

# The Inner Beauty of Firms

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# Motivation: A Tale of Two Salons

**Internal Organization:** The assignment of workers to tasks within the firm.

## Westwood Barber Shop



1 2

★★★★★ 12/10/2014 · Updated review

A lovely stylist named Minoo did an incredible job. She colored my hair, freshened up my bob and gave me a great blow dry. The prices are unbelievable, 25 for color, 20 for haircut and 20 for blow dry.



0 18 12

★★★★★ 3/10/2019

Throughly enjoyable quality cut from the delightful owners of the salon. At 81 she cut while he cleaned.

## John Frieda Salon



33 65 14

★★★★★ 6/9/2011

In addition to seeing a different person for your cut and color all the stylists have assistants and they are usually the ones that take you back for washing and drying if your stylist is busy. I've had days where I swear 4-5 people worked on me like I'm a celebrity or something, which speaking of there are often quite a few getting their hair done as well.



24 54 14

★★★★★ 1/23/2013

A cut and color here costs more than a monthly payment for some cars.

**Source:** Yelp.com. Review text truncated for brevity.

## Motivation

- ▶ The two salons are organizationally unique.
  - ▶ John Frieda is an international brand.
  - ▶ Westwood Barber Shop is a local family-owned business.
- ▶ The two salons are 4.7 miles apart.
  - ▶ They compete for workers in the same labor market.
  - ▶ They compete for customers in the same product market.
- ▶ The two salons chose different prices and different internal organizations.

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- ▶ Research Question 1: How do firms choose their internal structure?
- ▶ Research Question 2: What are the implications for product markets, labor markets, and government policy?
- ▶ These questions are important:
  - ▶ The assignment of workers to tasks is a determinant of productivity.
  - ▶ Large literature on specialization across industries/occupations/countries.
  - ▶ Much of specialization occurs within the firm via internal organization.

## Summary of Paper

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- ▶ **Answer to Research Question 1:** Salons choose more complex internal organizations in order to produce higher quality products, but are constrained by firm-specific organization costs.
- ▶ **Answer to Research Question 2:** Endogenous and heterogeneous internal organization introduces new economic forces.

## Summary of Paper

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  - ▶ **Example 1:** A minimum wage hike  $\uparrow$  specialization for minimum wage workers and  $\downarrow$  specialization for non-minimum wage workers, generating wage spillovers non-monotone in initial wage.

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  - ▶ **Example 2:** A sales tax cut  $\uparrow$  specialization and worker productivity.

# Contribution

An industry equilibrium model of internal organization...

- ▶ **Task-Based Labor Models.** Lazear 2009 (firm-specific task demand); Haanwinckel 2020 (multi-worker firms); Adenbaum 2021 (org. costs); Lindenlaub 2017 (multi-skill workers)

...with organizationally unique firms...

- ▶ **Organizational Economics.** Baker, Gibbons, and Murphy 2002 (relational contracts); Garicano and Wu 2012 (knowledge); Meier, Stephenson, and Perkowsky 2019 (trust); Martinez et al. 2015 (culture); Alchian and Demsetz 1972 (monitoring)

...that can be identified and estimated using task assignment data.

- ▶ **Using Wages.** Caliendo et al. 2012, Caliendo, Monte, and Rossi-Hansberg 2015
- ▶ **Rational Inattention.** Jung et al. 2019; Tian 2019; Mat jka and McKay 2015; Lipnowski and Ravid 2022

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## Data

- ▶ Salon management software company founded in 2016
- ▶ Nationwide, but clients are concentrated in NYC and LA
- ▶ Observe 13 million assignments of services to hair stylists across hundreds of salons from 2016 to Q3 2021

# A Data Snapshot

Firm	Salon	App.	Cust.	Service	Staff	Time Stamp	Price	Duration
1	1A	123	Blake	Advanced Cut	Rosy	3/26/2021 16:15	100	72
1	1A	123	Blake	Full Head - Highlights	Rosy	3/26/2021 16:15	243	127
1	1A	123	Blake	Treatment Add On (Olaplex)	Rosy	3/26/2021 16:15	39	72
2	2A	9982	Grace	Women's Cut	Tyler	3/17/2021 11:00	225	43
2	2A	9982	Grace	Single Process	Ben	3/17/2021 11:00	200	77

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- ▶ Services are aggregated to form one representative product per firm-quarter.
- ▶ A firm's **price** is the sum of service prices divided by total customers.
- ▶ A firm's **required labor** is the sum of durations divided by total customers.
- ▶ A firm's **task-mix** is the fraction of labor classified as each task.

## Creating Tasks

- ▶ 20,560 unique text descriptions of services.
- ▶ Hired a certified cosmetologist via UpWork to classify into 6 categories.
- ▶ For multi-category services: time is split across the tasks.
- ▶ Patterns are robust to method of classification (i.e. NLP classification)

## Firm-Quarter Statistics

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Revenue	4,558	213,201.30	248,359.90	5	58,912.5	271,236.5	2,559,703
Price	4,558	199.73	135.16	0.20	111.71	261.88	3,180.44
Employees	4,558	13.38	10.79	1	6	17	92
Customers	4,558	1,159.23	1,098.45	1	397	1,619	16,768
Task Categories	4,558	4.45	0.86	1	4	5	5
Labor per. Customer	4,558	2.15	1.63	0.10	1.52	2.57	61.33

Task-Mix Variation

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# What is an Organization Structure?

## Definition 1

A firm's organization structure ( $B_j$ ), is a matrix where element  $(i, k)$  is the fraction of labor assigned to worker  $i$  and task  $k$ .

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		Tasks			Tasks				Worker Share ( $E$ )
		Cut	Color	Dry	Cut	Color	Dry		
Worker	A	1/2	0	0	1/6	1/12	1/12	1/3	
	B	0	1/4	0	1/6	1/12	1/12	1/3	
	C	0	0	1/4	1/6	1/12	1/12	1/3	
	Tot.	1/2	1/4	1/4	1/2	1/4	1/4	1/4	
Task-Mix ( $\alpha$ )									

# What is Organizational Complexity?

## Definition 2

The complexity of an organization structure  $B_j$  is:

$$I(B_j) = \sum_{i,k} B_j(i, k) \log \left( \frac{B_j(i, k)}{\sum_{k'} B_j(i, k') \sum_{i'} B_j(i', k)} \right)$$

- ▶ Instructions (measured in bits) that must be communicated within the firm to implement  $B_j$

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## Definition 2

The complexity of an organization structure  $B_j$  is:

$$I(B_j) = \sum_{i,k} B_j(i, k) \log \left( \frac{B_j(i, k)}{\alpha_j(k) E_j(i)} \right)$$

- ▶ Instructions (measured in bits) that must be communicated within the firm to implement  $B_j$
- ▶ Within-firm specialization Formal Proof Correlation

# What is Organizational Complexity?

## Definition 2

The complexity of an organization structure  $B_j$  is:

$$I(B_j) = H(T) - H(T|E)$$

where  $H()$  is Shannon entropy,  $E$  and  $T$  are random variables representing employees and tasks.

- ▶ Instructions (measured in bits) that must be communicated within the firm to implement  $B_j$
- ▶ Within-firm specialization Formal Proof Correlation
- ▶ Managerial Attention Formal Microfoundation

# Complexity of the Two Structures

“Employee” Salon

		Tasks			
		Cut	Color	Dry	
Employee	A	1/2	0	0	1/2
	B	0	1/4	0	1/4
	C	0	0	1/4	1/4
	Tot.	1/2	1/4	1/4	

Exactly match tasks and workers

If cut send “0” assign to A

If color send “01” assign to B

If dry send “10” assign to C

$$\frac{1}{2}(1\text{bit}) + \frac{1}{4}(2\text{bit}) + \frac{1}{4}(2\text{bit}) = 1.5$$

“Chair Renter” Salon

		Tasks			
		Cut	Color	Dry	
Employee	A	1/6	1/12	1/12	1/3
	B	1/6	1/12	1/12	1/3
	C	1/6	1/12	1/12	1/3
	Tot.	1/2	1/4	1/4	

Randomly match tasks and workers

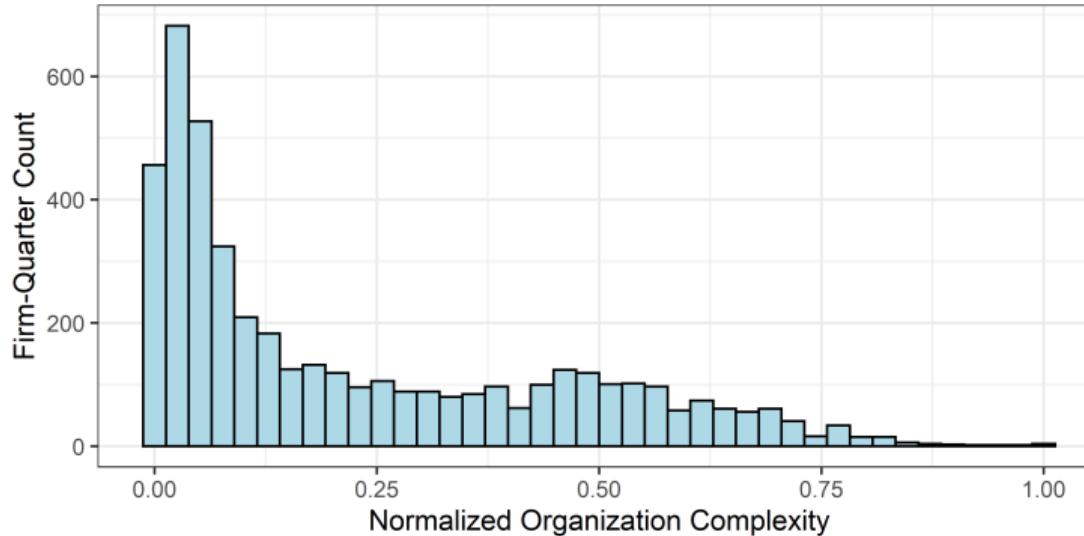
If cut send nothing roll dice

If color send nothing roll dice

If dry send nothing roll dice

$$\frac{1}{2}(0\text{bit}) + \frac{1}{4}(0\text{bit}) + \frac{1}{4}(0\text{bit}) = 0$$

## Fact 1: Complexity is heterogeneous and firm-specific.



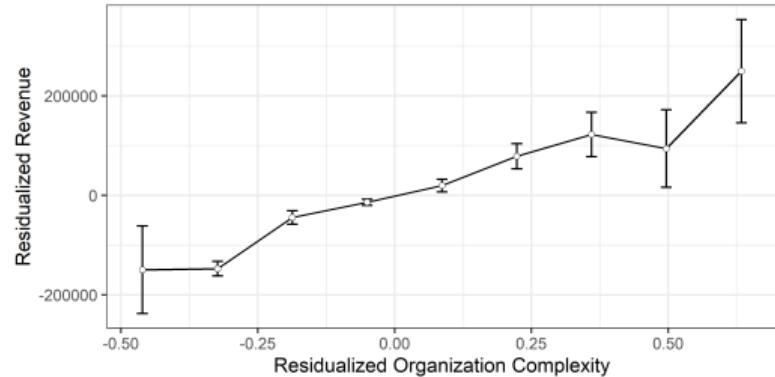
$$I_{j,t} = \bar{I}_j + \bar{I}_t + e_{j,t}$$

$$\begin{aligned}Var(I_{j,t}) &= Var(\bar{I}_j) + Var(\bar{I}_t) + 2Cov(\bar{I}_j, \bar{I}_t) + Var(e_{j,t}) \\.0516 &\quad .0464 & .0002 & -.0009 & 0.0059\end{aligned}$$

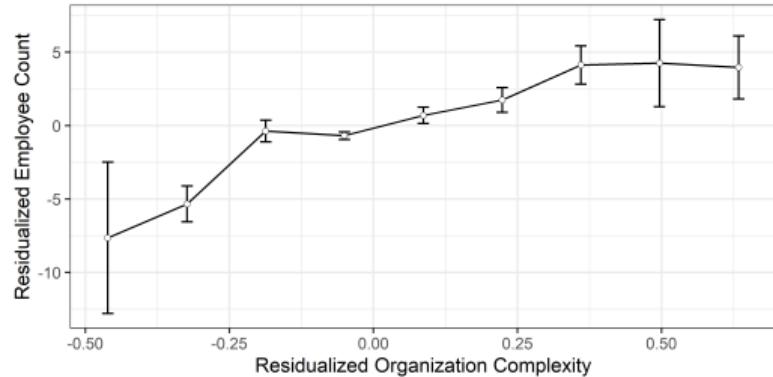
**Takeaway:** Internal complexity is driven by a deep characteristic of the firm.

Within-Visit Specialization

## Fact 2: Complex salons have higher revenue and employment



(a) Revenue



(b) Employees

Regressions

Manhattan

Manhattan Regs.

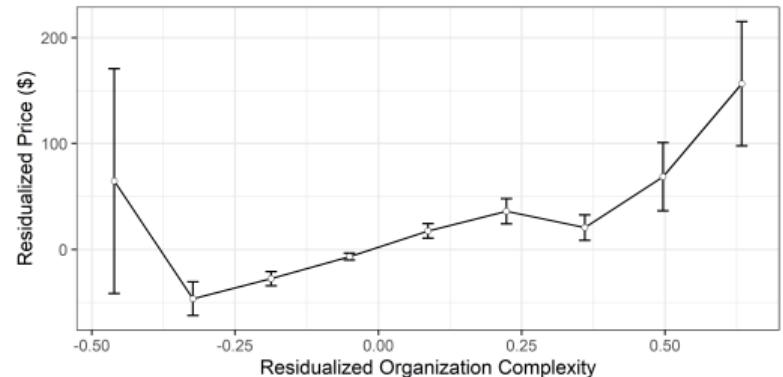
Customers and Visits

Within Firm Size

Within-Visit Specialization

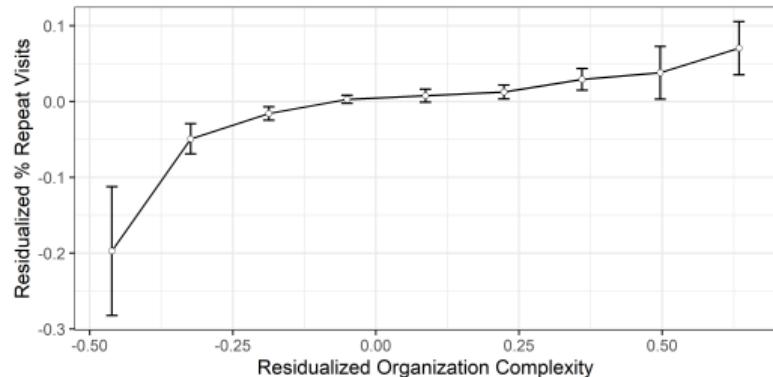
**Takeaway:** There is an organizational competitive advantage.

## Fact 3: Complex salons have higher prices and repeat customers



(a) Prices

Manhattan Only   Within Firm Size   Within-Visit Specialization



(b) Repeat Customers

Takeaway: This advantage operates through quality NOT quantity. Theory

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# Model: Salons and Workers

## $J$ Salons

- ▶ Salon-specific internal organization cost  $\gamma_j \geq 0$
- ▶ Leontief task-based production function with task-mix parameter  $\alpha \in \mathbb{R}_+^K$ 
  - ▶ Producing 1 unit requires assigning  $\alpha_k$  labor to task  $k$ . Normalize  $\sum_k \alpha_k = 1$
  - ▶ Homogeneous  $\alpha$  for exposition only

## $N$ Worker Types

- ▶ Skill set  $\theta_i = \{\theta_{i,1}, \dots, \theta_{i,k}, \dots, \theta_{i,K}\}$
- ▶ Inelastic total labor supply  $L_i$  and wage  $w_i$  determined in equilibrium

# Model: Salon Choices and Consumers

## Salon Choices

- ▶ Org. structure  $B_j \in \Delta^{N \times K}$  s.t.  $\sum_i B_j(i, k) = \alpha_k$ 
  - ▶ Product Quality:  $\xi(B_j) = \sum_{i,k} \theta_{i,k} B_j(i, k)$
  - ▶ Per-Unit Wage Bill:  $W(B_j) = \sum_{i,k} w_i B_j(i, k)$
  - ▶ Per-Unit Internal Organization Cost:  $\gamma_j I(B_j)$  where  $I(B_j)$  is complexity
- ▶ Price  $p_j \in \mathbb{R}_+$

## Consumer Demand $D_j$

- ▶ Demand depends only on and is strictly increasing in the quality-price index  $\xi(B_j) - \rho p_j$ 
  - ▶ multinomial logit, nested logit, mixed logit with constant price sensitivity

# The Firm's Problem

Denote feasible organization structures  $\mathbb{B} = \{B_j \in \Delta^{N \times K} | \sum_i B_j(i, k) = \alpha_k\}$

$$\max_{p_j, B_j \in \mathbb{B}_j} \underbrace{\frac{\exp(\xi(B_j) - \rho p_j)}{\sum_{j'} \exp(\xi(B_{j'}) - \rho p_{j'})}}_{\text{market share, } s_j} \left[ p_j - \underbrace{\left( \widehat{\gamma_j I(B_j)} + \widehat{W(B_j)} \right)}_{\text{constant marginal cost, } MC_j} \right]$$

