The Inner Beauty of Firms

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Motivation

- Organizational differences are well-documented across firms.
- Motivating Question: Do these differences matter?
- They determine firm ability to make use of individual talents.

Motivation

- Research Question: How does internal organization interact with product and labor markets?
- Empirical Challenge: Rarely observe task assignments within competing firms.
- Theoretical Challenge: Do not have a model where firms with different abilities choose their structure based on product/labor market conditions.

This Paper

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 and Estimation for Manhattan Hair Salons: Firm-specific org. costs are identified. Provide a computationally light estimation procedure.

4. Policy Experiments
   - Minimum wage to $20: ↓ position of firms intense in min. wage workers, ↓ tasks assigned to minimum wage workers within firms
   - Eliminate Sales Tax: ↑ position of specialized firms, ↑ specialization within firms

Contributions

- To the Labor Literature on Tasks: Incorporate product market power, specialization costs, horizontal worker skills, firm-level task data
  - Lazear 2009, Haanwinckel 2020, Adenbaum 2021
- To Organizational Economics: Measure heterogeneity in organizational capabilities and understand how it impacts economic outcomes
  - Baker, Gibbons, and Murphy 2002 (relational contracts), Garicano and Wu 2012 (knowledge), Meier, Stephenson, and Perkowski 2019 (trust), Martinez et al. 2015 (culture)

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Data

- Salon management software company founded in 2016
- Clients concentrated in New York City and Los Angeles, but scattered salons throughout US
- 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.

Why Aggregation?

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
Organization Complexity	4,558	0.22	0.22	0.00	0.03	0.42	1.02
Share Haircut/Shave	4,558	0.41	0.23	0.00	0.26	0.52	1.00
Share Color/Highlight/Wash	4,558	0.38	0.20	0.00	0.29	0.52	1.00
Share Blowdry/Style/Treatment/Extensions	4,558	0.09	0.12	0.00	0.03	0.11	1.00
Admininstrative	4,558	0.05	0.11	0.00	0.002	0.04	1.00
Nail/Spa/Eye/Misc.	4,558	0.06	0.16	0.00	0.00	0.05	1.00

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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"Employee" Salon

Employee	Tasks: 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	

"Chair Renter" Salon

	Tasks: 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	

Task-Mix

What is Organizational Complexity?

Definition 2

The complexity of an organization structure B_j is:

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

- Intuition: the amount of instructions (measured in bits) that must be communicated within the firm to implement B_j
  - Data plan required to communicate assignments to employees

- Several Micro-Foundations: Manager Attention | Task-Specialization | Highly Correlated with Specialization

Complexity of the Two Structures

"Employee" Salon

Employee	Tasks: 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	

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	Tasks: 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	

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

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

Randomly match tasks and workers

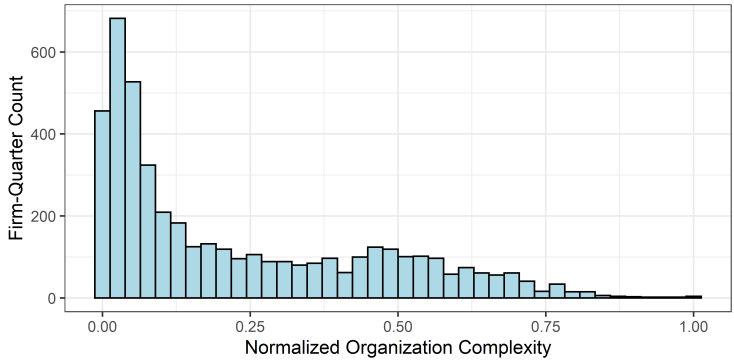
If cut send nothing roll dice

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.

