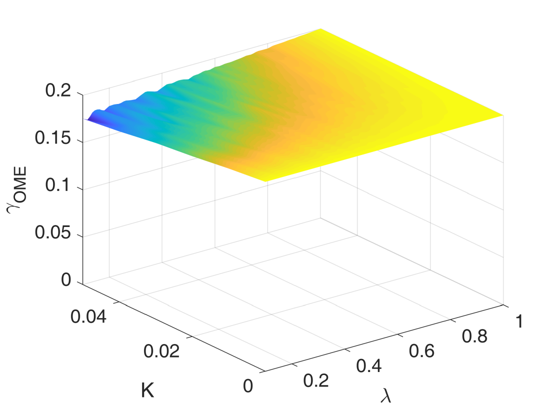
  - $h'(R)$ is marginal willingness to accept R
  - $\frac{d \ln w}{dR}$ is attenuated estimate of preferences, attenuation depends on incumbency hiring advantage $\Omega(\bar{u})$

Connection between Theoretical and Empirical Wage Models

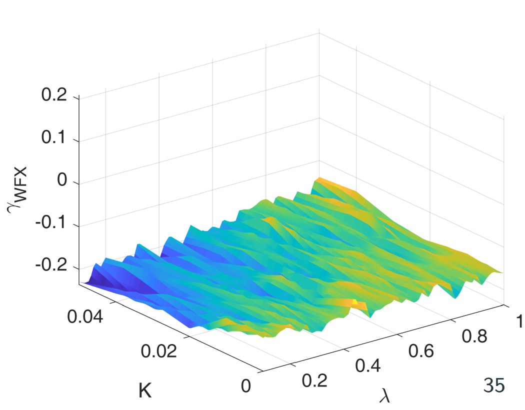
- Case 1: $\lambda = 1$ ($\Rightarrow \Omega(\bar{u}) = 1$)
  - OME is identical to equilibrium wage equation
  - $\widehat{\gamma} = h'(R)$ is preference-based measure of aversion to risk
  - Implication: Rosen framework can be adapted to accommodate imperfect competition (without search frictions)
- Case 2: $\lambda < 1$
  - $\Omega(\bar{u})$ is *partially* contained in OME residual
  - $\widehat{\gamma} = \frac{\partial \mathbb{E}[\ln w | x, \theta, \Psi]}{\partial R}$ interpretation is treatment effect on wages of risk conditional on covariates

Figure 3: Monte Carlo Estimates of $\widehat{\gamma}$ when True $\gamma = 0.2$

(a) OME Specification



(b) Worker Effects Specification



Evaluating Empirical Model Restrictions

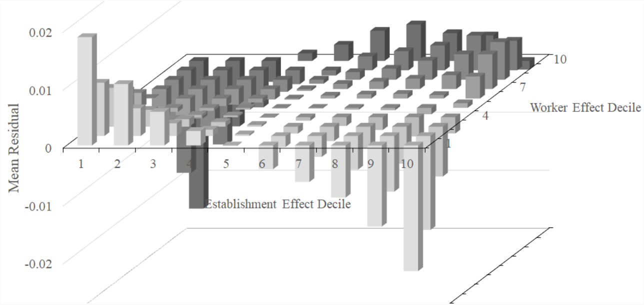
Evaluating Orthogonality Conditions

- Key empirical question is whether there is are a systematic Ω component in wage residual that drives job mobility choices or is correlated with model components
  - Ω is job-type level unobservable, so it's fully contained within match effect $\Phi_{i,Jk(i,t)}$
  - Question 1: Do match effects exist? Do they drive job mobility?

Match Effects Exist but are a Small Component of Wage Variation

- Decomposing components of wage variation:
  - 97% of variation in wages is across jobs
  - Of this, 95% explained by worker and establishment effects alone
  - Including establishment-occupation effects increases explained share to 97%
  - Including unrestricted match effect increases explained variation to 98%, small improvement

Average OME Residual by (θ, Ψ) Decile



- Fact 2: the *Potential* for match effects to exist is primarily in lowest-wage (θ, Ψ) deciles (potentially due to minimum wage policies)
- What happens to estimates when these jobs are excluded?

Sensitivity of $\widehat{\gamma}$ to Excluding Tails of the (θ, Ψ) Joint Distribution

Sample	Pooled	Worker Effects	OME
Full Distribution	0.279	0.037	0.170
	(0.001)	(0.001)	(0.001)
10th to 90th Percentiles	0.282	0.035	0.170
(64% of jobs)	(0.001)	(0.001)	(0.001)
25th to 75th Percentiles	0.223	0.043	0.180
(25% of jobs)	(0.001)	(0.001)	(0.001)
40th to 60th Percentiles	0.154	0.054	0.204
(9% of jobs)	(0.001)	(0.001)	(0.001)

- OME estimates increase slightly as sample is restricted to jobs with least potential for match effects

Match Effects do not Drive Job Mobility

Mean Wage Change of Movers by Decile of Origin & Destination ψ

		Destination Establishment Effect Decile									
		1	2	3	4	5	6	7	8	9	10
	1	-0.001	0.123	0.230	0.319	0.406	0.489	0.580	0.705	0.867	1.190
	2	-0.123	0.000	0.075	0.150	0.224	0.300	0.383	0.483	0.621	0.909
	3	-0.233	-0.074	-0.001	0.062	0.136	0.210	0.291	0.390	0.525	0.793
	4	-0.320	-0.150	-0.063	0.000	0.063	0.132	0.207	0.303	0.436	0.701
Origin	5	-0.403	-0.226	-0.135	-0.061	0.000	0.062	0.137	0.235	0.367	0.623
Decile	6	-0.491	-0.300	-0.206	-0.131	-0.064	0.005	0.066	0.160	0.287	0.543
	7	-0.589	-0.382	-0.288	-0.212	-0.141	-0.067	0.000	0.082	0.203	0.457
	8	-0.706	-0.483	-0.387	-0.305	-0.238	-0.158	-0.078	-0.001	0.110	0.352
	9	-0.864	-0.623	-0.522	-0.437	-0.366	-0.284	-0.200	-0.108	0.001	0.193
	10	-1.192	-0.906	-0.790	-0.705	-0.624	-0.548	-0.454	-0.356	-0.189	-0.002