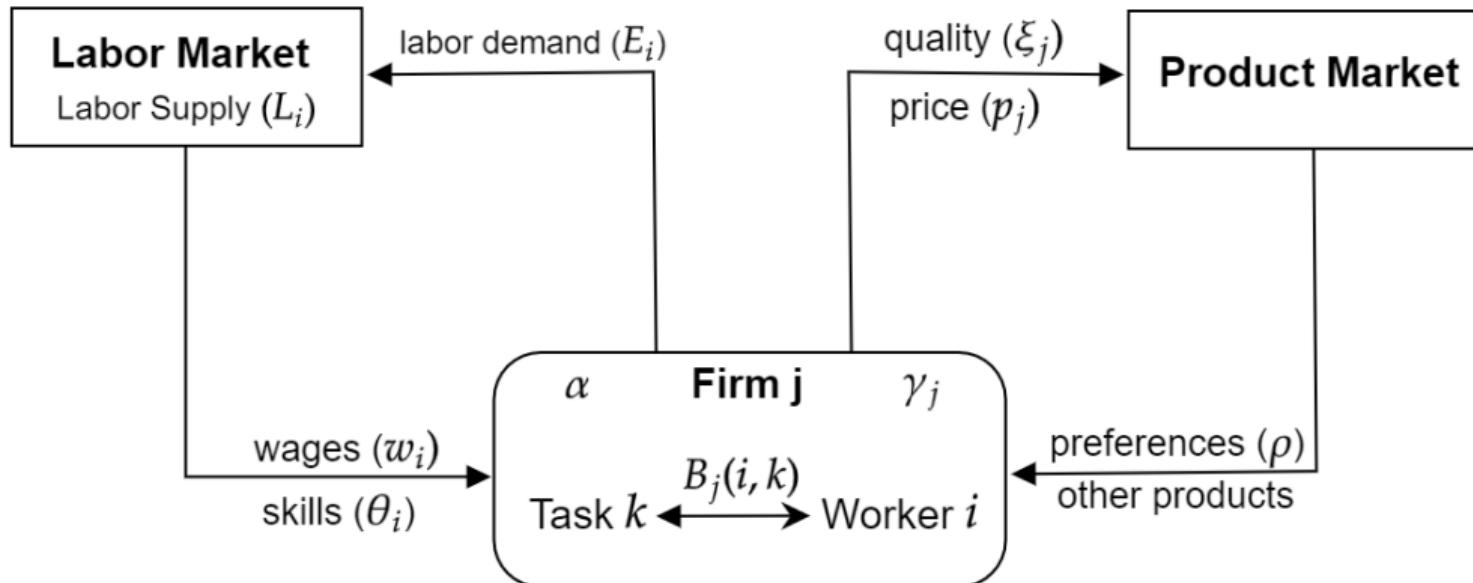
# Equilibrium

An equilibrium consists of firm strategies  $\{p_j, B_j\}_{j=1}^J$  and wages  $w$  such that:

1. Firm strategies maximize profits.
2. Labor markets for each worker type clear:

$$\sum_j \frac{\exp(\xi(B_j) - \rho p_j)}{\sum_{j'} \exp(\xi(B_{j'}) - \rho p_{j'})} \sum_k B_j(i, k) = L_i \quad \forall i = 1, \dots, N$$

# Summary of the Model



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# Characterizing the Firm's Problem

## Theorem

An organizational structure  $(B_j^*)$  is profit-maximizing if and only if it solves:

$$\min_{B_j \in \mathbb{B}} \gamma_j I(B_j) + W(B_j) - \rho^{-1} \xi(B_j)$$

Proof

# Characterizing the Firm's Problem

## Theorem

An organizational structure ( $B_j^*$ ) is profit-maximizing if and only if it solves:

$$\min_{B_j \in \mathbb{B}} I(B_j) + \gamma_j^{-1} \sum_{i,k} B_j(i, k)(w_i - \rho^{-1}\theta_{i,k})$$

- ▶ Rate-distortion problem (information theory)

Proof

# Characterizing the Firm's Problem

## Theorem

An organizational structure ( $B_j^*$ ) is profit-maximizing if and only if it solves:

$$\max_{B_j \in \mathbb{B}} \sum_{i,k} B_j(i, k) (\rho^{-1} \theta_{i,k} - w_i) - \gamma_j I(B_j)$$

- ▶ Rate-distortion problem (information theory)
- ▶ Rational inattention problem with MI costs (behavioral econ)
  - ▶ Org. frictions make the firm act as if it is run by a manager with limited attention

Proof

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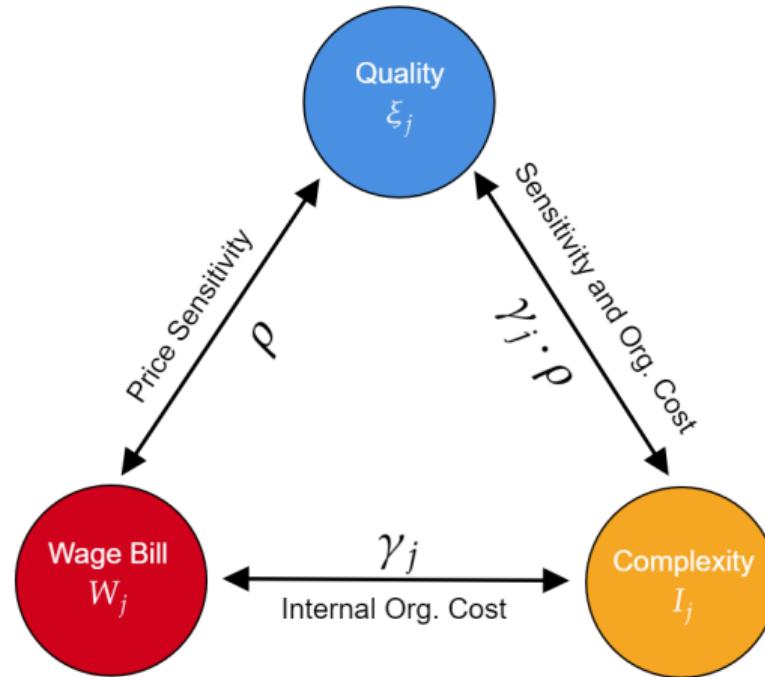
$$\min_{B_j \in \mathbb{B}} \gamma_j I(B_j) + W(B_j) - \rho^{-1} \xi(B_j)$$

- ▶ Rate-distortion problem (information theory)
- ▶ Rational inattention problem with MI costs (behavioral econ)
  - ▶ Org. frictions make the firm act as if it is run by a manager with limited attention
- ▶ Internal organizations are connected only via wages

Proof

# The Quality-Wage-Complexity Trade-Off

$$\min_{B_j \in \mathbb{B}} \gamma_j \rho I(B_j) + \rho W(B_j) - \xi(B_j)$$



# Organization Frontier

$$\min_{B_j \in \mathbb{B}} \underbrace{I(B_j)}_{\text{complexity}} + \gamma_j^{-1} \left[ \underbrace{W(B_j) - \rho^{-1} \xi(B_j)}_{\text{quality-adjusted wages}} \right]$$

## Definition

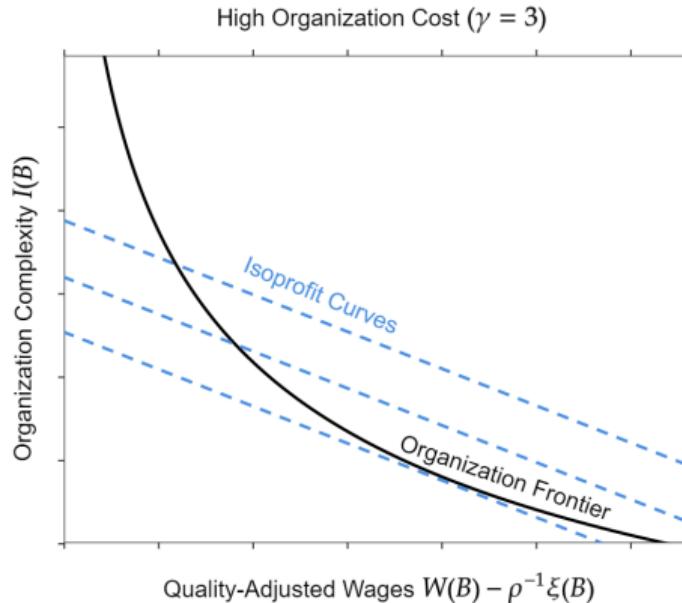
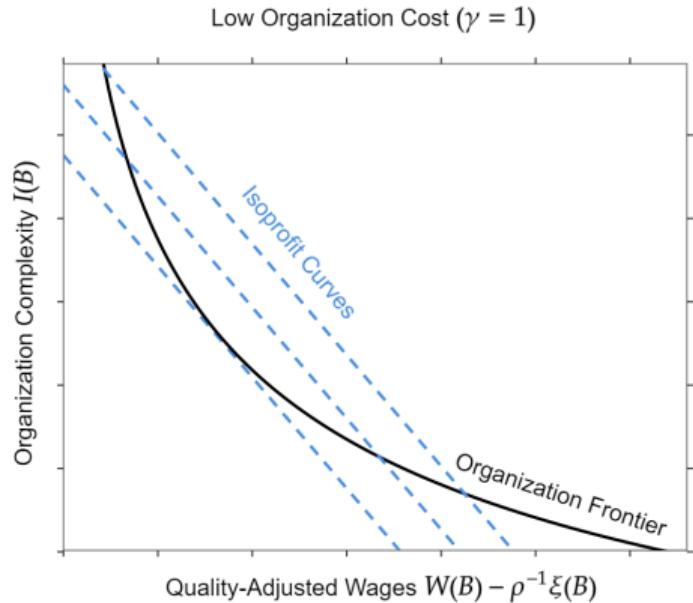
The organization frontier is the set of organization structures which minimize complexity for some quality-adjusted wages.

Because this is a rate-distortion problem:

## Proposition

Complexity along the organization frontier is continuous, convex and decreasing in quality-adjusted wages. Proof

# Choosing an Organizational Structure



Back

## Fitting the Facts

1. Fact 1: Complexity is heterogeneous and firm-specific
  - ▶ Firms in the same product and labor market choose different internal structures based on individual org. cost ( $\gamma_j$ ).
2. Fact 2: Complex salons have more employees and higher revenue
  - ▶ In equilibrium complexity and market share are positively correlated.
3. Fact 3: Complex salons have higher prices and higher quality
  - ▶ Quality is the main benefit of complexity.

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## Simple Example

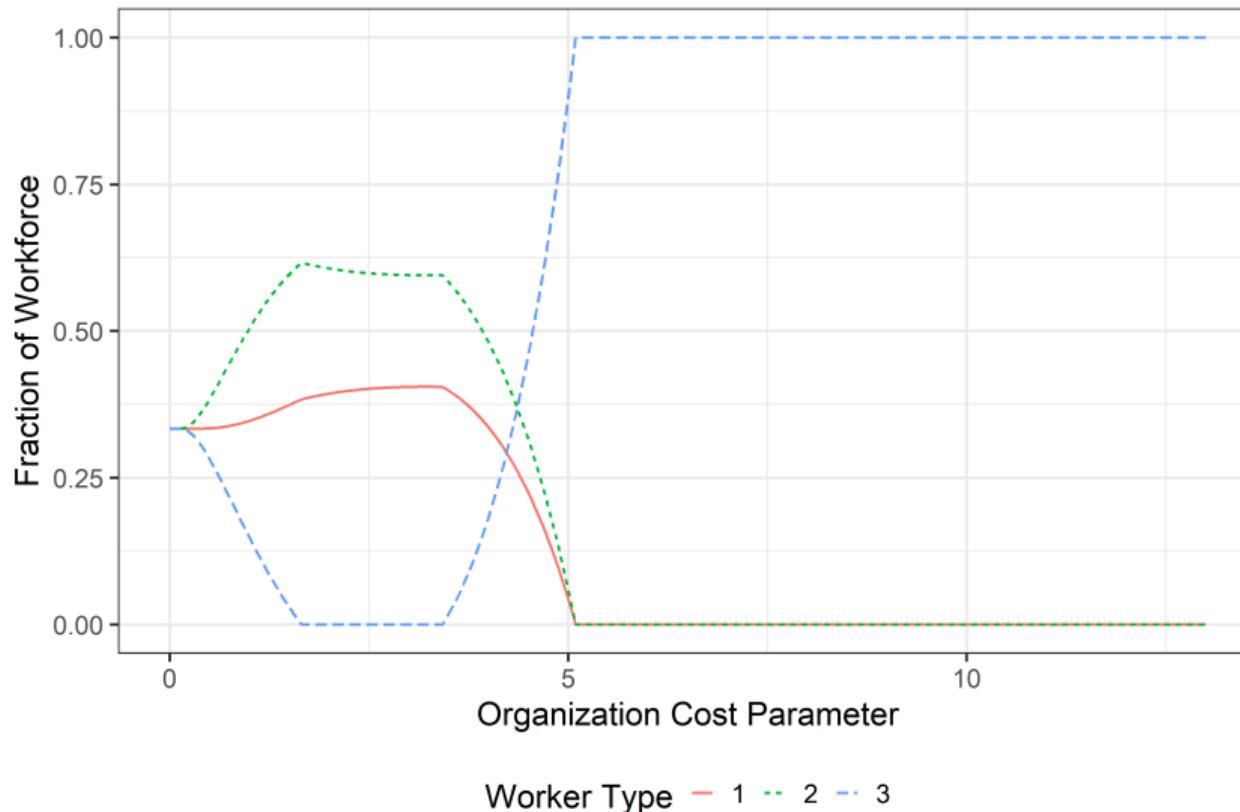
- ▶ 3 tasks with uniform task-mix  $\alpha = (1/3, 1/3, 1/3)$ , price sensitivity  $\rho = 1$
- ▶ 3 worker types with wages  $w = (21, 20, 15)$  and skill set:

$$\Theta = \begin{bmatrix} 15 & 19 & 26 \\ 23 & 19 & 15 \\ 15 & 15 & 15 \end{bmatrix}$$

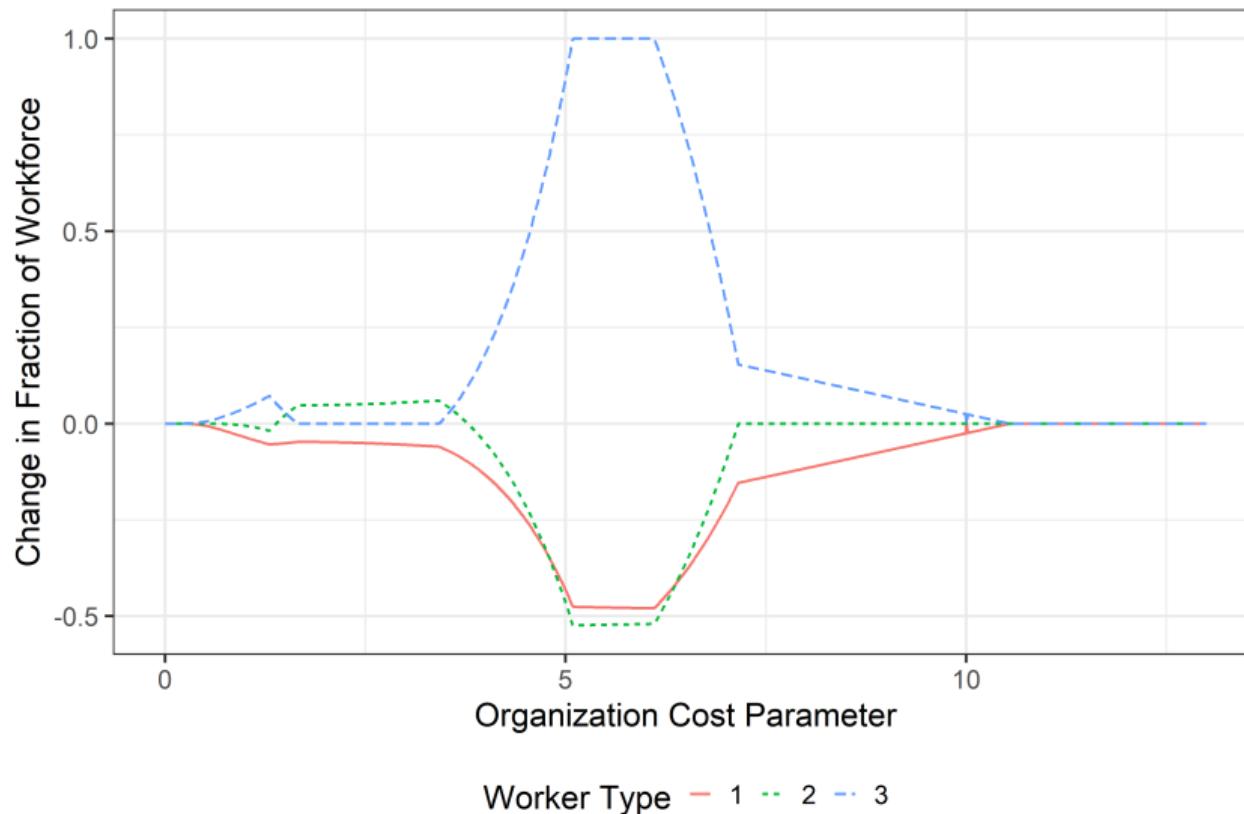
- ▶ Wage-adjusted quality:

$$\Theta - \rho w = \begin{bmatrix} -6 & -2 & 5 \\ 3 & -1 & -5 \\ 0 & 0 & 0 \end{bmatrix}$$

# Workforce Composition Heterogeneity



# Labor-Labor Substitution Heterogeneity



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# The Econometric Model

- ▶ **Market:** Analyze Manhattan 2021 Q2 with sales tax  $\tau = 4.5\%$ 
  - ▶ Outside option is no purchase. Compute via Consumer Expenditure Survey.
- ▶ **Utility for good  $j$ :**  $u_{z,j} = \xi(B_j) - \rho p_j + \epsilon_{z,j}$ ,  $\epsilon \sim$  i.i.d. Type-1 E.V.
- ▶ **Workers:** Base skill  $\beta_k$ , skill gap  $\theta_k$ 
  - ▶ Color Specialist:  $\theta = \{\beta_{cut}, \beta_{color} + \theta_{color}, \beta_{dry}, \beta_{admin}, \beta_{misc}\}$
- ▶ **Labor Supply:** Individual workers also differ in their labor supply
  - ▶ 2 workers with same skills may supply different hours
- ▶ **Task Heterogeneity:** Different material costs ( $m$ )
- ▶ **Firm Heterogeneity:** Firm-specific task-mix ( $\alpha_j$ ), effective labor per unit ( $\bar{a}_j$ ), exogenous quality ( $\nu_j$ ), marginal cost shifter ( $\phi_j$ )

What does firm profit look like?

