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 do differences in firm ability to assign workers to tasks 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.

Summary of Results

1. **Facts**: Internal complexity is heterogeneous and firm-specific. Complex firms have ↑ revenue, employees, prices, repeat customers.

2. **Theory**: The firm's optimal organization structure also solves a more tractable, well-understood problem.

3. **Trilemma**: Firms trade-off complexity, quality and wages when choosing an organization structure.

4. **Policy Experiments for Manhattan Hair Salons**
   ► **Minimum wage to $20**: ↑ (↓) specialization of (non-)binding workers, $+$ and $-$ wage spillovers based on whether worker is employed alongside binding workers

   ► **Service Sales Tax Elimination**: $+10\%$ service quality, ↑ task-specialization, workers capture most welfare gains through higher wages

Contributions

- **Task-Based Perspective**: Imperfectly competitive product market, horizontal worker skill heterogeneity, firm-specific organizational heterogeneity, activity data
  - Lazear 2009, Haanwinckel 2020, Adenbaum 2021

- **Organizational Heterogeneity**: Aggregate sources of differences and understand market impact
  - Baker, Gibbons, and Murphy 2002 (relational contracts), Garicano and Wu 2012 (knowledge), Dessein et al. 2003 (coordination), 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 > 10 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

A Data Snapshot

Firm	Salon	App.	Cust.	Service	Staff	Time Stamp	Price	Duration
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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

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

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

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

"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	

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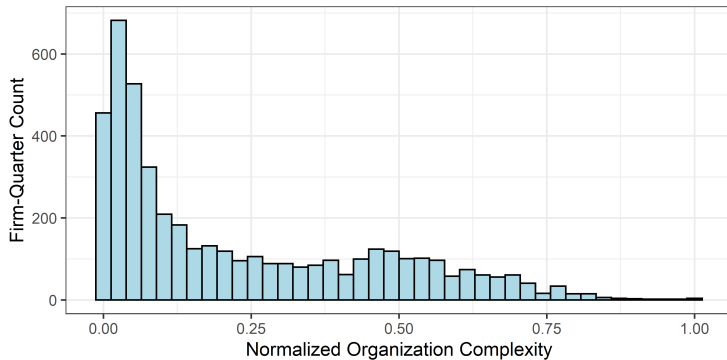
$$I_{j,t} = \bar{I}_j + \bar{I}_t + e_{j,t}$$

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

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

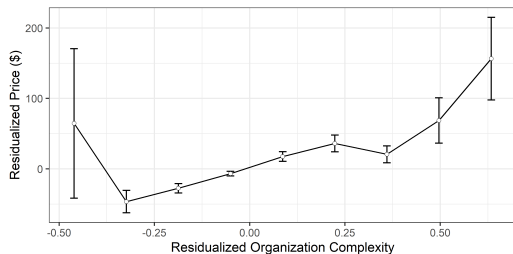# Fact 2: Complex salons have higher revenue and employment
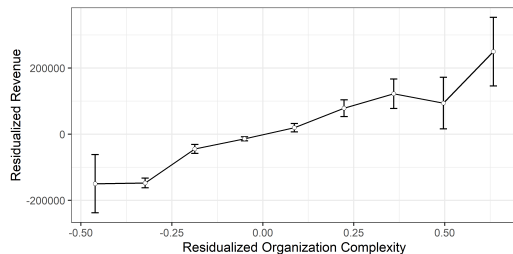
(a) Revenue
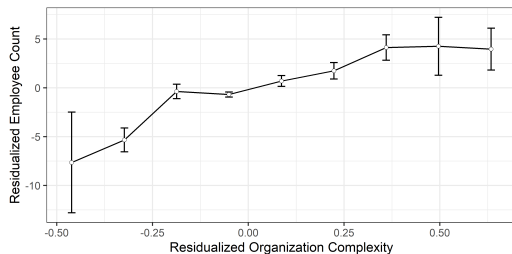
(b) Employees