Wage Changes are Highly Symmetric

Mean Wage Change of Movers by Decile of Origin & Destination ψ

		Destination Establishment Effect Decile									
		1	2	3	4	5	6	7	8	9	10
	1	-0.001	0.123	0.230	0.319	0.406	0.489	0.580	0.705	0.867	1.190
	2	-0.123	0.000	0.075	0.150	0.224	0.300	0.383	0.483	0.621	0.909
	3	-0.233	-0.074	-0.001	0.062	0.136	0.210	0.291	0.390	0.525	0.793
	4	-0.320	-0.150	-0.063	0.000	0.063	0.132	0.207	0.303	0.436	0.701
Origin	5	-0.403	-0.226	-0.135	-0.061	0.000	0.062	0.137	0.235	0.367	0.623
Decile	6	-0.491	-0.300	-0.206	-0.131	-0.064	0.005	0.066	0.160	0.287	0.543
	7	-0.589	-0.382	-0.288	-0.212	-0.141	-0.067	0.000	0.082	0.203	0.457
	8	-0.706	-0.483	-0.387	-0.305	-0.238	-0.158	-0.078	-0.001	0.110	0.352
	9	-0.864	-0.623	-0.522	-0.437	-0.366	-0.284	-0.200	-0.108	0.001	0.193
	10	-1.192	-0.906	-0.790	-0.705	-0.624	-0.548	-0.454	-0.356	-0.189	-0.002

- If workers sort into jobs based on match effects, we should see asymmetric wage changes when workers move $\uparrow$ versus $\downarrow$ the Ψ_J distribution

Zero Wage Gains without Ψ Gains

Mean Wage Change of Movers by Decile of Origin & Destination ψ

		Destination Establishment Effect Decile									
		1	2	3	4	5	6	7	8	9	10
	1	-0.001	0.123	0.230	0.319	0.406	0.489	0.580	0.705	0.867	1.190
	2	-0.123	0.000	0.075	0.150	0.224	0.300	0.383	0.483	0.621	0.909
	3	-0.233	-0.074	-0.001	0.062	0.136	0.210	0.291	0.390	0.525	0.793
	4	-0.320	-0.150	-0.063	0.000	0.063	0.132	0.207	0.303	0.436	0.701
Origin	5	-0.403	-0.226	-0.135	-0.061	0.000	0.062	0.137	0.235	0.367	0.623
Decile	6	-0.491	-0.300	-0.206	-0.131	-0.064	0.005	0.066	0.160	0.287	0.543
	7	-0.589	-0.382	-0.288	-0.212	-0.141	-0.067	0.000	0.082	0.203	0.457
	8	-0.706	-0.483	-0.387	-0.305	-0.238	-0.158	-0.078	-0.001	0.110	0.352
	9	-0.864	-0.623	-0.522	-0.437	-0.366	-0.284	-0.200	-0.108	0.001	0.193
	10	-1.192	-0.906	-0.790	-0.705	-0.624	-0.548	-0.454	-0.356	-0.189	-0.002

- If workers sort into jobs based on match effects, we should see systematic wage increases when workers move to another firm with the same Ψ_J
- Conclusion: no evidence that job mobility is driven my match effects

Control Function Approach

- Question 2: Do estimates change if we include a control function for Ω?
  - In theoretical model, if we control for Ω then $\widehat{\gamma} = h'(R)$
  - Recall that $\Omega \equiv 1 - (1-\lambda) K \exp(\bar{u}) = 1 - (1-\lambda) p$ where p is the probability of a worker accepting a job offer
  - In the model, p is also equal to the probability of retaining a worker
  - Intuition: the length of completed job spells at firm j tells us p, so include as a control function

Completed Tenure at Control Function

	Pooled		Worker Effects		OME	
	(1)	(2)	(3)	(4)	(5)	(6)
Fatality Rate	0.373*	0.407*	0.037*	0.043*	0.199*	0.200*
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Zero Fatality Rate	0.064*	0.061*	0.009*	0.010*	0.018*	0.018*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Completed Job Tenure		0.003*		0.001*		0.001*
		(0.000)		(0.000)		(0.000)
N			23,520,871			
R-Sq	0.441	0.464	0.902	0.903	0.924	0.924

Network-Based IV Model

- Question 3: When workers change jobs, are changes in match effects correlated with changes in risk?
  - If so, $\mathbb{E}\left[R\phi_{i,J(i,t)}\right] \neq 0$ would violate conditional exogeneity assumption
- Solution: Instrument change in R with former coworkers' subsequent changes
- Intuition:
  1. Workers in the same firm-occupation sample from the same distribution of outside offers
  2. Because $\phi_{i,J(i,t)}$ is mean zero for all workers and all firms, my former coworkers' change in R should be uncorrelated with my change in $\phi_{i,J(i,t)}$ if I move jobs

