The Inner Beauty of Firms

Jacob Kohlhepp

UCLA

January 28, 2023

Motivation: A Tale of Two Salons

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

Westwood Barber Shop	John Frieda Salon
[redacted] 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.	[redacted] 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.
[redacted] 0 18 12 3/10/2019 Throughly enjoyable quality cut from the delightful owners of the salon. At 81 she cut while he cleaned.	[redacted] 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.

Research Questions

- Research Question 1: How do firms choose their internal structure?

Research Questions

- 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?

Research Questions

- 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

- Contribution: An industry equilibrium model of internal organization with organizationally unique firms that can be identified and estimated using task assignment data.

Summary of Paper

- Contribution: An industry equilibrium model of internal organization with organizationally unique firms that can be identified and estimated using task assignment data.
- Research Question 1: How do firms choose their internal structure?
  - Answer: Salons choose more complex internal organizations in order to produce higher quality products, but are constrained by firm-specific organization costs.

Summary of Paper

- Contribution: An industry equilibrium model of internal organization with organizationally unique firms that can be identified and estimated using task assignment data.
- Research Question 2: What are the implications for product markets, labor markets, and government policy?
  - Answer: Endogenous and heterogeneous internal organization introduces new economic forces.
    - **Example:** 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.
    - **Example:** 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 Perkowski 2019 (trust); Martinez et al. 2015 (culture); Alchian and Demsetz 1972, Baker and Hubbard 2003 (monitoring)

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

- **Wage Data.** Garicano and Rossi-Hansberg (2006); Caliendo et al. (2012); Garicano and Hubbard (2016)

- **Rational Inattention.** Jung et al. (2019); Tian (2019); Matêjka and McKay (2015); Lipnowski and Ravid (2022)

Table of Contents

Data

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

A Data Snapshot

Firm	Salon	App.	Cust.	Task	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

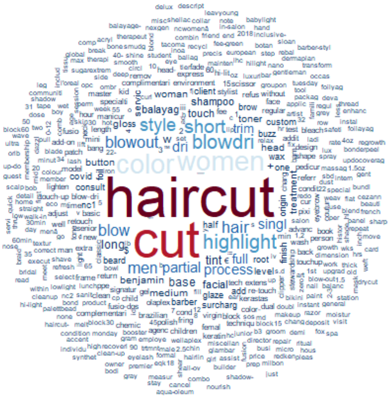
A Data Snapshot

Firm	Salon	App.	Cust.	Task	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

- Tasks 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 Task Categories

- 20,560 unique task descriptions.
- A certified cosmetologist was paid to group into 6 categories.
- Two categories merged due to sparsity to yield 5 task categories.



Task Categories

Share of Labor	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Haircut/Shave	4,558	0.41	0.23	0.00	0.26	0.52	1.00
Color/Highlight/Wash	4,558	0.38	0.20	0.00	0.29	0.52	1.00
Blowdry/Etc	4,558	0.09	0.12	0.00	0.03	0.11	1.00
Administrative	4,558	0.05	0.11	0.00	0.002	0.04	1.00
Nail/Etc	4,558	0.06	0.16	0.00	0.00	0.05	1.00

Firm-Quarter Stats.

Table of Contents

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.

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.

"Specialist" Salon

Worker	Cut	Color	Dry	
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	

"Generalist" Salon

Worker	Cut	Color	Dry	Worker Share (E)
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	

Task-Mix (α)

What is Organizational Complexity?

Definition 2

The complexity of an organization structure B_j is:

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

- Within-firm specialization Formal Proof Correlation

What is Organizational Complexity?

Definition 2

The complexity of an organization structure B_j is:

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

- Within-firm specialization Formal Proof Correlation
- Managerial Attention Formal Microfoundation

What is Organizational Complexity?

Definition 2

The complexity of an organization structure B_j is:

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

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

Complexity of the Two Structures

Specialist Salon

Tasks

Employee	Cut	Color	Dry	
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

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

Generalist Salon

Tasks

Employee	Cut	Color	Dry	
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

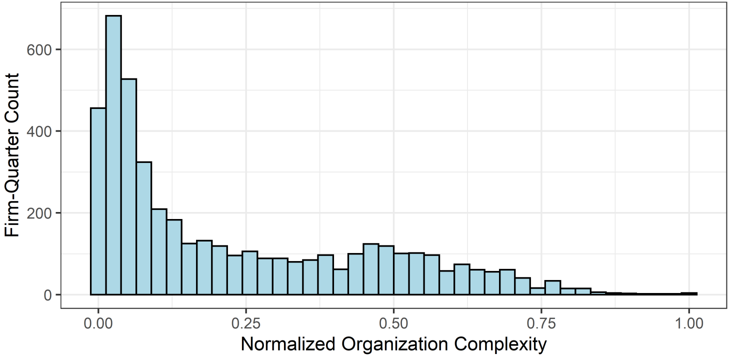
If cut send nothing roll dice

If color send nothing roll dice

If dry send nothing roll dice

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

Fact 1: Complexity is heterogeneous and firm-specific.



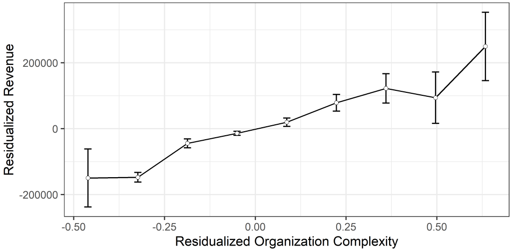
$$I_{j,t} = \bar{I}_j + \bar{I}_t + e_{j,t}$$

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

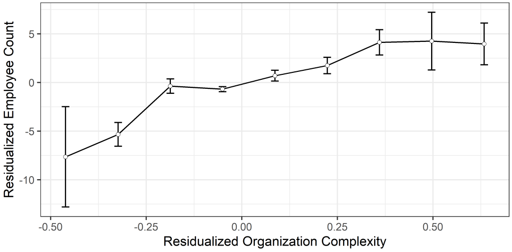
Takeaway: Internal complexity is driven by a deep characteristic of the firm.

Placebo Simulation

Fact 2: Complex salons have higher revenue and employment



(a) Revenue



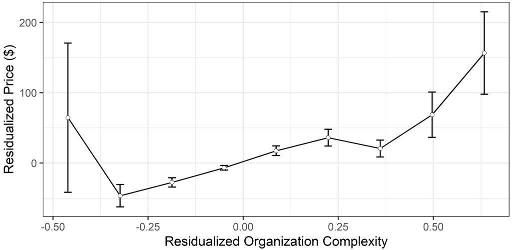
(b) Employees

Was Staff Requested? | Robustness Regs. | Within Firm Size | Within-Visit Specialization

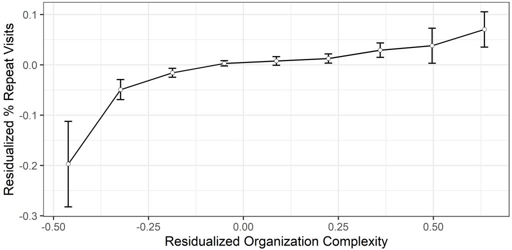
Regressions | Manhattan | Manhattan Regs. | Customers and Visits

Takeaway: There is an organizational competitive advantage.

Fact 3: Complex salons have higher prices and repeat customers



(a) Prices



(b) Repeat Customers

Manhattan Only | Within Firm Size | Within-Visit Specialization

Takeaway: This advantage operates through quality NOT quantity. Theory

Table of Contents

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 α_k labor to task k. Normalize $\sum_k \alpha_k = 1$
  - Homogeneous α for exposition only

N Worker Types

- Skill set $\theta_i = \{\theta_{i,1}, \ldots \theta_{i,k}, \ldots \theta_{i,K}\}$
- 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 $\mathbb{B} = \{B_j \in \Delta^{N \times K} | \sum_i B_j(i,k) = \alpha_k\}$

$$\max_{p_j, B_j \in \mathbb{B}_j} \underbrace{D_j(\overbrace{\xi(B_j)}^{\text{quality}} - \rho p_j, p_{-j}, \xi_{-j})}_{\text{Demand}} \left[p_j - \underbrace{\left(\overbrace{\gamma_j I(B_j)}^{\text{org.}} + \overbrace{W(B_j)}^{\text{avg. wage}} \right)}_{\text{constant marginal cost, } MC_j} \right]$$

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:

$$\sum_j D_j(\xi(B_j) - \rho p_j, p_{-j}, \xi_{-j}) \sum_k B_j(i,k) = L_i \;\forall\, i = 1, ..., N$$