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
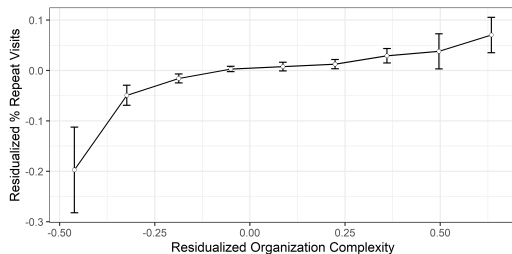
(b) Repeat Customers

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

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

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:

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

Summary of the Model
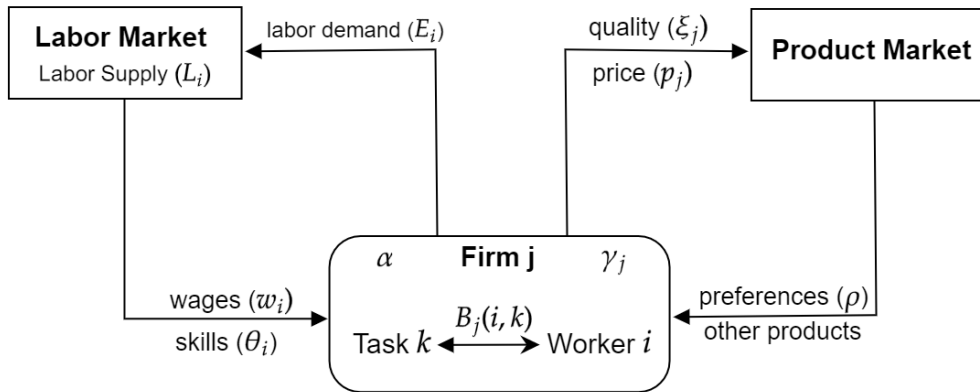
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Characterizing the Firm's Problem

Theorem

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

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

which is a rate-distortion problem and a linear rational inattention problem.

▶ Rate-distortion problems are well-studied in information theory.

▶ Rational inattention problems are well-studied in behavioral economics.

▶ Org. structure depends on other salon actions only indirectly via wages.

Proof

The Complexity-Wage-Quality Trilemma

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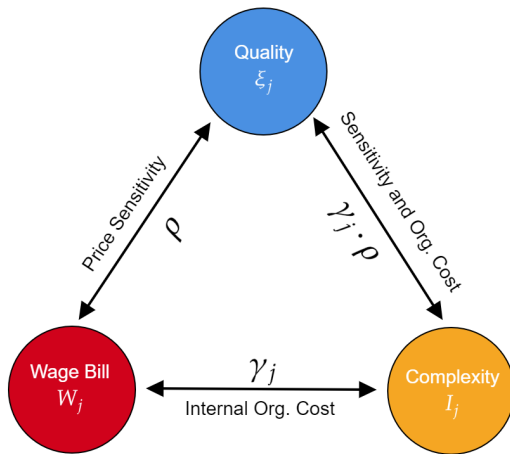
Organization Frontier

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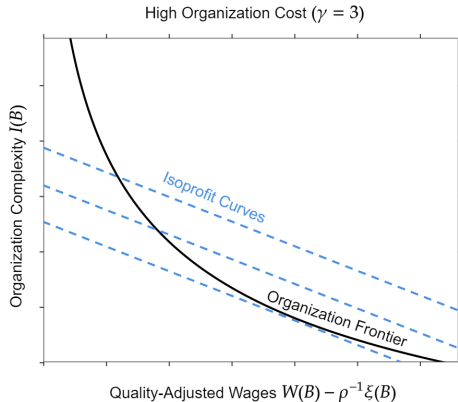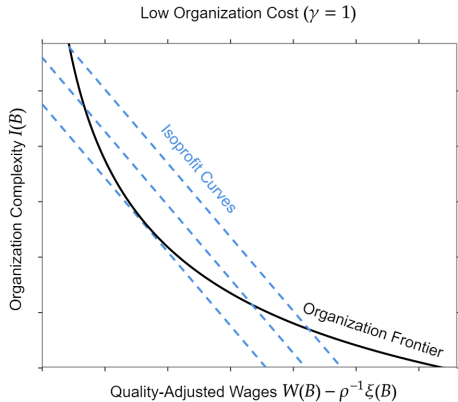
Definition

