Over-the-Counter Intermediation, Customers' Choice and Liquidity Measurement

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Liquidity in Over the Counter Markets

- In OTC markets, dealers intermediate trades between customers.

  Two trading mechanisms:
  - Principal: Dealers trade against their inventories.
  - Agency: Dealers search and match customers with offsetting trading needs.

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  - Dodd-Frank Act, Basel III (details).
  - Electronification (details).

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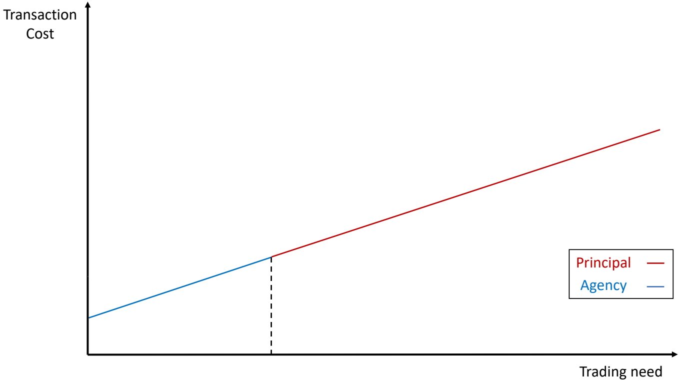
- Literature has focused on the dealers' trading mechanism choice.

  This paper studies the **customers' choice:**
  - What determines customers' trading mechanism choice?
  - What is their optimal response when market conditions change?
  - Is this response homogeneous?
  - What are the implications for market liquidity and its measurement?

This Paper:

I build and estimate a quantitative search model to address:

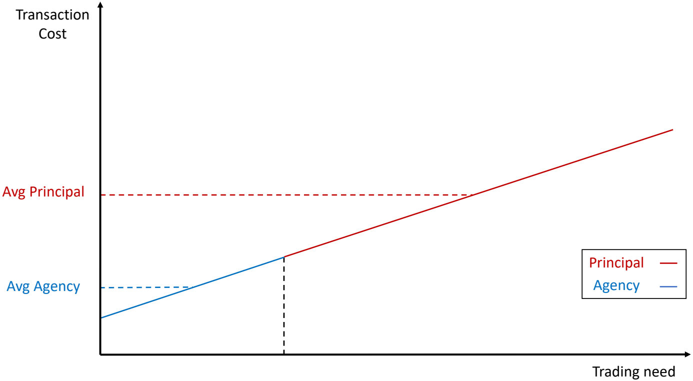
1. What determines customers' trading mechanism choice?
   - Customers bargain over transaction costs and choose a mechanism.
   - Those with larger trading needs choose to trade on principal.



This Paper:

I build and estimate a quantitative search model to address:

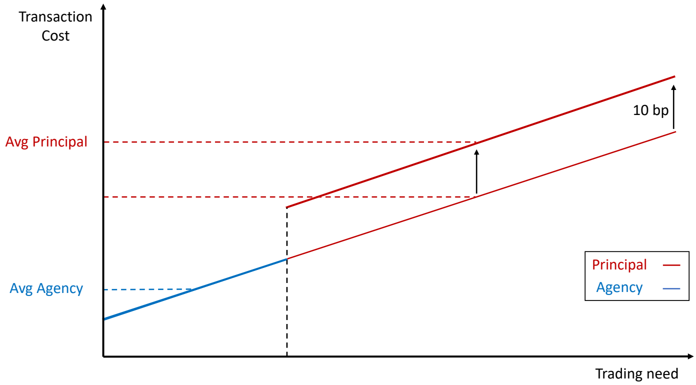
2. How this mechanism choice affects transaction cost measures?
   - A customer's transaction cost increases in her trading needs.
   - Each mechanism's average cost comprises the trading needs of its customers.



This Paper:

I build and estimate a quantitative search model to address:

3. How transaction costs change if market conditions change?
   - Standard practice: measure change in transaction costs of each mechanism.
   - ✓ Unbiased measure of liquidity change when customers don't migrate.



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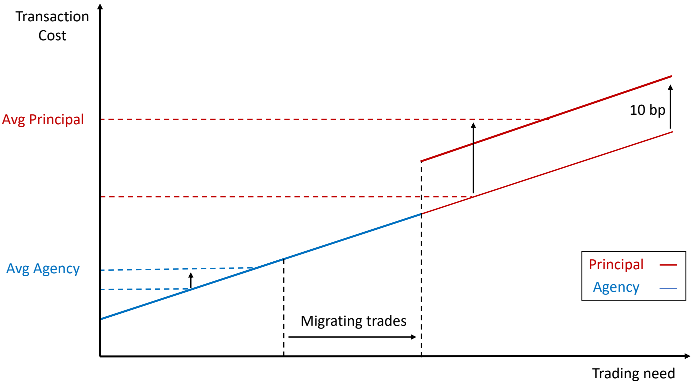
   - X Composition effect when customers do migrate.