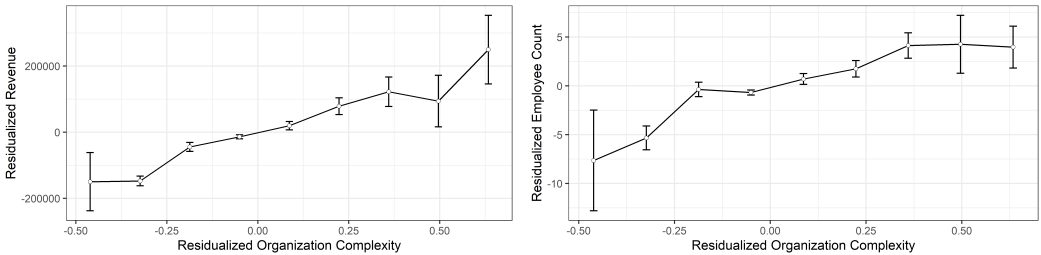


$$I_{j,t} = \bar{I}_j + \bar{I}_t + e_{j,t}$$

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

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

Fact 2: Complex salons have higher revenue and employment

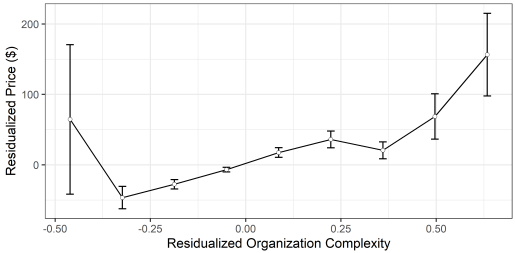


(a) Revenue (b) Employees

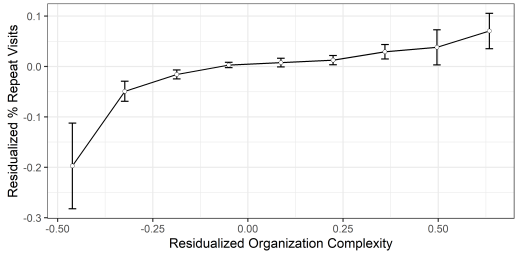
Regressions | Manhattan | Manhattan Regs. | Customers and Visits

Takeaway: There is an organizational competitive advantage.

Fact 3: Complex salons have higher prices and repeat customers



(a) Prices



(b) Repeat Customers

Manhattan Only

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 parameter $\alpha \in \mathbb{R}_+^K$
  - Producing 1 unit requires assigning α_k labor to task k. Normalize $\sum_k \alpha_k = 1$

N Worker Types

- Skill set $\theta_i = \{\theta_{i,1}, ...\theta_{i,k}, ...\theta_{i,K}\}$
- 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 $p_j \in \mathbb{R}_+$

Mass M Consumers

- 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.

The Firm's Problem

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

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

Equilibrium

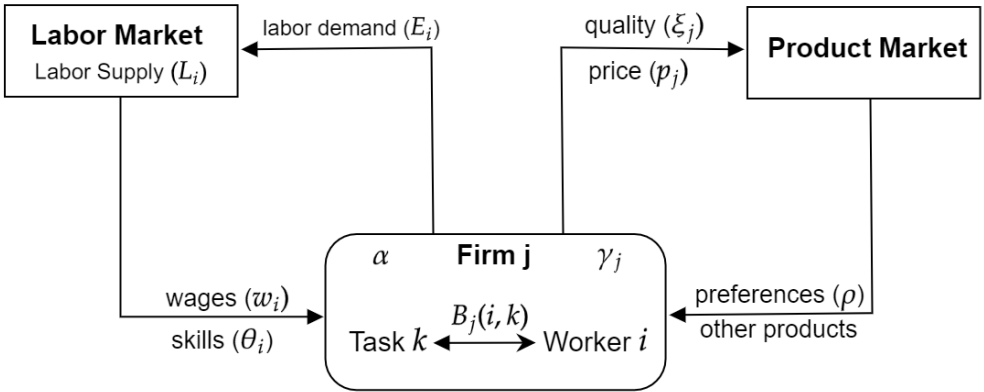
An equilibrium consists of firm strategies $\{p_j, B_j\}_{j=1}^{J}$ and wages w such that:

1. Firm strategies maximize profits.

2. Labor markets for each worker type clear:

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

Summary of the Model



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Characterizing the Firm's Problem

Theorem

The profit-maximizing organizational structure B^* also solves:

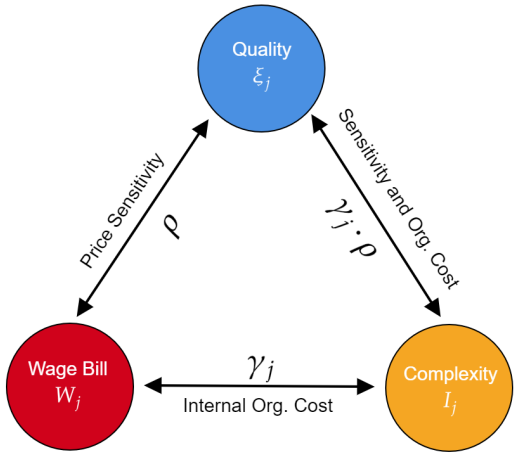
$$\min_{B_j \in \mathbb{B}} I(B_j) + \gamma^{-1}\left[W(B_j) - \rho^{-1}\xi(B_j)\right] \tag{1}$$

- (1) is a rational inattention problem with MI cost function (behavioral econ)
- (1) is a rate-distortion problem (information theory)
- B_j depends on other salon actions only indirectly via wages.

Proof

The Complexity-Wage-Quality Trilemma

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



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

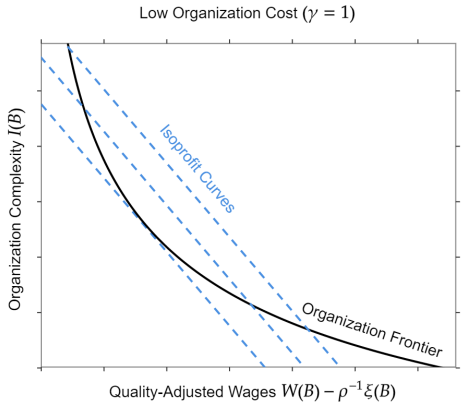
The organization frontier is the set of organization structures which minimize complexity for some quality-adjusted wages.