Summary of the Model

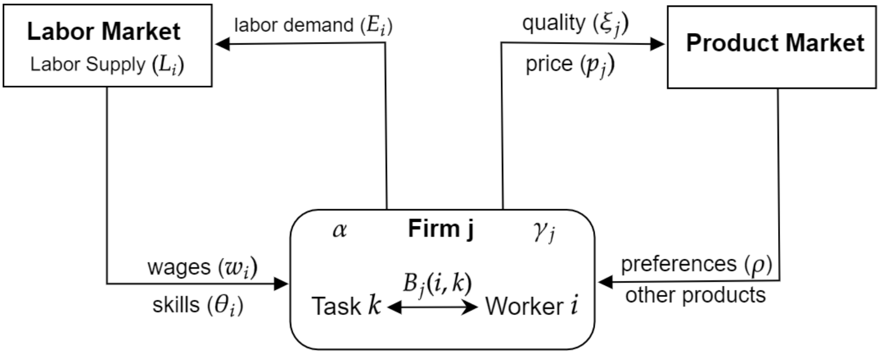


Table of Contents

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

Characterizing the Firm's Problem

Theorem

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

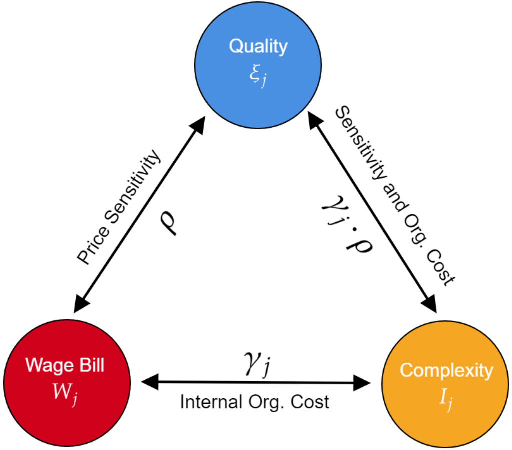
$$\min_{B_j \in \mathbb{B}} \gamma_j I(B_j) + W(B_j) - \rho^{-1} \xi(B_j)$$

- 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

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

Definition

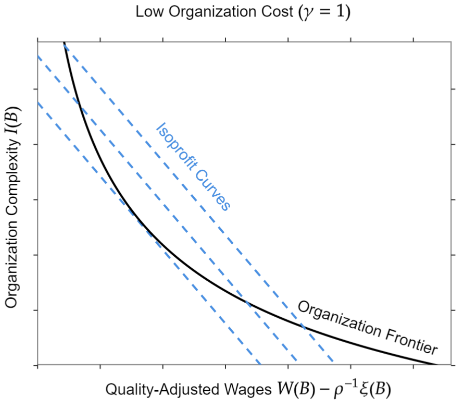
The organization frontier is the set of organization structures which minimize complexity for some quality-adjusted wages.

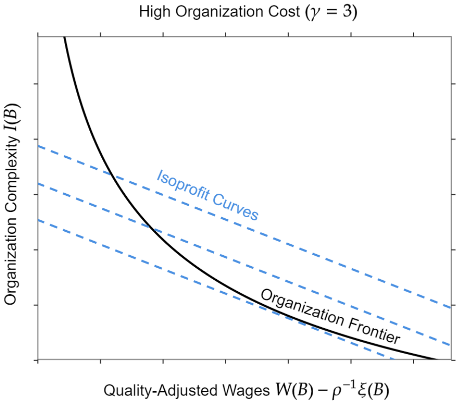
Because this is a rate-distortion problem:

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 (γ_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.

Table of Contents

Simple Example

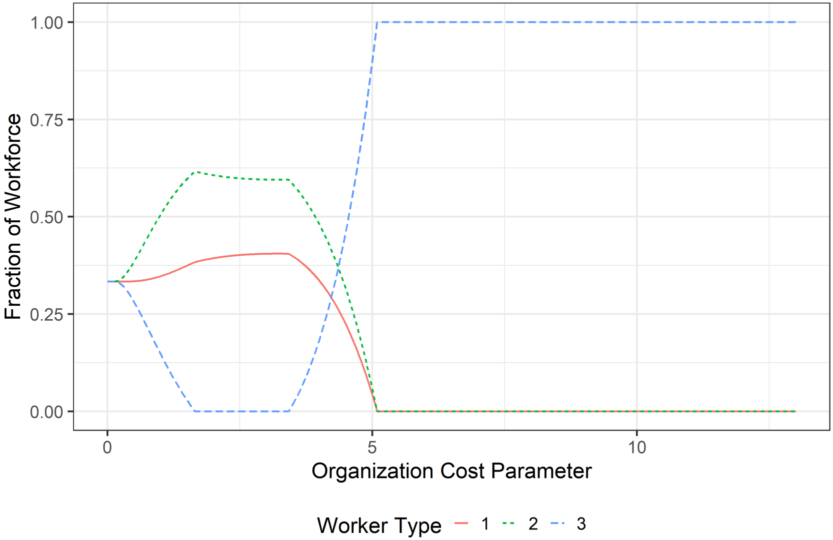
- 3 tasks with uniform task-mix $\alpha = (1/3, 1/3, 1/3)$, price sensitivity $\rho = 1$
- 3 worker types with wages $w = (21, 20, 15)$ and skill set:

$$\begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \end{bmatrix} = \begin{bmatrix} 15 & 19 & 26 \\ 23 & 19 & 15 \\ 15 & 15 & 15 \end{bmatrix}$$

- Wage-adjusted quality:

$$\begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \end{bmatrix} - \rho w = \begin{bmatrix} -6 & -2 & 5 \\ 3 & -1 & -5 \\ 0 & 0 & 0 \end{bmatrix}$$

Workforce Composition Heterogeneity



Labor-Labor Substitution Heterogeneity

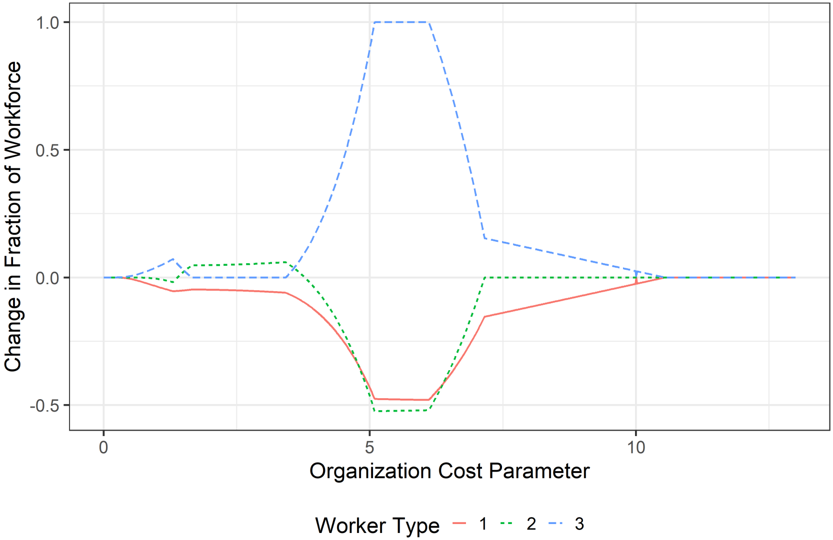


Table of Contents

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 β_k, skill gap θ_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 (α_j), effective labor per unit ($\bar{a}_j$), exogenous quality (ν_j), marginal cost shifter (ϕ_j)

What does firm profit look like?

The Econometric Model

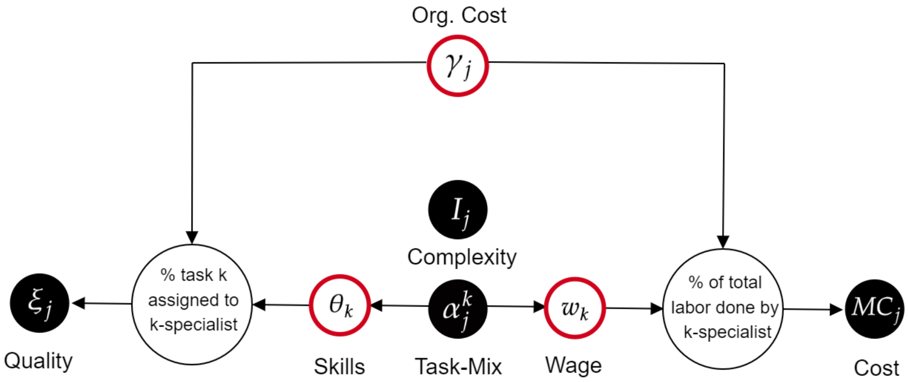
- A natural notion of task-specialization:

Definition 3

Task-specialization is the fraction of total labor where a task is assigned to the associated specialist.