IV Strategy

- Construct instruments for R using the set of 'neighbors' of i in the realized mobility network
  - Definition: for each worker in each year, $N(i,t)$ is set of former co-workers at the same establishment and occupation as worker i, who exited that job within previous two years
- Exclusion restriction requires

$$E\left(\tilde{R}_{it}\xi_{it}\right) = 0$$

  - Workers are not compensated for their past co-workers' subsequent job amenities
  - Predicted sequence of i's match effects can't be improved by knowing average change in fatality rates of i's neighbor set

IV Analysis Sample

- $N(i, t)$ constructed by workers departing from the same establishment-3 digit occupation during the prior two years
- Limits focal years to 2008-2010, with $N(i, t)$ constructed using 2006-2009 data
- Limit to direct job-to-job transitions
- Sample size 5,403,738 person-years

IV Estimates

	(1) First-Differenced	(2) Establishment Effects	(3) IV First Stage	(4) IV	(5) OME on IV Sample
ΔFatality Rate	-0.048	0.236*		0.210*	
	(0.003)	(0.000)		(0.011)	
Avg. Δ Fat. Rate in $N(i.t)$			0.338*		
			(0.001)		
Fatality Rate					0.203*
					(0.009)
N	5,653,428	5,403,738	5,403,738	5,403,738	5,403,738

- IV and OME estimates are very similar, suggesting $\mathbb{E}\left[R\phi_{i,J(i,t)}\right] = 0$ in our setting
- Neither of the two exogeneity conditions required to interpret OME $\widehat{\gamma}$ as $h'(R)$ appears to be violated

Summary of Empirical Model Restrictions

- Structural wage equation is:

$$\ln w^{\star} = \ln T_j + \ln \theta_s + \ln \pi_k + h(R) + \ln \left(\frac{1}{1+\Omega(\bar{u})} \right)$$

- In our empirical setting, we conclude that:
  - $\ln \left(\frac{1}{1+\Omega(\bar{u})} \right)$ is small in magnitude, and is unrelated to job mobility patterns
  - Including a control function for Ω has very little impact on $h'(R)$
  - $\ln \left(\frac{1}{1+\Omega(\bar{u})} \right)$ appears to be uncorrelated with all other components of wage equation
- Conclude that in our setting $\widehat{\gamma} = h'(R)$ identifies marginal willingness to accept risk

Conclusions

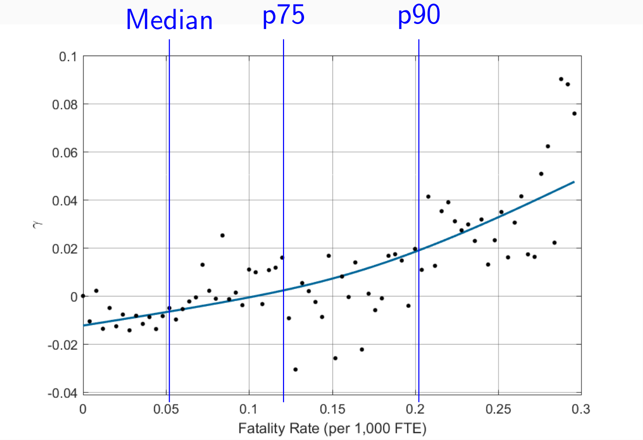
- Under imperfect competition, adding worker effects can amplify bias caused by non-random job assignment
- Including firms in the model of wage dispersion reconciles ability bias puzzle and matches predictions of hedonic search theory and empirical wage processes well
    - Provides a bridge between structural, theoretical, and reduced-form compensating wage differentials literatures
- Develop a model of imperfect competition that clarifies mapping between restrictions on wage equation and parameter interpretation
    - Use this model to guide diagnostics, suggest workers do not sort on match quality in ways correlated with safety or Ψ
    - Under model assumptions, this implies a preference-based interpretation of our estimates

Bonus Slides

Fatality Rates by Major Industry and Occupation

Industry	Average Fatality Rate	Number of Job-Years
Agriculture and Fishing	10.25	22,762,420
Mining	10.48	1,814,957
Manufacturing	5.24	76,712,576
Utilities	4.19	2,023,931
Construction	13.77	26,098,278
Trade and Repair	6.04	82,004,063
Food, Lodging, and Hospitality	4.99	15,589,304
Transportation, Storage, and Communication	14.53	20,941,098
Financial and Intermediary Services	1.01	6,947,728
Real Estate, Renting, and Services	4.59	57,447,503
Public Administration, Defense, and Public Security	0.84	72,055,976
Education	1.58	12,418,485
Health and Social Services	1.67	14,089,834
Other Social and Personal Services	3.98	15,469,519
Domestic Services	5.76	116,086
Occupation		
Public Administration and Management	2.63	18,035,409
Professionals, Artists, and Scientists	1.09	39,178,629
Mid-Level Technicians	2.50	40,972,375
Administrative Workers	1.87	78,792,943
Service Workers and Vendors	4.40	98,796,568
Agriculture Workers, Fishermen, Forestry Workers	9.26	25,417,204
Production and Manufacturing I	11.65	94,955,794
Production and Manufacturing II	5.28	15,947,072
Repair and Maintenence Workers	7.39	13,871,753

Linearity Assumption



- We largely follow literature in assuming linear wage model
- Estimate semi-parametric model with 75 binary R bins