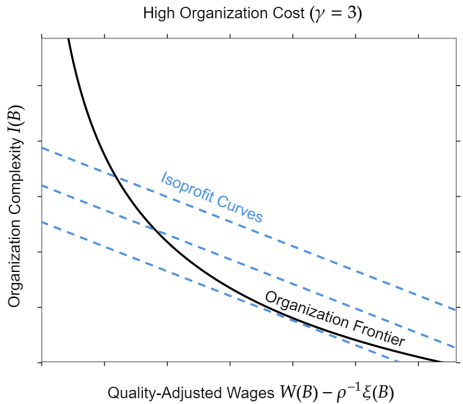
Because this is a rate-distortion problem:

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 (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
   - Price-complexity relationship depends on parameters.
   - Quality is the main benefit of complexity.

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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.
- 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
  - For example: two color specialists may supply different number of 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

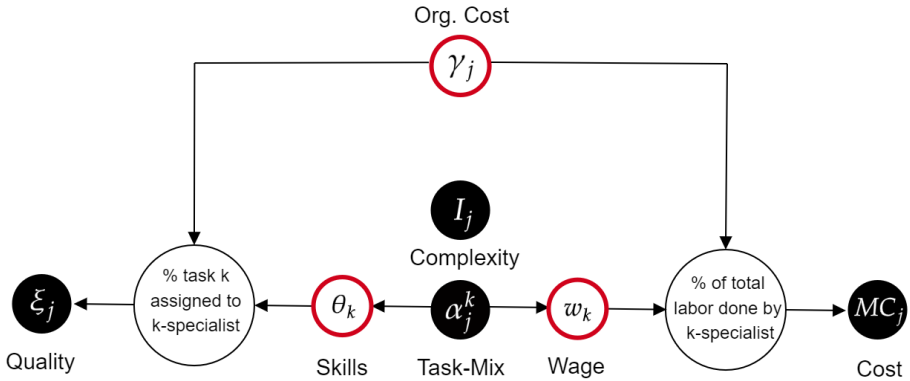
- A natural notion of task-specialization:

Definition 3

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

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

Identification Problem



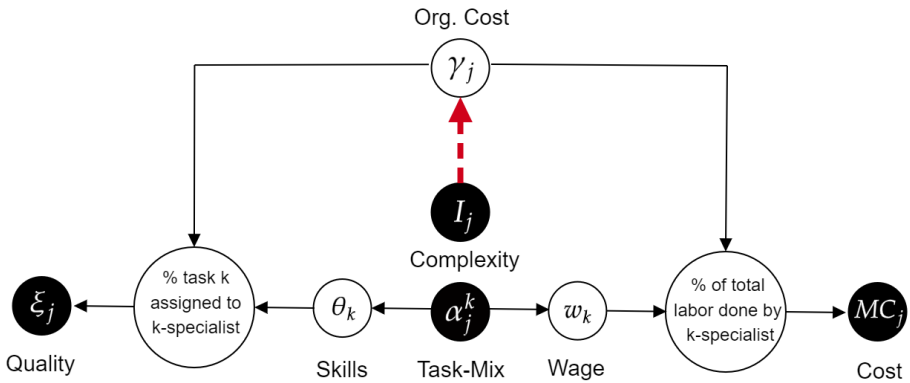
Identification: Firm-Specific Organization Costs γ_j

Proposition 1

Organization costs (γ_j) and organization structures (B_j) are a known function of firm task-mixtures (α_j), complexities (I_j) and market parameters (Ω) for all firms with positive complexity, except for a set of market parameters with measure 0. Visual Intuition

- $\{\gamma_j\}_{j=1}^{J}$ do not need to be estimated
- α_j, I_j are sufficient for the internal organization of the firm
- There is a one-to-one mapping from observed complexity to unobserved γ_j
- 2-part Proof: Complexity = Mutual Information | Essential Equilibrium Uniqueness

Identification: Firm-Specific Organization Costs γ_j



Identification: Market Parameters

- Use firm price FOC (supply side moments):

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

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

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

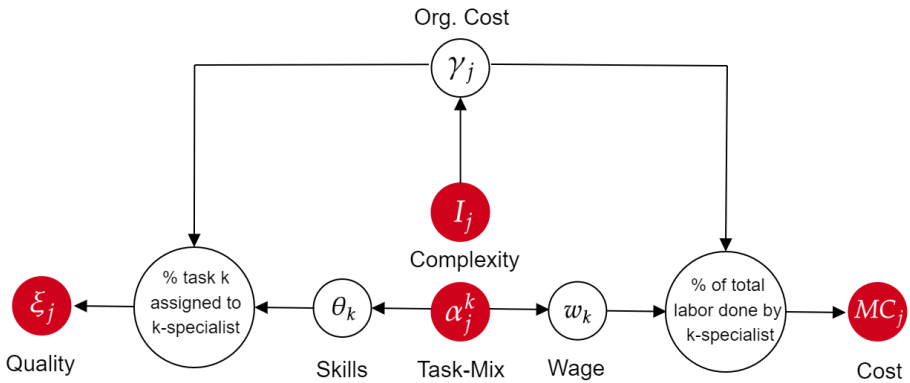
- Match avg. beauty salon QCEW wage bill with measurement error:

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

- The model is globally identified if Ω uniquely satisfies:

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

Identification: 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 get γ_j
  - Must solve for γ_j 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

Estimation Routine Summarized

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.