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

Low Organization Cost ($\gamma = 1$)

High Organization Cost ($\gamma = 3$)

Organization Complexity $I(B)$

Isoprofit Curves

Organization Frontier

Quality-Adjusted Wages $W(B) - \rho^{-1}\xi(B)$

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
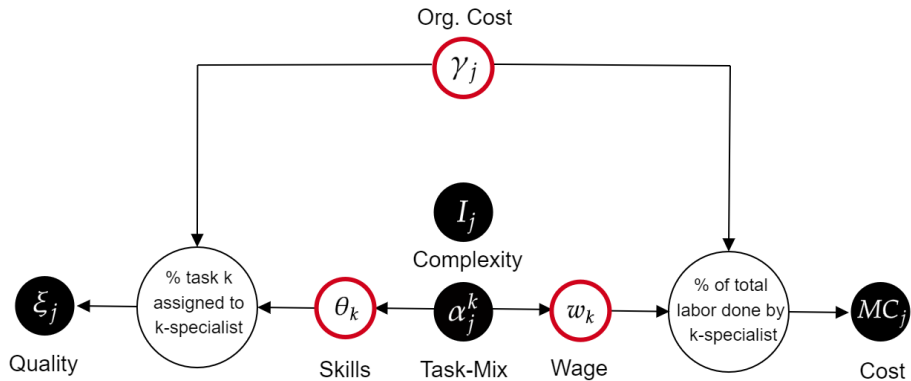
# Identification: Firm-Specific Organization Costs γ_j

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
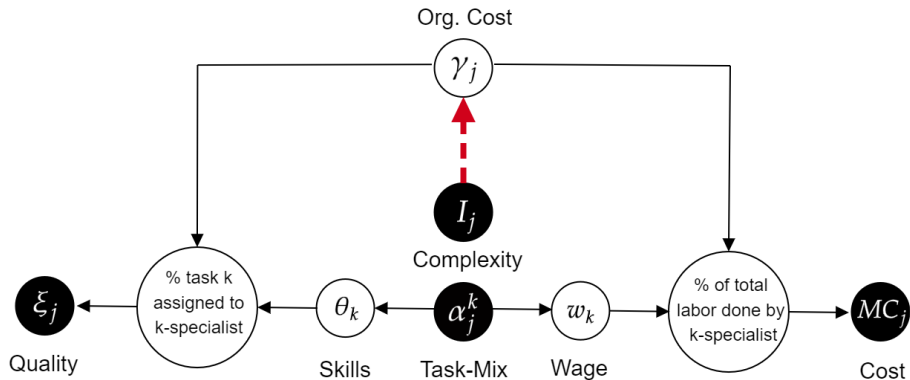
Identification: Market Parameters

▶ Use firm price FOC (supply side moments):

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

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

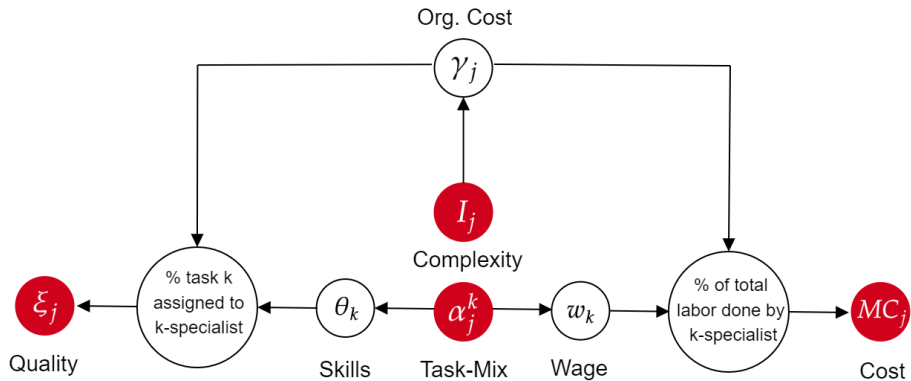$$log(s_j) - log(s_0) = \xi(\Omega, I_j, \alpha_j) - \rho(1+\tau)p_j + \beta\alpha_j + \nu_j$$