Sensitivity to OME Specification

Table 3: Sensitivity of OME Estimates to Model Specification

	(1)	(2)	(3)	(4)	(5)
Fatality Rate	0.168*	0.190*	0.165*	0.172*	0.152*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Zero Fatality Rate	0.013*	0.014*	0.012*	0.013*	0.007*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
1st Stage Exp. by Educ. Effects	Y	N	N	N	N
1st Stage Replace Exp. with Tenure Effects	N	Y	Y	N	N
2nd Stage Include Exp. Effects	N	N	Y	N	N
2nd Stage Include Hiring Year by Year Effects	N	N	N	Y	N
1st Stage Cubic in Exp. Interacted with Race	N	N	N	N	Y
N	83,411,371	83,418,032	83,418,032	83,418,032	83,418,032
R-Sq	0.914	0.935	0.936	0.931	0.967
VSL (millions R$)	1.71	1.93	1.69	1.75	1.55
95% CI	[1.70, 1.73]	[1.92, 1.95]	[1.67, 1.70]	[1.74, 1.77]	[1.53, 1.58]

Single-Step AKM Specifications

Table 4: Alternative AKM TWFE Model Specifications

	(1)	(2)	(3)	(4)	(5)	(6)
Fatality Rate	0.165*	0.168*	0.165*	0.165*	0.169*	0.153*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Zero Fatality Rate	0.014*	0.013*	0.014*	0.014*	0.013*	0.018*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
1-Digit Occ. Effects	Y	Y	Y	Y	Y	N
Linear Tenure Control	Y	N	Y	Y	Y	Y
Tenure Effects	N	Y	N	N	N	N
Experience by Education Effects	N	N	Y	N	N	N
Hiring Year Effects	N	N	N	Y	Y	N
Year-by-Hiring Year Effects	N	N	N	N	Y	N
N	83,418,032	83,418,032	83,411,371	83,418,032	83,418,032	83,418,032
R-Sq	0.931	0.931	0.931	0.931	0.931	0.930
VSL (millions R$)	1.68	1.72	1.68	1.68	1.72	1.56
95% CI	[1.67, 1.70]	[1.70, 1.73]	[1.67, 1.70]	[1.67, 1.70]	[1.71, 1.74]	[1.55, 1.58]

Inference

Table 5: Estimates with Clustered Standard Errors

	(1) Pooled	(2) Worker Effects	(3) Match Effects	(4) OME
Fatality Rate	0.279	0.037	–0.006	0.170
Unclustered SE	(0.001)*	(0.001)*	(0.001)*	(0.001)*
Clustered by Establishment	(0.018)*	(0.004)*	(0.009)	(0.003)*
Clustered by Occupation*Industry	(0.163)	(0.033)	(0.029)	(0.032)*
Zero Fatality Rate	0.073	0.008	–0.006	0.014
Unclustered SE	(0.000)*	(0.000)*	(0.000)*	(0.000)*
Clustered by Establishment	(0.004)*	(0.001)*	(0.001)*	(0.001)*
Clustered by Occupation*Industry	(0.022)*	(0.006)	(0.009)	(0.006)
N	83,411,371	83,418,032	83,418,032	83,418,032
N Establishment Clusters	1,634,452	1,634,464	1,634,464	1,634,464
N Occupation-Industry Clusters	624	624	624	624
R-Sq	0.458	0.913	0.978	0.930

Mass Displacement Events

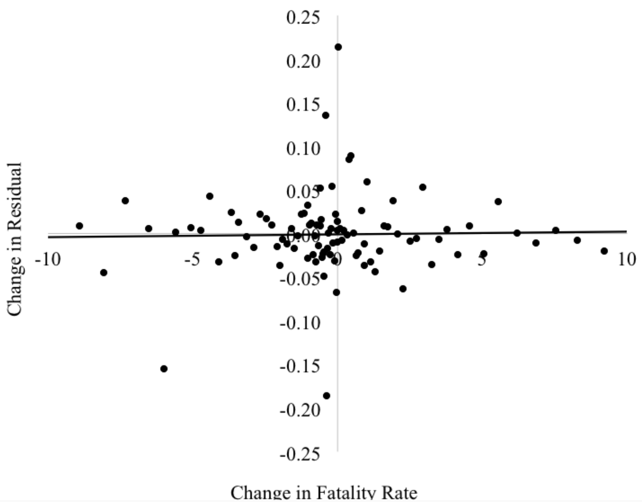
- Potential violation of OME assumptions could occur if workers learn about ability or match quality over time, and sort into jobs based on this [Solon (1988); Gruetter and Lalive (2009)]
- Gibbons and Katz (1992) use mass displacement events as source of job transitions unlikely to be affected by this concern
- OME estimates are very similar if we isolate variation induced by mass displacements

Mass Displacement Estimates

	(1) Pooled	(2) Worker Effects	(3) Match Effects	(4) OME
Fatality Rate (3-Yr MA)	0.475*	0.079*	–0.011*	0.205*
	(0.001)	(0.002)	(0.002)	(0.001)
Fatality Rate × Mass Disp.	0.209*	0.003		–0.014*
	(0.002)	(0.002)		(0.002)
Zero Fatality Rate	0.089*	0.013*	–0.004*	0.016*
	(0.000)	(0.000)	(0.000)	(0.000)
Zero Fatality Rate × Mass Disp.	–0.006*	0.004*		0.005*
	(0.001)	(0.001)		(0.000)
Mass Disp. Origin	–0.023*	0.016*		0.009*
	(0.000)	(0.000)		(0.000)
Mass Disp. Destination	–0.031*	0.002*		0.001
	(0.000)	(0.000)		(0.000)
N	44,220,194	44,224,540	44,224,540	44,224,540
R-Sq	0.448	0.914	0.976	0.925

IV Residual Diagnostics

Figure 4: Average Change in Residual by Change in Fatality Rate



Identifying Variation

- After controlling for worker, establishment, and one-digit occupation effects, is there still variation left in R to identify γ?
- 97% of variation in R is across jobs
- 69% of the across-job variation is across 3-digit occupation
- 55% of the 3-digit occ risk variation is within establishment