# The Econometric Model

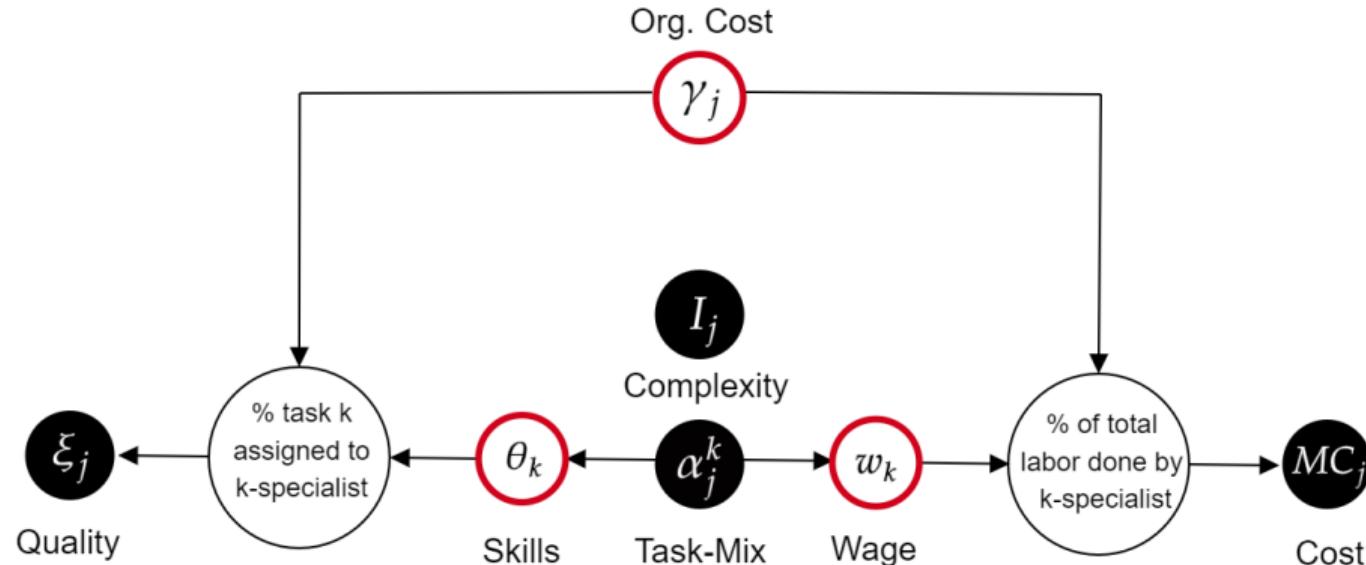
- ▶ A natural notion of task-specialization:

## Definition 3

Task-specialization is the fraction of total labor spent on specialty tasks.

- ▶ 6 utility + 5 cost + 5 wages + 5 skills = 21 parameters
- ▶ Call these market parameters and denote  $\Omega$
- ▶ 42 salons  $\implies$  42 org. cost parameters

# Identification Problem



# Identification: Firm-Specific Organization Costs $\gamma_j$

## Proposition 1

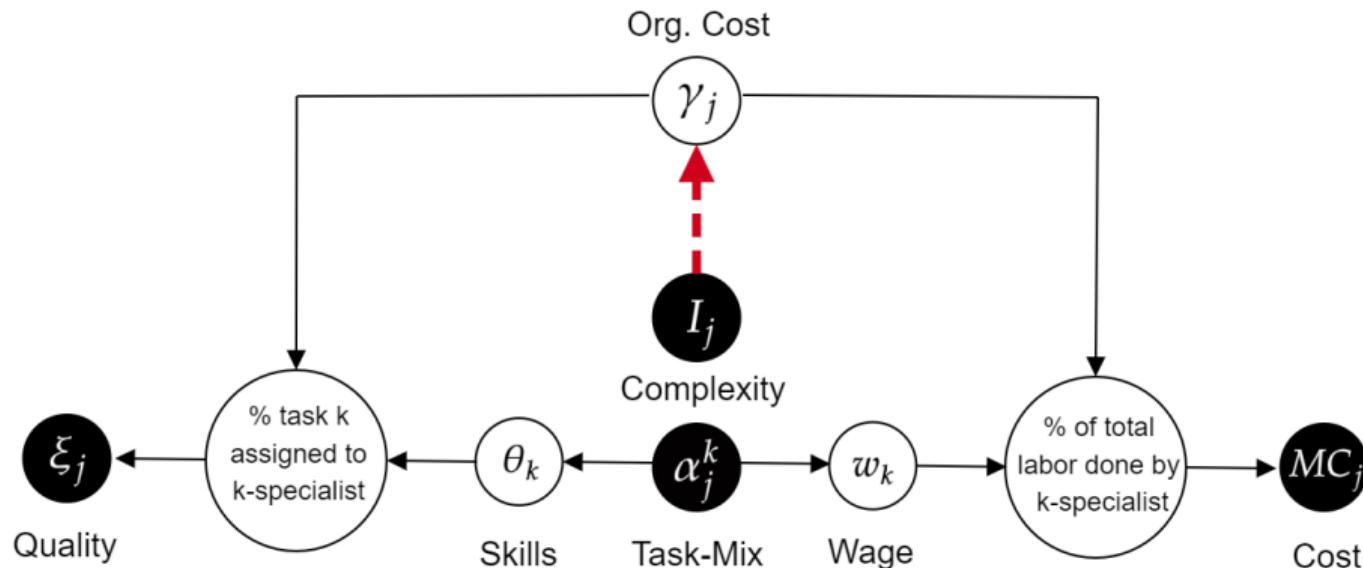
Organization costs ( $\gamma_j$ ) and organization structures ( $B_j$ ) are a known function of firm task-mixtures ( $\alpha_j$ ), complexities ( $I_j$ ) and market parameters ( $\Omega$ ) for all firms with positive complexity, except for a set of market parameters with measure 0.

*Visual Intuition*

- ▶ There is a one-to-one mapping from observed complexity to unobserved  $\gamma_j$
- ▶  $\{\gamma_j\}_{j=1}^J$  do not need to be estimated.
- ▶ Instead invert complexity, similar to market share inversion in BLP
- ▶ Proof uses an Essential Equilibrium Uniqueness Result

Measure 0 Set

## Identification: Firm-Specific Organization Costs $\gamma_j$



## Identification: Market Parameters

- ▶ Use firm price FOC (supply side moments):

$$p_j = \frac{1}{\rho(1+\tau)(1-s_j)} + \bar{a}_j \left[ \gamma(\Omega, I_j, \alpha_j) I_j + wE(\Omega, I_j, \alpha_j) \right] + m\alpha_j + \phi_j$$

- ▶ Use market-share equation (demand side moments):

$$\log(s_j) - \log(s_0) = \xi(\Omega, I_j, \alpha_j) - \rho(1+\tau)p_j + \beta\alpha_j + \nu_j$$

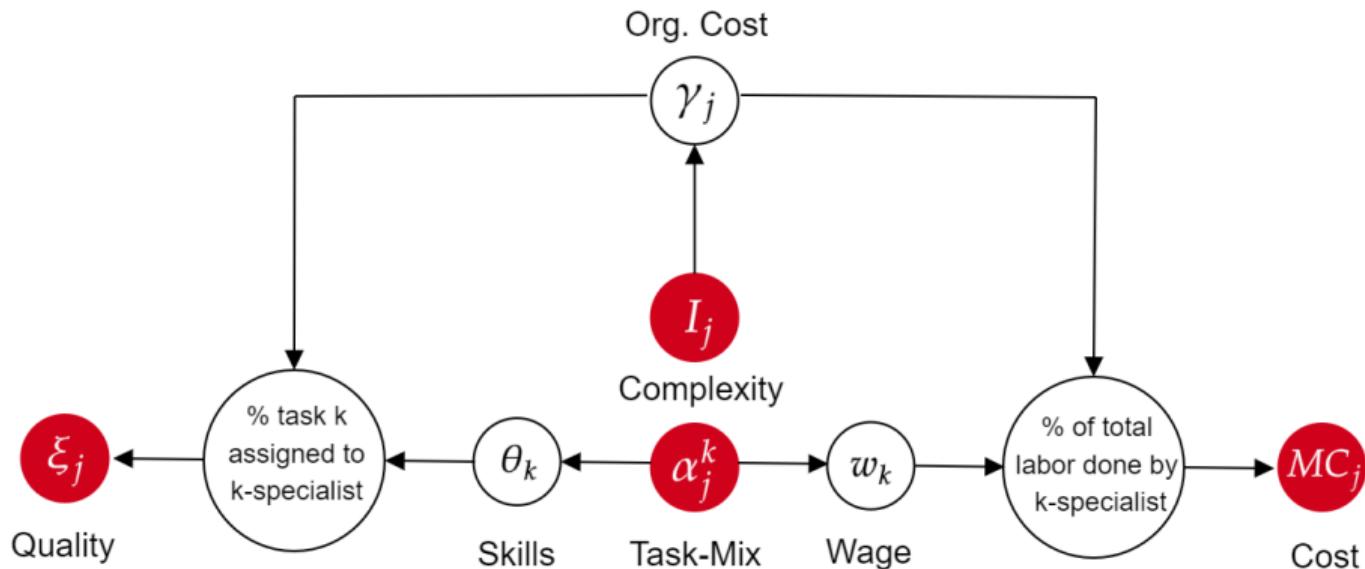
- ▶ Match avg. beauty salon QCEW wage bill with measurement error:

$$W_j = M s_j a_j w E(\Omega, I_j, \alpha_j) + e_j$$

- ▶ The model is globally identified if  $\Omega$  uniquely satisfies:

$$\mathbb{E} \begin{bmatrix} \begin{pmatrix} \phi_j(\Omega, I_j, \alpha_j) \\ \nu_j(\Omega, I_j, \alpha_j) \end{pmatrix} & \begin{pmatrix} \alpha_j & \alpha_j I_j \end{pmatrix} \end{bmatrix} = 0 \quad \mathbb{E}[e_j(\Omega, I_j, \alpha_j)] = 0$$

## Identification: Market Parameters ( $\Omega$ )



# From Identification to Estimation

- ▶ **Issue**
  - ▶  $B_j$  is a  $5 \times 5$  matrix which solves a non-linear minimization problem
  - ▶ Must solve for  $B_j$  repeatedly to obtain  $\gamma_j$  which makes model complexity match observed complexity
  - ▶ Must repeat process for each firm and for each set of market parameters  $\Omega$
- ▶ **Solution:** Blahut-Arimoto algorithm
  - ▶ Fixed point algorithm which is globally convergent
  - ▶ Can use because of equivalence to a rate-distortion problem
  - ▶ Algorithm

## Nested Fixed Point GMM Estimation Routine

Construct the sample analogue of the moment conditions, call it  $G(\cdot)$ . Then solve:

$$\arg \min_{\hat{\Omega}} G(\hat{\Omega})' W G(\hat{\Omega})$$

This amounts to:

1. Guess  $\hat{\Omega}$ .
2. Recover implied quality, marginal costs, and organization cost parameters using the Blahut-Arimoto algorithm.
3. Evaluate GMM objective. If minimum achieved, stop. Otherwise return to 1.

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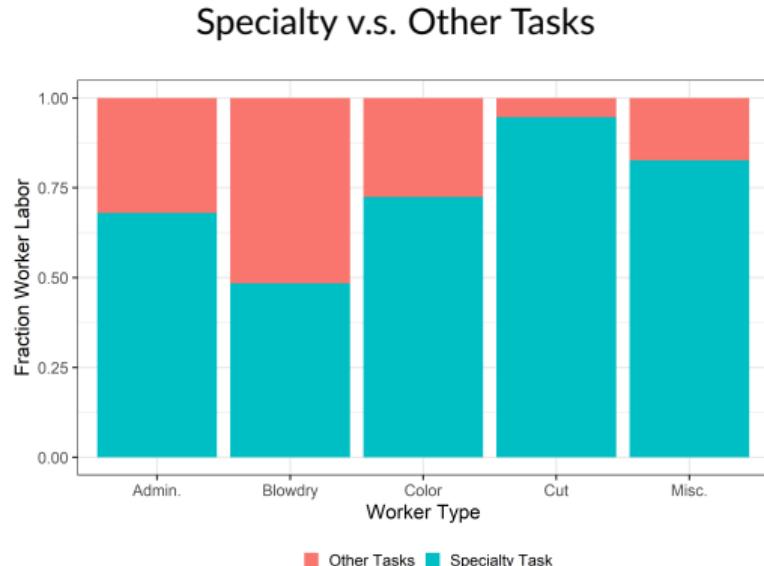
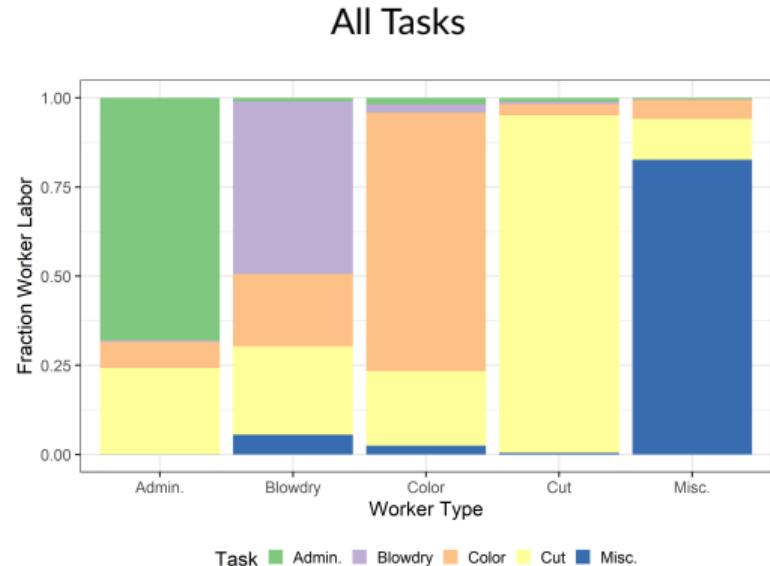
# Task Parameter Estimates

Task	Associated Specialist			
	Skill Gap	Wage	Skill Base	Material Cost
Administrative	43.29*	26.99	-16.16	-147.60*
	( 21.66)	(63.75)	( 14.58)	( 13.47)
Blowdry/Etc.	141.69*	20.91	-70.56*	12.39
	( 36.67)	(40.22)	( 13.57)	( 16.65)
Color/Highlight/Wash	60.03*	37.75*	-9.69	56.49*
	( 21.24)	( 7.00)	( 11.97)	( 15.79)
Haircut/Shave	32.45*	16.96*	.	.
	( 13.07)	( 8.32)	.	.
Nail/Spa/Eye/Misc.	66.48	81.16	-252.58*	-1061.12*
	( 37.72)	(53.52)	( 11.47)	( 10.73)

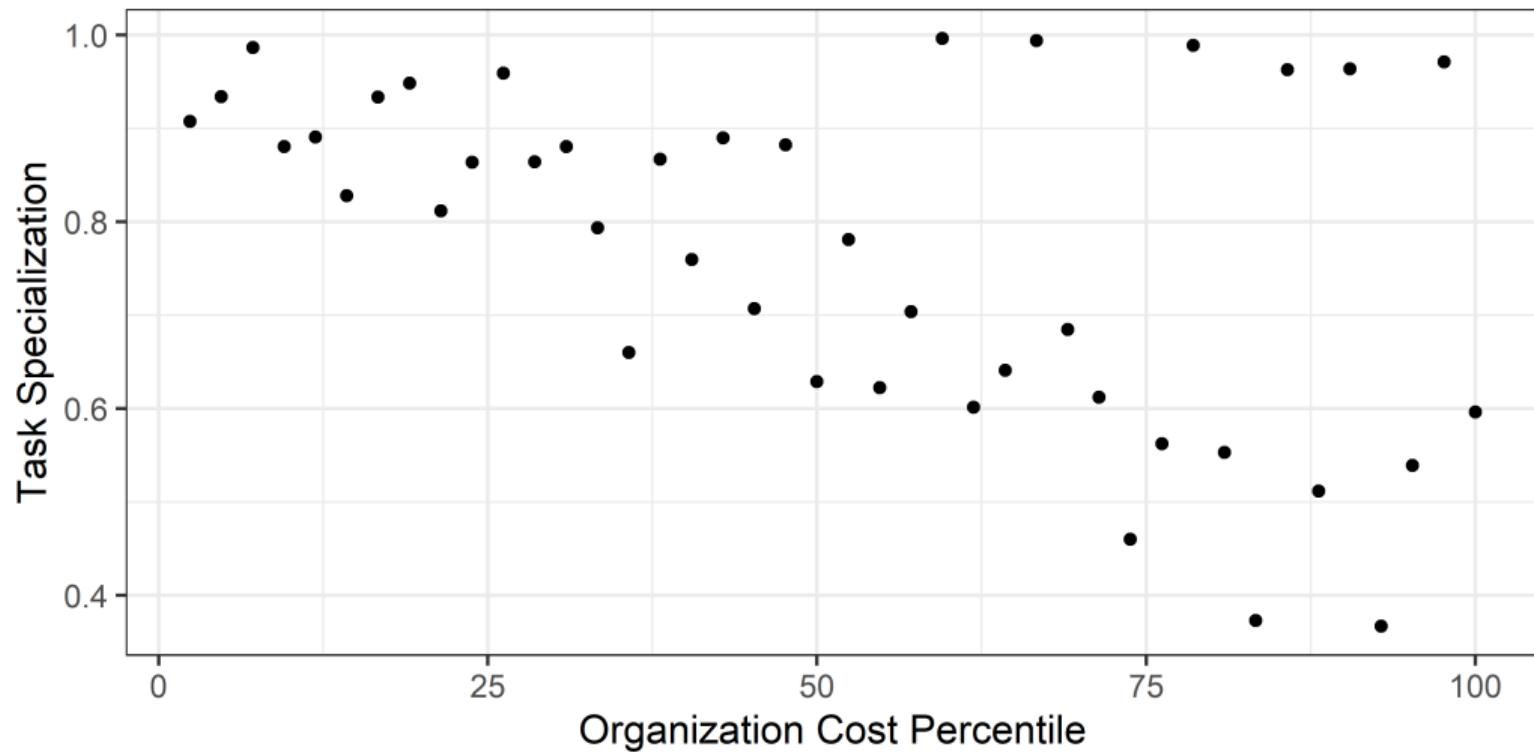
Standard errors from 500 bootstrap replications in parentheses.