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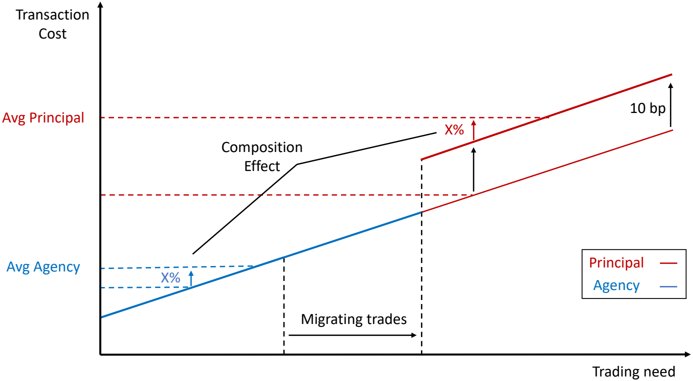
I build and estimate a quantitative search model to address:

4. What is the size and sign of the composition effect?
   - I compute average and counterfactual (fixed sample) measures:
   - Composition Effect $\equiv (\Delta \text{Avg} - \Delta \text{Count})/\Delta \text{Avg}$



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I estimate the model using corporate bond transaction data and revisit:

- Post '08 crisis regulations ($\uparrow$ inventory cost):
  Composition Effect: 32.2% in principal, -1.2% in agency.
- Electronification ($\uparrow$ speed of agency execution):
  Composition Effect: 89.5% in principal, -1.3% in agency.

Contribution

1. Search literature of OTC markets.

   Duffie, Gârleanu and Pedersen (2005), Lagos and Rocheteau (2009), Weill (2020), Dyskant, Silva and Sultanum (2023).

   + Alternative trading mechanisms.
   ✓ I study theoretically customers' speed-cost trade-off.

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   + Customers' trading mechanism choice and bargaining.
   ✓ Non-degenerate distribution of transaction costs.
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3. Empirical literature of OTC market liquidity.

   Bao, O'Hara, and Zhou (2018), Bessembinder, Jacobsen and Venkataraman (2018), Dick-Nielsen and Rossi (2019), Goldstein and Hotchkiss (2020), O'Hara and Zhou (2021), Kargar et.al. (2021), Choi, Huh and Shin (2023), Rapp and Waibel (2023).

   + Model of endogenous mechanism choice.
   ✓ I quantify the composition effect when market conditions change.

Agenda

Introduction

Model

Model Outcomes

Estimation

Quantitative Exercises

Model Outline

Lagos and Rocheteau (2009) + 2 trading mechanisms.

- Continuous time and infinitely lived agents.

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    1. Principal: immediate exchange.
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  - Bargain trade size and transaction costs.

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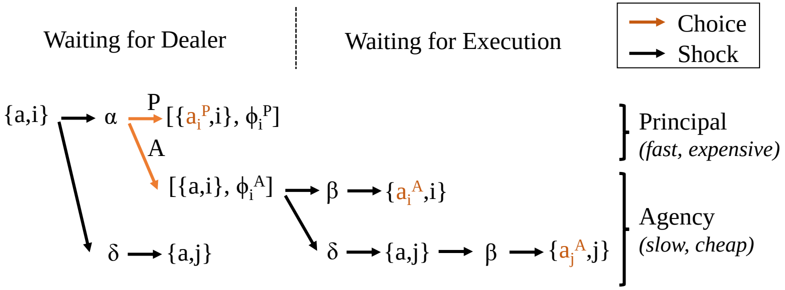
  - Choose trading mechanism:
    1. Principal: immediate exchange.
    2. Agency: delayed exchange.
  - Bargain trade size and transaction costs.
- Dealers execute orders in a frictionless inter-dealer market:
  1. Principal: immediate costly execution.
  2. Agency: delayed non-costly execution.

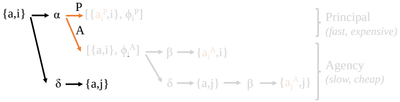
Customer's Path



Shocks:

- δ: preference shift.
- α: contact with dealers.
- β: execution of agency trade.

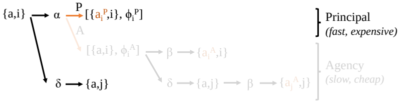
Customer's Value Function: contact dealers and choose mechanism.



$$V_{i_0}(a) = \mathbb{E}_{i_0}\Big[\underbrace{\int_0^{\tau_\alpha} e^{-rs} u_{i_s}(a)ds}_{\text{utility of holding } a} + e^{-r\tau_\alpha} \max\Big\{\underbrace{V^P_{i_\alpha}(a)}_{\textit{principal}}, \underbrace{V^A_{i_\alpha}(a)}_{\textit{agency}}\Big\}\Big]$$

- τ_α: time it takes to contact a dealer.
- i_s: preference type at time $t = s$.
- $u_i(a) = \epsilon_i \times \frac{a^{1-\sigma}}{1-\sigma}$: ut. function of customer $\{i, a\}$.
- $\mathbb{E}$ over:
  1. next contact with dealers $\rightarrow$ Poisson rate α.
  2. preference shocks $\rightarrow$ Poisson rate δ.
  3. execution of agency trade $\rightarrow$ Poisson rate β.