Nested fixed-point GMM, similar to Berry, Levinsohn, and Pakes (1995)

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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)

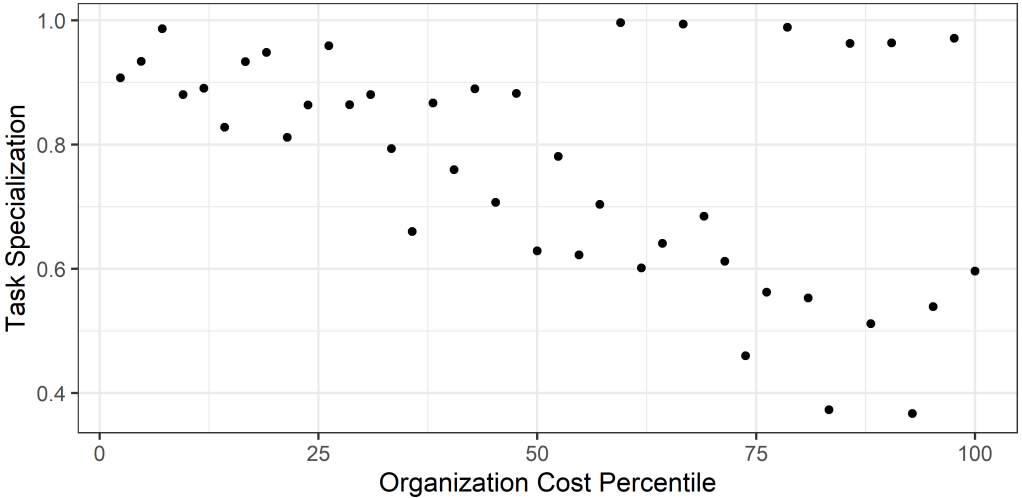
Standard errors from 500 bootstrap replications in parentheses.
* indicates significance at the 0.05 level.

