14.273: Advanced Topics in IO

Empirical Models of Search

Motivation — why search?

"Price dispersion is a manifestation – and, indeed it is the measure – of ignorance in the market" (Stigler 1961, p. 214)

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- *Law of one price* empirically almost never holds.
- Search models explain **price dispersion** for **homogeneous goods**.
- In markets with symmetric firms and homogeneous products, prices may differ in equilibrium if consumers incur search costs to obtain price information.

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Normative

- Search costs are a source of market power!
- Search costs are pure social costs.
- Search costs can lead to mis-allocation.

Motivation — search in negotiated price markets

Relevance

- Common in many retail markets: automobiles, real estate, mortgages, all kinds of services.
- Knowing the "fair" price is hard for consumers if there is an element of idiosyncratic pricing.
- Distributional implications of pricing.

Empirical Challenge

- Typically, only transaction prices are observed, which are a selected set of offered prices.

Outline

1. Hong and Shum (2006).
2. Allen, Clarke, and Houde (2014): search and negotiations in mortgage markets.
3. Salz (2022): intermediation in a decentralized market.

Hong and Shum (2006)

Hong and Shum (2006) — overview

Estimation + identification:

- Back to Stigler's quote: what is the empirical content of the price distribution?
- Identify and estimate search cost distribution under the assumption of a mixed strategy pricing equilibrium. Burdett and Judd (1983)

Data:

- Observe only prices, no quantity data.

Sequential vs. non-sequential:

- Non-sequential: commit to taking N draws, pick lowest price.
- Sequential: Draw and observe price, decide whether to draw again $\longrightarrow$ Cut-off strategy.

Hong and Shum (2006) — non-sequential search

Consumer objective function:

$$\ell^*(c_i) \equiv \text{argmin}\, c_i \cdot (\ell - 1) + \int_{\underline{p}}^{\overline{p}} \ell \cdot p \left(1 - F_p(p)\right)^{\ell-1} f_p(p) dp$$

Consumers are assumed to draw i.i.d. samples from the equilibrium price distr. F_p.

Hong and Shum (2006) — non-sequential search

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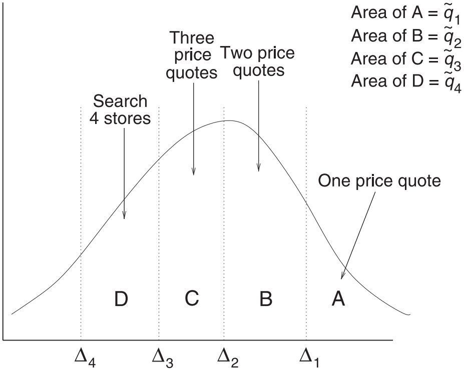
Consumers are assumed to draw i.i.d. samples from the equilibrium price distr. F_p. The marginal expected savings from searching $i + 1$ versus i stores is:

$$\Delta_i \equiv Ep_{1:i} - Ep_{1:i+1}, \quad i = 1, 2, ...$$

- The sequence of marginal expected savings Δ_i , $i = 1, 2, ...$ is non-increasing in i for any price distribution F_p, while the cost per search is constant.
- A consumer will search as long as the marginal expected savings Δ_i exceeds his marginal search cost c.

Hong and Shum (2006) — non-sequential search

Let $F_c(\cdot)$ be the distribution of search cost



- $\tilde{q}_1 \equiv 1 - F_c(\Delta_1)$: proportion of consumers with one price quote;
- $\tilde{q}_2 \equiv F_c(\Delta_1) - F_c(\Delta_2)$: proportion of consumers with two price quotes;

Hong and Shum (2006) — non-sequential search

A firm's profits from following the **mixed pricing** strategy $F_p(\cdot)$ (See Burdett and Judd (1983)):

$$\Pi(p) = (p - r) \cdot \left[\sum_{k=1}^{K} \tilde{q}_k \cdot k \cdot \left(1 - F_p(p)\right)^{k-1} \right]$$

Equilibrium: Firm must be indifferent between charging the monopoly price $\overline{p}$ (selling only to people who never search but receive an initial free draw) and any other price p in the equilibrium support $[\underline{p}, \overline{p}]$:

$$(\overline{p} - r) \cdot \tilde{q}_1 = (p - r) \cdot \left[\sum_{k=1}^{K} \tilde{q}_k \cdot k \cdot \left(1 - F_p(p)\right)^{k-1} \right]$$

Hong and Shum (2006) — non-sequential search

Let $K \leq n-1$ denote the maximum number of firms from which a consumer obtains price quotes in this market.

Indifference condition and estimation:

$$(\overline{p}-r)\cdot\tilde{q}_1 = (p_i - r)\cdot\left[\sum_{k=1}^{K}\tilde{q}_k\cdot k\cdot\left(1-\hat{F}_p(p_i)\right)^{k-1}\right]$$

Since $\tilde{q}_K = 1-\sum_{k=1}^{K-1}\tilde{q}_k$ the above constitutes $n-1$ linear equations from which we can solve for $\{r,\tilde{q}_1,\ldots,\tilde{q}_{K-1}\}$.

Hong and Shum (2006) — sequential search

After each search, consumers can choose to purchase at the lowest price observed so far, or make an additional search. At any price, there is an option value associated with searching again.

Cut-off rule: A standard result in the sequential-search literature is that the consumers' optimal stationary-search strategy is a reservation price policy, where they search until they obtain a price that is no larger than some reservation price $z^\star$.

For consumer i, who has per-price search costs c_i , let $z^\star(c_i)$ denote the price z that satisfies the indifference condition, then:

$$c_i = \int_{\underline{p}}^{z(c_i)} (z - p) f_p(p) dp$$

Hong and Shum (2006) — sequential search

Can't use the same argument for identification

Let the reservation price be $p_i = min\{z^*(c_i), \bar{p}\}$ and $G(p_i)$ be the mass of customers with reservation values less than p.