Principal choice: customers pay ϕ^P to trade immediately.



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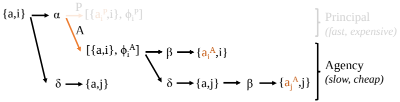
$$V^P_{i_\alpha}(a) = \underbrace{V_{i_\alpha}(a^P_{i_\alpha}) - p(a^P_{i_\alpha} - a) - \phi^P_{i_\alpha}}_{\text{immediate trade}}$$

- $a^P_{i_\alpha}$: optimal principal asset holdings of customer $\{i_\alpha, a\}$.
- p: inter-dealer price.
- $\phi^P_{i_\alpha}$: transaction cost charged in the principal trade.

Agency choice: customers pay ϕ^A and wait to trade.



$$V_{i_0}(a) = \mathbb{E}_{i_0}\left[\underbrace{\int_0^{\tau_\alpha} e^{-rs} u_{i_s}(a)ds}_{\text{utility of holding } a} + e^{-r\tau_\alpha} \max\left\{V^P_{i_\alpha}(a), \underbrace{V^A_{i_\alpha}(a)}_{agency}\right\}\right]$$

$$V^A_{i_\alpha}(a) = \underbrace{\int_0^{\tau_\beta} e^{-rs} u_{i_{\alpha+s}}(a)ds}_{\text{utility of holding } a} + e^{-r\tau_\beta}\left(\underbrace{V_{i_\beta}(a^A_{i_\beta}) - p(a^A_{i_\beta} - a) - \phi^A_{i_\alpha}}_{\text{delayed trade}}\right)$$

- τ_β: time it takes to execute agency trades.
- $a^A_{i_\beta}$: optimal agency asset holdings of customer $\{i_\beta, a\}$. Chosen at execution.
- $\phi^A_{i_\alpha}$: transaction cost charged when agency. Arranged at contact with dealers.

Dealer's Value Function: principal intermediation is costly.

Dealers pay inventory costs to intermediate on principal:

$$W_t = \mathbb{E}\Big[e^{-r(\tau_\alpha)}\Big(\int \Phi_{i_\alpha}(a)dH_{t+\tau_\alpha} + W(t+\tau_\alpha)\Big)\Big],$$

$$\Phi_i(a) = \begin{cases} \phi_i^P - \theta p|a_i^P - a| & \text{if principal,} \\ e^{-r(T_\beta - T_\alpha)}\phi_i^A & \text{if agency,} \end{cases}$$

where

- H_t: distribution of customers at time t.
- θ is the marginal inventory cost per dollar traded.

Transaction Costs as functions of liquidity needs.

Nash Bargaining where dealers hold η power:

- Optimal holdings a_i^P and a_i^A maximize total trading surplus.

Transaction Costs as functions of liquidity needs.

Nash Bargaining where dealers hold η power:

- Optimal holdings a_i^P and a_i^A maximize total trading surplus.
- Principal Problem: Immediate and costly execution.

$$\phi_i^P(a) = \eta\big[\underbrace{V_i(a_i^P) - V_i(a) - p(a_i^P - a)}_{\text{Customer's Surplus}}\big] + (1-\eta)\big[\underbrace{\theta p|a_i^P - a|}_{\text{Inventory Cost}}\big]$$

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- Agency Problem: Delayed and non-costly execution.

$$\mathbb{E}[e^{-r\tau_\beta}]\phi_{i_\alpha}^A(a) = \eta\Big[\underbrace{\mathbb{E}_{i_\alpha}\Big[\int_0^{\tau_\beta} e^{-rs}u_{i_{\alpha+s}}(a)ds + e^{-r\tau_\beta}\big(V_{i_\beta}(a_{i_\beta}^A) - p[a_{i_\beta}^A - a]\big)\Big] - V_{i_\alpha}(a)}_{\text{Customer's Surplus}}\Big]$$

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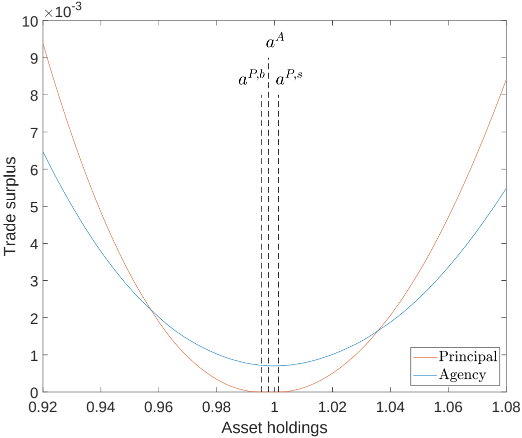
$\Longrightarrow$ Both principal and agency costs are increasing in consumers' surplus.

$\Longrightarrow$ Principal trades pay premium cost $(1-\eta)\theta p|a_i^P - a|$.