Correlation Matrix

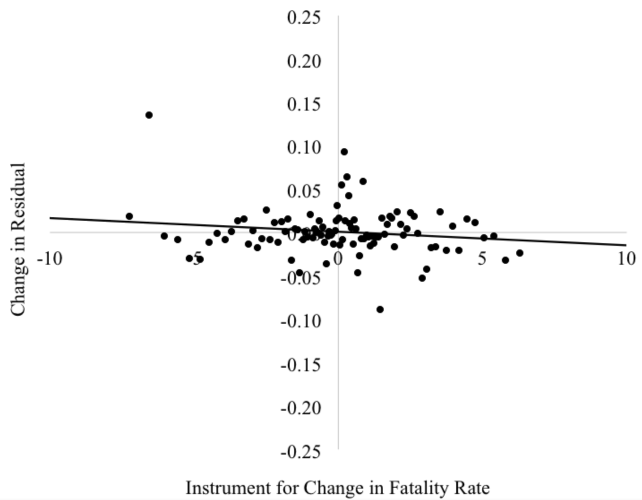
			Correlation					
	Mean	Std. Dev.	Log Wage	$X\beta$	θ	ψ	ε	Πa
Log Wage	1.30	0.760	1					
Time-varying characteristics	1.30	0.377	0.243	1				
Worker effect	−0.00	0.502	0.599	−0.476	1			
plant-occup. effect	−0.00	0.397	0.800	0.118	0.333	1		
Residual	0.00	0.196	0.258	−0.000	0.000	0.000	1	
Fatality Rate	5.28	10.594	−0.063	0.042	−0.095	−0.041	−0.000	1

Causes of Job Separation

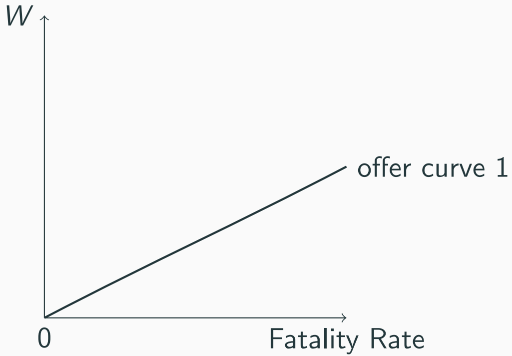
Value	Label Portuguese	Label English
0	nao desl ano	no separation this year
10	dem com jc	terminated with just cause
11	dem sem jc	terminated without just cause
12	term contr	end of contract
20	desl com jc	resigned with just cause
21	desl sem jc	resigned without just cause
30	trans c/onus	xfer with cost to firm
31	trans s/onus	xfer with cost to worker
40	mud. regime	Change of labor regime
50	reforma	military reform - paid reserves
60	falecimento	demise, death
62	falec ac trb	death - at work accident
63	falec ac tip	death - at work accident corp
64	falec d prof	death - work related illness
70	apos ts cres	retirement - length of service with contract termination
71	apos ts sres	retirement - length of service without contract termination
72	apos id cres	retirement - age with contract termination
73	apos in acid	retirement - disability from work accident
74	apos in doen	retirement - disability from work illness
75	apos compuls	retirement - mandatory
76	apos in outr	retirement - other disability
78	apos id sres	retirement - age without contract termination
79	apos esp cre	retirement - special with contract termination
80	apos esp sre	retirement - special without contract termination

IV Residual Diagnostics

Figure 5: Average Change in Residual by Change in Instrument



Corner Solutions



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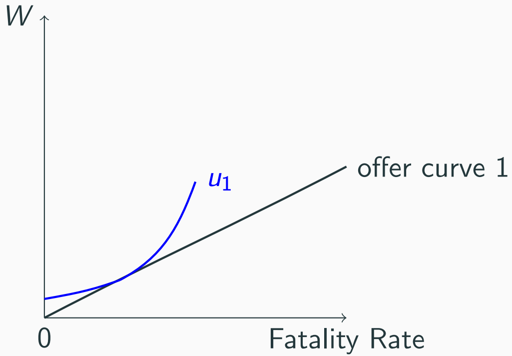

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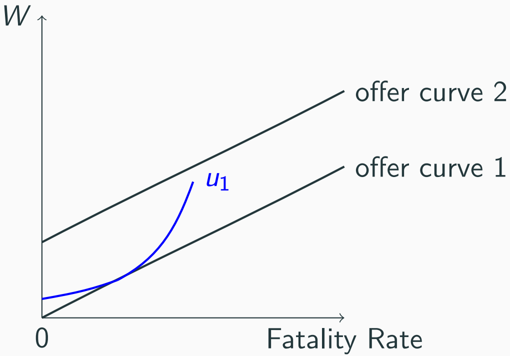

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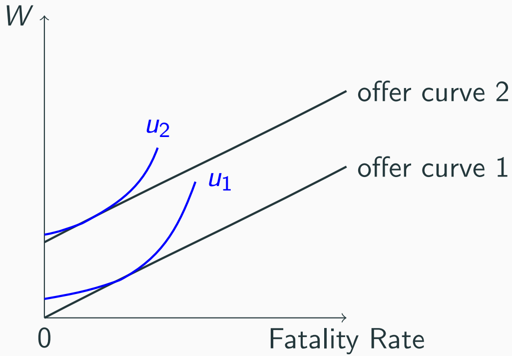