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Let the reservation price be $p_i = min\{z^*(c_i), \bar{p}\}$ and $G(p_i)$ be the mass of customers with reservation values less than p. A firm charging price p will only sell to consumers with a reservation price higher than p. Indifference condition:

$$(\overline{p} - r) \cdot (1 - G(\overline{p})) = (p_i - r) \cdot (1 - G(p_i))$$

Hong and Shum (2006) — sequential search

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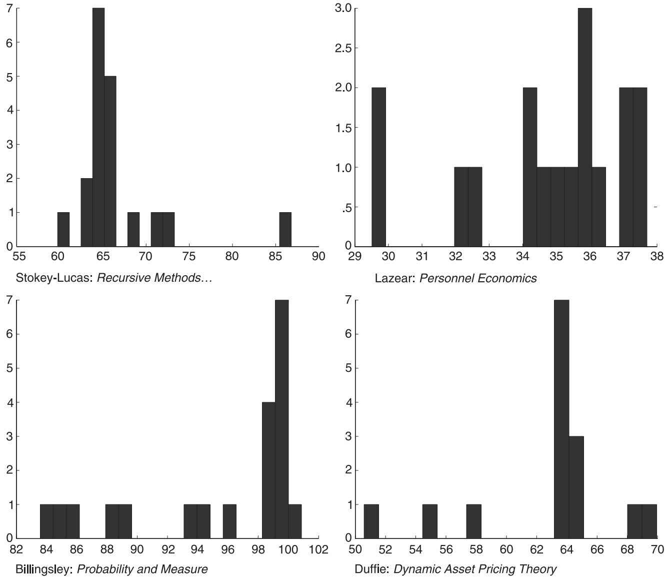
$$(\bar{p} - r) \cdot (1 - G(\bar{p})) = (p_i - r) \cdot (1 - G(p_i))$$

- n+1 unknowns ($G(p_i)$ i and r) but only $n - 1$ indifference conditions
- Intuition: for non-sequential search there are only K possible cutoff-types, whereas for sequential search there is a continuum of reservation values.
- Instead, they estimate a parametric search cost distribution $f_c(\cdot|\theta)$.

Hong and Shum (2006) — results



x-axis: prices (in dollars)

Hong and Shum (2006) — results, sequential search

Product	K[a]	M[b]	$\tilde{q}_1^c$	$\tilde{q}_2$	$\tilde{q}_3$	Selling Cost r	MEL Value
Parameter estimates and standard errors: nonsequential-search model							
Stokey-Lucas	3	5	.480 (.170)	.288 (.433)		49.52 (12.45)	102.62
Lazear	4	5	.364 (.926)	.351 (.660)	.135 (.692)	27.76 (8.50)	84.70
Billingsley	3	5	.633 (.944)	.309 (.310)		69.73 (68.12)	199.70
Duffie	3	5	.627 (1.248)	.314 (.195)		35.48 (96.30)	109.13
Search-cost distribution estimates							
	Δ_1	$F_c(\Delta_1)$	Δ_2	$F_c(\Delta_2)$	Δ_3	$F_c(\Delta_3)$	
Stokey-Lucas	2.32	.520	.68	.232			
Lazear	1.31	.636	.83	.285	.57	.150	
Billingsley	2.90	.367	2.00	.058			
Duffie	2.41	.373	1.42	.059			

Hong and Shum (2006) — comments

Makes the most of a very limiting data scenario. One of the first empirical papers on search.

Is the **mixed strategy** pricing equilibrium plausible?

In many settings homogeneous marginal cost not very realistic.

Some issues that many empirical search models have in common:

- Typically find very large search cost.
- All price variation is interpreted as structural. When might this be problematic?

Allen, Clarke, and Houde (2013)

Allen, Clarke, and Houde (2013) — overview

Research Question: what is the effect of a merger in a negotiated price market?

- Different people get different prices $\longrightarrow$ mergers might have distributional implications.

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Setting: Canadian mortgage market.

- Administrative data on insured mortgage contracts, collected from insurer.
- Extremely homogeneous product, idiosyncratic risk is insured away.

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Setting: Canadian mortgage market.

- Administrative data on insured mortgage contracts, collected from insurer.
- Extremely homogeneous product, idiosyncratic risk is insured away.

Research Design: structural model + treatment effect analysis.

- Use quasi-experimental variation induced by horizontal merger between two large Canadian mortgage lenders. Creates discrete changes in choice sets for consumers.
- Examine estimates in light of a search model.

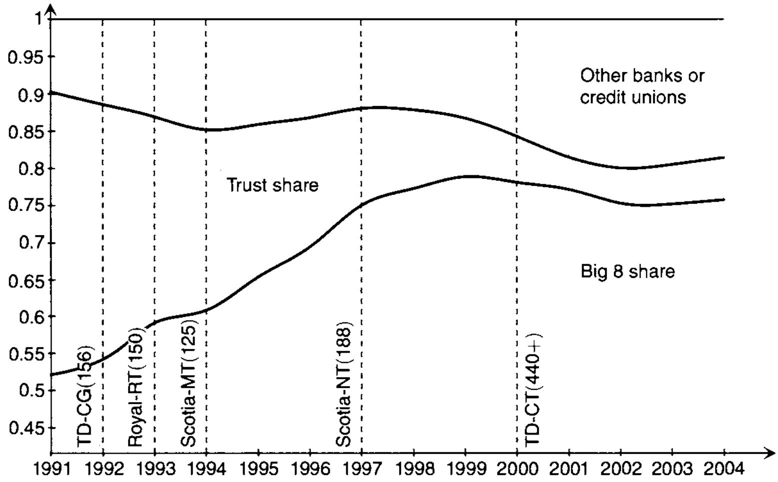

FIGURE 1. EVOLUTION OF FINANCIAL INSTITUTION MARKET SHARES FOR NEWLY INSURED MORTGAGES (*Smoothed*)

Allen, Clarke, and Houde (2013) — overview

Institutional details:

- Banks post rates and consumers can negotiate discounts with local branch managers.
- Branch managers receive commission that are affected by discounts.