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

$$W_j = Ms_ja_jwE(\Omega, I_j, \alpha_j) + e_j$$

▶ The model is globally identified if Ω uniquely satisfies:

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

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:

$$\underset{\hat{\Omega}}{\arg\min}\ G(\hat{\Omega})'WG(\hat{\Omega})$$

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

| Task | Associated Specialist | | Skill Base | Material Cost |
	Skill Gap	Wage		
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.
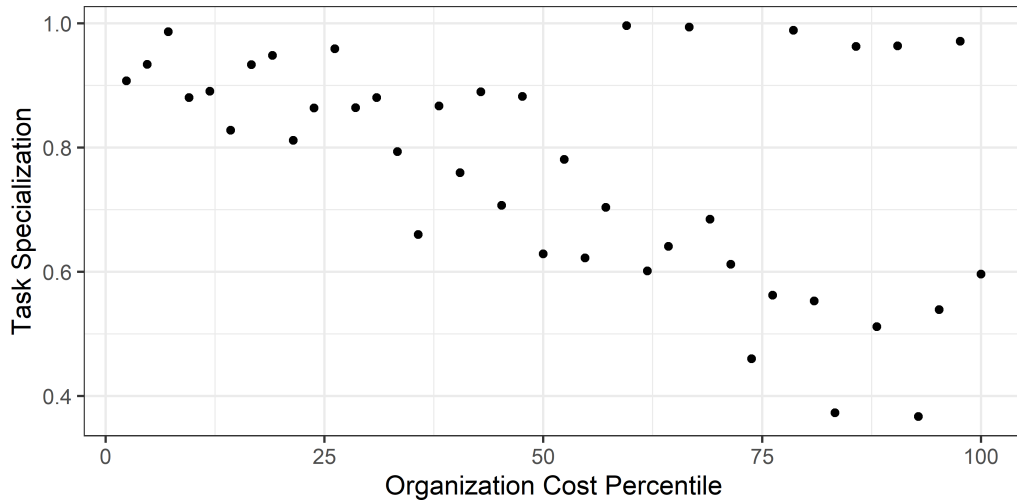
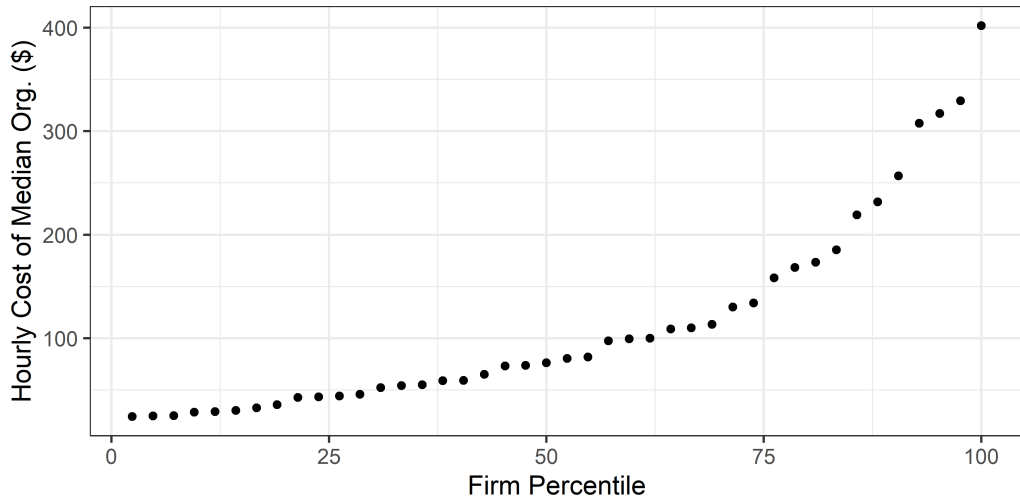# Equilibrium Task Specialization Across Workers