Optimal Trading Mechanism: A speed-cost trade-off

Indifference Condition (details) :

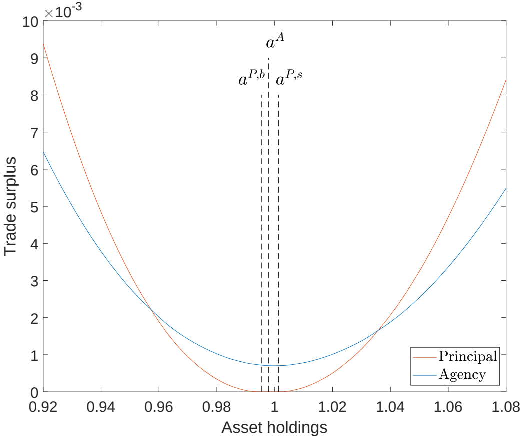
$$[V_i(a_i^P) - V_i(a)] - p(a_i^P - a) - p\theta|a_i^P - a| = \left[\bar{U}_i^\beta(a) + \hat{\beta}\bar{V}_i^A - V_i(a)\right] - \hat{\beta}p(\bar{a}_i^A - a)$$



Optimal Trading Mechanism: A speed-cost trade-off

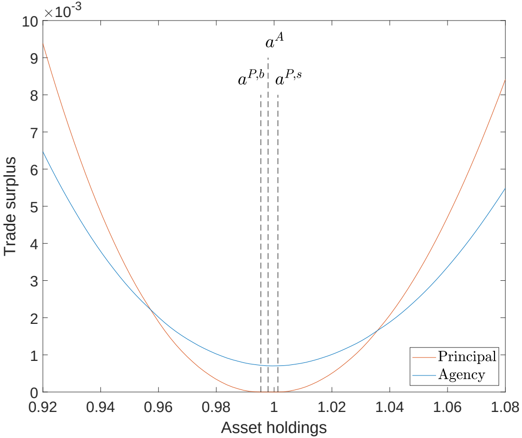
Indifference Condition for buyers when $\delta \to 0$:

$$\underbrace{\left[\frac{rV_i(a_i^A) - u_i(a)}{r+\beta}\right]}_{\text{cost of delay}} = \underbrace{p(1+\theta-\hat{\beta})(a_i^A - a)}_{\text{price discount}} + \underbrace{[V_i(a_i^A) - pa_i^A] - [V_i(a_i^P) - pa_i^P]}_{\text{gains from trade diff}} - \underbrace{p\theta(a_i^A - a_i^P)}_{\text{adjustment}}$$



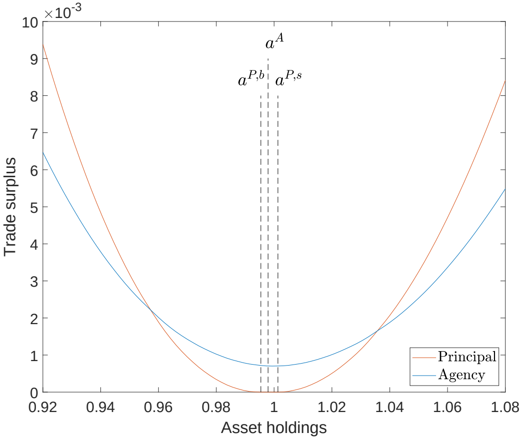
Optimal Trading Mechanism: A speed-cost trade-off

$$\text{As} \uparrow a_i^A - a \implies \underbrace{\frac{\left(rV_i(a_i^A) - u_i(a)\right)/(r+\beta)}{a_i^A - a}}_{\text{Avg cost of delay}} > \underbrace{p(1+\theta-\hat{\beta})}_{\text{Avg price discount}}.$$



Optimal Trading Mechanism: A speed-cost trade-off

As $\uparrow |a_i^* - a| \implies$ Principal surplus $>$ Agency surplus.



Steady State Distribution

- Define $n_{[a,i,\omega]}$ as the mass of customers with:
  - $a \in \mathcal{A}^*$: Asset holdings.
  - $i \in \{1 : I\}$: Preference shocks.
  - $\omega \in \{\omega_1, \omega_2\}$: Waiting for dealer ($\omega_1$) or for execution ($\omega_2$).
- Flow across states:

$$\begin{aligned}
\text{Contact dealer at rate } \alpha : & \begin{cases} n_{[a,i,\omega_1]} \rightarrow n_{[a',i,\omega_1]} & \forall\{a,i\} \quad \text{if principal.} \\ n_{[a,i,\omega_1]} \rightarrow n_{[a,i,\omega_2]} & \forall\{a,i\} \quad \text{if agency.} \end{cases} \\
\text{Pref. shock at rate } \delta : & \quad n_{[a,i,\omega]} \rightarrow n_{[a,j,\omega]} \qquad \forall\{a,\omega\}. \\
\text{Execution shock at rate } \beta : & \quad n_{[a,i,\omega_2]} \rightarrow n_{[a',i,\omega_2]} \qquad \forall\{i\}.
\end{aligned}$$

- Shocks + Policy Functions $\rightarrow T_{[3I \times I \times 2]}$. (see details here)

$$n = \lim_{k \rightarrow \infty} n_0 T^k$$

Steady State Equilibrium

The steady-state equilibrium is defined as:

1. Optimal asset holdings $\{a_i^P(a), a_i^A\}_{i=1}^I$.
2. Fees $\{\phi_i^P(a), \phi_i^A(a)\}_{i=1}^I$.
3. Trading mechanism sets $\{\Gamma_i^P, \Gamma_i^A\}_{i=1}^I$ where $\Gamma = \{Buy, Sell, NoT\}$.
4. Stationary distribution $n_{[a,i,\omega]}$.
5. Inter-dealer price p.