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Market definition / consumer choice sets:

- Financial characteristics of the contract, i.e., rate, loan size, house price, debt ratio, risk type. Demographics: income, prior relationship with banks, ...
- Market defined as a 5KM radius around consumer's home FSA.

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Treatment and control group:

- Focus on short-run effect of a merger. Long run market-conditions (branch openings and closings) might reflect unobserved local market conditions.
- No effects on consumers who had only one or neither type of branch in their neighborhood (Control Group). Number of competing branches reduced in the neighborhoods that have both types of branches. Markets with branches of both merging firms are in the Treatment Group.

Allen, Clarke, and Houde (2013) — Overview

Descriptive statistics / outcome variables:

- Few consumers pay a rate equal to the posted rate.
- Residual margin is the main outcome variable of interest:

$$\text{Margin}_i = \beta' \mathbf{X}_i + m_i$$

where: $Margin_i = Rate_i - Bond_i$, $\mathbf{X}_i$ is a vector of control variables.

- The residual, m_i, is called the negotiated margin.

Allen, Clar

TABLE 2—SUMMARY STATISTICS ON MORTGAGE CONTRACTS AND HOUSEHOLD CHARACTERISTICS

	Control/before				Control/after			
	Mean	SD	$P(25)$	$P(75)$	Mean	SD	$P(25)$	$P(75)$
Margin	1.07	0.46	0.73	1.42	1.43	0.56	1.02	1.82
N-Margin	1.07	0.43	0.78	1.35	1.67	0.46	1.36	2.02
$1(r_i = \overline{r}_i)$	36.38	48.12			26.92	44.36		
Income	61.95	25.00	43.70	74.77	62.84	24.49	45.37	75.29
House	121.11	55.49	82.18	145.30	118.25	52.16	81.18	143.74
Loan	113.4	49.7	78.7	137.2	110.0	46.9	76.9	133.5
LTV	91.58	4.26	90.00	95.00	91.25	4.34	90.00	95.00
FICO	67.23	46.95			64.27	47.93		
Renter	68.30	46.55			70.05	45.82		
Parents	5.73	23.24			6.64	24.90		
Switch	30.21	45.93			36.84	48.25		
Broker	21.91	41.37			30.05	45.86		
	Treatment/before				Treatment/after			
	Mean	SD	$P(25)$	$P(75)$	Mean	SD	$P(25)$	$P(75)$
Margin	0.93	0.49	0.65	1.27	1.44	0.56	1.12	1.82
N-Margin	1.06	0.43	0.78	1.35	1.72	0.47	1.44	2.00
$1(r_i = \overline{r}_i)$	23.67	42.51			22.23	41.58		
Income	69.33	26.48	50.71	82.23	70.99	26.49	52.46	84.11
House	162.93	63.38	116.77	201.83	161.07	64.58	114.84	200.72
Loan	152.3	57.6	110.5	188.2	149.9	57.6	108.2	187.0
LTV	91.35	4.25	90.00	95.00	90.99	4.48	89.60	95.00
FICO	62.40	48.44			62.56	48.40		
Renter	68.28	46.54			71.15	45.31		
Parents	8.31	27.61			9.32	29.08		
Switch	26.68	44.23			38.43	48.65		
Broker	15.66	36.34			27.73	44.77		

Notes: The sample size is 18,121 divided between the control and treatment group, pre- and post-merger with 62.8 percent of contracts in the treatment and 42.2 percent observed post-merger. It includes a random sample of homogenous term and amortization contracts insured by CMHC or Genworth within one year of the merger. Margins and

Table 3—Average Effect of the Merger on Margins and Discounts

	Margin		Zero discount	
	Baseline	With trend	Baseline	With trend
Linear DiD (OLS)				
Merger ATE	0.0607***	0.0719***	0.0646***	0.0477***
	(0.0183)	(0.0242)	(0.0154)	(0.0188)
Observations	18,121	18,121	18,121	18,121
R^2	0.408	0.420	0.181	0.189
Matching DiD				
Merger ATE	0.0739***	0.0692**	0.0670***	0.0538**
	(0.0249)	(0.0273)	(0.0206)	(0.0218)
Observations	17,220	17,220	17,220	17,220
Change-in-change				
Merger ATE	0.057***	0.0661***		
	(0.015)	(0.021)		
Observations	18,103	18,103		

Notes: Standard errors clustered at the FSA level are in parentheses. The dependent variable in columns 1 and 2 is the transaction rate minus bond rate, in columns 3 and 4 is an indicator variable for the transaction rate within ten basis points of the posted rate, which we take to imply

Allen, Clarke, and Houde (2013) — summary DiD results

- ATE margin corresponds to 10 to 15% of standard deviation in sample.
- Rejects the null that merger did not increase market power.
- Not consistent with models that explain interest rate dispersion purely in terms of cost and risk.
- For an average loan size ($152000) merger led to $5.7 increase in monthly loan payments.
- For informed customers, this should be a fairly competitive market.

Allen, Clarke, and Houde (2013) — distributional impacts

Let $\hat{F}_{G,T}(m)$ be the CDF where (G) indexed treatment status and (T) time period. **Want:** $\hat{F}^c_{1,1}$.

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Changes-in-Changes Estimator (Athey and Imbens (2006)):

$$\hat{F}^{-1}_{1,0}\left(\hat{F}^c_{1,1}(m_i)\right) = \hat{F}^{-1}_{0,0}\left(\hat{F}_{0,1}(m_i)\right)$$

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Intuitively, obtain counterfactual distribution by transforming the observed negotiated margin distribution in the treatment group ($F_{1,0}(m)$) to mimic the changes in the control group.