\* indicates significance at the 0.05 level.

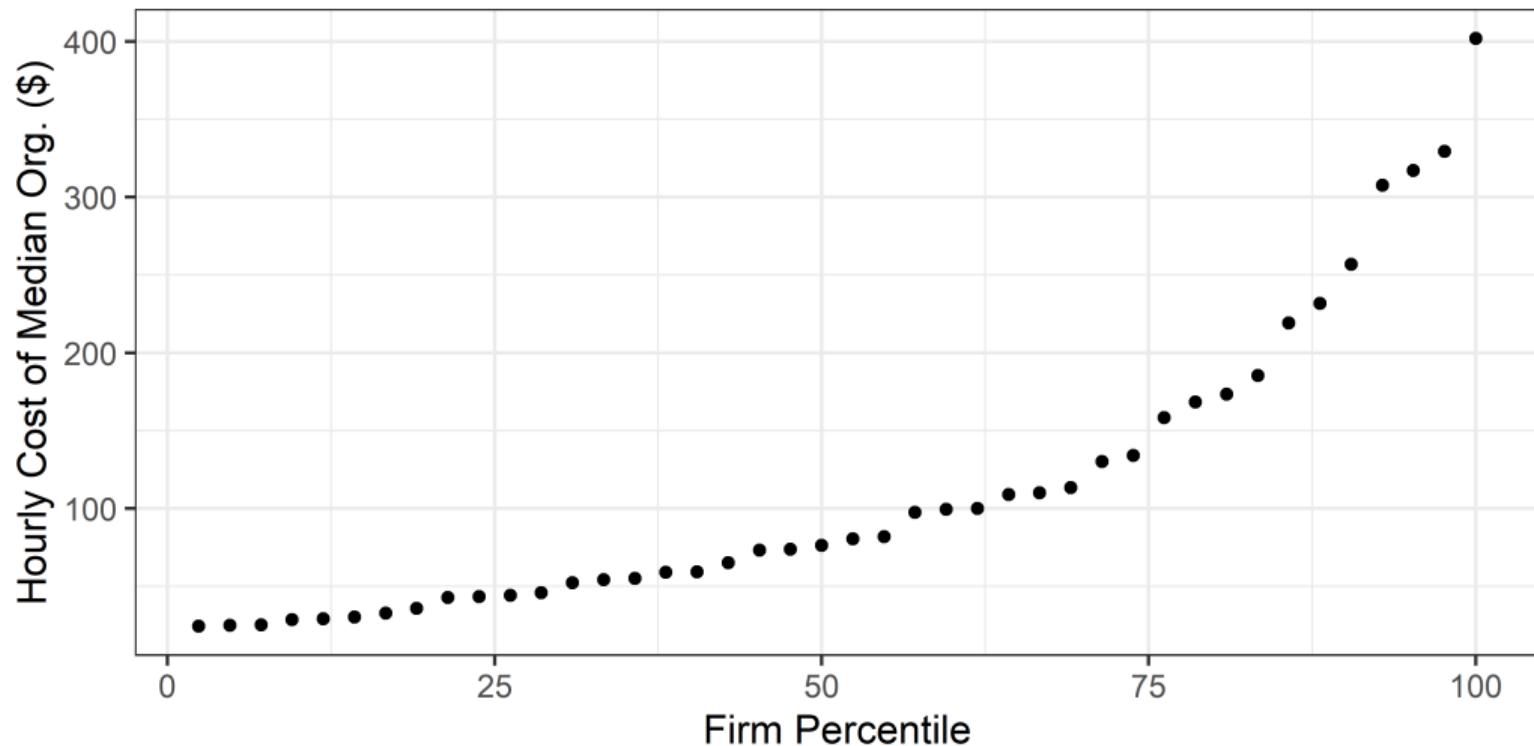
# Equilibrium Task Specialization Across Workers



# Equilibrium Task Specialization Across Firms



# Cost of Median Complexity Organization Across Firms



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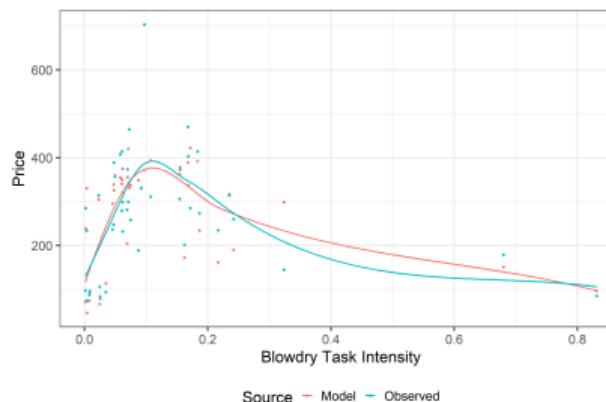
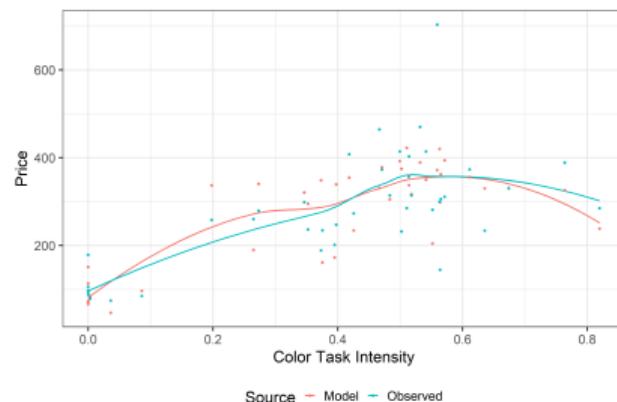
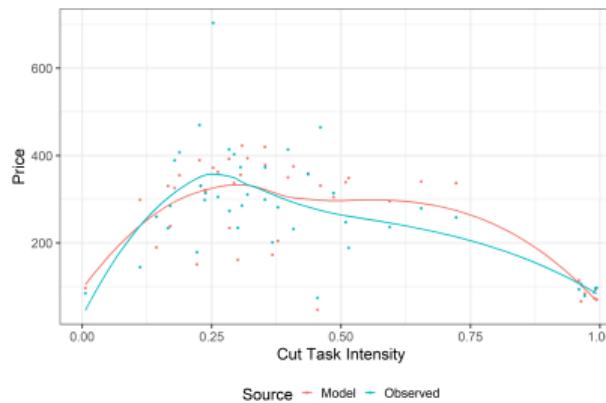
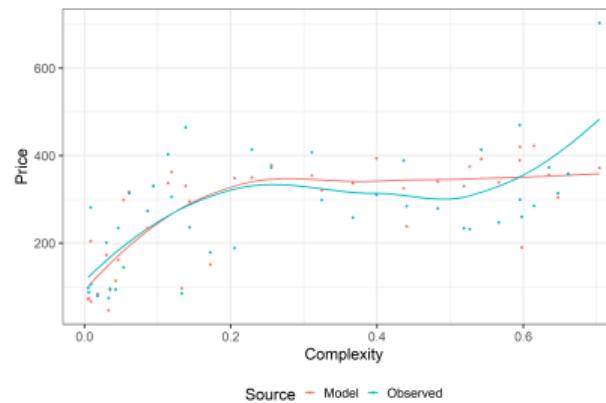
Estimation Results

**Model Fit and Validation**

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# Fit: Supply Side Relationships



## Validation: The Task Content of Jobs

Model generated jobs:

$$b_j(i, k) = \alpha_k \frac{\exp(-\gamma^{-1}w_i + (\rho\gamma)^{-1}\theta_{i,k})}{\sum_{i'} E_j(i') \exp(-\gamma^{-1}w_{i'} + (\rho\gamma)^{-1}\theta_{i',k})}$$

Task	Total Variance		Between Firm Variance	
	Model	Observed	Model	Observed
Haircut/Shave	0.1110	0.1268	0.0597	0.0597
Color/Highlight/Wash	0.1127	0.1105	0.0365	0.0365
Blowdry/Style/Treatment/Extension	0.0472	0.0194	0.0111	0.0111
Administrative	0.0098	0.0080	0.0063	0.0063
Nail/Spa/Eye/Misc.	0.0120	0.0171	0.0050	0.0050

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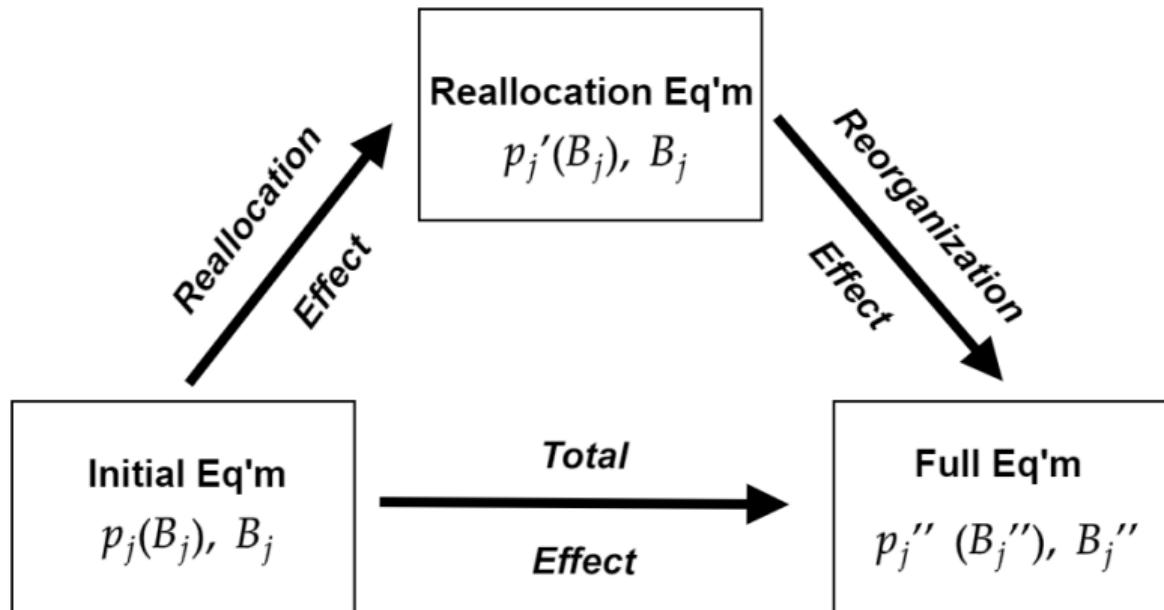
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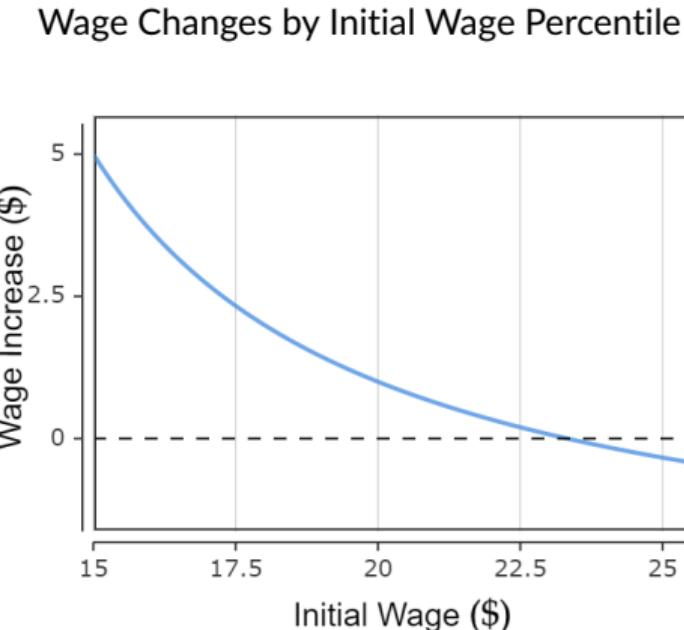
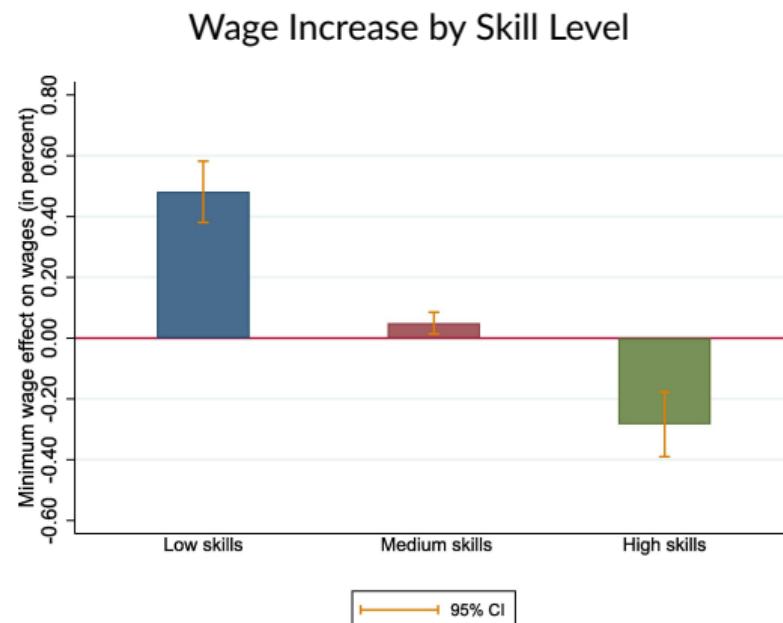
## Counterfactual Implementation

- ▶ Preparation
  - ▶ Weight salons so that observed demand equals CEX market demand.
  - ▶ Derive type total labor using estimated wages and firm labor demands.
  - ▶ Change deep parameter.
- ▶ Solving for a new equilibrium
  1. Guess wages, solve for organization structures.
  2. Use organization structures to obtain costs and qualities.
  3. Solve for Nash equilibrium prices.
  4. If labor markets clear stop. If not return to step 1.
- ▶ Compute consumer welfare using closed form

# Decomposing Mechanisms



# Minimum Wage Increases In Models with Distance Dependent Substitution



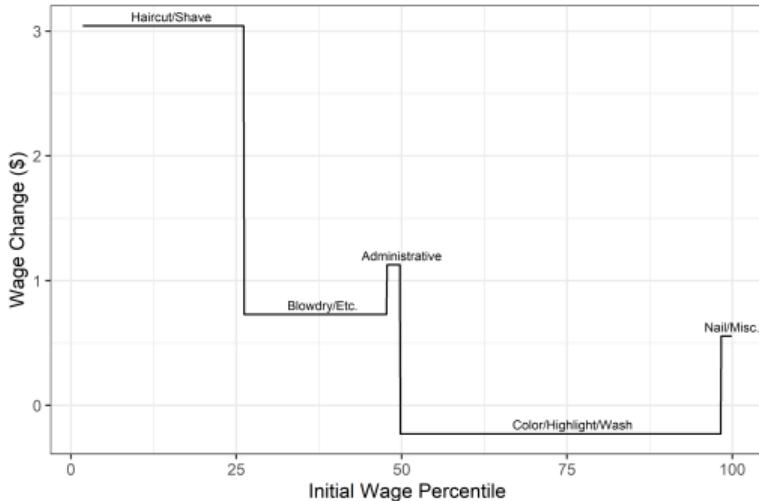
Left is from Gregory and Zierahn (2022), right is stylized example

# Minimum Wage Increase from \$15 to \$20

## Wages Changes

Type	Wage Change	Total Wages Gained/Lost
Haircut/Shave - UNEMPLOYED	-100.00%	-\$600,240
Haircut/Shave - EMPLOYED	17.95%	\$1,528,205
Color/Highlight/Wash	-0.61%	-\$228,453
Blowdry/Style/Treatment/Extension	3.48%	\$323,374
Administrative	4.17%	\$47,154
Nail/Spa/Eye/Misc.	0.68%	\$19,319