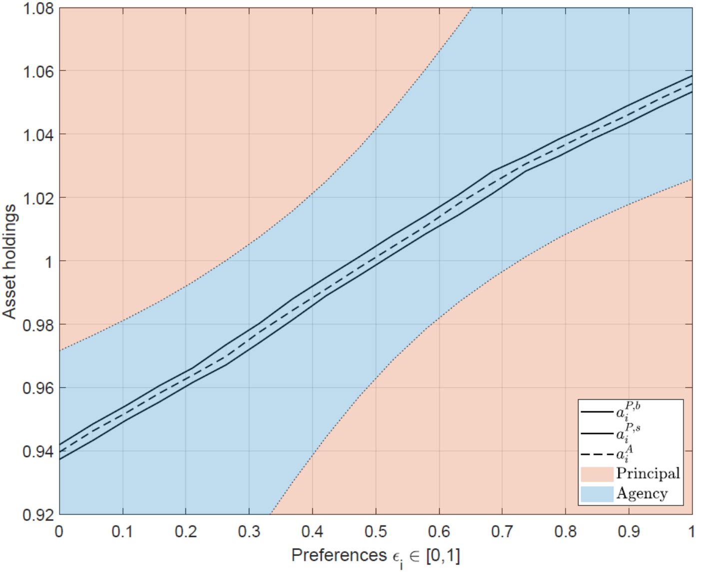
Such that

1. Optimal assets maximize consumer trading surplus.
2. Fees maximize Nash products.
3. Sets $\{\Gamma_i^P, \Gamma_i^A\}_{i=1}^I$ are defined using thresholds satisfying the indifference conditions.
4. Distribution $n_{[a,i,\omega]}$ satisfies inflow-outflow equations.
5. Price satisfy $\sum_{j=1}^2 \sum_{i=1}^I \sum_{a\in\mathcal{A}^*} an_{[a,i,\omega_j]} = A$.

Solution Method

Agenda

Trade choice and optimal holdings



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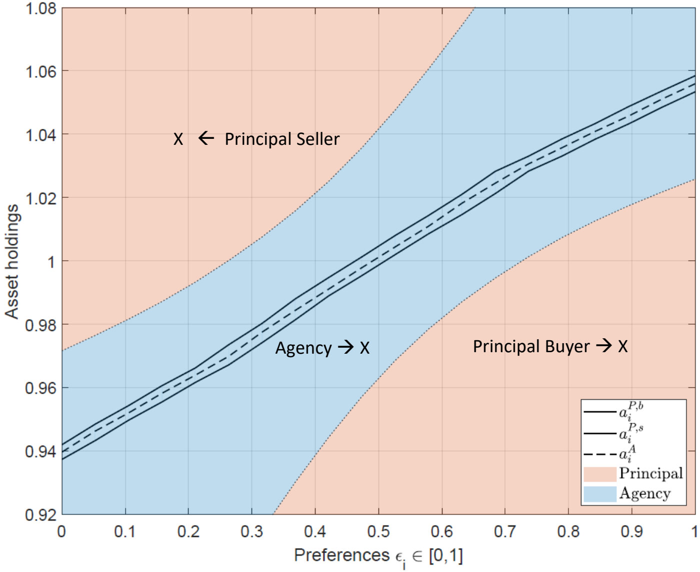