Distributional effect:

$$\alpha(q_i) = \hat{F}^{-1}_{1,1}(q_i) - \hat{F}^{c-1}_{1,1}(q_i)$$

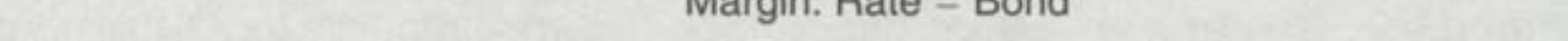

FIGURE 2. EMPIRICAL DISTRIBUTION OF NEGOTIATED MARGINS WITH AND WITHOUT THE MERGER

TABLE 4—DISTRIBUTIONAL EFFECT OF THE MERGER ON NEGOTIATED MARGINS

	Baseline			With trend		
	Est.	95% CI		Est.	95% CI	
Quantile effects						
q_5	0.0766	0.0123	0.157	0.0782	0.0080	0.18
q_{10}	0.0914	0.0505	0.13	0.0844	0.0379	0.138
q_{25}	0.0762	0.0454	0.0994	0.0767	0.0397	0.119
q_{50}	0.0842	0.0433	0.114	0.0874	0.0446	0.128
q_{75}	−0.0008	−0.0621	0.0686	0.0185	−0.0473	0.0885
q_{90}	−0.0042	−0.0485	0.0383	0.0069	−0.0393	0.0591
q_{95}	0.056	0.0053	0.0949	0.0513	−0.0125	0.0973
Dispersion effects						
ΔSD	−0.0287	−0.0587	−0.0066	−0.0256	−0.056	−0.0034
ΔCV	−0.0462	−0.0766	−0.0211	−0.0455	−0.0792	−0.0184
$\Delta q_{75} - q_{25}$	−0.077	−0.131	−0.0099	−0.0582	−0.114	−0.0044
$\Delta q_{90} - q_{10}$	−0.0957	−0.153	−0.0457	−0.0776	−0.134	−0.0261
$H_0 : F^c_{1,1} = F_{1,1}$						
KS	4.7***			4.84***		

Notes: The dependent variable is negotiated margins. ΔSD and ΔCV measure the changes in the standard deviations and coefficient of variation respectively. Confidence intervals were cal-

Allen, Clarke, and Houde (2013) — model

Interpret results through a **search model:** $n + 1$ lenders, negotiation takes place over three stages.

1. Consumers get an initial quote m_i^0 from some lender.
2. Can reject offer and engage in search effort e_i to get additional quotes. With $s(e_i)$ matched with all n banks and with $(1 - s(e_i))$ they receive two quotes.
3. Competition takes place, consumers choose lowest price offer.

Allen, Clarke, and Houde (2013) — model: competition stage

Working backwards starting with competition (Stage 3):

- English auction.
- Lenders have a common cost component c and an idiosyncratic cost component ϵ_j.
- Unique dominant strategy price eq: banks offer up to their private cost $c + \epsilon_j$. The most efficient bank wins the contract at $c_{(2)} = c + \epsilon_{(2)}$
- Let $E\left(m^* | \tilde{n}\right) = c + E\left(\epsilon_{(2)} | \tilde{n}\right)$ denote the expected second stage transaction price under $\tilde{n}$ quotes.
- Gain from searching: $\Delta(n) = E\left(\epsilon_{(2)} | 2\right) - E\left(\epsilon_{(2)} | n\right) > 0$

Allen, Clarke, and Houde (2013) — model: search effort stage

Search effort decision (Stage 2):

- Effort cost has variable and fixed component: $\kappa_i = u_i(1 + e_i) + \eta_i$. Assume that marginal cost of effort (u_i) is publicly observed and fixed cost component (η_i) privately observed.

Allen, Clarke, and Houde (2013) — model: search effort stage

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- Effort cost has variable and fixed component: $\kappa_i = u_i(1 + e_i) + \eta_i$. Assume that marginal cost of effort (u_i) is publicly observed and fixed cost component (η_i) privately observed.
- Matching probability assumed to be pareto: $s(e) = 1 - (1 + e)^{-\lambda}$
- Consumers optimize:

$$r(u_i, n) \equiv \min_{e \geq 0} u_i \cdot (1 + e) + c + E\left(\epsilon_{(2)} | 2\right) - s(e)\Delta(n) = c + \pi(u_i, n)$$

- Optimal effort level has a threshold property: zero effort with marginal cost larger than $\overline{u}(n)$.

Allen, Clarke, and Houde (2013) — model: initial offer stage

Initial offer stage (Stage 1), **search probability:** $H_\eta\left(m_i^0|u_i,n\right) = \Pr\left(\eta_i < m_i^0 - r\left(u_i,n\right)\right)$.

Allen, Clarke, and Houde (2013) — model: initial offer stage

Initial offer stage (Stage 1), **search probability:** $H_\eta\left(m_i^0|u_i,n\right) = \Pr\left(\eta_i < m_i^0 - r\left(u_i,n\right)\right)$.

Bank that makes **initial offer** maximizes expected profits:

$$\max_{m_i^0 \geq r(u_i,n)} \left(m_i^0 - c\right)\left[1 - H_\eta\left(m_i^0|u_i,n\right)\right]$$

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This leads to a monopolist pricing rule in which consumers earn some information rent due to η_i:

$$m_i^0 - c = \frac{1 - H_\eta\left(m_i^0|u_i,n\right)}{h_\eta\left(m_i^0|u_i,n\right)}.$$

However, in the empirical implementation $\eta_i = 0$, consumers **earn no information rent** and are offered the reservation value implied by their search cost type $m_i = m_i^0 = r\left(u_i,n\right)$.

Allen, Clarke, and Houde (2013) — model: estimation (sym. info)

Map to observed distribution of **negotiated margins**:

$$F_{1,1}(m) = \Pr\left(c + \pi\left(u_i, n\right) < m\right) = H_u\left(\pi^{-1}(m - c, n)\right)$$

→ quantiles of marginal search cost map to quantiles of negotiated margins.