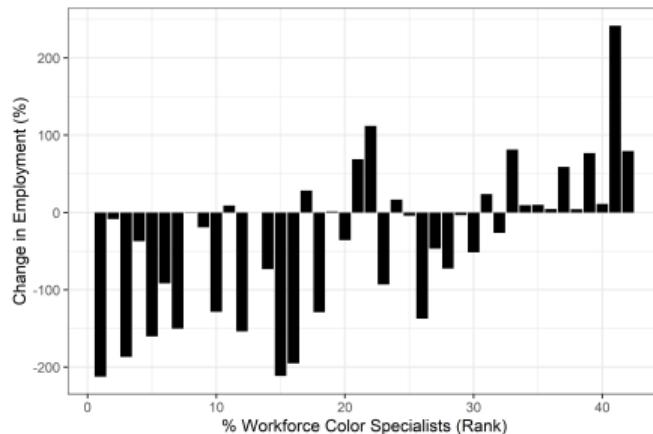
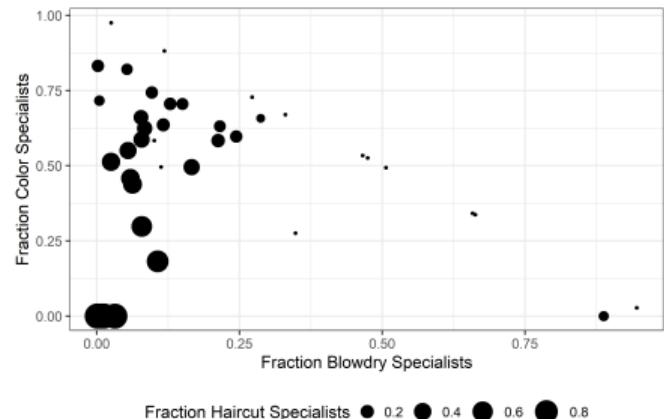
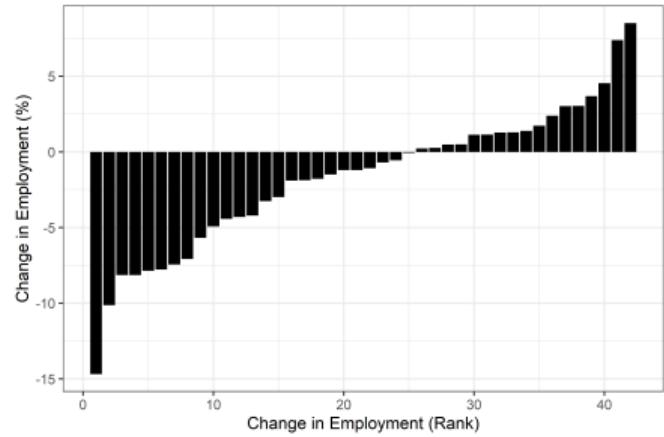
## Wage Changes by Initial Wage Percentile



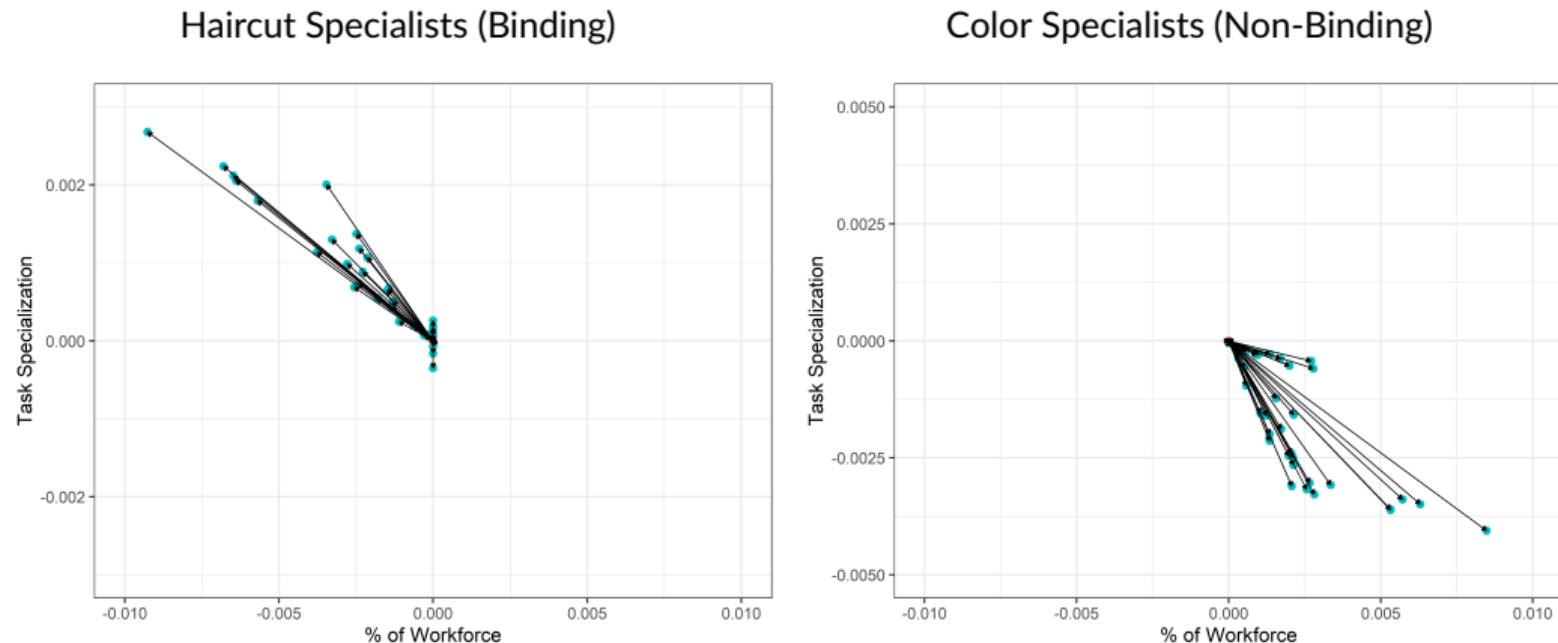
Employment and Wages

Technical Details

# The Reallocation Effect



# The Reorganization Effect



# Decomposing Minimum Wage Spillovers

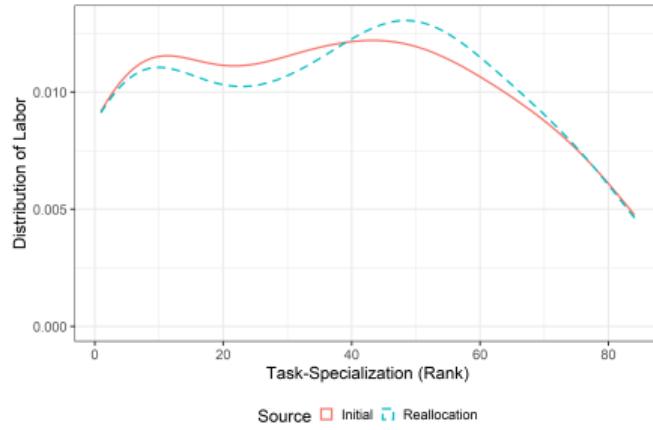
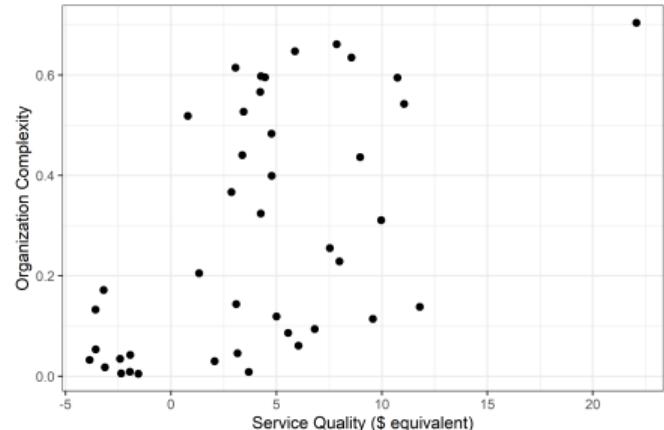
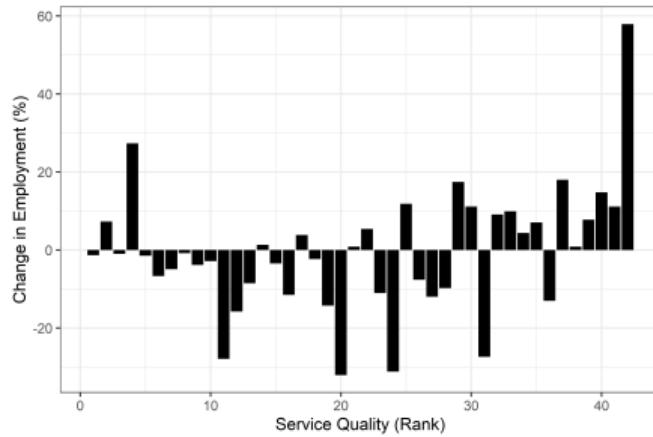
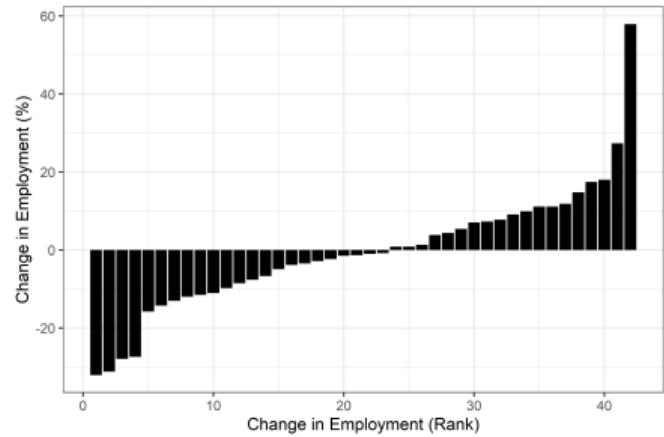
Type	Reallocation Change			Type	Reorganization Change		
	Employment	Task-Spec.	Wage		Employment	Task-Spec.	Wage
Haircut/Shave	-5.85%	-0.04%	17.95%	Haircut/Shave	-0.73%	0.12%	0%
Color/Highlight/Wash	0%	-0.17%	-1.13%	Color/Highlight/Wash	0%	-0.33%	0.52%
Blowdry/Style/Treatment/Extension	0%	-0.40%	4.63%	Blowdry/Style/Treatment/Extension	0%	0.03%	-1.15%
Administrative	0%	0.09%	5.22%	Administrative	0%	0.03%	-1.05%
Nail/Spa/Eye/Misc.	0%	-0.03%	0.58%	Nail/Spa/Eye/Misc.	0%	-0.00%	0.10%

## Service Sales Tax Elimination (4.5% to 0%)

Firm Choices		Welfare		
Statistic	Total	Source	Change	Percent Change
Avg. Price	8.68%	Salon Profit	\$942,740	0.58%
Avg. Complexity	5.53%	Consumer Welfare	-\$494,199	-0.30%
Avg. Quality	10.03%	Wages	\$11,603,777	7.12%
Task Specialization	1.83%	Tax Revenue	-\$11,739,300	-7.20%
		Total Welfare	\$313,017	0.19%

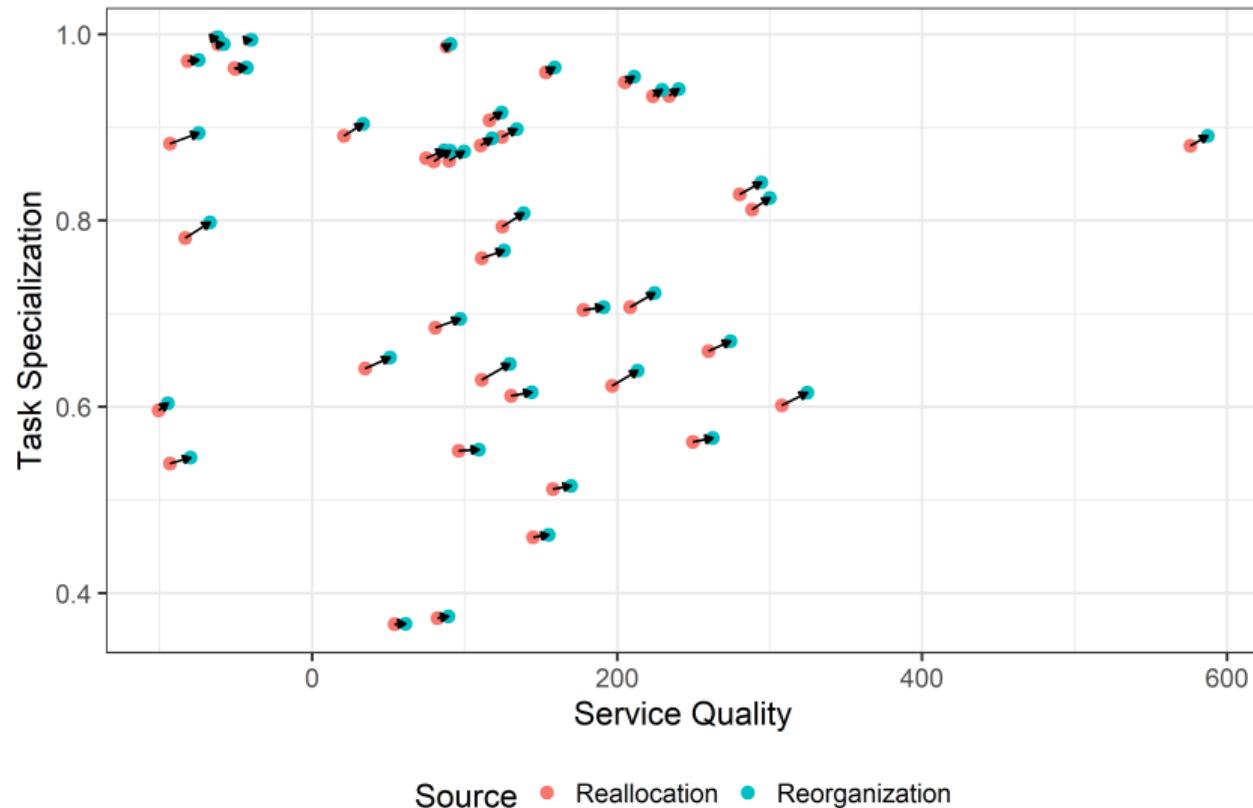
Effects by Worker Type

# Sales Tax Elimination Reallocation Effect



Source █ Initial █ Reallocation

# Sales Tax Elimination Reorganization Effect



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## Extensions

- ▶ In the paper:
  - ▶ Multiplicative quality (i.e. Kremer's O-Ring)
  - ▶ Quantity-based productivity (i.e. manufacturing)
  - ▶ Large firms (continuous tasks, worker types)
- ▶ Future work:
  - ▶ Imperfectly competitive labor markets with task-content as amenity
  - ▶ Accumulation of task-specific human capital

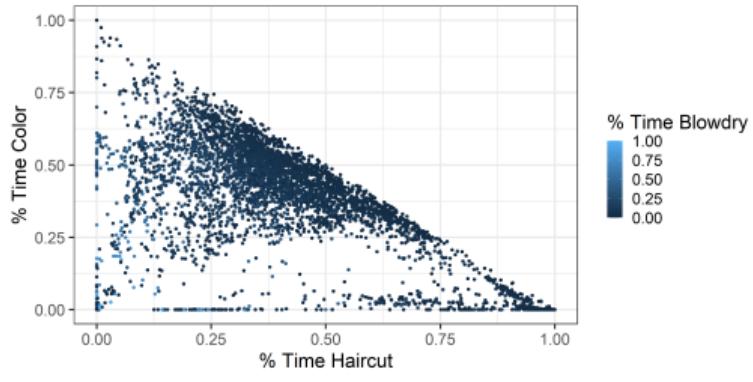
## Summary

1. **Stylized Facts:** Internal complexity is heterogeneous and firm-specific.  
Complex firms have ↑ revenue, employees, prices, repeat customers.
2. **Theory:** Oligopolistic firms with shared labor market choose their internal structure s.t. heterogeneous organization costs. Complex assignments are costly but improve product quality by better matching workers to tasks.
3. **Identification of Org. Costs and Estimation for Manhattan Hair Salons**
4. **Policy Experiments**
  - ▶ **Minimum wage to \$20:** ↓ competitive position of firms intense in min. wage workers & shifts tasks away from min. wage workers within firms  $\implies$  + and - wage spillovers that are non-monotone in initial wage
  - ▶ **Eliminate Sales Tax:** ↓ competitive position of specialized firms & ↑ specialization within firms  $\implies$  increased specialization for all workers

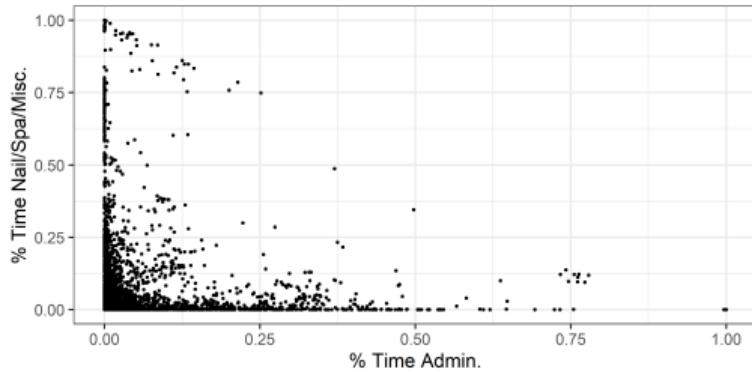
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## Appendix

# Task-Mix Variation



(a) Cut, Color, Blowdry



(b) Admin.,Misc.

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# Organization Costs As Average Task-Specialization

Define the generalist job as the job as:  $b_j^G(k) = \alpha_k$

## Proposition 2

Complexity ( $I(B_j)$ ) is the weighted-average Kullback-Leibler divergence between the jobs at a firm and the firm's generalist job  $b_j^G(k)$ , where the weights are the share of each worker type.