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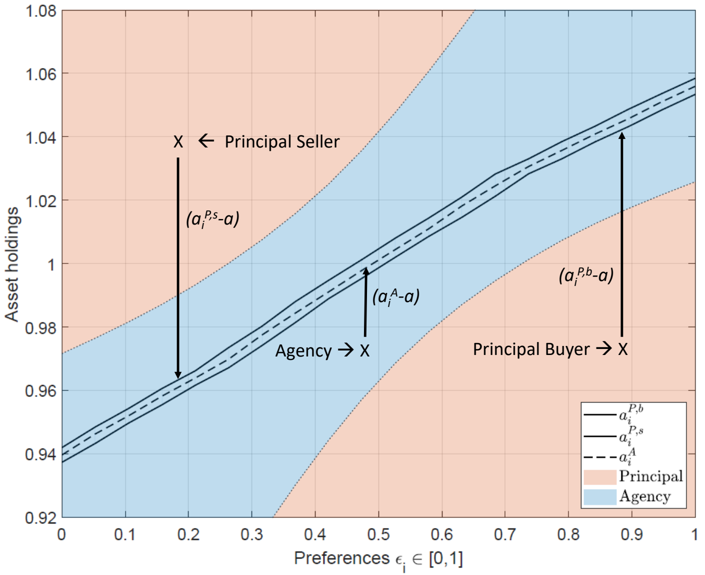
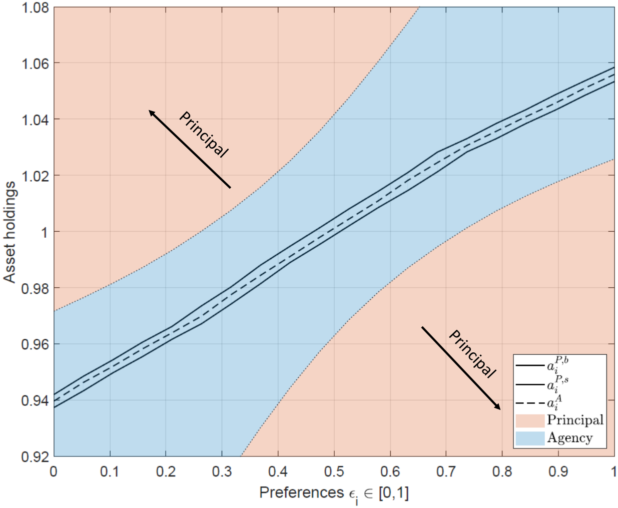


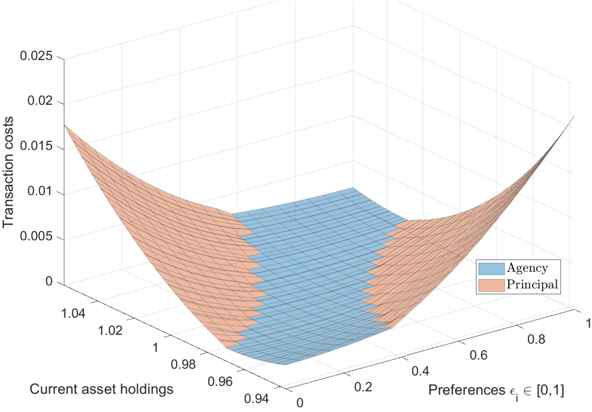
Trade choice and optimal holdings

1. Fix preference, principal is performed by customers with extreme positions.
2. Fix trade size, principal is performed by customers with extreme preferences.



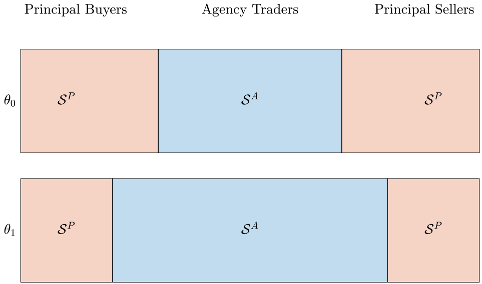
Transaction Costs per trading mechanism.

1. Transaction costs are increasing in trade size
2. Principal costs are larger than agency costs:
   a. Inventory cost.
   b. Optimal Sorting.



Transaction costs per dollar

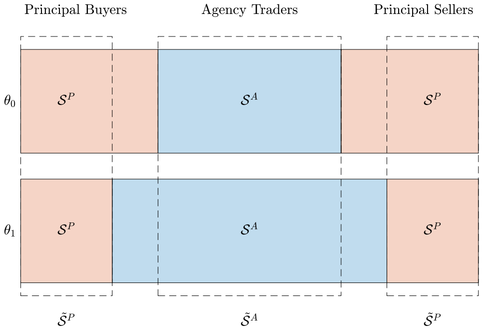
Counterfactual Transaction Costs and Composition Effect



Alter some parameter, say $\theta_1 > \theta_0$, and:

1. Compute average measures $\mathcal{S}^P$ and $\mathcal{S}^A$ as vol weighted transaction costs.

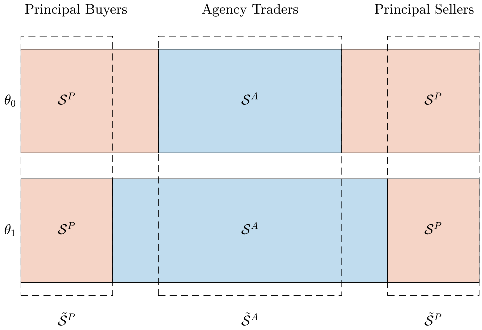
Counterfactual Transaction Costs and Composition Effect



Alter some parameter, say $\theta_1 > \theta_0$, and:

1. Compute average measures $\mathcal{S}^P$ and $\mathcal{S}^A$ as vol weighted transaction costs.
2. Compute counterfactual measures $\tilde{\mathcal{S}}^P$ and $\tilde{\mathcal{S}}^A$ using only non-migrant trades.