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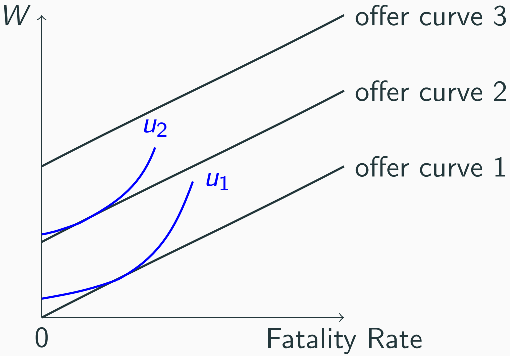
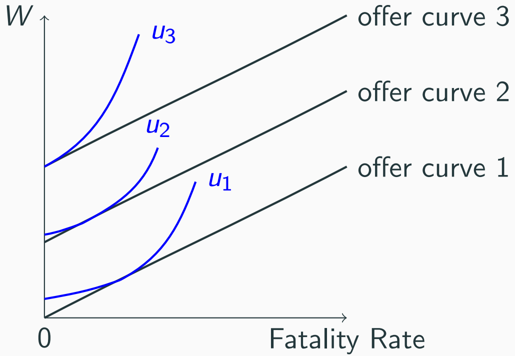
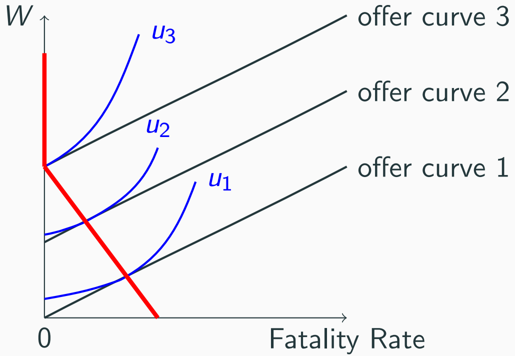