**Proof.** Using the definition of mutual information, we can write out complexity as:

$$\begin{aligned} I(B_j) &= \sum_{i,k} B(i, k) \log \left( \frac{B(i, k)}{\sum_{k'} B(i, k') \sum_{i'} B(i', k)} \right) = \sum_{i,k} E_i \frac{B(i, k)}{E_i} \log \left( \frac{B(i, k)}{E_i \alpha_k} \right) \\ &= \sum_i E_i \sum_k b_i(k) \log \left( \frac{b_i(k)}{\alpha_k} \right) = \sum_i E_i \sum_k b_i(k) \log \left( \frac{b_i(k)}{b_j^G(k)} \right) \\ &= \sum_i E_i D_{KL}(b_i || b_j^G) \end{aligned}$$

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## Managerial Attention

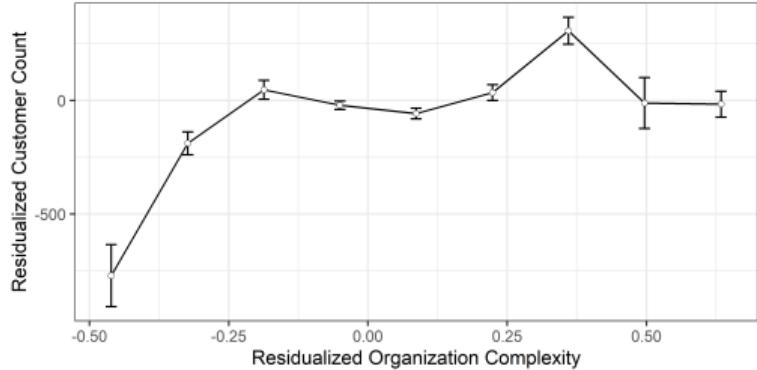
- ▶  $X$  is the task type, with prior  $\alpha$ .  $Y$  is assigned worker type. Manager's payoff from the assignment of workers to tasks is  $m(X, Y)$ .
- ▶ Manager chooses any signal  $Z$  with info about the task type and an assignment function  $\delta(Z)$  mapping signal to an assignment.
- ▶ Cost of signal is  $\gamma_j$  multiplied by the mutual information between the signal and the task type:

$$\max_{\delta, Z} \mathbb{E}[m(X, \delta(Z))] - \gamma_j I(X, Z)$$

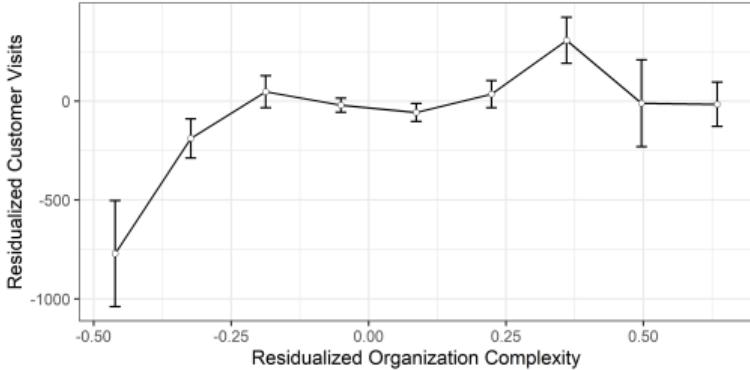
- ▶ Jung et al. (2019) show it is WLOG to choose joint distribution directly:

$$\max_{B_j \in \mathbb{B}_j} \mathbb{E}[m(X, Y)] - \gamma_j I(X, Y)$$

# Relationship Between Complexity and Customers/Visits



(a) Customers



(b) Visits

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# Firm Size and Complexity Regressions

Dependent Variables:	Revenue	Employees	Utilized Labor	Customers	Visits
Model:	(1)	(2)	(3)	(4)	(5)
<i>Variables</i>					
Org. Complexity	347549.2*** (79546.2)	9.75** (3.016)	26481 (35653.2)	334.6 (259.6)	731.7 (450.1)
<i>Fixed-effects</i>					
Quarter-Year	Yes	Yes	Yes	Yes	Yes
County	Yes	Yes	Yes	Yes	Yes
<i>Fit statistics</i>					
Observations	4,558	4,558	4,558	4,558	4,558
R <sup>2</sup>	0.32465	0.34319	0.28918	0.34901	0.35004

*Standard-errors clustered at the salon level.*

*Signif. Codes:* \*\*\*: 0.001, \*\*: 0.01, \*: 0.05

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# Manhattan Firm Size and Complexity Regressions

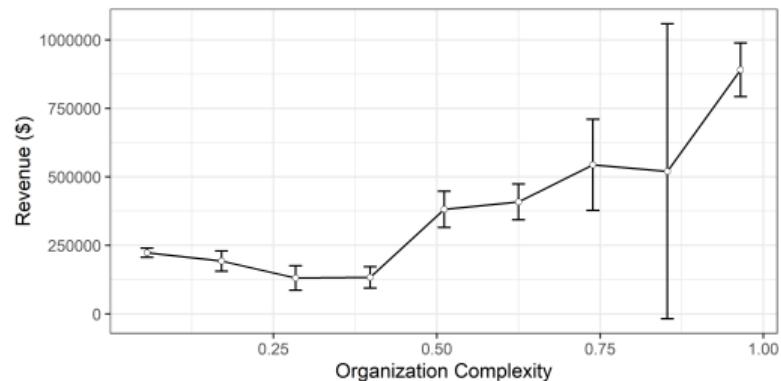
Dependent Variables:	Revenue	Employees	Utilized Labor	Customers	Visits
Model:	(1)	(2)	(3)	(4)	(5)
<i>Variables</i>					
Org. Complexity	430406.6*	12.55	-17733.9	277.2	876.9
	(179977.4)	(6.531)	(70765.2)	(600)	(907.1)
<i>Fixed-effects</i>					
Quarter-Year	Yes	Yes	Yes	Yes	Yes
<i>Fit statistics</i>					
Observations	595	595	595	595	595
R <sup>2</sup>	0.33485	0.21039	0.20359	0.44164	0.48831

*Clustered standard-errors in parentheses*

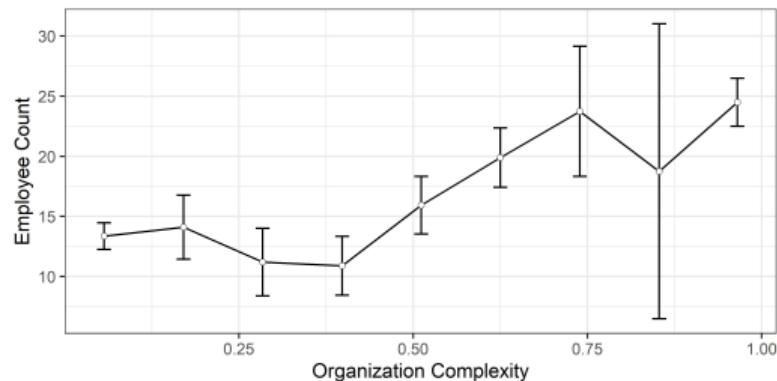
*Signif. Codes:* \*\*\*: 0.001, \*\*: 0.01, \*: 0.05

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## Fact 2: Complex salons have higher revenue and employment



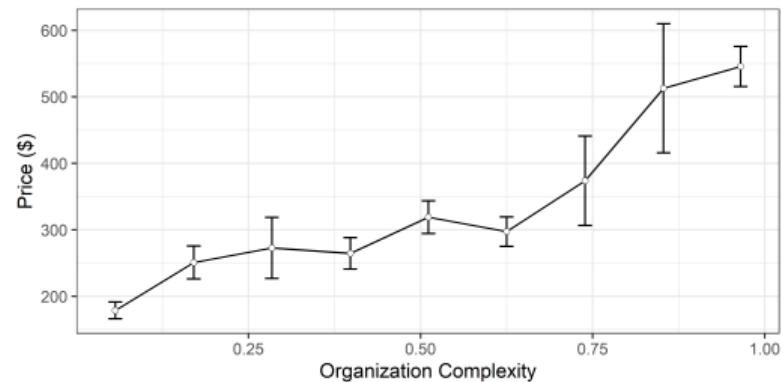
(a) Revenue



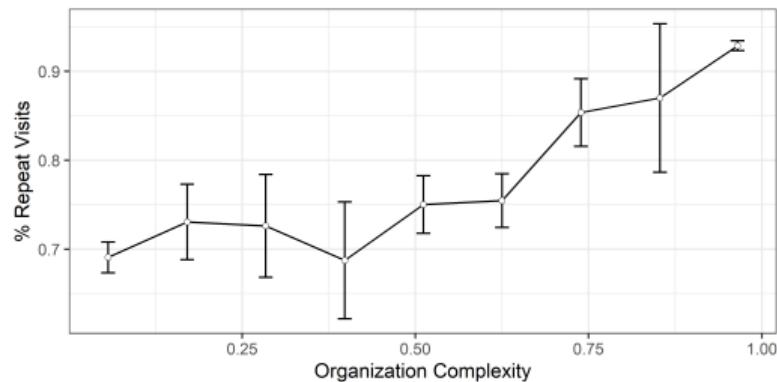
(b) Employees

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## Fact 3: Complex salons have higher prices and repeat customers



(a) Prices



(b) Repeat Customers

Back

## Quantity Model Implies Price ↓ Complexity

$$F_{\alpha, B}(a_j) = \min \left\{ \frac{a_1}{\alpha_1 \sum_i \theta_{i,1} B_j(i, 1)}, \dots, \frac{a_k}{\alpha_k \sum_i \theta_{i,k} B_j(i, k)}, \dots, \frac{a_K}{\alpha_K \sum_i \theta_{i,K} B_j(i, K)} \right\}$$

Given any fixed organizational structure, the efficient way to produce a single unit of output is to set  $a_k = \alpha_k \sum_i \theta_{i,k} B_j(i, k)$ . Thus marginal costs are constant and consist of the per-unit wage bill and organization costs:

$$MC_j = \sum_i w_i \sum_k \alpha_k \sum_i \theta_{i,k} B_j(i, k) + \gamma_j I(B_j)$$

### Proposition 3

*Under these assumptions, prices are decreasing with organizational complexity.*

Back

## Proof of Theorem: Only if Direction 1/2

- ▶ Consider any feasible  $(p', B'_j)$  where price is higher than marginal cost.<sup>1</sup>
- ▶ There always exists  $B_j^*$  which solves the equivalent problem.<sup>2</sup>
- ▶ Construct  $p_j = p'_j + \gamma_j I(B_j^*) + W(B_j^*) - \gamma_j I(B'_j) - W(B'_j)$ . This price is feasible b/c  $p'_j - \gamma_j I(B'_j) - W(B'_j)$  is price less MC and  $\gamma_j I(B_j^*) + W(B_j^*)$  is positive.
- ▶ By construction, price less marginal cost is equal under  $(p_j, B_j^*)$  and  $(p', B'_j)$ .
- ▶ To show profit is higher under  $(p_j, B_j^*)$  we need only show demand is higher.

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1. When  $p < MC$  profit is always negative.
2. b/c it is an RI problem (convex objective over compact set).

## Proof of Theorem: Only If Direction 2/2

To show demand is higher we need only show the quality-price index is higher:

$$= \xi(B_j^*) - \rho[p'_j + \gamma_j I(B_j^*) + W(B_j^*) - \gamma_j I(B'_j) - W(B'_j)] \quad (1)$$

$$= \xi(B_j^*) - \rho[p'_j + \gamma_j I(B_j^*) + W(B_j^*) - \gamma_j I(B'_j) - W(B'_j)] + \xi(B'_j) - \xi(B_j^*) \quad (2)$$

$$= \xi(B'_j) - \rho[p'_j + \gamma_j I(B_j^*) + W(B_j^*) - \gamma_j I(B'_j) - W(B'_j) - \rho^{-1}\xi(B_j^*) + \rho^{-1}\xi(B'_j)] \quad (3)$$

$$= \xi(B'_j) - \rho p'_j - \underbrace{\rho[\gamma_j I(B_j^*) + W(B_j^*) - \rho^{-1}\xi(B_j^*) - \{\gamma_j I(B'_j) + W(B'_j) - \rho^{-1}\xi(B'_j)\}]}_{\leq 0 \text{ because } B_j^* \text{ minimizes}} \quad (4)$$

$$\geq \xi(B'_j) - \rho p'_j \quad (5)$$

Back

## Proof of Theorem: If Direction

- ▶ Suppose there exists  $B'_j$  which maximizes profit but does not solve the RI problem.
- ▶ As before, there exists  $B_j^*$  which does solve.
- ▶ Construct  $p_j$  as before.
- ▶ Because  $B'_j$  does not solve the RI problem, we have that
$$\xi(B_j^*) - \rho p_j > \xi(B'_j) - \rho p'_j$$
- ▶ This implies  $B_j^*$  does not maximize profit, a contradiction.

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## Proof of Frontier Shape and Profit/Complexity Relationship 1/2

- ▶ Denote  $Q$  as quality-adjusted wages. Denote  $I^*(Q)$  as optimal complexity as a function of quality-adjusted wages.
- ▶ RD equivalence  $\implies I^*(Q)$  is continuous, convex and decreasing. Also strictly decreasing above some threshold  $\bar{Q}$  (Chen, n.d.).
- ▶ The firm's choice of quality-adjusted wages solves:

$$V := \min_Q \gamma I^*(Q) + Q$$

- ▶ Envelope theorem implies the index and thus profit are increasing in  $\gamma$ :

$$\frac{\partial V}{\partial \gamma} = I^*(Q) \geq 0$$

## Proof of Frontier Shape and Profit/Complexity Relationship 1/2

- ▶ Examining the FOC:

$$\frac{dI^*(Q) + \gamma^{-1}Q}{dQ} = \frac{dI^*(Q)}{dQ} + \gamma^{-1} = 0 \implies \frac{dI^*(Q)}{dQ} = -\gamma^{-1}$$

- ▶ Because  $I^*$  is decreasing and convex, its derivative is negative and increasing.
- ▶ Therefore  $Q$  which solves is increasing in  $\gamma$ .
- ▶ Thus profit and complexity will be positively correlated via  $\gamma$ .

Back

# Profit Under the Econometric Model

$$\frac{\exp(\xi(B_j) - \rho(1 + \tau)p_j + \beta\alpha_j + \nu_j)}{\sum_{j'} \exp(\xi(B_{j'}) + -\rho(1 + \tau)p_{j'} + \beta\alpha_{j'} + \nu_{j'})} \left[ p_j - \bar{a}_j \left( \gamma_j I(B_j) + W(B_j) + m\alpha \right) - \phi_j \right]$$

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# A Full Solution Method for Optimal Organization Structure

A globally convergent fixed point algorithm to fully solve based on Blahut (1972):

0. Guess some labor demand  $E^0$ . Create matrix  $V$ :

$$V_{i,k} = \exp[\gamma^{-1}(\rho^{-1}\theta_{i,k} - W_i)]$$

1. Compute  $B^t$  as:

$$B_{i,k}^t = \alpha_k \frac{V_{i,k} E_k^t}{\sum_i E_i^t V_{i,k}}$$

2. Compute  $E^{t+1}$  as:

$$E_i^{t+1} = \sum_k B_{i,k}^t$$

3. If converged exit, else return to Step 1 and advance  $t$ .

Back

## Minimum Wage Counterfactual Details

- ▶ Counterfactuals assume the utility of not getting a service remains fixed.
- ▶ Ruling out Multiple Equilibria
  - ▶ Assume beforehand which wages bind (i.e. which wages are \$20)
  - ▶ 0 excess labor supply for all types except binding types.
  - ▶ Check that assumed binding types have excess labor supply.
  - ▶ If yes, count as an equilibria. If not exclude.
- ▶ I do this for all  $2^5$  combinations.
- ▶ This results in only one equilibrium.

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## Consumer Welfare

Therefore expected utility of consumer  $i$  has the well-known closed form:

$$V_i = \mathbb{E}[\max_j\{\xi_j - \rho p_j + \epsilon_{i,j}\}] = \ln \left[ \sum_{j=1}^J \exp(\xi_j - \rho p_j) \right] + C$$

where  $C$  is Euler's Constant. There are a mass  $M$  of consumers, therefore total consumer expected utility is  $M \cdot V_i$ . We then can denominate this in dollar terms by dividing by the coefficient on price,  $\rho$ . Our measure of total consumer welfare in dollar terms is:

$$CS = \frac{M}{\rho} \left\{ \ln \left[ \sum_{j=1}^J \exp(\xi_j - \rho p_j) \right] + C \right\}$$

With a sales tax  $\tau$ , it is:

$$CS = \frac{M}{\rho} \left\{ \ln \left[ \sum_{j=1}^J \exp(\xi_j - \rho(1 + \tau)p_j) \right] + C \right\}$$

# Equilibrium Uniqueness

## Proposition 4

Suppose wages are fixed parameters. A pure strategy equilibrium always exists, and it is unique except over a set of parameters with measure 0.

### Proof Sketch:

- ▶ Bertrand oligopoly with logit demand has unique NE Caplin and Nalebuff (1991)
- ▶ Profit is strictly incr. in quality-adjusted (QA) cost Main Characterization
- ▶ QA wages and org. costs with mult. equilibria is null Lipnowski and Ravid (2022)
- ▶ Union of countable null sets (all combinations of  $J$  org. costs) is null
- ▶ QA wages are function  $F$  of params; Jacobian of  $F$  is rank  $N \times K \implies$  parameters which generate mult. equilibria are measure 0.