- 1 utility + 5 cost + 5 wages + 10 skills = 21 parameters
- Call these market parameters and denote Ω
- 42 salons $\implies$ 42 org. cost parameters

Identification Problem



Identification: Firm-Specific Organization Costs γ_j

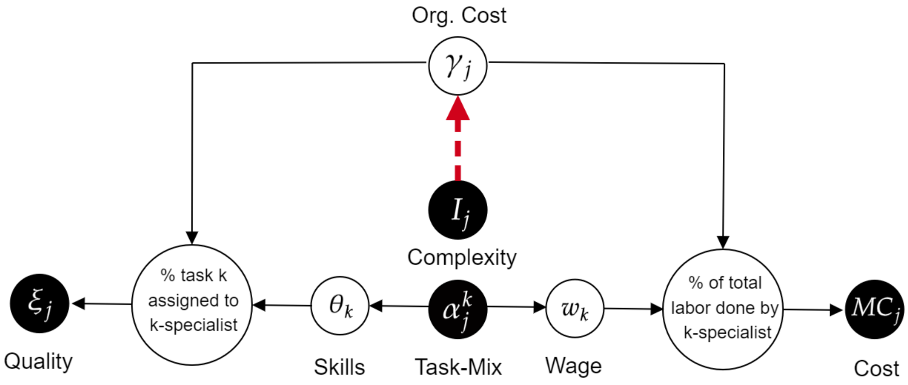
Proposition 1

Organization costs (γ_j) and organization structures (B_j) are a known function of firm task-mixtures (α_j), complexities (l_j) and market parameters (Ω) 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 γ_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 γ_j



Identification: Market Parameters

- Use firm price FOC (supply side moments):

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

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

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

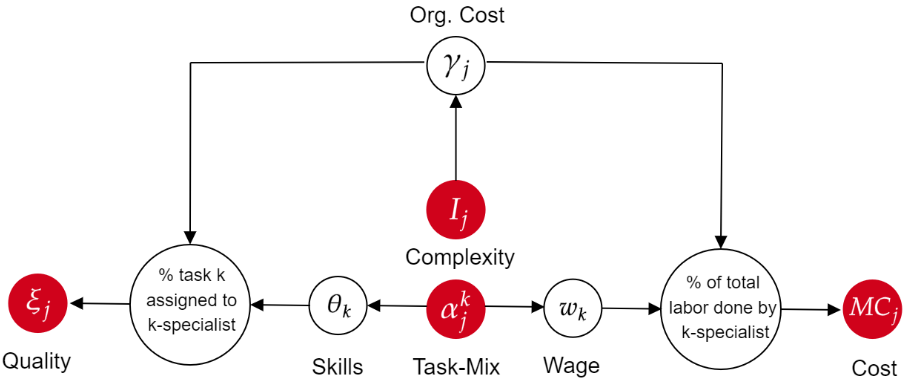
- Match avg. beauty salon QCEW wage bill with measurement error:

$$W_j = Ms_j a_j wE(\Omega, I_j, \alpha_j) + e_j$$

- The model is globally identified if Ω uniquely satisfies:

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

Heuristic Identification: Market Parameters (Ω)



From Identification to Estimation

- Issue
  - B_j is a 5×5 matrix which solves a non-linear minimization problem
  - Must solve for B_j repeatedly to obtain γ_j which makes model complexity match observed complexity
  - Must repeat process for each firm and for each set of market parameters Ω
- 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.

Table of Contents

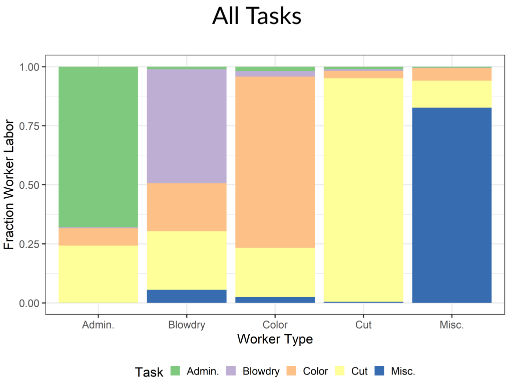
Task Parameter Estimates

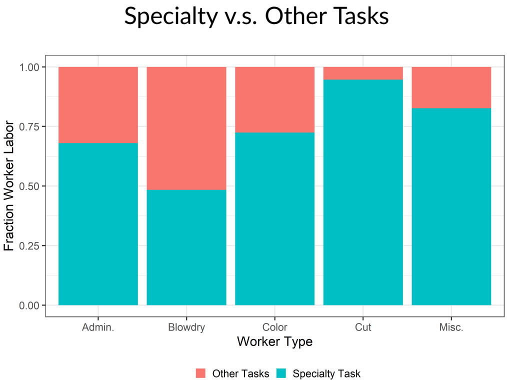
	Associated Specialist			
Task	Skill Gap	Wage	Skill Base	Material Cost
Administrative	43.29*	26.99	-16.16	-147.60*
	(21.66)	(63.75)	(14.58)	(13.47)
Blowdry/Etc.	141.69*	20.91	-70.56*	12.39
	(36.67)	(40.22)	(13.57)	(16.65)
Color/Highlight/Wash	60.03*	37.75*	-9.69	56.49*
	(21.24)	(7.00)	(11.97)	(15.79)
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.

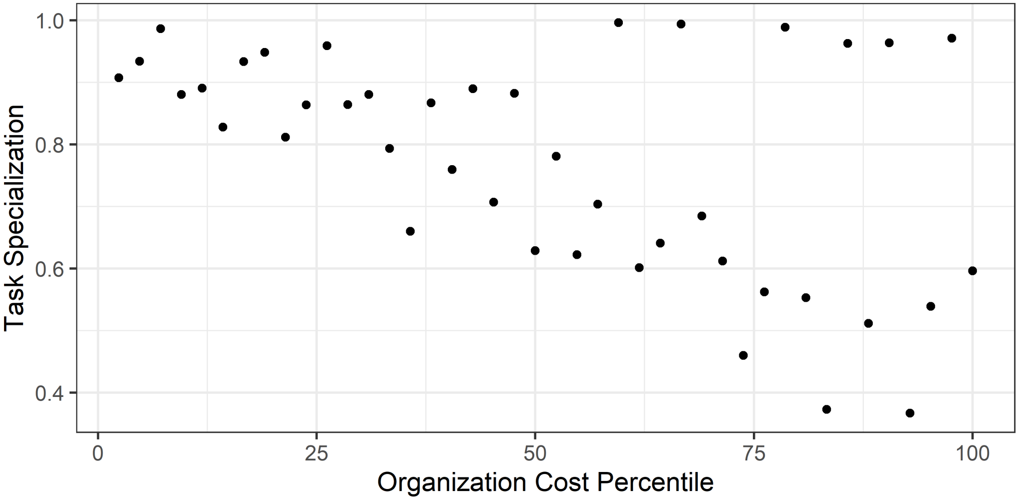
Two Orgs.