Equilibrium Task Specialization Across Workers

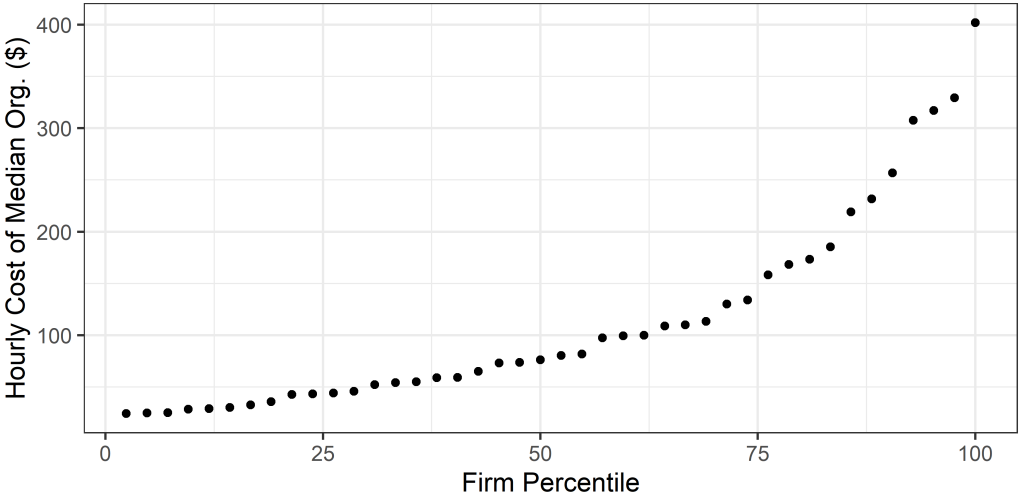
All Tasks

Specialty v.s. Other Tasks

Equilibrium Task Specialization Across Firms



Cost of Median Complexity Organization Across Firms



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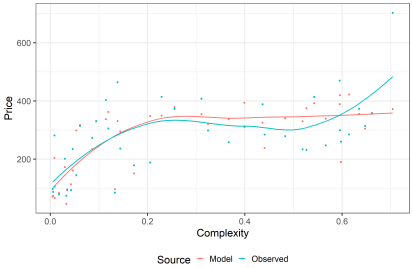
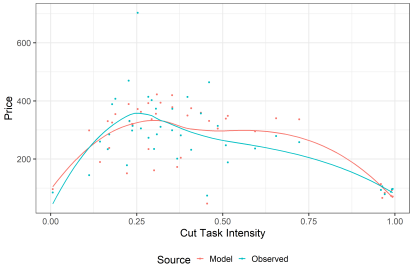
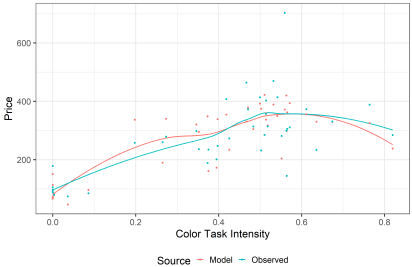
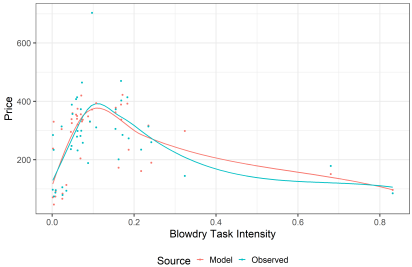
Fit: Supply Side Relationships









Validation: The Task Content of Jobs

Model generated jobs:

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

	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

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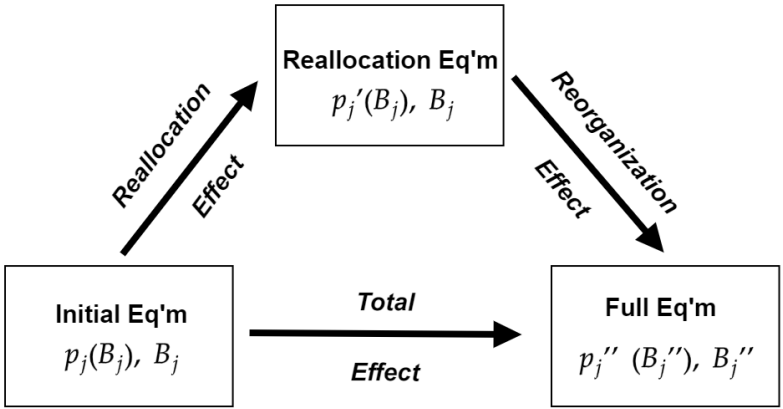
Counterfactual Implementation

- 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 org. structures to solve for prices.
  3. Check labor market clearing, if not return to 1 and repeat.
  4. Compute consumer welfare using closed form.

Decomposing Mechanisms

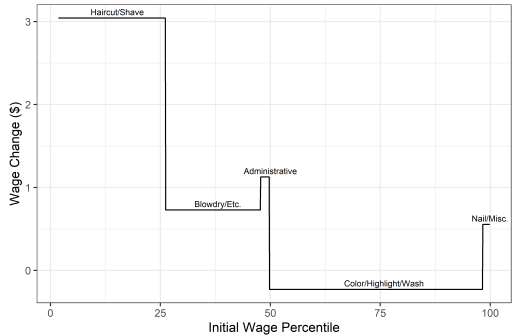


Minimum Wage Increase from $15 to $20

Wages Changes

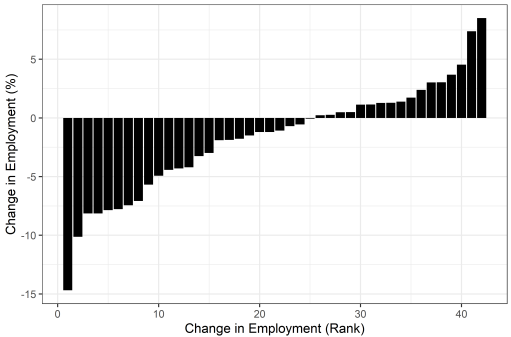
Type	Wage Change	Total Wages Gained/Lost
Haircut/Shave - UNEMPLOYED	-100.00%	-$600,240
Haircut/Shave - EMPLOYED	17.95%	$1,528,205
Color/Highlight/Wash	-0.61%	-$228,453
Blowdry/Style/Treatment/Extension	3.48%	$323,374
Administrative	4.17%	$47,154
Nail/Spa/Eye/Misc.	0.68%	$19,319

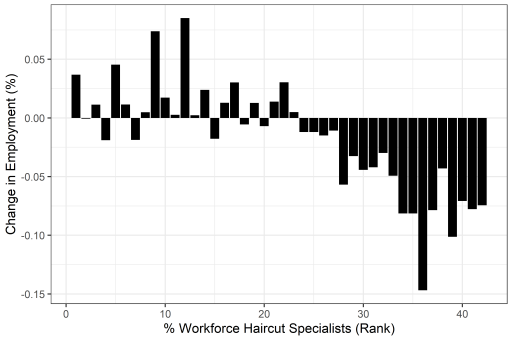
Wage Changes by Initial Wage Percentile



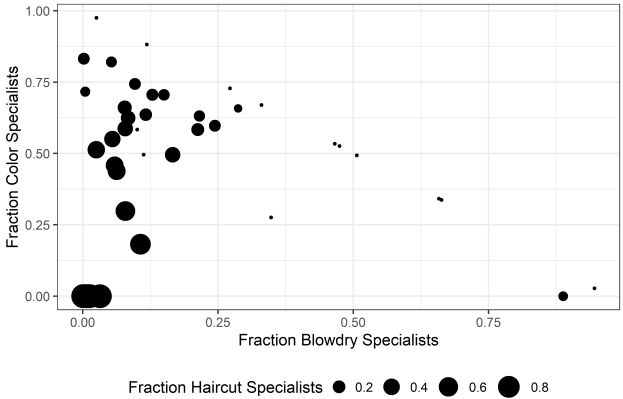
Employment and Wages | Technical Details