Counterfactual Transaction Costs and Composition Effect



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1. Compute average measures $\mathcal{S}^P$ and $\mathcal{S}^A$ as vol weighted transaction costs.
2. Compute counterfactual measures $\tilde{\mathcal{S}}^P$ and $\tilde{\mathcal{S}}^A$ using only non-migrant trades.
3. Compute Composition Effect (CE) as:

$$CE^P \equiv (\Delta\mathcal{S}^P - \Delta\tilde{\mathcal{S}}^P)/\Delta\mathcal{S}^P,$$
$$CE^A \equiv (\Delta\mathcal{S}^A - \Delta\tilde{\mathcal{S}}^A)/\Delta\mathcal{S}^A.$$

Details

Agenda

Estimation Strategy

Baseline Calibration:

- Normalized: asset supply, A, and preference shifter range, ϵ_i.
- Externally calibrated: discount rate, r, preference shifter distribution, π_i, and dealer's bargaining power η.
- Estimated: contact with dealer rate, α, preference shock rate, δ, agency execution rate β, inventory cost, θ, and utility curvature , σ.

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Moments Choice:

- Relevant sources of identification:
  - All parameters affect prices and quantities (directly or through GE effects). $\implies$ Moments cover both prices, quantities, and the relation among them.

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Moments Choice:

- Relevant sources of identification:
  - All parameters affect prices and quantities (directly or through GE effects).
    $\Longrightarrow$ Moments cover both prices, quantities, and the relation among them.
- Target quantitative goal:
  - Composition effects rely on transaction costs diff paid by migrants.
  - Migrants located in the extreme of the trading size distribution.
    $\Longrightarrow$ transaction costs - trading size slopes informs about such diff (recall intro graph).

GMM Estimation

Given normalized and calibrated parameters, I estimate:

$$\hat{\upsilon} = \arg\min_{\upsilon \in \Upsilon} [(m(\upsilon) - m_s) \oslash m_s]'[(m(\upsilon) - m_s) \oslash m_s]$$

where $\upsilon = [\alpha, \delta, \beta, \theta, \sigma]$, $m = [\mathcal{S}^P, \mathcal{S}^A, \mathcal{T}, \gamma^P, \gamma^A]$.

Moment	Empirical			Theoretical
	p50 (m_s)	p25	p75	
$\mathcal{S}^P$, Principal Vol Weighted Avg Costs	9.12	5.87	14.20	10.29
$\mathcal{S}^A$, Agency Vol Weighted Avg Costs	5.00	2.56	8.73	4.04
$\mathcal{T}$, Monthly Turnover	3.27	2.28	4.61	3.47
	$\hat{\gamma}$ (m_s)	$\hat{\gamma} - s.e.$	$\hat{\gamma} + s.e.$	
γ^P, Principal Cost-Size slope	1.45	1.33	1.58	1.31
γ^A, Agency Cost-Size slope	0.61	0.50	0.73	0.69

Sample moments computed from TRACE 2016-2019, using IG bonds with at least 10 observations in all variables used. Percentiles represent the cross-section of bond-level computed variables. n=2829 bonds.

Emp. moments details Th. moments details Sources of Identification

Baseline Calibration

Unit of time = 1 month | $u_i(a) = \epsilon_i \times \frac{a^{1-\sigma}}{1-\sigma}$

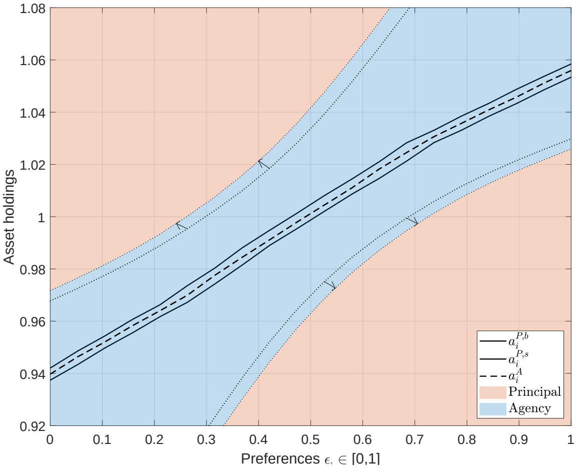
Parameter	Description	Value
- Normalization-		
A	Asset supply	1
ϵ_i	Preference shifter	$\left\{\frac{i-1}{I-1}\right\}_{i=1}^{20}$
- External calibration-		
r	Discount rate	0.5%
π_i	Preference shifter distribution	$1/I$
η	Dealer's bargaining power	0.95
- GMM calibration-		
α	Contact with dealer rate	9.15
δ	Preference shock rate	2.59
β	Agency execution rate	1.00
θ	Inventory cost	0.89 bp
σ	Utility curvature	2.73

θ Discussion

Agenda

Inventory costs increase: customers migrate away from principal.