All Tasks

Specialty v.s. Other Tasks
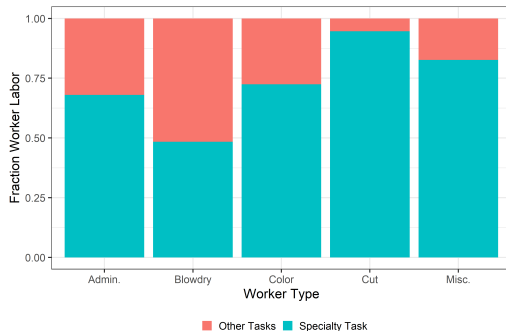
Equilibrium Task Specialization Across Firms

Cost of Median Complexity Organization Across Firms

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Fit: Supply Side Relationships
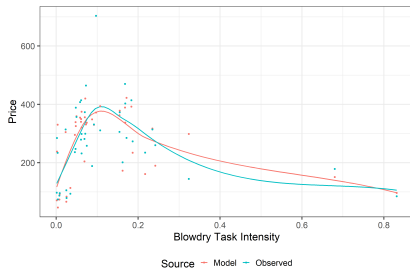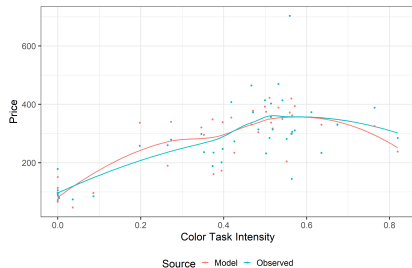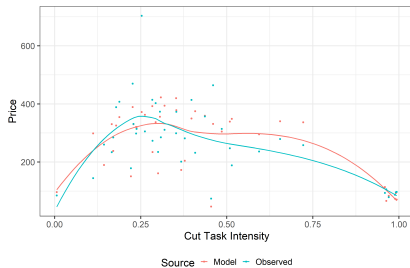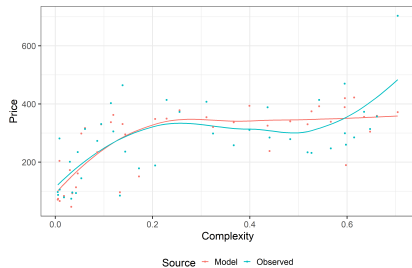
Validation: The Task Content of Jobs

Model generated jobs:

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

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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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
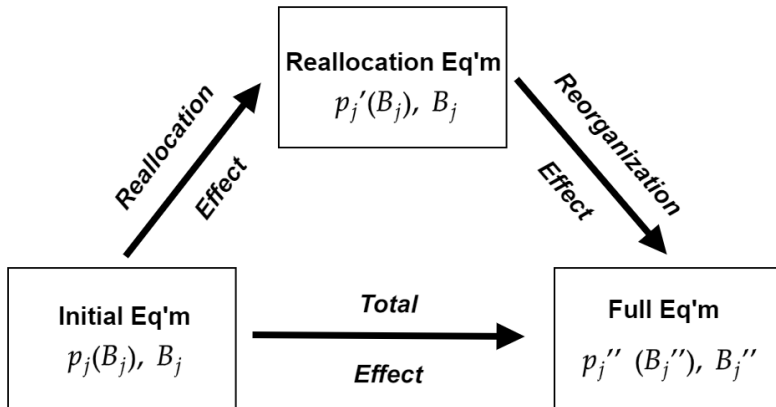
Minimum Wage Increase from $15 to $20