Equilibrium Task Specialization Across Workers





Equilibrium Task Specialization Across Firms



Cost of Median Complexity Organization Across Firms

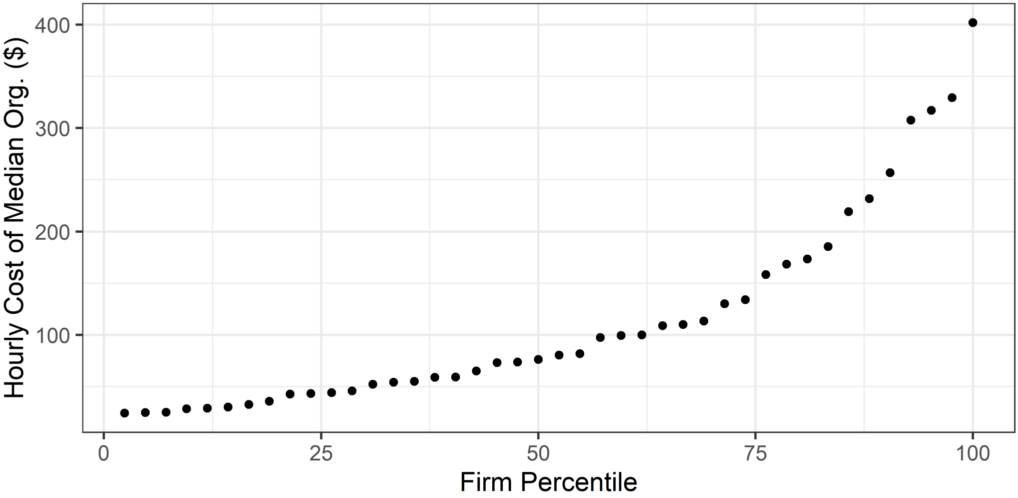
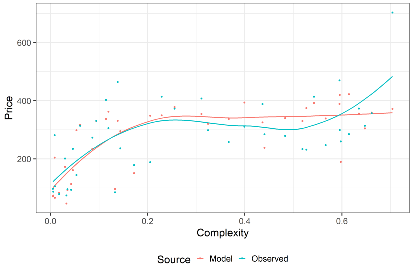
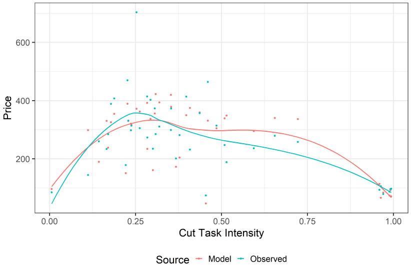
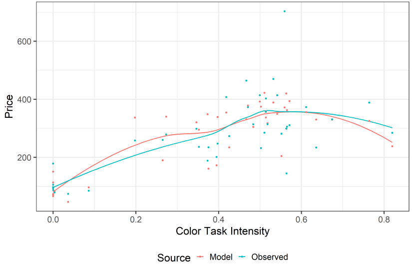


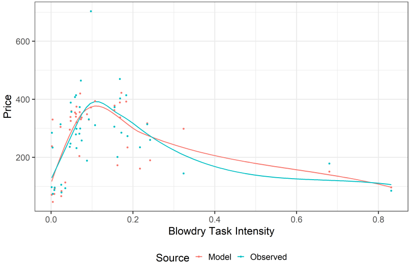
Table of Contents

Fit: Supply Side Relationships









Validation: The Task Content of Jobs

Model generated jobs:

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

	Total Variance		Between Firm Variance	
Task	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

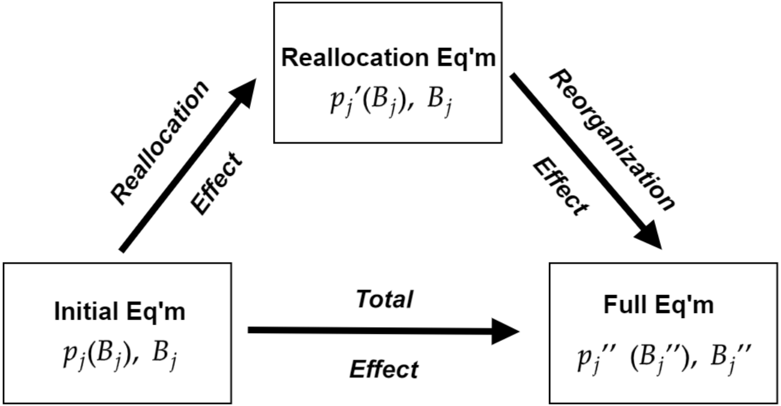
Var. Decomp.

Table of Contents

Counterfactual Implementation

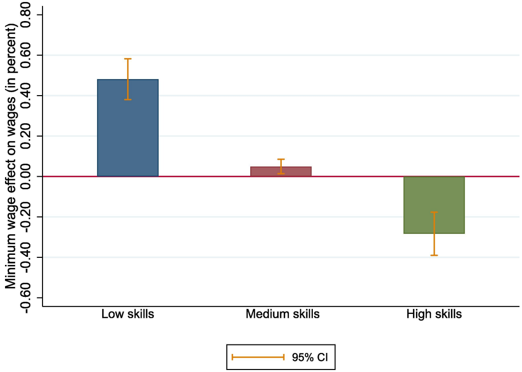
- Solving for a new equilibrium
  1. Guess wages, solve for organization structures.
  2. Use organization structures to obtain costs and qualities.
  3. Solve for Nash equilibrium prices.
  4. If labor markets clear stop. If not return to step 1.
- Compute consumer welfare using closed form

Decomposing Mechanisms

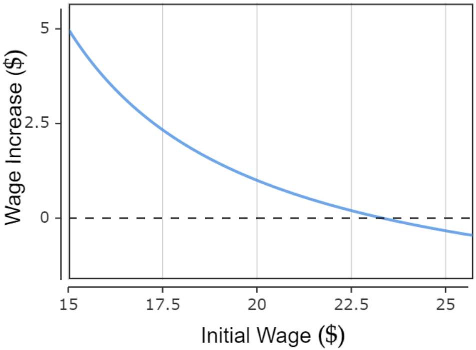


Minimum Wage Increases In Models with Distance Dependent Substitution

Wage Increase by Skill Level



Wage Changes by Initial Wage Percentile



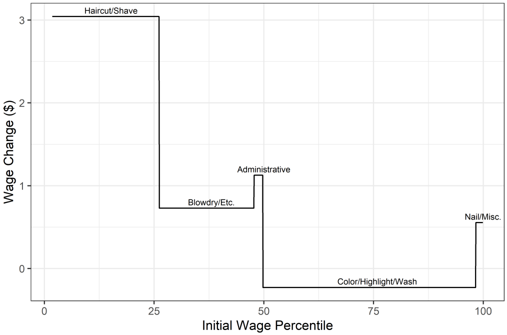
Left is from Gregory and Zierahn (2022), right is stylized example

Minimum Wage Increase from $15 to $20

Wages Changes

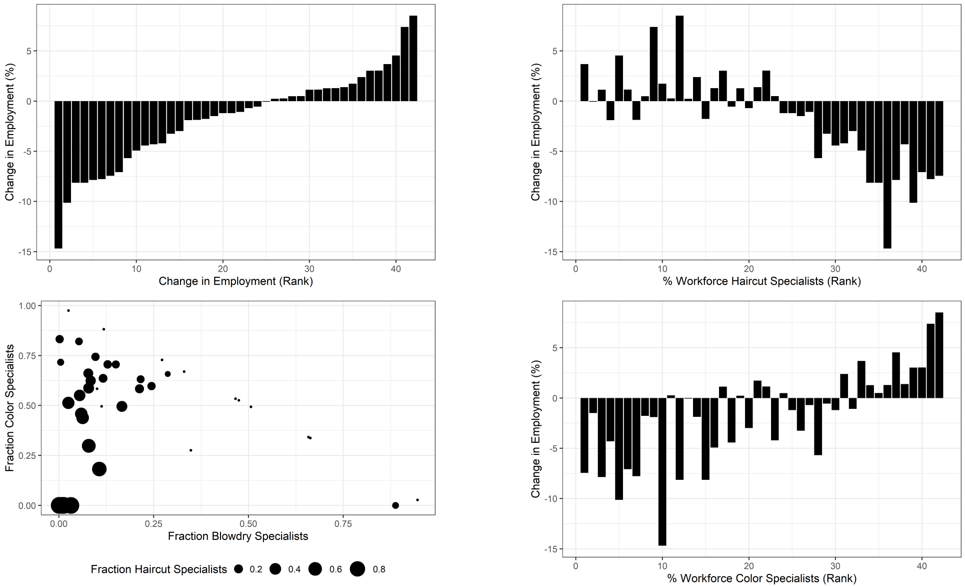
Type	Wage Change	Total Wages Gained/Lost
Haircut/Shave - UNEMPLOYED	-100.00%	-$600,240
Haircut/Shave - EMPLOYED	17.95%	$1,528,205
Color/Highlight/Wash	-0.61%	-$228,453
Blowdry/Style/Treatment/Extension	3.48%	$323,374
Administrative	4.17%	$47,154
Nail/Spa/Eye/Misc.	0.68%	$19,319