The Reallocation Effect





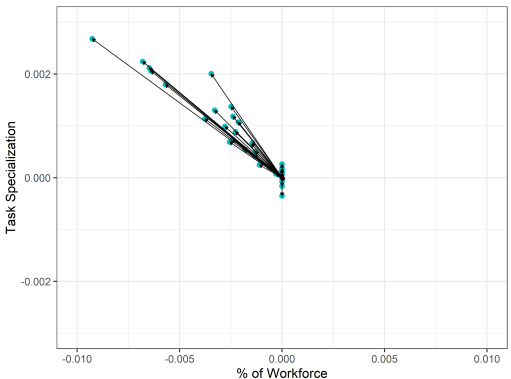
The Reallocation Effect: Wage Spillovers



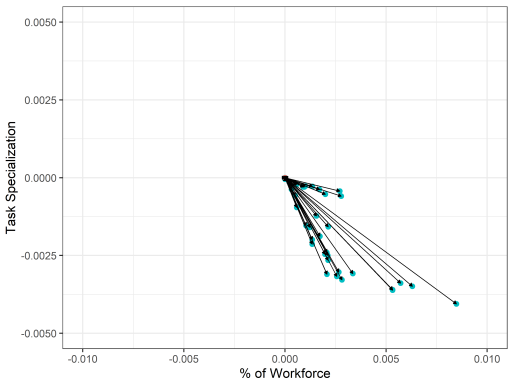
	Reallocation Change	
Type	Employment	Wage
Haircut/Shave	-5.85%	17.95%
Color/Highlight/Wash	0%	-1.13%
Blowdry/Style/Treatment/Extension	0%	4.63%

The Reorganization Effect

Haircut Specialists (Binding)



Color Specialists (Non-Binding)



The Reorganization Effect: Wage Spillovers

Type	Reorganization Change		
	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

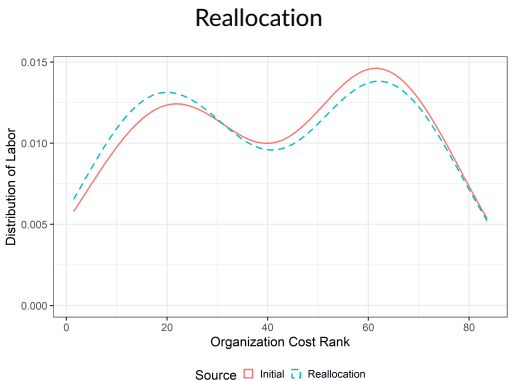
Statistic	Total
Avg. Price	8.68%
Avg. Complexity	5.53%
Avg. Quality	10.03%
Task Specialization	1.83%

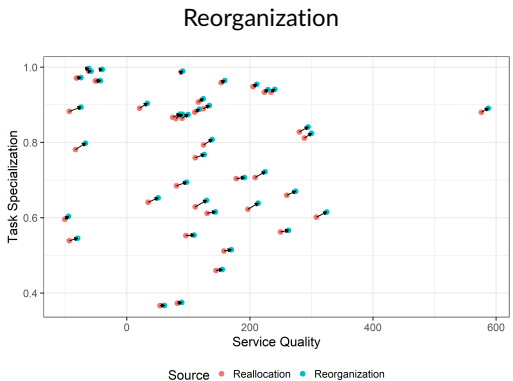
Welfare

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

Service Sales Tax Elimination (4.5% to 0%)





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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 of Results

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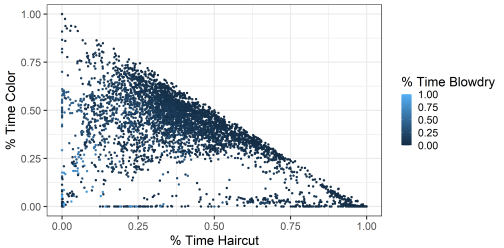
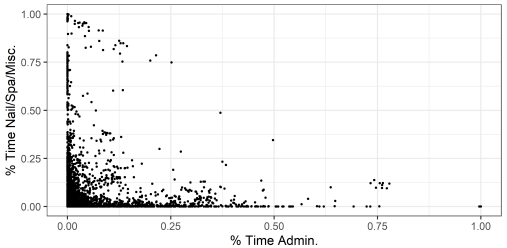
Task-Mix Variation



(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:

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

$$= \sum_i E_i \sum_k b_i(k) log\left(\frac{b_i(k)}{\alpha_k}\right) = \sum_i E_i \sum_k b_i(k) log\left(\frac{b_i(k)}{b_j^G(k)}\right)$$

$$= \sum_i E_i D_{KL}(b_i || b_j^G)$$

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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 $\gamma I(Z, X)$ where I is the mutual information:

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

Jung et al. (2019) (and others) show this is equivalent to:

$$\max_{B_j} \mathbb{E}[m(X, Y)] - \gamma I(X, Y)$$

- Thus complexity measures the attention paid to assignments.