## Identification Proof Sketch 1/2

- ▶ Task assignments over worker identities ( $\tilde{B}_j$ ) are observed. Task assignments over worker types ( $B_j$ ) are not
- ▶ Lemma:  $I(\tilde{B}_j) = I(B_j)$ 
  - ▶ Workers w/ same skill set assigned same tasks
- ▶ Then apply data processing inequality or algebra
- ▶ Denote model-generated complexity as  $\tilde{I}(\Omega, \gamma_j, \alpha_j)$
- ▶  $\tilde{I}(\Omega, \gamma_j, \alpha_j)$  is a known function
  - ▶  $\tilde{I}(\Omega, \gamma_j, \alpha_j)$  can be arbitrarily well approximated by the Blahut-Arimoto algorithm

Distraction-Free Property (Tian 2019)

RD Equivalence (Blahut 1972)

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## Identification Proof Sketch 2/2

- ▶ Define  $Q_j := W(B_j) - \rho^{-1}\xi(B_j)$ . By RD equivalence:

$$V := \min_{B_j \in \mathbb{B}_j} \gamma_j I(B_j) + W(B_j) - \rho^{-1}\xi(B_j) = \min_{Q_j \in \mathbb{Q}_j} \gamma_j I_j^*(Q_j) + Q_j$$

where  $I_j^*$  is a decreasing, convex function. The FOC  $\frac{dV}{dQ_j} = \gamma_j \frac{dI_j^*(Q_j)}{dQ_j} + 1 = 0$  and convexity imply  $Q_j$  is increasing in  $\gamma_j$ .

- ▶  $I_j^*$  is decreasing in  $Q_j$  when  $I_j^* > 0$  thus decreasing in  $\gamma_j$ .
- ▶  $I_j^*(B_j) = \tilde{I}(\Omega, \gamma_j, \alpha_j) \implies \frac{\partial \tilde{I}(\Omega, \gamma_j, \alpha_j)}{\partial \gamma_j} < 0 \implies \gamma_j$  is identified. Similar to BLP, can recover  $\gamma_j$  by inversion:  $\tilde{I}(\Omega, \gamma_j, \alpha_j) = I(\tilde{B}_j)$
- ▶  $\{B_j\}_{j=1}^J$  unique except over a set with measure 0

Essential Equilibrium Uniqueness

# A Sufficient Condition for the Uniqueness of $B_j$

## Assumption

*Define the wage-quality vector of a worker of type  $i$  at firm  $j$  as*

$v_{i,j} = \{\exp(\gamma_j^{-1}(\rho^{-1}\theta_{i,k} - w_i))\}_{k=1}^K$ . Each firm's wage-quality vector  $\{v_{i,j}\}_{i \in \mathcal{I}}$  is affinely independent.

Source: Mat  jka and McKay (2015)

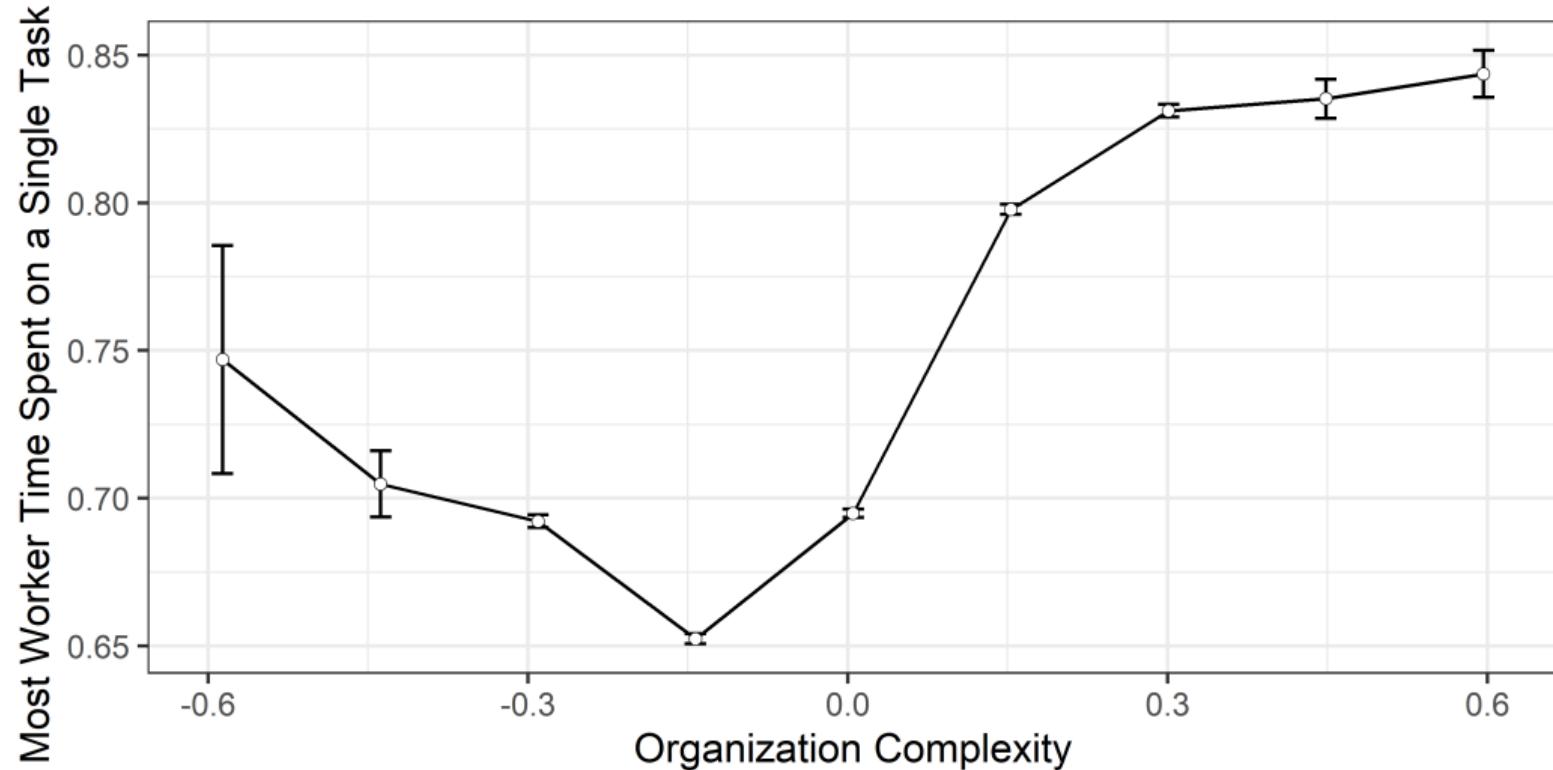
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# Minimum Wage Counterfactual Employment and Wages

Worker Type	Initial			Reallocation		Counterfactual
	Hours	Wage	Hours	Wage	Hours	Wage
Haircut/Shave	537550	\$16.96	506090	\$20.00	502152	\$20.00
Color/Highlight/Wash	997053	\$37.75	997053	\$37.33	997053	\$37.52
Blowdry/Style/Treatment/Extension	444040	\$20.91	444040	\$21.88	444040	\$21.64
Administrative	41860	\$26.99	41860	\$28.40	41860	\$28.12
Nail/Spa/Eye/Misc.	34844	\$81.16	34844	\$81.63	34844	\$81.71

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## Regressions of Worker Specialization on Organization Complexity



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## Why Aggregation?

- ▶ A single product allows me to focus on the effects of organization on overall salon quality.
- ▶ Consumers buy a bundle of services at salons.
- ▶ It buys significant numerical/theoretical tractability.
- ▶ Nocke and Schutz (2018): any pricing game with multi-product firms and MNL demand can be represented as a single product firm game with transformed qualities and costs:

$$\tilde{q}_j = \rho \log \left( \sum_k \exp((q_k - c_k)/\rho) \right) + 1 \quad \tilde{c}_j = 1$$

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## Sales Tax Elimination Effects by Worker Type

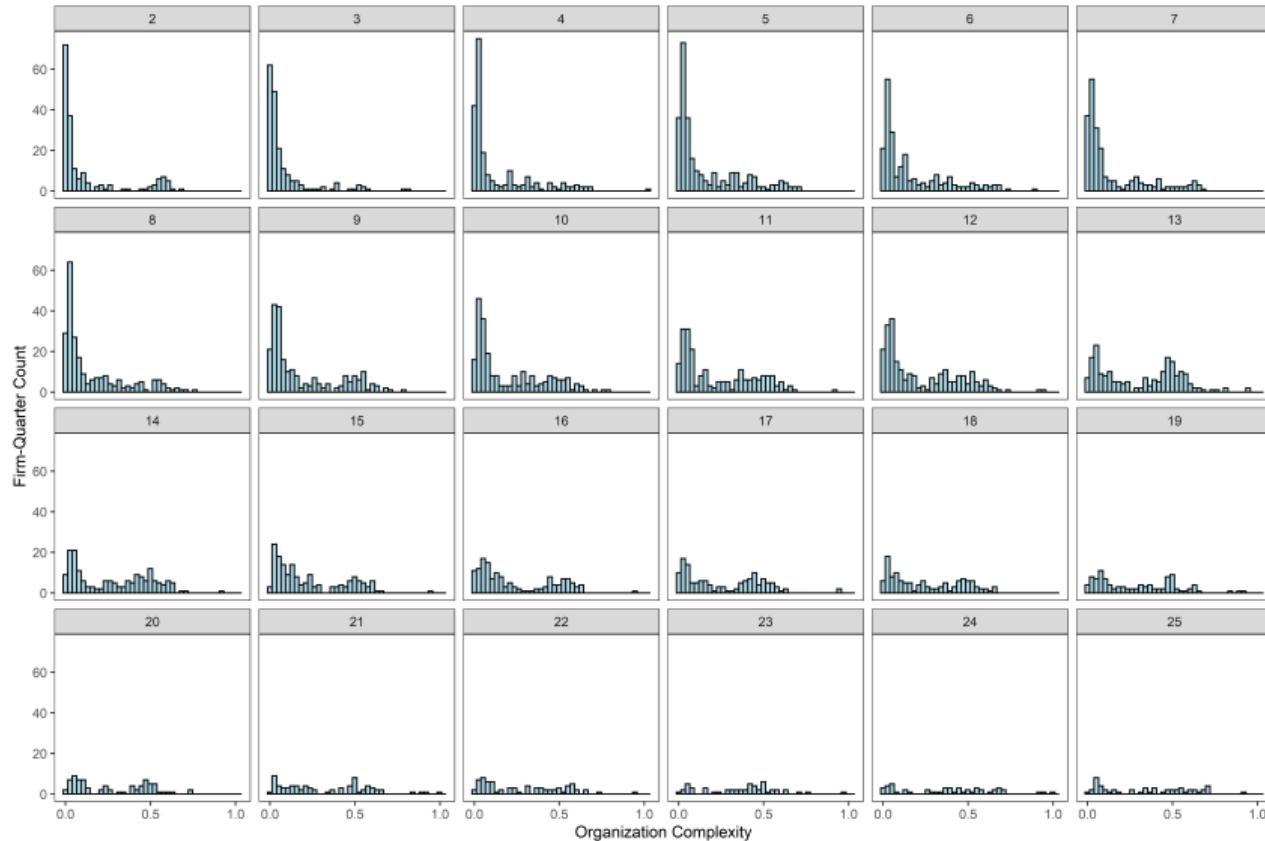
Type	Wage Change	Task-Spec. Change
Haircut/Shave	31.99%	0.29%
Color/Highlight/Wash	20.09%	2.57%
Blowdry/Style/Treatment/Extension	6.06%	3.01%
Administrative	17.99%	1.03%
Nail/Spa/Eye/Misc.	12.74%	2.39%

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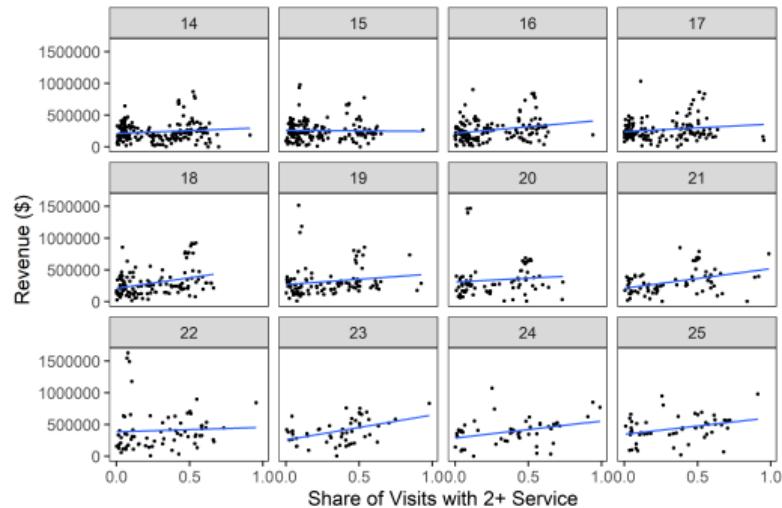
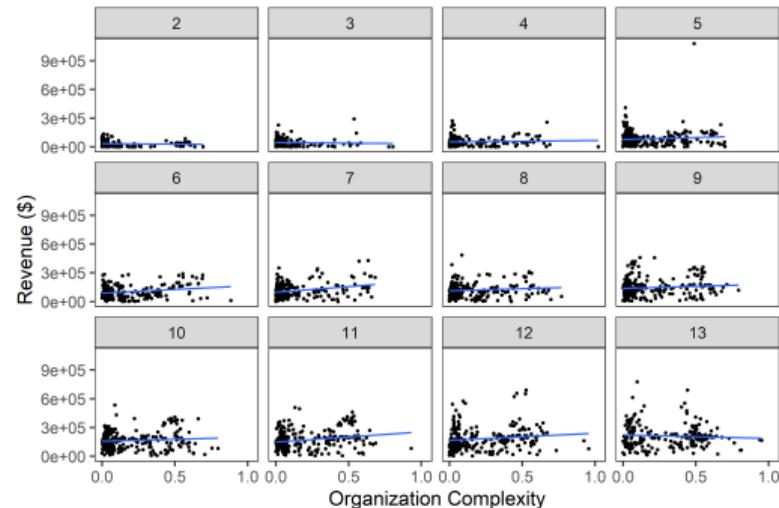
# Minimum Wage Welfare Effects

Source	Change	Percent Change
Salon Profit	-\$714,413	-0.472%
Consumer Welfare	-\$2,528,784	-1.671%
Employed Wages	\$1,689,600	1.116%
Unemployed Wages	-\$600,240	-0.397%
Total Welfare	-\$2,153,838	-1.423%

# Complexity Histograms Among Similar Size Firms

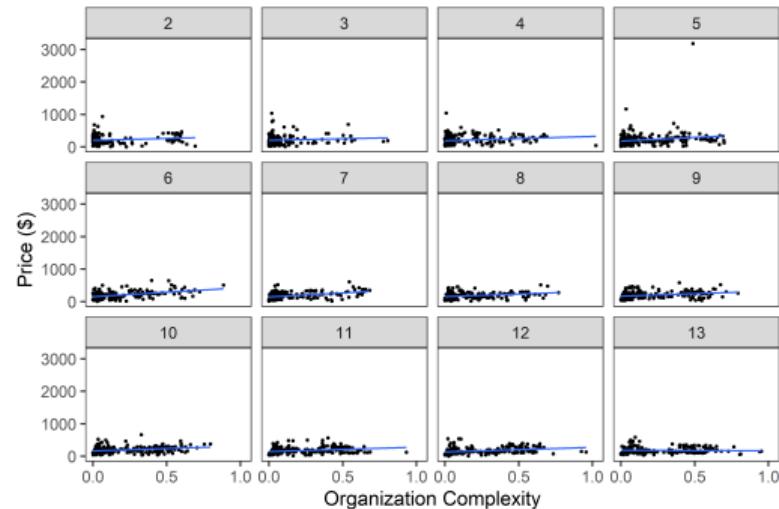


# Revenue and Complexity Among Similar Size Firms

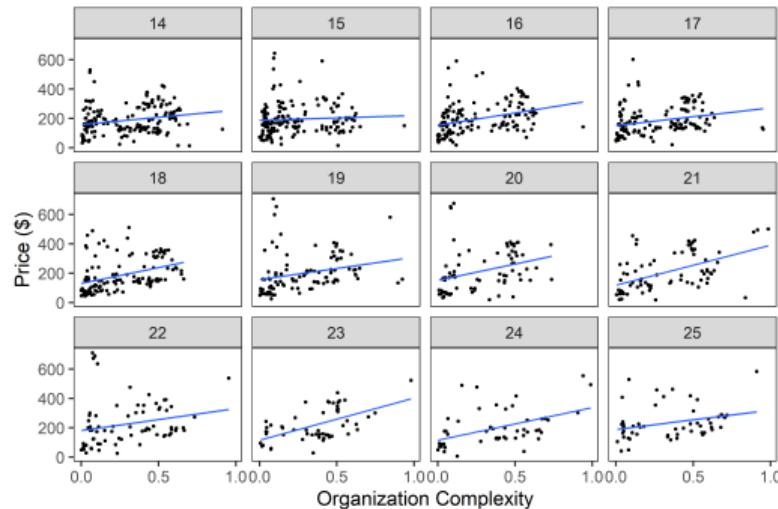


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# Price and Complexity Among Similar Size Firms