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Heterogeneous treatment effects:

$$\begin{aligned} \alpha(u) &= \pi(u, n-1) - \pi(u, n) \\ &\geq \pi\left(u', n-1\right) - \pi\left(u', n\right) = \alpha\left(u'\right), \quad \text{for all} \quad u' \geq u \end{aligned}$$

→ pricing function under symmetric information has the following properties: (i) monotonically increasing in u_i, (ii) weakly decreasing in n, (iii) increasing marginal effects of u_i with respect to n.

Allen, Clarke, and Houde (2013) — model: estimation (sym. info)

Construct moment estimator that targets those changes:

$$J = \min_{\theta=\{c,\lambda,\sigma_\epsilon\}} (\mathbf{M}(\theta) - \hat{\mathbf{M}})^T \Omega^{-1} (\mathbf{M}(\theta) - \hat{\mathbf{M}})$$

$$\text{s.t. } u_{q_i} = \pi^{-1}\left(m_i^l - c, n-1|\theta\right), \quad i = 1, \dots, S$$

Moments describe distributional effect of the merger. **Parameters**: λ: search effort parameter, c: bank's common cost parameter, σ_ϵ: variance of banks idiosyncratic cost component.

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Results of the structural model:

- Bank markup 5% to 10%, large differences across consumers (perfect price discrimination).
- Average search cost correspond to $1760 for a $152000 (25 year) loan.
- Market power effect much more consequential for consumers with low search cost.

Allen, Clarke, and Houde (2013) — comments

Nice paper that...

- ...highlights a new angle of the effects of mergers
- ...tight link between treatment effect analysis and the structural model.

Some shortcomings of the model:

- No information asymmetries imply that there is no search in equilibrium. $\longrightarrow$ Sunk cost of search are never incurred in equilibrium.
- No information rents for consumers is a strong assumption. Implies no search externalities.

Salz (2022) — research question

How do intermediaries affect buyers and sellers?

- Delegating buyers benefit directly from better "search technology" (*direct effect*).
- Selection creates search-externality, Salop and Stiglitz (1977), (*indirect effect*).

What is the welfare effect? No quantity distortion, but:

- Demand side: Reduction in search cost.
- Supply side: More efficient production (reallocation).

Salz (2022) — Motivation

Modeling contribution:

- Tractable model for a decentralized market with two-sided heterogeneity

Data contribution:

- Identify setting where decentralized market prices can be observed.

Intermediaries

- **Large fraction of economic activity**, Spulber (1996).
- Focus here: search for **prices**.

Salz (2022) — NYC trade waste

The Market

- Non-residential waste disposal market, fully decentralized.
- **Sellers:** waste carters, **buyers:** all private entities in the city.
- $\approx$ 100,000 buyers and $\approx$ 100 sellers.

Why looking at this market?

- Rare insight in segmented, decentralized market.
- Many contract characteristics are observed.
- Institutional features aid identification.

Salz (2022) — the regulator and the data

Business Integrity Commission (BIC)

- Established by city in 1995
- Response to property rights and racketeering system.

Data

- Ranging from 2009 to 2014.
- Price, quantity, composition, transfer station, business type, zip-code, ...

Salz (2022) — empirical model (overview)

The buyers

- Delegate or search (non-sequential).

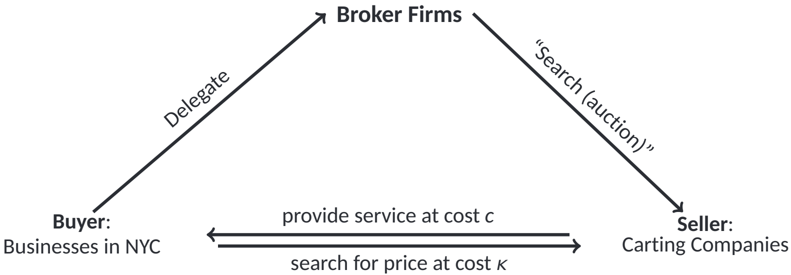
The sellers

- Price competition for customers.

The brokers

- Procure through competitive bidding (exogenous market share/technology).

Salz (2022) — empirical model (overview)



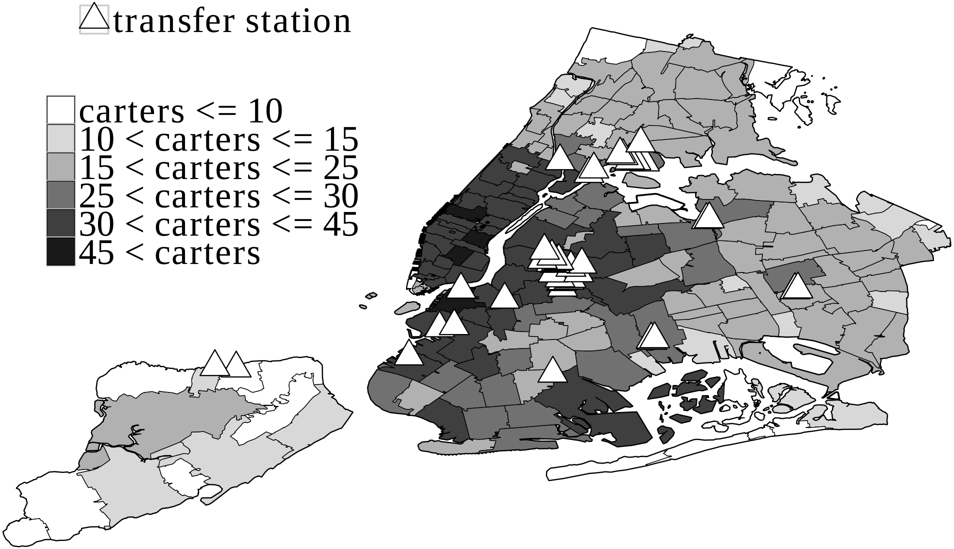
- **Most previous search models** avoid two-sided unobserved heterogeneity. Hortacsu and Syverson (2003), Hong and Shum (2006)
- Idiosyncratic service → customer-specific cost, prices.
- **Identification**: observe two different markets + price formation in brokered market known.