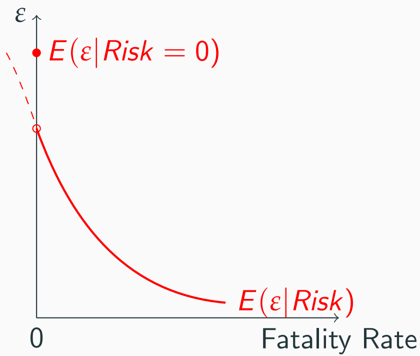
Corner Solutions



Corner Solutions

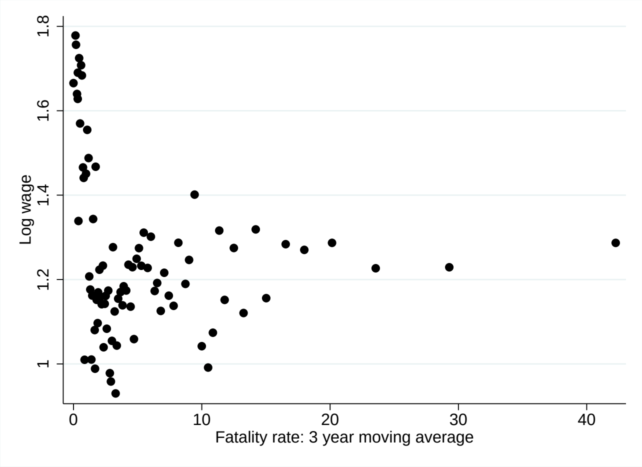


Implications of Misspecification



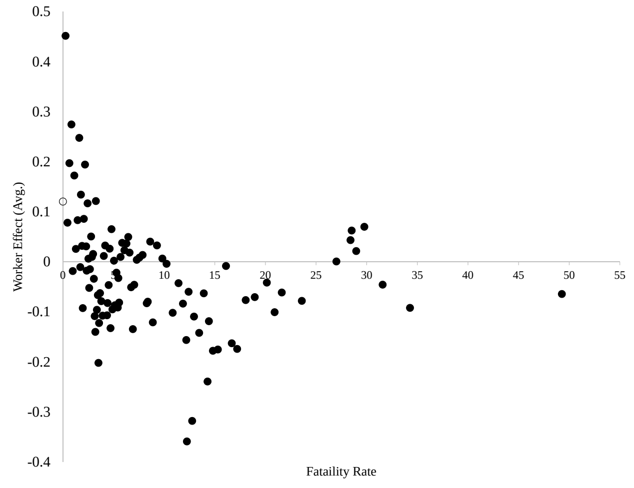
This Matters

Figure 6: Fatality Rate versus Log Wage: Binned Scatterplot



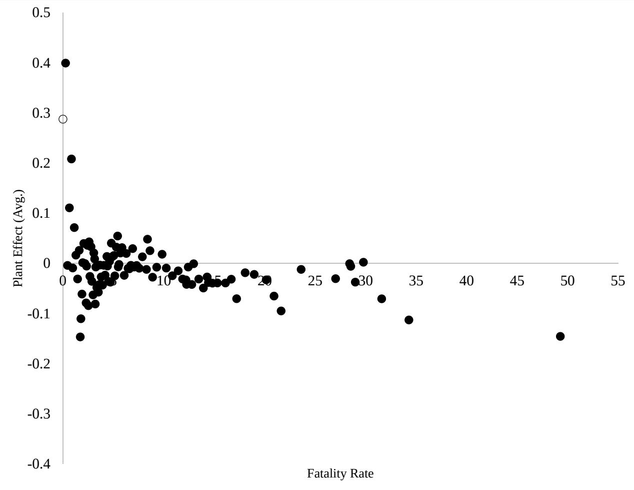
Caetano (2015) Diagnostics

Figure 7: Average Worker Wage Effect by Percentile of the Fatality Rate



Caetano (2015) Diagnostics

Figure 8: Average Establishment Wage Effect by Percentile of the Fatality Rate

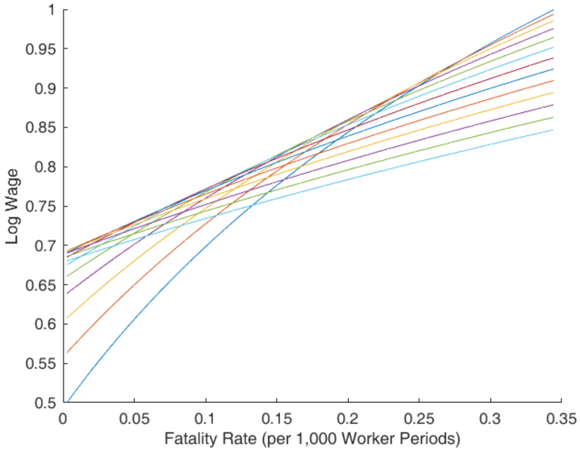


Monte Carlo Simulation

- Evaluate performance of OME versus worker effects model in simulated search model
- Workers have a common utility function $U(w, R) = w - \alpha R$
- Heterogeneous worker types θ and firm types (ψ, c_k)
  - c_k determines the firm's offer curve type, correlated with ψ
- Workers receive λ offers of (w, R) per period, and switch whenever an offer increases utility
- Offers are determined by random draws from empirical joint distribution of (θ, ψ, R) and corresponding compensating differential $y_{c_k}(R)$

Firm Types

Figure 9: Firm Offer Curves



Monte Carlo Simulation

- Simulate 1000 draws, each with 1000 workers and T=15
- Randomly vary α between 0.4 and 0.6 in each simulation

Table 6: Simulated Performance of Worker Effects and OME Models at Recovering Preference Parameter α

	Worker Effects	OME
Bias	-0.7367	-0.0181
Bias (% of α)	-149.9%	-3.7%
RMSE	0.5748	0.0059

Gender-Specific Compensating Wage Differentials, OME Model

	Fatality Rate Industry*Occupation		Fatality Rate Gender*Industry*Occupation		
	(1) Men	(2) Women	(3) Men	(4) Women	(5) Both
Fatality Rate	0.233*	0.161*	0.174*	0.174*	0.174*
	(0.002)	(0.005)	(0.002)	(0.005)	(0.002)
Fatality Rate*Female					0.001
					(0.005)
VSL (million reais)	3.41	2.06	2.55	2.23	2.43
	[3.34, 3.47]	[1.94, 2.18]	[2.49, 2.60]	[2.11, 2.35]	[2.34, 2.53]
N	13,985,793	8,131,646	13,985,793	8,131,646	22,117,439
R-Sq	0.959	0.970	0.959	0.970	0.971

Theoretical Model

- Purpose: write down model of imperfect competition with endogenous amenity-wage choices that clarifies interpretation of $\widehat{\gamma}_{OME}$ relative to model primitives
- Framework: extend frictional hedonic search framework (Hwang et al. 1998) by introducing differentiated firms (Card et al. 2018) and endogenizing amenity choices
- Takeaways:
    1. OME wage model is equivalent to profit-maximizing equilibrium wage equation under assumptions we will clarify
    2. Interpretation of $\widehat{\gamma}_{OME}$ depends on testable empirical conditions related to residual match quality
    3. The canonical Rosen (1974) model of hedonic prices in implicit markets can be extended to accommodate imperfect competition

Model Setup: Workers

- Workers $i \in \{1, \ldots, N\}$ supply a unit of labor inelastically each period for infinite time
- Each worker has fixed skill level $s(i) \in \{1, \ldots, S\}$
- Workers receive offers at fixed rate that expire at end of period, choose where to work to maximize (instantaneous) utility
- Utility has the form $u_{ijkt} = \bar{u}_{sjkt} + \epsilon_{ijkt}$
    - $\bar{u}_{sjkt}$ is common to all workers with skill s, employed at firm j, in occupation k, in period t
    - ϵ_{ijkt} is EV1 idiosyncratic taste for employment at jk in period t, unobserved to firm

Model Setup: Firms and Jobs

- Large number of firms $j \in \{1, \ldots, J\}$ differentiated by industry, $b(j) \in \{1, \ldots, B\}$
- Firms exogenously endowed with:
  - a_j firm-specific amenity
  - T_j productivity
- Firms can offer employment across set of occupations, $k \in \{1, \ldots, K\}$
- Occupations have exogenous amenity d_k and endogenous risk of death R_{jkt} chosen by each firm

Model Setup: Firms and Jobs

- Firms attract workers by choosing wages w_{sjkt} and risk R_{jkt} to provide indirect utility $\bar{u}_{sjkt} = f(w_{sjkt}, R_{jkt}) + g_s(a_j, d_k)$
  - $f(w_{sjkt}, R_{jkt})$ increasing, concave in w; decreasing, convex in R
  - $g_s(a_j, d_k)$ increasing in both arguments

- Profit of firm j in period t given by

$$L_{sjkt}\left[Q_{sjkt} - C_{bk}(w_{sjkt}, R_{jkt})\right]$$

  - L_{sjkt} = total employment of type s labor
  - Q_{sjkt} = revenue per worker
  - $C_{bk}(w_{sjkt}, R_{jkt})$ = unit cost of labor in industry b occupation k

Model Setup: Labor Market and Timing

- In each period four events occur:
  1. Firms choose offers (w_{sjkt}, R_{jkt}) to maximize expected steady-state profits
  2. Offers delivered to all incumbent workers, and with probability λ to each outside worker
  3. Workers obtain a new draw from ϵ distribution
  4. Workers accept available offer that yields highest period-utility