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

Welfare

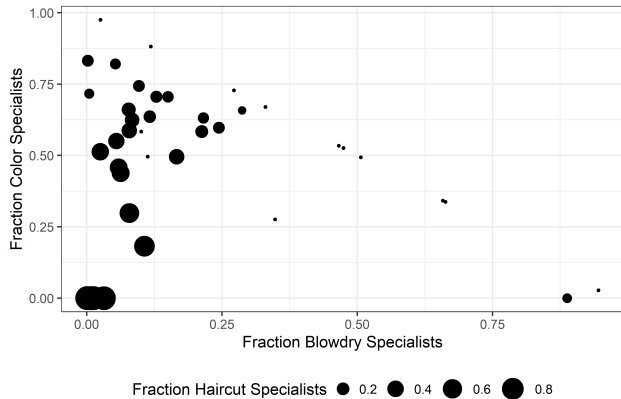| Source	Change	Percent Change
Salon Profit	-$714,413	-0.472%
Consumer Welfare	-$2,528,784	-1.671%
Employed Wages	$1,689,600	1.116%
Unemployed Wages	-$600,240	-0.397%
Total Welfare	-$2,153,838	-1.423%

Employment and Wages   Technical Details

The Reallocation Effect
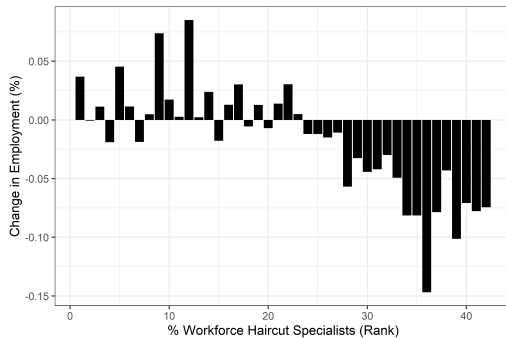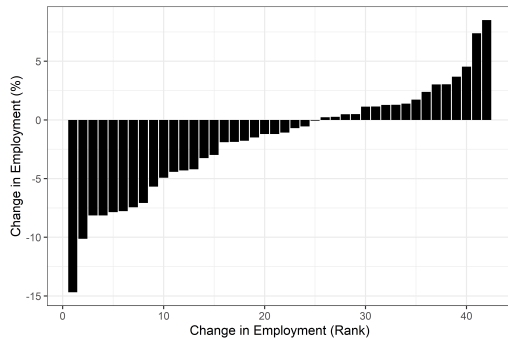
The Reallocation Effect: Wage Spillovers

	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)
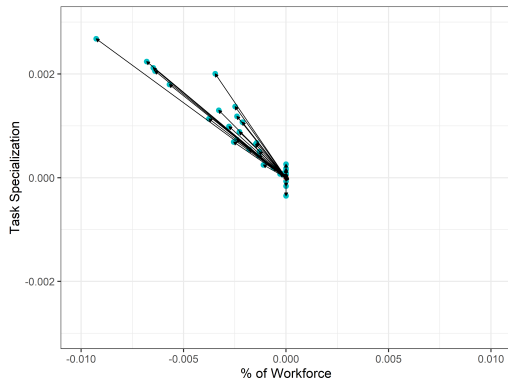
Color Specialists (Non-Binding)
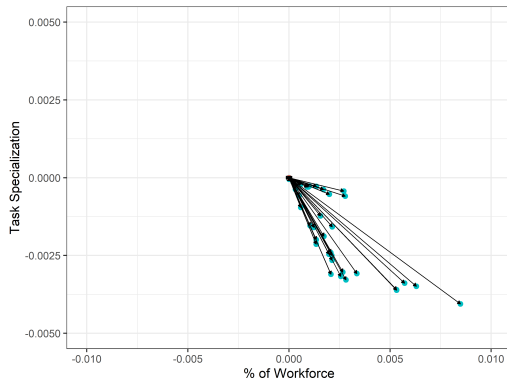
The Reorganization Effect: Wage Spillovers

| | 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			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

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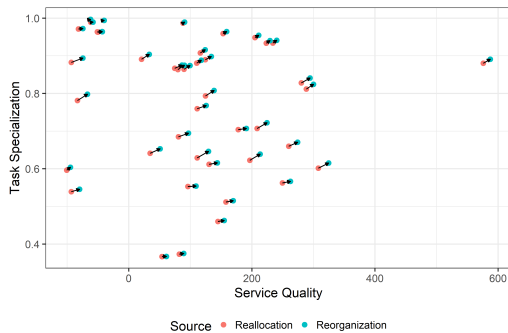
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Extensions

- 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

1. **Facts**: Salon complexity explains over 10% of variation of individual worker specialization. Internally complex firms have ↑ revenue, employees, prices, repeat customers.