Wage Changes by Initial Wage Percentile

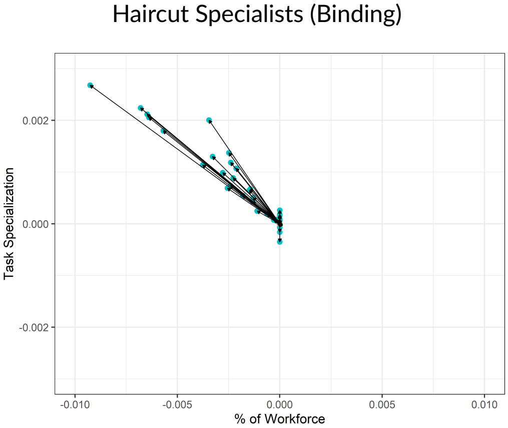


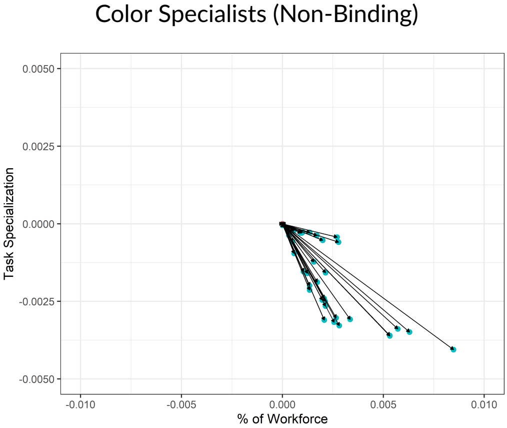
Employment and Wages Technical Details

The Reallocation Effect



The Reorganization Effect





Decomposing Minimum Wage Spillovers

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

	Reorganization Change		
Type	Employment	Task-Spec.	Wage
Haircut/Shave	-0.73%	0.12%	0%
Color/Highlight/Wash	0%	-0.33%	0.52%
Blowdry/Style/Treatment/Extension	0%	0.03%	-1.15%
Administrative	0%	0.03%	-1.05%
Nail/Spa/Eye/Misc.	0%	-0.00%	0.10%

Service Sales Tax Elimination (4.5% to 0%)

Firm Choices

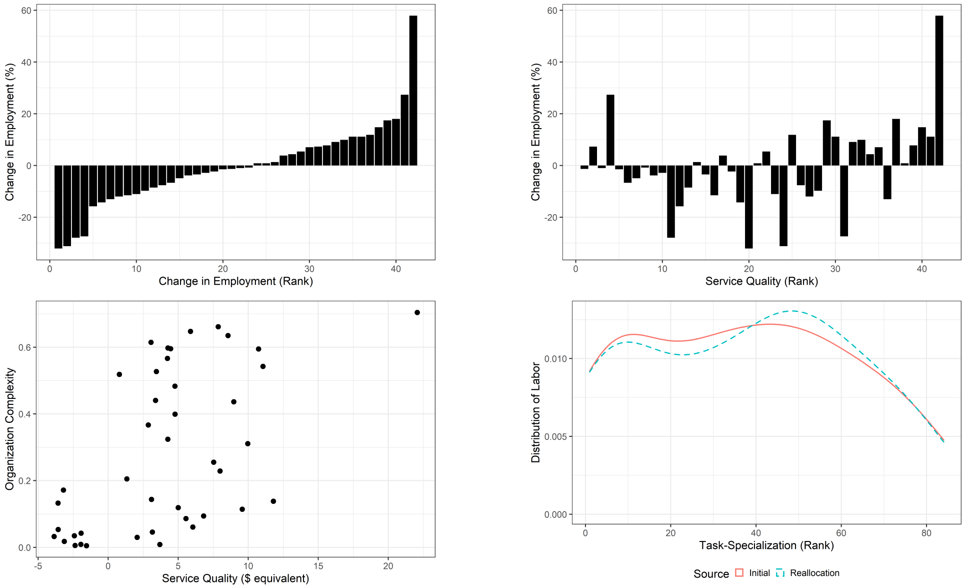
Statistic	Total
Avg. Price	8.68%
Avg. Complexity	5.53%
Avg. Quality	10.03%
Task Specialization	1.83%

Welfare

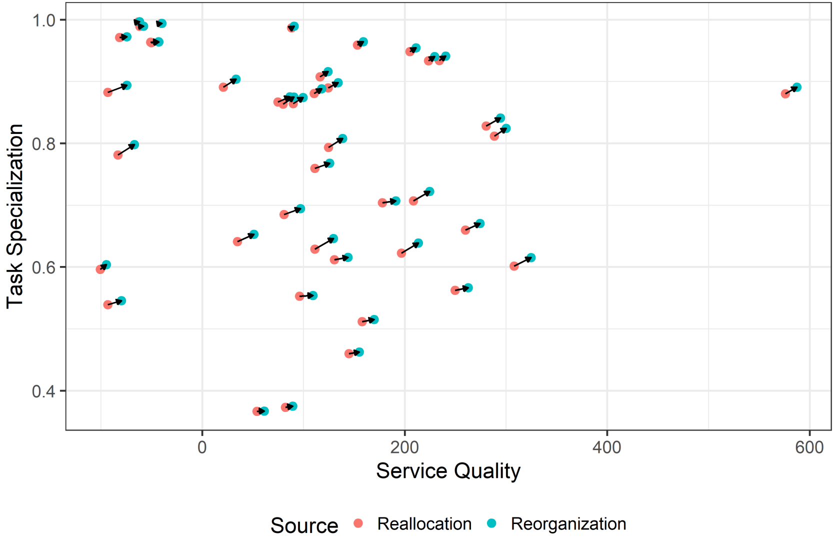
Source	Change	Percent Change
Salon Profit	$942,740	0.58%
Consumer Welfare	-$494,199	-0.30%
Wages	$11,603,777	7.12%
Tax Revenue	-$11,739,300	-7.20%
Total Welfare	$313,017	0.19%

Effects by Worker Type

Sales Tax Elimination Reallocation Effect



Sales Tax Elimination Reorganization Effect



Conclusion

- This paper incorporates firm organizational capabilities into an estimable industry equilibrium model.
- The model is general and can be easily extended.
  - Multiplicative quality (i.e. Kremer's O-Ring)
  - Quantity-based productivity (i.e. manufacturing)
  - Large firms (continuous tasks, worker types)
- Endogenous and heterogeneous internal org $\implies$ classic policies have new effects.
- Many new questions:
  - How does internal organization affect human capital accumulation?
  - How does labor market power impact internal organization?
  - How do workers value generalized or specialized jobs?
  - Are economies with specialized firms less resilient?

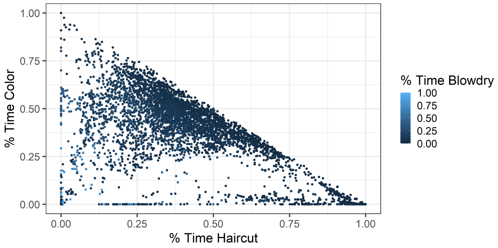
Table of Contents

Firm-Quarter Statistics

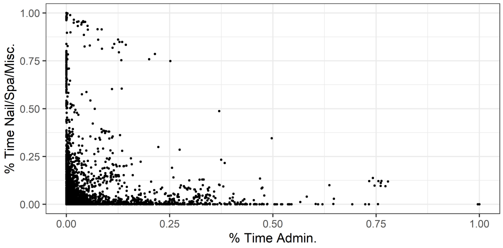
Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Revenue	4,558	213,201.30	248,359.90	5	58,912.5	271,236.5	2,559,703
Price	4,558	199.73	135.16	0.20	111.71	261.88	3,180.44
Employees	4,558	13.38	10.79	1	6	17	92
Customers	4,558	1,159.23	1,098.45	1	397	1,619	16,768
Task Categories	4,558	4.45	0.86	1	4	5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

Back Task-Mix Variation

Task-Mix Variation



(a) Cut, Color, Blowdry



(b) Admin.,Misc.

Back

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:

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

Back

Managerial Attention

- X is the task type, with prior α. 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 γ_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:

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

Back

Revenue Regressed on Complexity

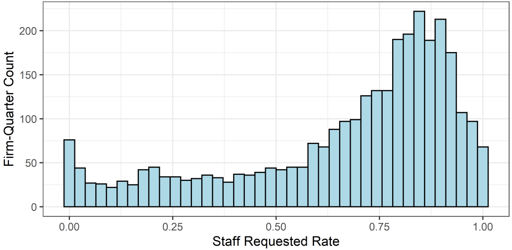
Model:	(1)	(2)	(3)	(4)	(5)	(6)
Organization Complexity	456571.3***	440904.1***	485026.4***	486995.5***	271694.6**	261697**
	(100394.8)	(108427.1)	(116918.9)	(125004.8)	(87031.1)	(80920.6)
Staff Request Rate						-94370.7
						(89112.9)
Task Mix Control				Yes	Yes	Yes
Fixed-effects						
Quarter-Year		Yes	Yes	Yes	Yes	Yes
County			Yes	Yes	Yes	Yes
Firm Size					Yes	Yes
Fit statistics						
Observations	5,116	5,116	5,116	5,116	5,116	5,116
R^2	0.01475	0.01915	0.3104	0.31047	0.34273	0.34365

Clustered standard-errors in parentheses

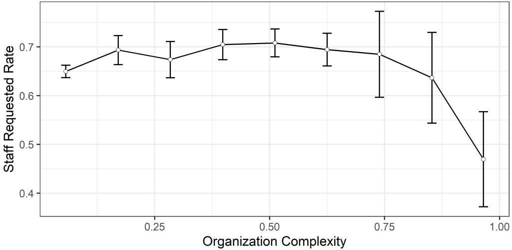
*Signif. Codes: ***: 0.001, **: 0.01, *: 0.05*

Back

Was Staff Requested?