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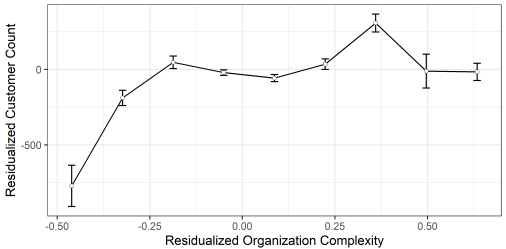
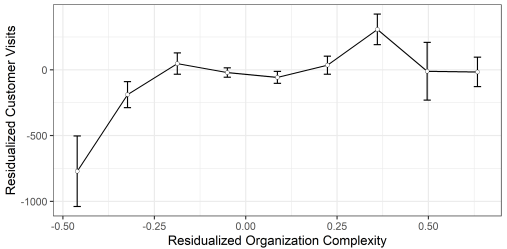
Relationship Between Complexity and Customers/Visits



(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)
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*

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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*

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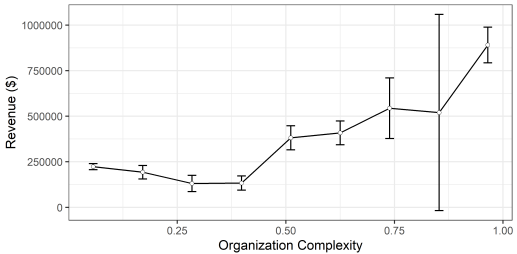
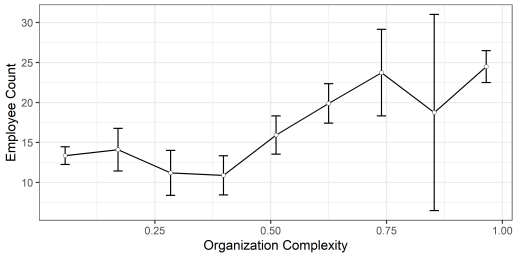
Fact 2: Complex salons have higher revenue and employment



(a) Revenue



(b) Employees

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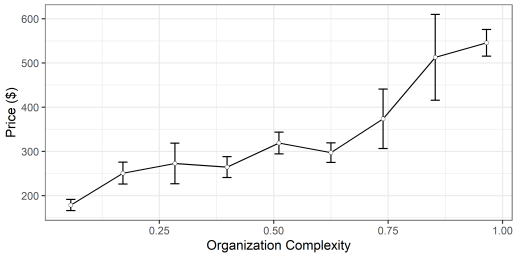
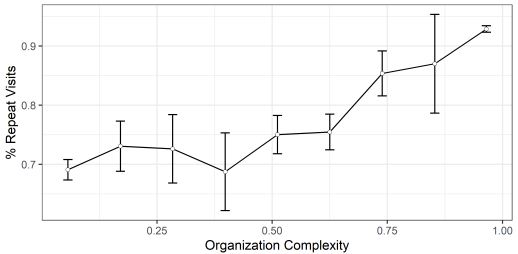
Fact 3: Complex salons have higher prices and repeat customers



(a) Prices



(b) Repeat Customers

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Quantity Model Implies Price ↓ Complexity

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

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.

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Proof of Main Result: Part 1/3

Take the FOC of profit to get the best-response price:

$$p_j^* = \frac{1}{\rho(1 - s_j)} + MC_j$$

Once this is plugged into profit, I prove:

Lemma 4

Maximized profit depends on organization structure only through quality-adjusted cost. Additionally, maximized profit is strictly decreasing in quality-adjusted cost.

Firms choose an organization structure which achieves the lowest quality-adjusted marginal cost:

$$\min_{B_j \in \mathbb{B}_j} MC_j(B_j) - \rho^{-1}\xi_j(B_j) \tag{2}$$

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Proof of Main Result: Part 2/3

$$\min_{B_j \in \mathbb{B}_j} MC_j(B_j) - \rho^{-1}\xi(B_j) = \min_{B_j \in \mathbb{B}} W(B_j) + \gamma_j I(B_j) - \rho^{-1}\xi_j(B_j) \tag{3}$$

$$= \gamma_j \min_{B_j \in \mathbb{B}} \left\{ I(B_j) + \gamma_j^{-1} \left[W(B_j) - \rho^{-1}\xi(B_j) \right] \right\} \tag{4}$$

I can re-write 4 as a maximization problem:

$$\max_{B_j \in \mathbb{B}} \left\{ \sum_{i,k} B_j(i,k)(\rho^{-1}\theta_{i,k} - W_i) \right] - \gamma_j I(B_j) \right\} \tag{5}$$

Comparing 5 to formulations in Jung et al. (2019) illustrates that this is a linear rational inattention problem.