2. **Theory**: The firm's optimal organization structure also solves a more tractable, well-understood problem.

3. **Trilemma**: Firms trade-off complexity, quality and wages when choosing an organization structure.

3. **Policy Experiments for Manhattan Hair Salons**
   ▶ **Minimum wage to $20**: ↑ (↓) specialization of (non-)binding workers, + and − wage spillovers based on whether worker is employed alongside binding workers

   ▶ **Service Sales Tax Elimination**: +10% service quality, ↑ task-specialization, workers capture most welfare gains through higher wages
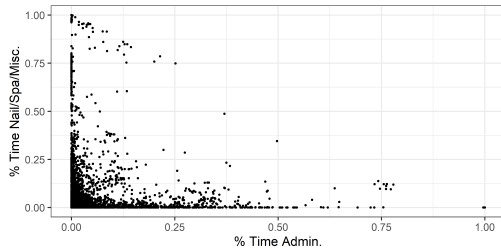
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Task-Mix Variation
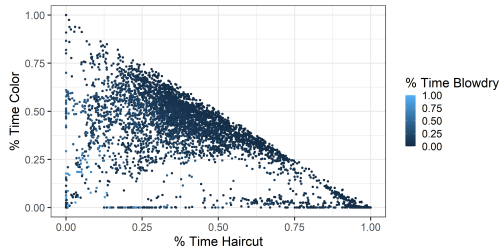
(a) Cut, Color, Blowdry

(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:

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

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

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

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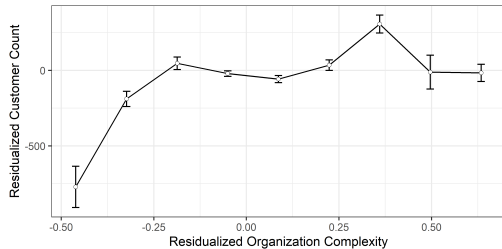
$$\max_{\delta, Z} \mathbb{E}[m(X, \delta(Z))] - \gamma I(X, Z)$$

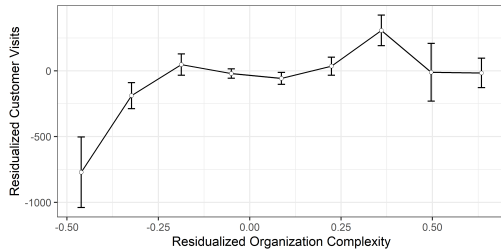Jung et al. (2019) (and others) show this is equivalent to:

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

- Thus complexity measures the attention paid to assignments.

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
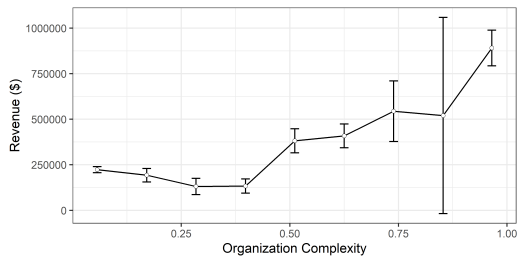
(a) Revenue   (b) Employees
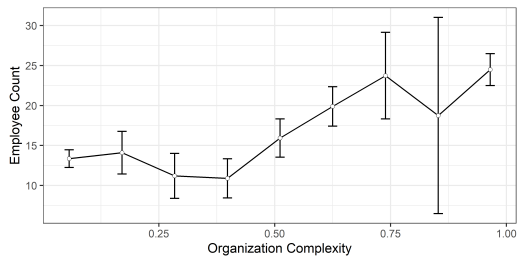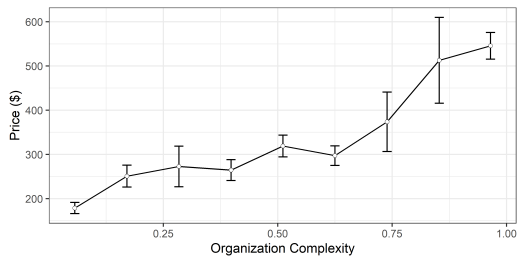
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Fact 3: Complex salons have higher prices and repeat customers