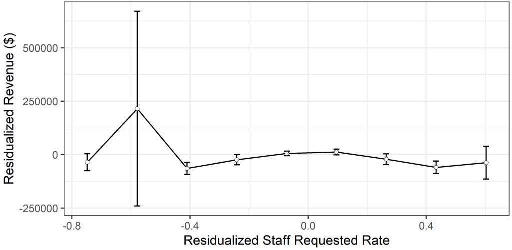
(a) Histogram



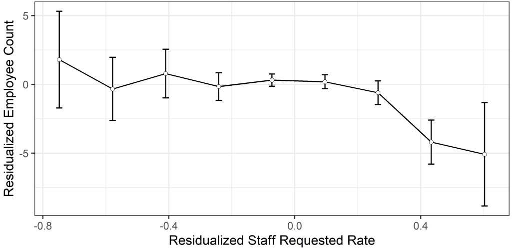
(b) Request Rate and Complexity

Back

Was Staff Requested?



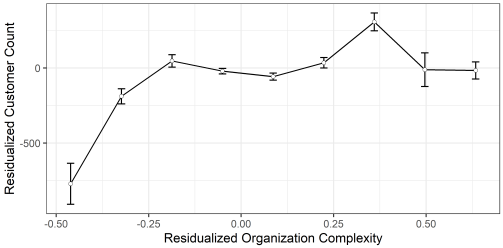
(a) Revenue



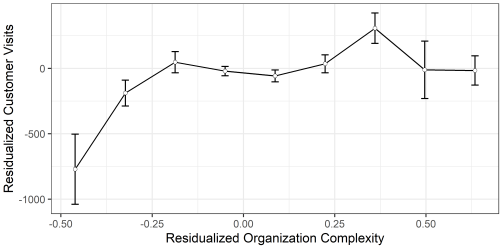
(b) Employees

Back

Relationship Between Complexity and Customers/Visits



(a) Customers



(b) Visits

Back

Firm Size and Complexity Regressions

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

Back

Manhattan Firm Size and Complexity Regressions

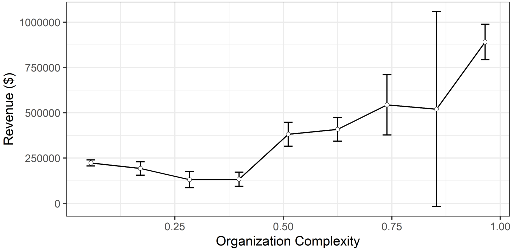
Dependent Variables:	Revenue	Employees	Utilized Labor	Customers	Visits
Model:	(1)	(2)	(3)	(4)	(5)
Variables					
Org. Complexity	430406.6*	12.55	-17733.9	277.2	876.9
	(179977.4)	(6.531)	(70765.2)	(600)	(907.1)
Fixed-effects					
Quarter-Year	Yes	Yes	Yes	Yes	Yes
Fit statistics					
Observations	595	595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

Clustered standard-errors in parentheses

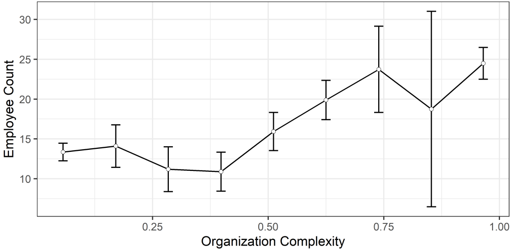
*Signif. Codes: ***: 0.001, **: 0.01, *: 0.05*

Back

Fact 2: Complex salons have higher revenue and employment



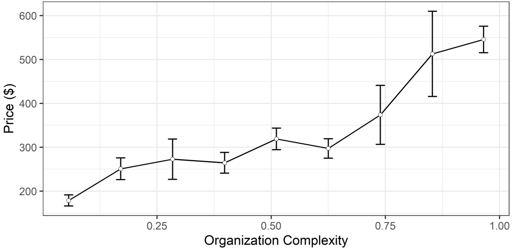
(a) Revenue



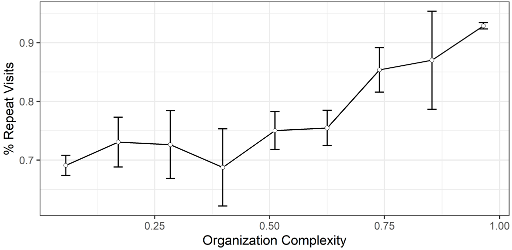
(b) Employees

Back

Fact 3: Complex salons have higher prices and repeat customers



(a) Prices



(b) Repeat Customers

Back

Quantity Model Implies Price $\downarrow$ Complexity

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

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.[1]
- There always exists B_j^* which solves the equivalent problem.[2]
- 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.

Back

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:

$$= \xi(B_j^*) - \rho[p_j' + \gamma_j I(B_j^*) + W(B_j^*) - \gamma_j I(B_j') - W(B_j')] \tag{1}$$

$$= \xi(B_j^*) - \rho[p_j' + \gamma_j I(B_j^*) + W(B_j^*) - \gamma_j I(B_j') - W(B_j')] + \xi(B_j') - \xi(B_j') \tag{2}$$

$$= \xi(B_j') - \rho[p_j' + \gamma_j I(B_j^*) + W(B_j^*) - \gamma_j I(B_j') - W(B_j') - \rho^{-1}\xi(B_j^*) + \rho^{-1}\xi(B_j')] \tag{3}$$

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

$$\geq \xi(B_j') - \rho p_j' \tag{5}$$

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.

Back

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 γ:

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

Back

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 γ.
- Thus profit and complexity will be positively correlated via γ.

Back

Profit Under the Econometric Model

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

Back

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:

$$B^t_{i,k} = \alpha_k \frac{V_{i,k} E^t_k}{\sum_i E^t_i V_{i,k}}$$

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

$$E^{t+1}_i = \sum_k B^t_{i,k}$$

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.

Back

Consumer Welfare

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

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

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, ρ. Our measure of total consumer welfare in dollar terms is:

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

With a sales tax τ, it is:

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

Back

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.

Back

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

    Distraction-Free Property (Tian 2019)

  - 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

  RD Equivalence (Blahut 1972)
  - $\tilde{I}(\Omega, \gamma_j, \alpha_j)$ can be arbitrarily well approximated by the Blahut-Arimoto algorithm

Back

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 γ_j.

- I_j^* is decreasing in Q_j when $I_j^* > 0$ thus decreasing in γ_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 γ_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

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: Matêjka and McKay (2015)

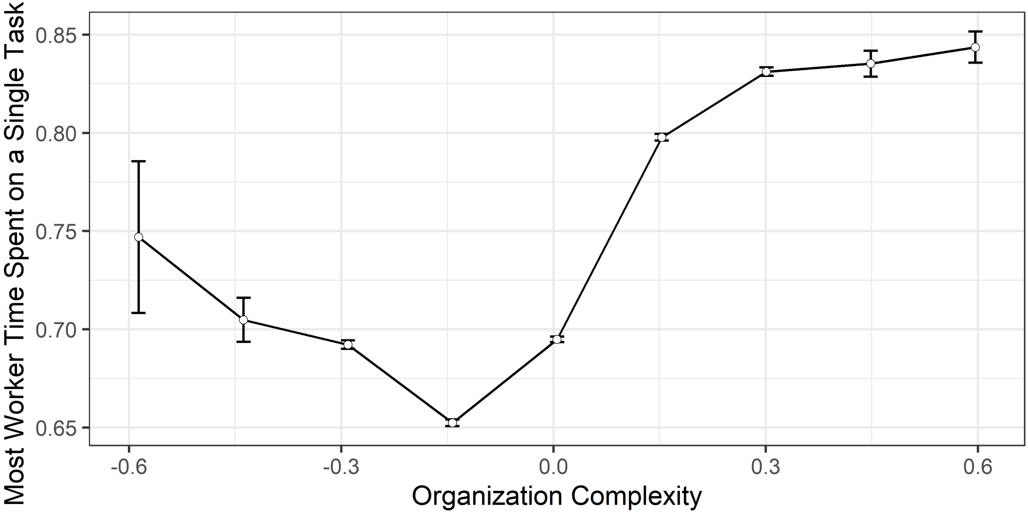
Back

Minimum Wage Counterfactual Employment and Wages

	Initial		Reallocation		Counterfactual	
Worker Type	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