Salz (2022) — fragmented supply

"When I recently walked down a four-block stretch of Broadway on the Upper West Side of Manhattan, I identified about forty businesses — restaurants, clothing shops, bodegas, banks. Licenses in windows listed the commercial-waste haulers they use — at least fourteen in all, by my count, for a stretch that covers only a fifth of a mile. If there was a pattern, I couldn't grasp it: the Starbucks at Ninety-third and Broadway uses a different commercial-waste company from the Starbucks at Ninety-fifth and Broadway." — **New Yorker (2009)**

"Both the data and customer outreach reveal a lack of consistency in how rates are established. Without posted rate formulas, customer-initiated service requests require a direct phone call to the carter or a quote request submitted on the carter's web site, making comparison shopping fairly difficult." — **DSNY, Private Carting Study, 2016**

Salz (2022) — fragmented supply



Salz (2022) — price dispersion

Specification

- $p_{ijt} = \mathbf{X}_{ijt} \cdot \beta + \tilde{p}_{ijt}$.
- Separate for broker and search-market.

Included Controls

$$\mathbf{X} = \{\text{business type FE, recyclables FE, time FE,} \\ \text{transfer station FE, zip code FE, } q, ..., q^5, \\ \text{Number of Pickup FE}\} \times \{\text{Carter FE, No Carter FE}\}$$

Salz (2022) — price dispersion

TABLE 2
DOCUMENTING PRICE DISPERSION

	First Specification (No Carter Fixed Effects)		Second Specification (Carter Fixed Effects)	
	Not Brokered	Brokered	Not Brokered	Brokered
$1 - R^2$	.71	.35	.51	.24
SD (p_{ijt})	2.9	4.4	2.9	4.4
SD ($\tilde{p}_{ijt}$)	2.5	2.2	2.13	1.97
Mean (p_{ijt})	12.4	10.9	12.4	10.9

- Coefficient of variation: $\frac{SD(\tilde{p}_{ijt})}{mean(p)} > 0.24$ versus 0.22 in Sorensen (2000).
- $+SD(\tilde{p}_{ijt})$ implies extra \$1280 additional chargers over two years for average customer

Salz (2022) — Model setup

Primitives:

- Search expenses: $\kappa \sim \mathscr{H}(.)$
- Carter cost: $\mathscr{C}(\mathbf{z}, c)$ with $c \sim \mathscr{G}(.)$

Timing:

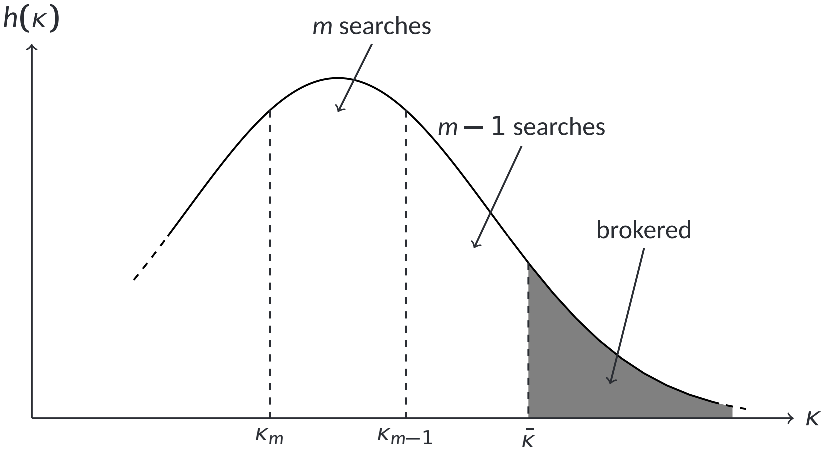
- Customer draws κ, carters c (both *private*, *iid*)
- Customer chooses:

  Delegate: Broker *RFP* amongst N_b carters, fee Φ
  Not Delegate: $\min_{m \in \{2,\dots,M\}} \left(q \cdot \mathbb{E}[p|m] + m \cdot \kappa \right)$

- Carters bid:

  If delegated: Knowing their N_b competitors.
  If not delegated: Under stochastic $m \in \{2, \dots, M\}$

Salz (2022) — sorting of customers



Salz (2022) — search weights and bidding

Fraction of customers that make m searches

- $w_m, m \in \{1, \ldots, M\}$.
- $w_m = \mathscr{H}(\kappa_{m-1}) - \mathscr{H}(\kappa_m)$.

Optimal strategies of carters:

- Broker market: $\beta_b(\cdot)$ for broker b with N_b bidders.
- Search market: $\beta_S(\cdot)$.

Salz (2022) — carter pricing

Carter objective function in the search market:

$$\max_{p}(p-c)\cdot\left[\sum_{m=1}^{M} w_m\cdot\left(1-\mathcal{G}(\beta_S^{-1}(p))\right)^k\right]$$

Price offer function:

$$\beta_S(c)=\sum_{m=1}^{M-1}\left[\frac{w_m\cdot(1-\mathcal{G}(c))^{(m-1)}}{\sum_{k=1}^{M-1}w_k\cdot(1-\mathcal{G}(c))^{(k-1)}}\cdot\left(c+\frac{1}{(1-\mathcal{G}(c))^{(m-1)}}\int_c^{\bar{c}}(1-\mathcal{G}(u))^{(m-1)}du\right)\right].$$

→ weighted average of symmetric first price procurement IPV auction bidding functions

Salz (2022): Identification and Estimation

Observed objects:

- Prices + contract covariates in both market, number of bidders for brokers, broker fees.