(a) Prices
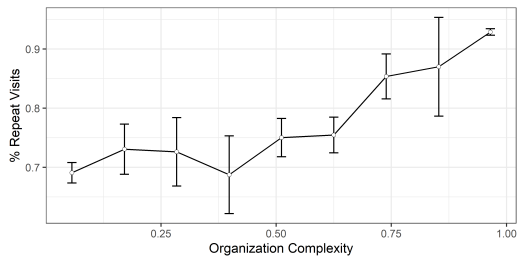
(b) Repeat Customers

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Quantity Model Implies Price ↓ Complexity

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

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:

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

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Proof of Main Result: Part 2/3

$$\min_{B_j \in \mathbb{B}_j} MC_j(B_j) - \rho^{-1}\xi(B_j) = \min_{B_j \in \mathbb{B}} W(B_j) + \gamma_j I(B_j) - \rho^{-1}\xi_j(B_j) \qquad (2)$$

$$= \gamma_j \min_{B_j \in \mathbb{B}} \left\{ I(B_j) + \gamma_j^{-1}\Big[W(B_j) - \rho^{-1}\xi(B_j) \Big] \right\} \qquad (3)$$

I can re-write 3 as a maximization problem:

$$\max_{B_j \in \mathbb{B}} \left\{ \sum_{i,k} B_j(i,k)(\rho^{-1}\theta_{i,k} - W_i) \Big] - \gamma_j I(B_j) \right\} \qquad (4)$$

Comparing 4 to formulations in Jung et al. (2019) illustrates that this is a linear rational inattention problem.

Proof of Main Result: Part 3/3

I re-write 3 one last time:

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

Comparing 5 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

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

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.

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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:

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

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.
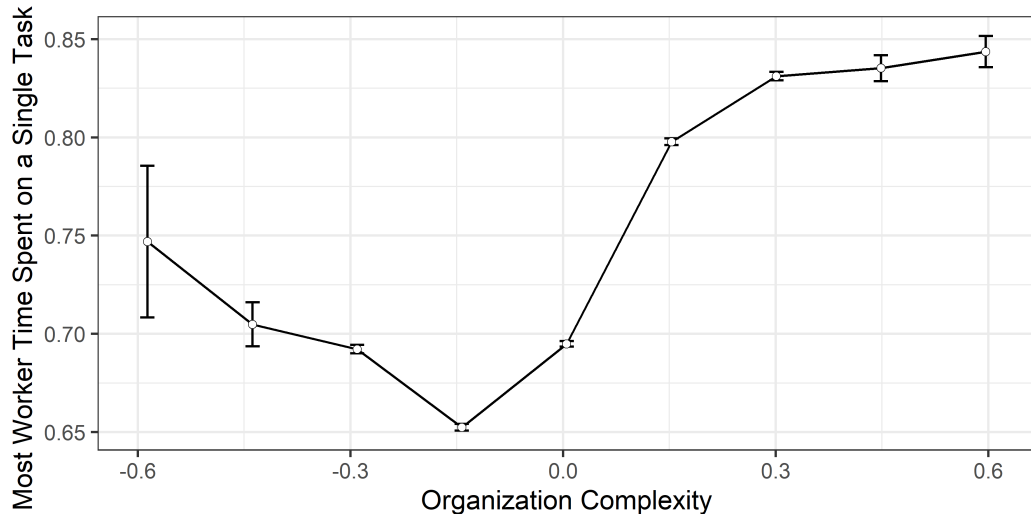
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Minimum Wage Counterfactual Employment and Wages

Worker Type	Initial		Counterfactual	
	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:

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

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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