Back

Regressions of Worker Specialization on Organization Complexity



Back

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:

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

Back

Sales Tax Elimination Effects by Worker Type

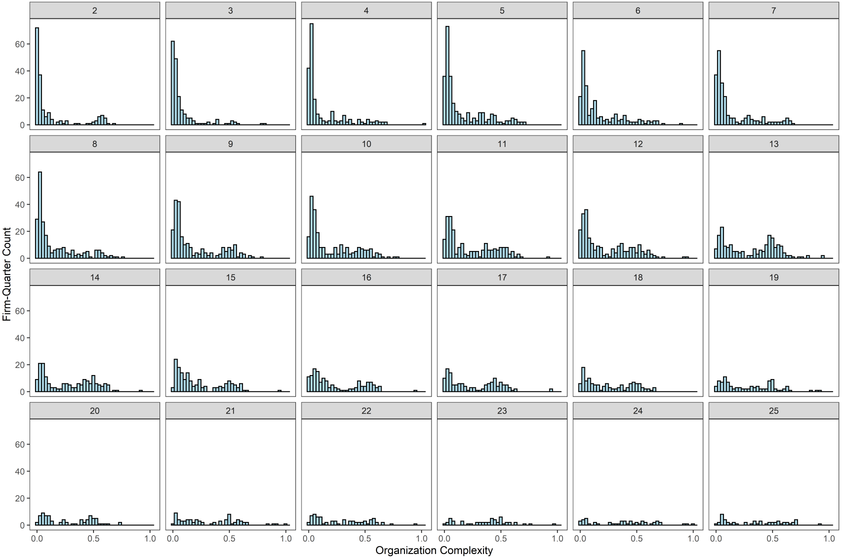
Type	Wage Change	Task-Spec. Change
Haircut/Shave	31.99%	0.29%
Color/Highlight/Wash	20.09%	2.57%
Blowdry/Style/Treatment/Extension	6.06%	3.01%
Administrative	17.99%	1.03%
Nail/Spa/Eye/Misc.	12.74%	2.39%

Back

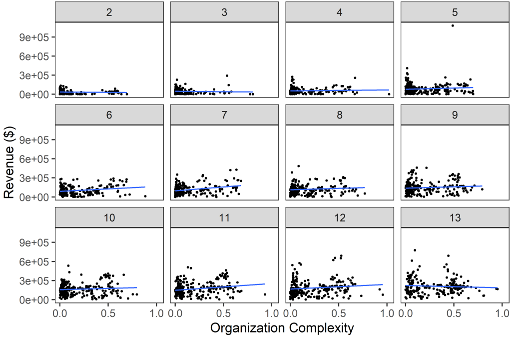
Minimum Wage Welfare Effects

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%

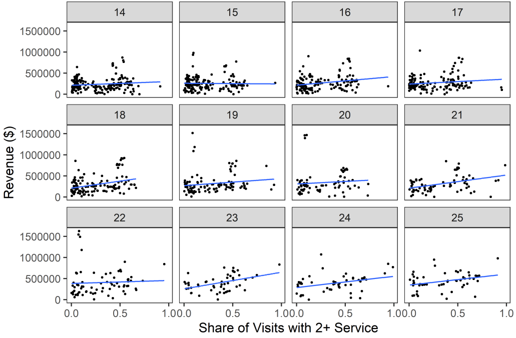
Complexity Histograms Among Similar Size Firms



Revenue and Complexity Among Similar Size Firms



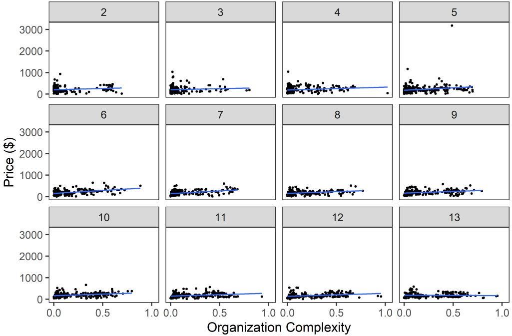
(a) 2-13 Employees



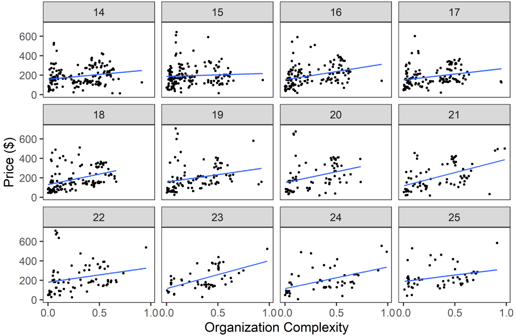
(b) 14-25 Employees

Back

Price and Complexity Among Similar Size Firms



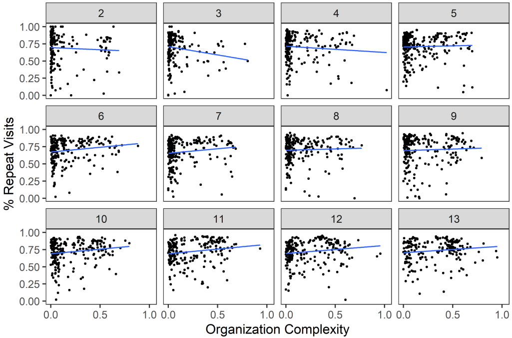
(a) 2-13 Employees



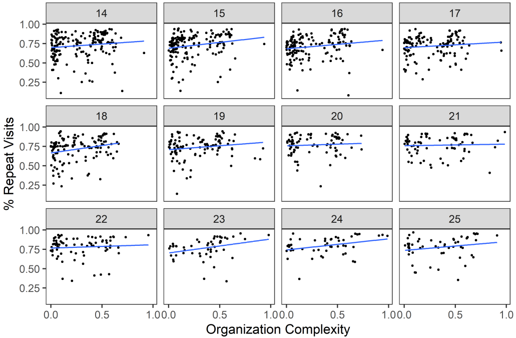
(b) 14-25 Employees

Back

Repeat Visits and Complexity Among Similar Size Firms



(a) 2-13 Employees



(b) 14-25 Employees

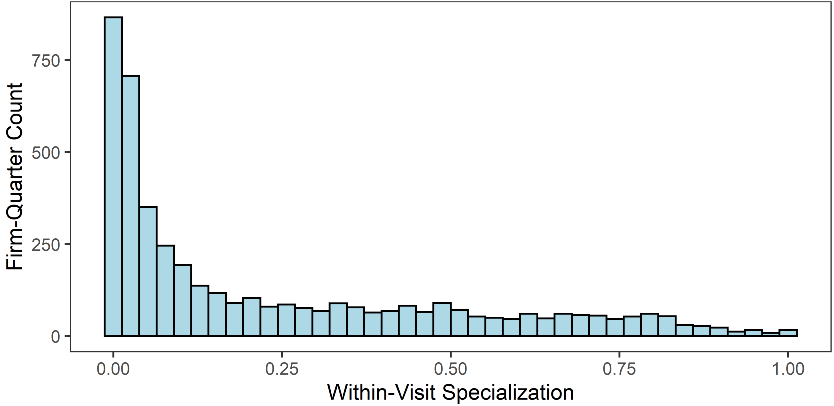
Back

Within-Visit Specialization

- Within-visit specialization: the number of customer visits[3] 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.

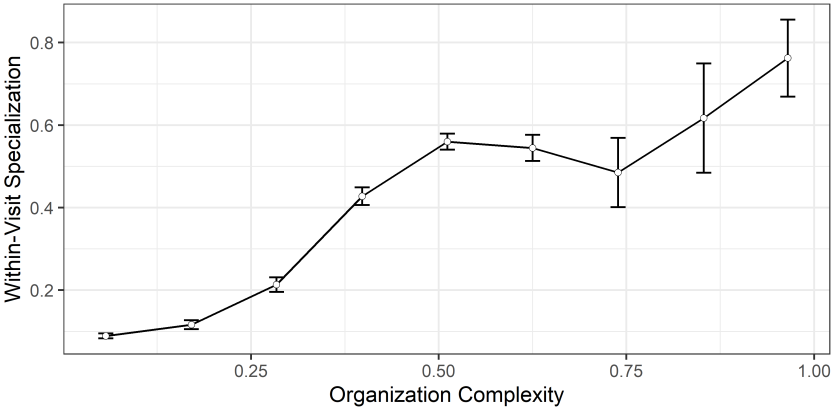
3. Visits are the number of unique customer-date pairs in a quarter.