Identification:

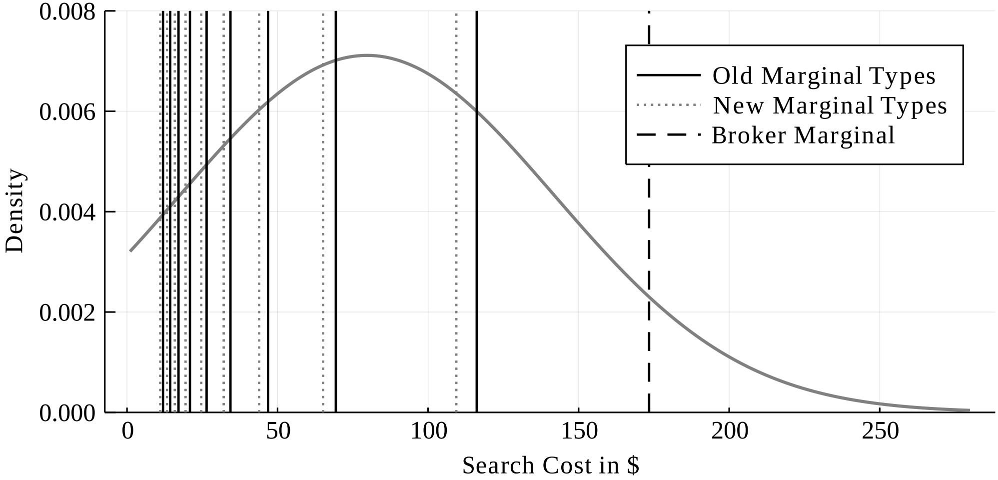
1. Carter cost in the broker market are identified by GPV (we will learn this later in semester).
2. Once $\mathscr{G}(c)$ is known the search-weights are uniquely identified from prices in the broker market.
3. Can fit a (flexible) parametric function to the weights.

Estimation:

1. Guess any w_m and iteratively update bidding function/search strategy. Contraction mapping.
2. Once converged, simulate prices for broker market and search market.
3. Match moments of the price distribution.

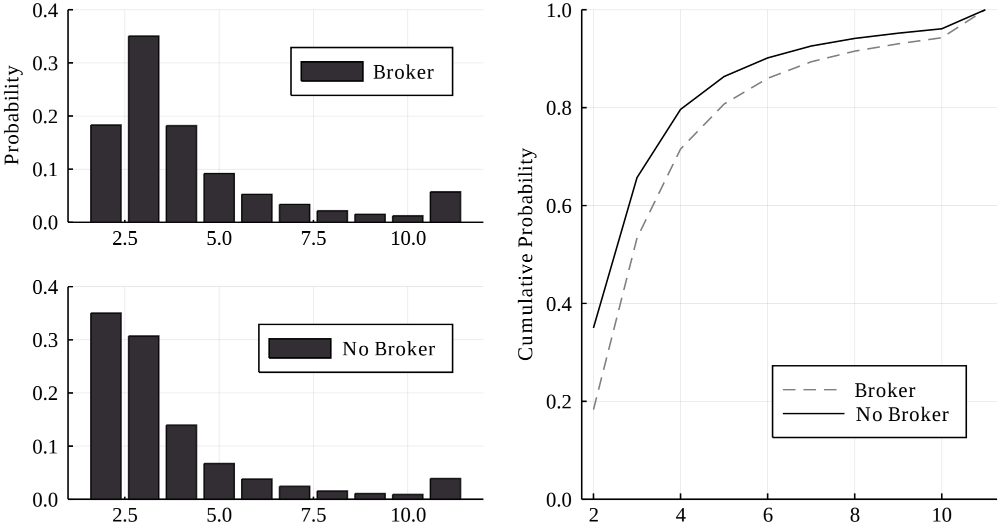
Salz (2022)

Counterfactual: No Brokers



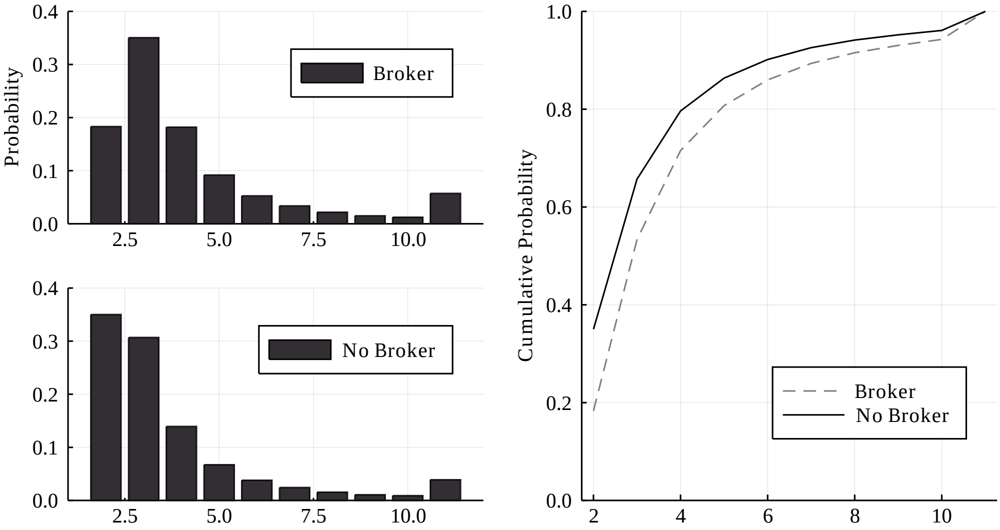
Salz (2022)

No Broker Counterfactual, Example



Salz (2022)

Consumer Welfare and Profits



Weitzman (1979)

Weitzman (1979)

General sequential search model that can handle ex-ante product heterogeneity.