Model Setup: Labor Market and Timing

- When each firm is small, expected probability of acceptance has approximate logit form
$$p_{sjkt} = K_s \exp(\bar{u}_{sjkt})$$
  - K_s skill-specific normalizing constant
  - $\bar{u}_{sjkt}$ common utility component
  - Approximate because expectation taken over all consideration sets
- Consider firm's steady-state decision about employing labor type s in occupation k

Steady State Employment

- Law of motion of employment is

$$L_{t+1} = p(\bar{u})L_t + \lambda p(\bar{u})[N - L_t]$$

  - $pL_t =$ expected number of period t workers retained in $t+1$
  - $\lambda p(N - L_t) =$ expected number of offers accepted by outside workers
- Substituting steady-state condition $L_{t+1} = L_t \equiv L$ and $p(\bar{u})$ gives steady-state employment level:

$$H(\bar{u}) = \frac{\lambda K \exp(\bar{u}) N}{[1 - (1-\lambda)K \exp(\bar{u})]} \tag{2}$$

  - Because of difference in offer rates, $(1-\lambda)$, firm faces two different upward-sloping labor supply curves each period
  - $\Omega(\bar{u}) \equiv 1 - (1-\lambda)K \exp(\bar{u})$ term is firm's relative advantage in re-hiring (retaining) current workers

Interpretation of λ

- If $\lambda = 1$, model simplifies to static model in Card et al. (2017) plus endogenous amenities
- If $\lambda < 1$, incumbent hiring advantage is larger for firms with greater exogenous endowments
  - High endowment firms will choose a high $\bar{u}$, and will grow larger

Firm's Choice of (w, R)

$$\pi = \max_{w,R} \left[Q - C(w,R) \right] H(\bar{u})$$

- Rearranging FOCs and substituting for $H(\bar{u})$ gives:

$$\frac{f_w(w,R)}{f_R(w,R)} = \frac{C_w(w,R)}{C_R(w,R)}$$

- Firm's profit maximizing (w, R) equates worker WTP for safety with MC of providing it
- Equivalent to classical frictionless hedonic wage model solution

Functional Form and Equilibrium Wages

- To solve for equilibrium wages, assume functional forms:

$$f(w, R) = \ln w - h(R)$$

$$\ln C(w, R) = \ln w - y_{bk}(R)$$

$$Q_{sjk} = T_j \theta_s \pi_k$$

- $y_{bk}(R)$ is industry-occupation specific cost of safety
- Implies:
  1. $y'_{bk}(R^\star) = h'(R^\star)$
  2. $\ln w^\star = \ln T_j + \ln \theta_s + \ln \pi_k + y_{bk}(R^\star) + \ln \left(\frac{1}{1+\Omega(\bar{u})}\right)$

Functional Form and Equilibrium Wages

- Differentiating equilibrium wage equation wrt R gives:

$$\frac{d \ln w}{dR} = h'(R) \left[1 - \left(\frac{1 - \Omega(\bar{u})}{1 + \Omega(\bar{u})} \right) \right] \tag{3}$$

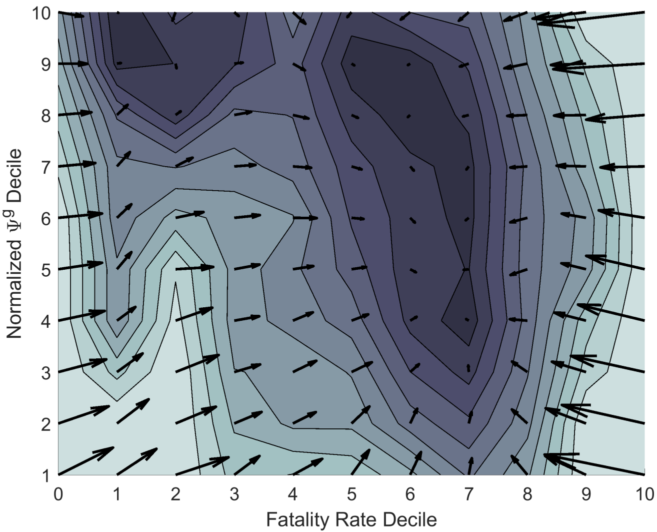
- $\frac{d \ln w}{dR}$ is attenuated estimate of workers' marginal aversion to risk
- Attenuation depends on incumbency hiring advantage $\Omega(\bar{u})$

Connection between Theoretical and Empirical Wage Models

- Case 1: $\lambda = 1$ ($\Rightarrow \Omega(\bar{u}) = 1$)
  - OME is identical to equilibrium wage equation
  - $\widehat{\gamma} = h'(R)$ is preference-based measure of aversion to risk
  - Implication: Rosen framework can be adapted to accommodate imperfect competition (without search frictions)

- Case 2: $\lambda < 1$
  - $\Omega(\bar{u})$ is *partially* contained in OME residual
  - $\widehat{\gamma} = \frac{\partial \mathbb{E}[\ln w | x, \theta, \Psi]}{\partial R}$ interpretation is treatment effect on wages of risk conditional on covariates
  - What affects bias in $\widehat{\gamma}$ as an estimate of $h'(R)$?
    - If every firm has a small share, $\Omega \approx 1$ and *Bias* ≈ 0
    - If firm and worker effects explain most of Ω, pure match-specific component in OME residual is small
    - If large firms have non-negligible Ω, worker retention probability can be used as control function for remaining structural error
  - Empirically test to inform interpretation of $\widehat{\gamma}$

J2J Gradient Vector Field: Men



J2J Gradient Vector Field: Women

sample