Within-Visit Specialization Histogram

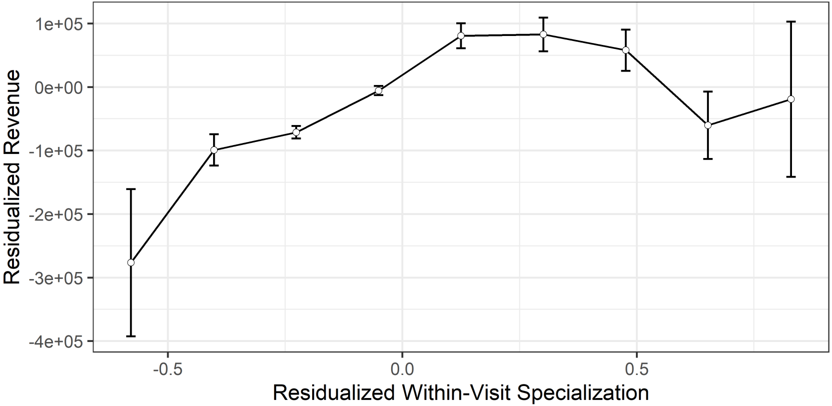


Back

Within-Visit Specialization and Complexity

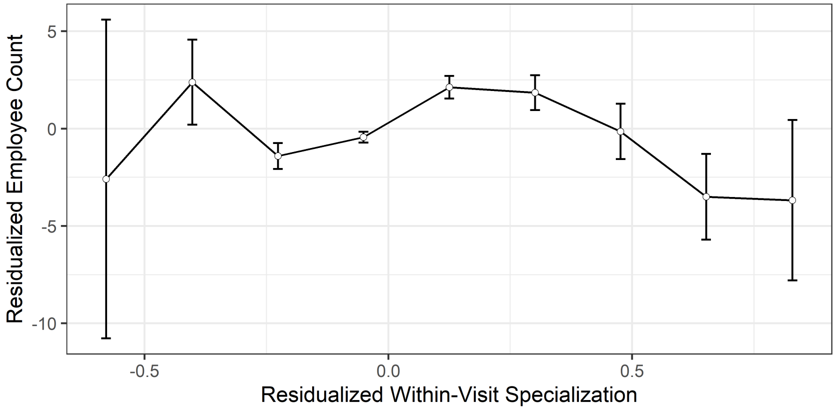


Within-Visit Specialization and Revenue



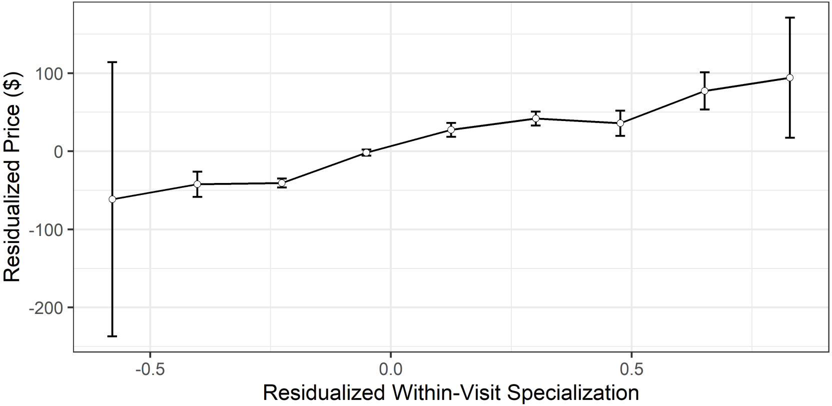
Back

Within-Visit Specialization and Employees



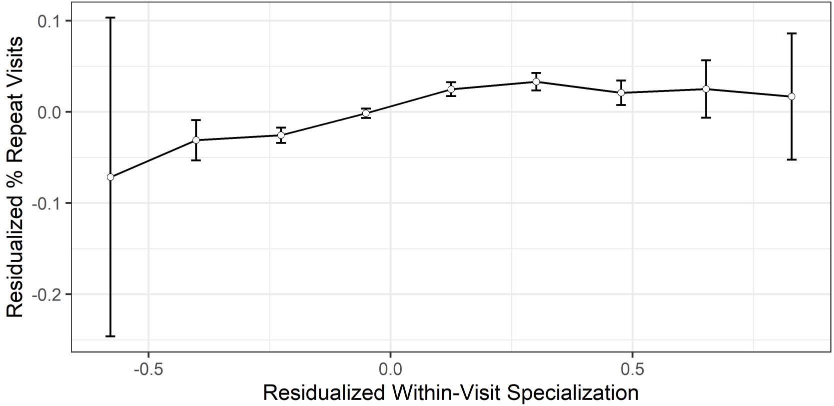
Back

Within-Visit Specialization and Price



Back

Within-Visit Specialization and Repeat Visits



Back

Estimated Organization Structures

		Task					
		Cut	Color	Blow Dry	Admin.	Nail/Misc.	Total
Specialist	Cut	0.15	0.01	0.001	0.06	0	0.22
	Color	0	0	0	0	0	0
	Blow Dry	0	0	0	0	0	0
	Admin.	0.31	0.03	0.003	0.45	0	0.784
	Nail/Misc.	0	0	0	0	0	0
	Tot.	0.455	0.036	0.004	0.505	0	1

(a) Salon 1, $I_j = 0.03$

		Task					
		Cut	Color	Blow Dry	Admin.	Nail/Misc.	Total
Specialist	Cut	0.180	0.003	0	0.006	0.003	0.193
	Color	0.057	0.553	0	0.016	0.009	0.116
	Blow Dry	0.012	0.002	0.097	0.003	0.002	0.636
	Admin.	0	0	0	0	0	0
	Nail/Misc.	0.004	0.001	0	0.001	0.050	0.055
	Tot.	0.253	0.559	0.097	0.026	0.064	1

(b) Salon 2, $I_j = 0.70$

Back

Variation in Job Task Content

Across Firms

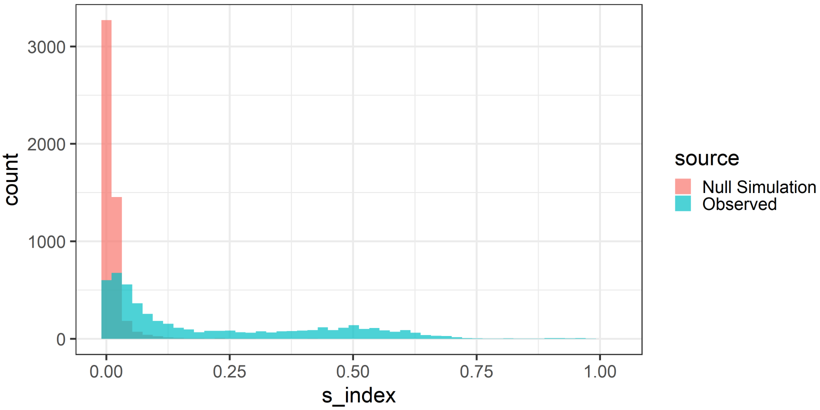
Task	Share of Labor	Share of Variance	
		Firm	Within-Firm
Haircut/Shave	0.4049	0.3744	0.6256
Color/Highlight/Wash	0.3902	0.2899	0.7101
Blowdry/Style/Treatment/Extension	0.0850	0.5056	0.4944
Administrative	0.0590	0.4900	0.5100
Nail/Spa/Eye/Misc.	0.0610	0.4124	0.5876

Across Quarters

Task	Share of Labor	Share of Variance	
		Quarter	Within-Quarter
Haircut/Shave	0.4049	0.0057	0.9943
Color/Highlight/Wash	0.3902	0.0062	0.9938
Blowdry/Style/Treatment/Extension	0.0850	0.0111	0.9889
Administrative	0.0590	0.0193	0.9807
Nail/Spa/Eye/Misc.	0.0610	0.0118	0.9882

Back

Simulated Complexity with Random Org. Structure



Back