Dynamic program:

$$W\left(\tilde{u}_i, \bar{S}_i\right) = \max \left\{ \tilde{u}_i, \max_{j \in \bar{S}_i} \left\{ -c_{ij} + F_j\left(\tilde{u}_i\right) W\left(\tilde{u}_i, \bar{S}_i - \{j\}\right) + \int_{\tilde{u}_i}^{\infty} W\left(u, \bar{S}_i - \{j\}\right) f_j(u) du \right\} \right\}$$

Notation:

- $\tilde{u}_i$: consumer *i*'s highest utility sampled so far.
- c_{ij}: consumer *i*'s cost of searching product *j*.
- $\bar{S}_i$: set of firms consumer *i* has not searched yet.

Weitzman (1979)

Weitzman (1979) shows that the solution to this problem can be stated in terms of J static optimization problems. Specifically, for each product j, consumer i derives a reservation utility z_{ij}. This reservation utility z_{ij} equates the benefit and cost of searching product j, i.e.,

$$c_{ij} = \int_{z_{ij}}^{\infty} \left(u_{ij} - z_{ij}\right) f_j(u) du$$

Given this, the optimal strategy is:

1. Search companies in a decreasing order of their reservation utilities z_{ij} (“selection rule”).
2. Stop searching when the maximum utility among the searched firms is higher than the largest reservation utility among the not-yet-searched firms (“stopping rule”).
3. Purchase from the firm with the highest utility among those searched (“choice rule”).

Weitzman (1979)

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Example:

Option	Reservation Utilities (z_{ij})	Utilities (u_{ij})
A	14	11
B	12	7
C	10	9

Choi, Dai, and Kim (2018)

Choi et al. (2018)

Setup:

- Suppose we have $u_{ij} = \delta_{ij} - p_j + \varepsilon_{ij}$, where δ_{ij} and p_j is known to the consumer but ϵ_{ij} is not.
- Consumers order products and search sequentially and their reservation utility for uncovering j is ϵ^*_{ij}.
- Consumers search for a good match.

Problem: many different search path that may have to be integrated out. With three firms there 3! = 6 paths. Especially for empirical purposes this is cumbersome. How to characterize demand for product j?

Choi et al. (2018)

In a **duopoly** product 1 gets purchased if:

1. $\delta_1 + \epsilon_1^* - p_1 > \delta_2 + \epsilon_2^* - p_2$ (visit 1 first) and $\delta_1 + \epsilon_1 - p_1 > \delta_2 + \epsilon_2^* - p_2$ (stop at 1)
2. $\delta_1 + \epsilon_1^* - p_1 > \delta_2 + \epsilon_2^* - p_2$ (visit 1 first), $\delta_1 + \epsilon_1 - p_1 < \delta_2 + \epsilon_2^* - p_2$ (visit 2 as well) and $\delta_1 + \epsilon_1 - p_1 > \delta_2 + \epsilon_2 - p_2$ (prefer 1 to 2)
3. $\delta_1 + \epsilon_1^* - p_1 < \delta_2 + \epsilon_2^* - p_2$ (visit 2 first), $\delta_1 + \epsilon_1^* - p_1 > \delta_2 + \epsilon_2 - p_2$ (visit 1 as well), and $\delta_1 + \epsilon_1 - p_1 > \delta_2 + \epsilon_2 - p_2$ (prefer 1 to 2)

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Note that:

1. First condition can be simplified to: $\delta_1 + \min\left\{\epsilon_1, \epsilon_1^*\right\} - p_1 > \delta_2 + \epsilon_2^* - p_2$
2. While the second and the third conditions together can be reduced to $\delta_1 + \min\left\{\epsilon_1, \epsilon_1^*\right\} - p_1 \leq \delta_j + \epsilon_2^* - p_2$ and $\delta_1 + \min\left\{\epsilon_1, \epsilon_1^*\right\} - p_i > \delta_2 + \epsilon_2 - p_2$.

Choi et al. (2018)

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Combining:

$$\delta_1 + \min\left\{\epsilon_1, \epsilon_1^*\right\} - p_1 > \delta_2 + \min\left\{\epsilon_2, \epsilon_2^*\right\} - p_2$$

Choi et al. (2018)

Eventual Purchase Theorem

Let $w_i \equiv \delta_i + \min\left\{\epsilon_i, \epsilon_i^*\right\}$ for each i. Given $G(\mathbf{p}, \delta, \epsilon)$, the consumer purchases product i if and only if $w_i - p_i > u_0$ and $w_i - p_i > w_j - p_j$ for all $j \neq i$.

- Reframes Weitzman's optimal search solution as a simple discrete choice problem.
- Can be extended to unobservable prices as long as believes are, on average, correct.
- Markup rule for firms can be derived in terms of simple consumer demand functions.
- Applications to new car purchases: Moraga-Gonzalez et al. (2018): *"Consumer Search and Prices in the Automobile Market"*.

Choi et al. (2018): Demand and Markups

Distribution Function of new random variable:

$$H_i\left(w_i\right) \equiv \int_{\underline{\epsilon}_i}^{\epsilon_i^*} F_i\left(w_i - \epsilon_i\right) dG_i\left(\epsilon_i\right) + \int_{\epsilon_i^*}^{\bar{\epsilon}_i} F_i\left(w_i - \epsilon_i^*\right) dG_i\left(\epsilon_i\right)$$

Then consumer's best alternative to product i is $X_i \equiv \max\left\{u_0, \max_{j \neq i} W_j - p_j\right\}$ and the corresponding distribution function $\tilde{H}_i\left(x_i\right) \equiv \Pr\left\{X_i \leq x_i\right\}$.

Aggregate demand:

$$D_i(\mathbf{p}) = \int \left(1 - H_i\left(x_i + p_i\right)\right) d\tilde{H}_i\left(x_i\right)$$

Optimal pricing:

$$\frac{1}{p_i - c_i} = -\frac{dD_i(\mathbf{p})/dp_i}{D_i(\mathbf{p})}$$