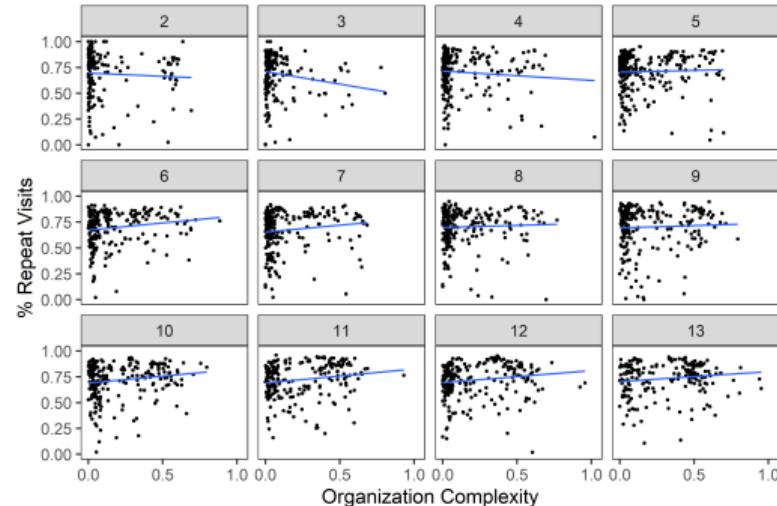
(a) 2-13 Employees



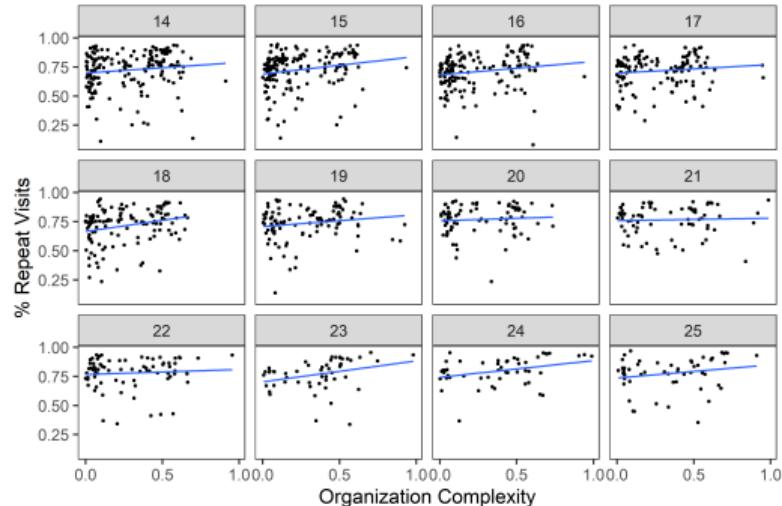
(b) 14-25 Employees

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# Repeat Visits and Complexity Among Similar Size Firms



(a) 2-13 Employees



(b) 14-25 Employees

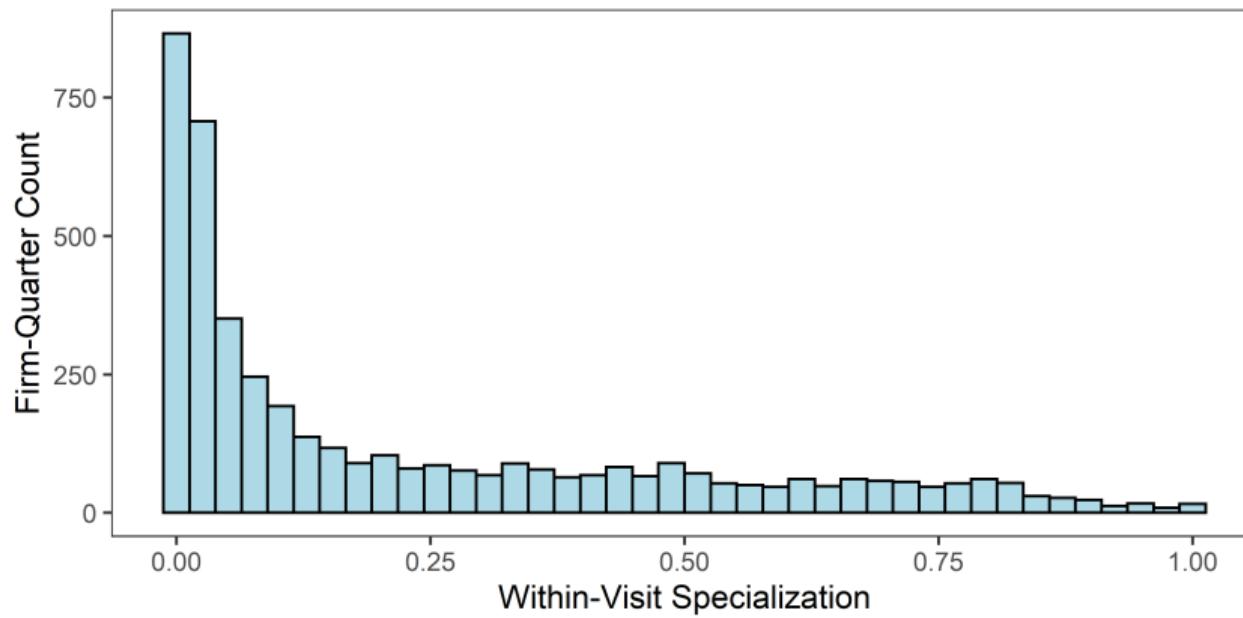
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## Within-Visit Specialization

- ▶ Within-visit specialization: the number of customer visits<sup>3</sup> with two or more employees assigned divided by the number of customer visits with two or more services performed.
- ▶ R-squared of complexity regressed on within-visit specialization is 0.5
- ▶ Two firm-quarters are drawn randomly their ordering according to complexity and within-visit specialization will be the same 74.4% of the time.

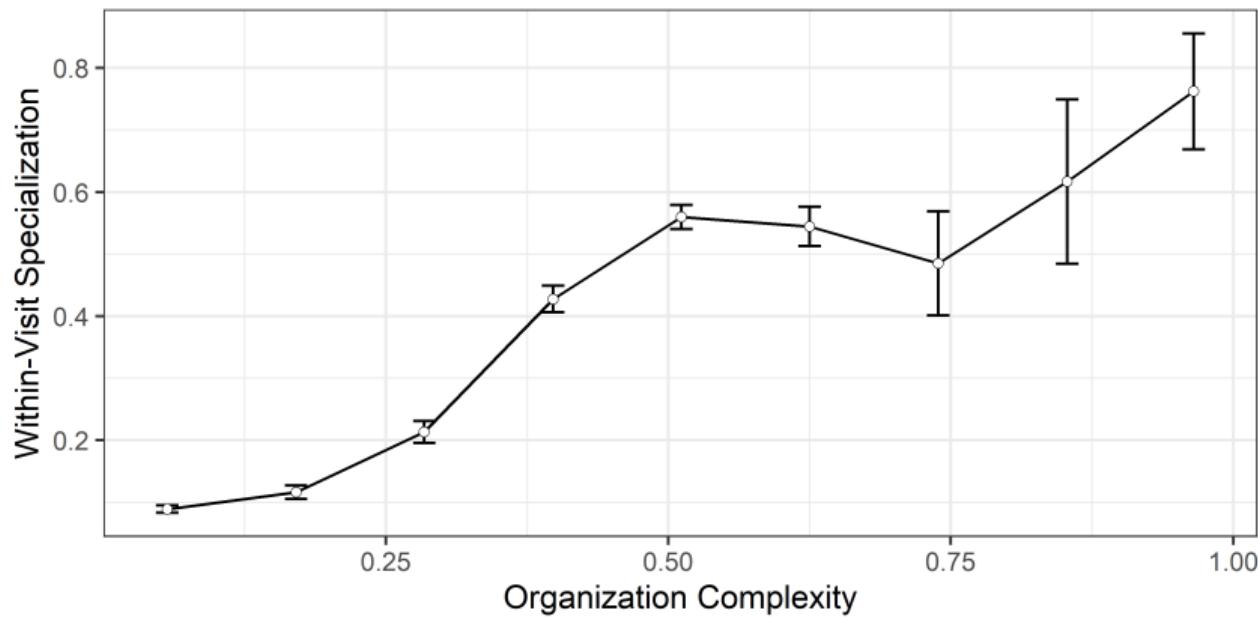
3. Visits are the number of unique customer-date pairs in a quarter.

# Within-Visit Specialization Histogram

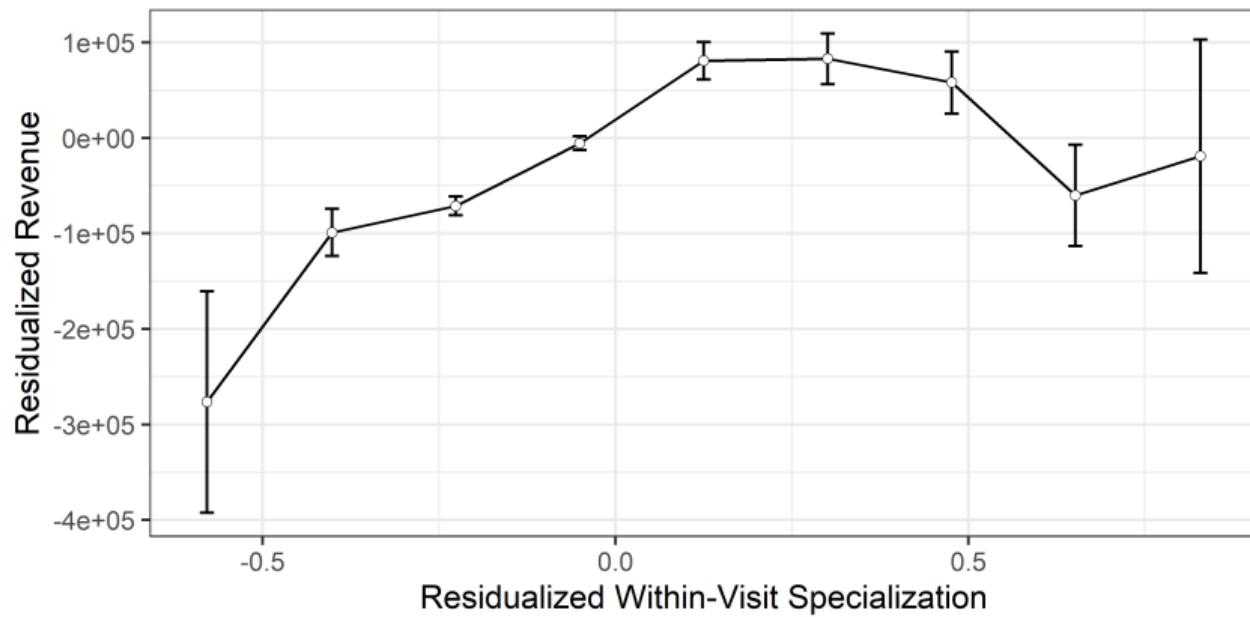


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# Within-Visit Specialization and Complexity

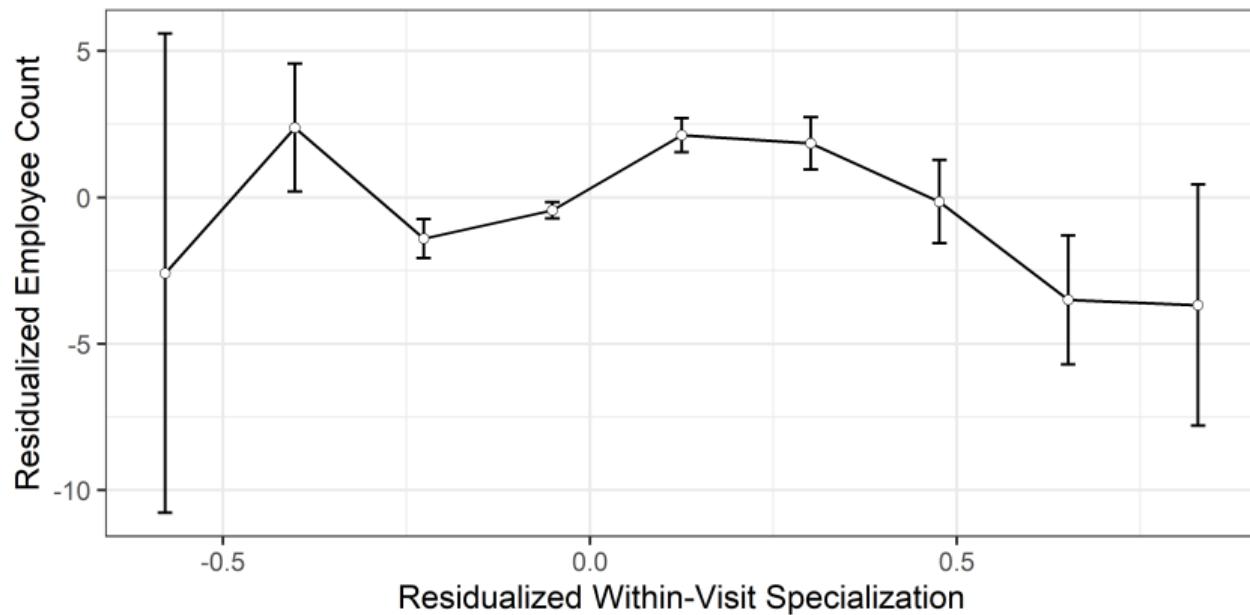


# Within-Visit Specialization and Revenue



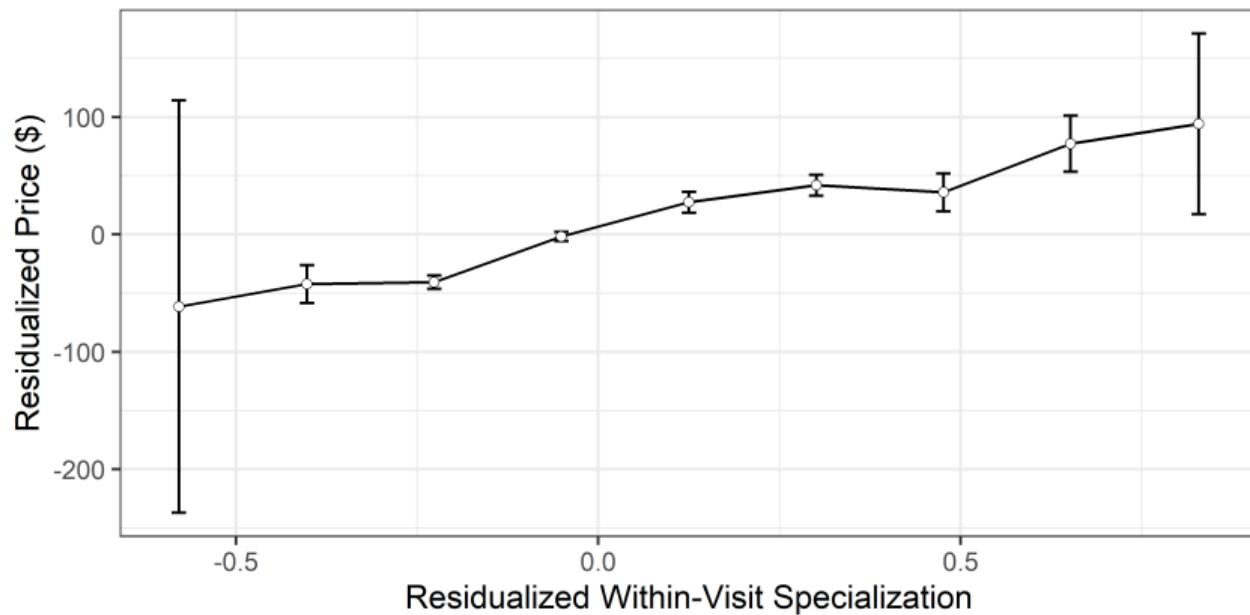
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## Within-Visit Specialization and Employees



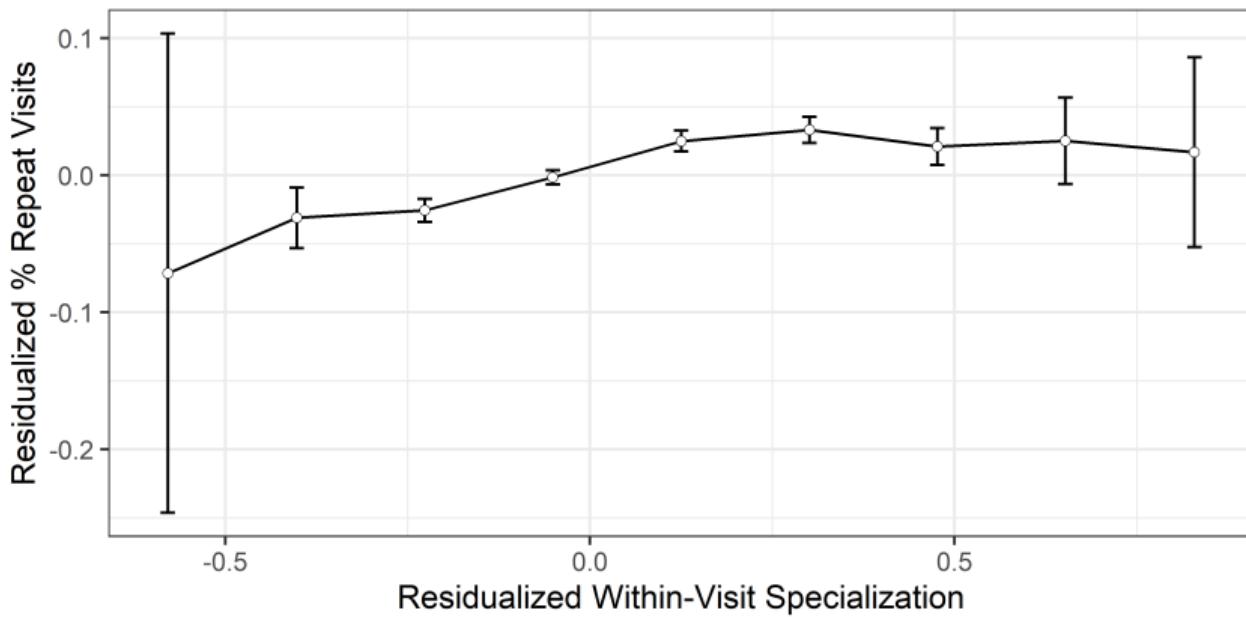
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## Within-Visit Specialization and Price



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# Within-Visit Specialization and Repeat Visits



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