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Proof of Main Result: Part 3/3

I re-write 4 one last time:

$$\gamma_j \min_{B_j \in \mathbb{B}} \left\{ I(B_j) + \gamma_j^{-1} \sum_{i,k} B_j(i,k)(W_i - \rho^{-1}\theta_{i,k}) \right] \right\} \tag{6}$$

Comparing 6 to formulations in like Equation 6 in Tishby, Pereira, and Bialek (2000) demonstrates this is well-understood minimization problem from information theory called a rate-distortion problem.

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Proof of Frontier Shape and Profit Increasing

- Denote Q as quality-adjusted wages. Because the problem is an RD problem:

$$\min_{Q} R(Q) + \gamma^{-1} Q$$

  where R is continuous, convex and decreasing. Taking the cross-partial derivative:

$$\frac{\partial R(Q) + \gamma^{-1} Q}{\partial Q \partial \gamma} = -\gamma^{-2} \leq 0$$

- This implies decreasing differences, which implies Q is increasing in γ_j.
- $R(Q)$ is decreasing, therefore complexity is increasing in γ_j
- Envelope condition implies quality-adjusted marginal cost is decreasing in γ_j.
- Profit and quantity are decreasing in quality-adjusted marginal cost, therefore they are decreasing in γ_j. 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.

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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 excluded.
- I do this for all possible binding combinations (2^5).
- There is only one equilibrium.

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Consumer Welfare

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

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

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

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

With a sales tax τ, it is:

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

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Equilibrium Uniqueness

Proposition 4

Suppose wages are fixed parameters. A pure strategy equilibrium exists, and is unique for almost any parameter values.

Proof Sketch:

- Bertrand oligopoly with logit demand has unique NE — Caplin and Nalebuff (1991)
- Profit is strictly incr. in quality-adjusted cost — Algebra + Aravindakshan and Ratchford (2011)
- Quality-adjusted cost matrices with mult. equilibria is null — Lipnowski et al. (2022)
- QA matrices are function F of params. Jacobian of F is rank $N \times K$
- Parameters which generate mult. equilibria are measure 0

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Identification Proof Sketch

- All workers with the same skill set are assigned the same distribution of tasks.
- To see why, suppose not. Then we can take any pair of tasks where the two have different distributions, and re-distributed so that they are more similar.
- Reduces org. cost, does not change wage or quality. This contradicts optimality.
- This with algebra implies complexity wrt identities is equal to complexity wrt just skill set.
- When $I_j > 0$, we have that I_j is strictly decreasing in γ_j.

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Condition for Uniqueness

For price uniqueness use Caplin and Nalebuff (1991). For uniqueness of B_j we require this condition derived from Matêjka and McKay (2015):

Assumption

Define the wage-quality vector of a worker of type i as $v_i = \{w_i - \rho^{-1}\theta_{i,k}\}_{k=1}^{K}$. The set of wage-quality vectors $\{v_i\}_{i\in\mathcal{I}}$ is affinely independent.

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Minimum Wage Counterfactual Employment and Wages

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

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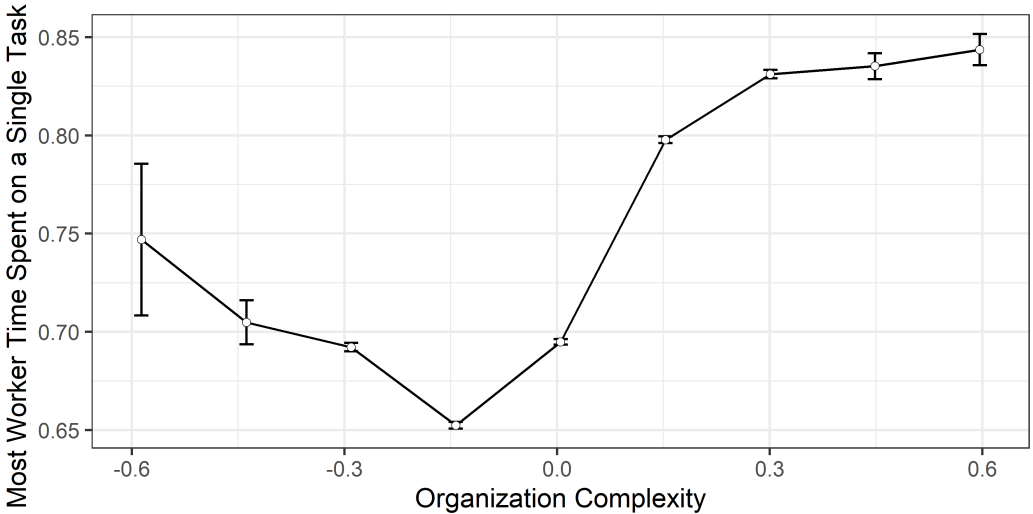
Regressions of Worker Specialization on Organization Complexity



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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:

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

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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%