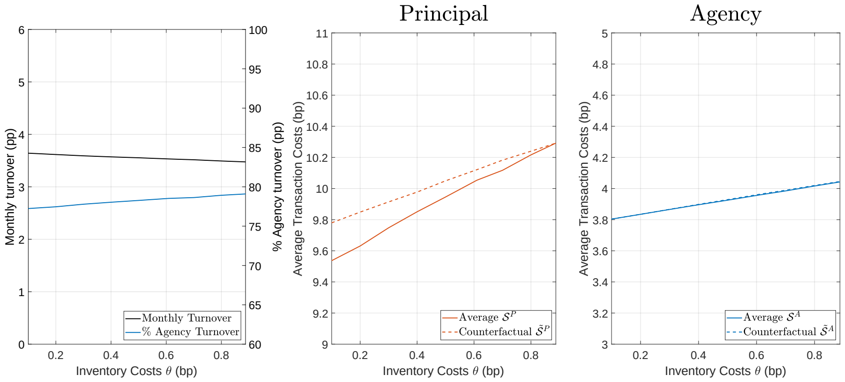
$$\theta : 0.1bp \to 0.89bp$$



1. Principal traders migrate towards agency.
2. Migration is not random: stronger when closer to optimal positions.

The rise in principal costs are overestimated by around 1/3.

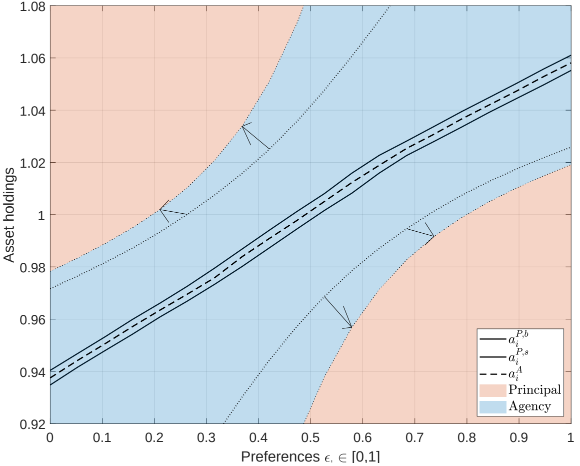
$$\theta : 0.1bp \rightarrow 0.89bp$$



- Turnover decreases as agency share increases.
- $\Delta\mathcal{S}^P = 0.76bp$ and $\Delta\tilde{\mathcal{S}}^P = 0.51bp$: $\implies$ $CE^P = 32.2\%$.
- $\Delta\mathcal{S}^A = 0.24bp$ and $\Delta\tilde{\mathcal{S}}^A = 0.24bp$: $\implies$ $CE^A = -1.2\%$.

Execution speed increase: customers migrate towards agency.

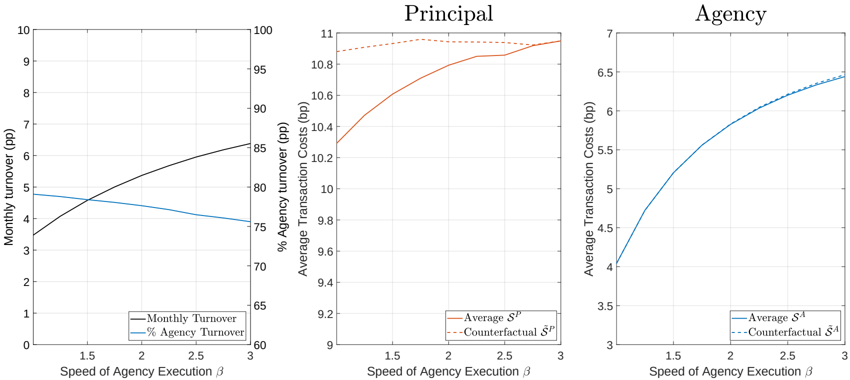
$$\beta : 1 \to 3$$



1. Principal trades migrate towards agency.
2. Non-random migration.

The rise in principal cost is mostly explained by the composition effect.

$$\beta : 1 \to 3$$



- Turnover increases and agency share decreases.
- $\Delta\mathcal{S}^P = 0.65bp$ and $\Delta\tilde{\mathcal{S}}^P = 0.07bp$: $\implies$ $CE^P = 89.5\%$.
- $\Delta\mathcal{S}^A = 2.40bp$ and $\Delta\tilde{\mathcal{S}}^A = 2.42bp$: $\implies$ $CE^A = -1.03\%$.

Conclusion

- Customers' trading mechanism choice matters:
  - Trading mechanisms are endogenous.
  - Choice is a function of each customer's speed-cost trade-off.
  - Transaction cost measures are subject to a composition bias.
- I study this choice and its effect on the market liquidity measures:
  - Secondary market with search frictions.
  - Immediate principal and delayed agency trading.
  - Speed-cost trade-off defines terms of trade of each customer.
- I build counterfactual measures and estimate the model to quantify the composition bias:
  - Inventory Cost: 32.2% in principal, -1.2% in agency.
  - Speed of Execution: 89.5% in principal, -1.03% in agency.
- Results suggest that policies affecting dealers' inventory costs had a smaller negative impact on market liquidity than previously thought.

Over-the-Counter Intermediation, Customers' Choice and Liquidity Measurement

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November 18, 2023

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Post-2008 regulation increased inventory costs

Basel III (finalized in 2013 in US)

- Liquidity Coverage Ratio (LCR): "high-quality" assets in proportion to any borrowing with term 30 days or less.
- Net Stable Funding Ratio (NSFR): fund assets that mature at various terms less than one year with financing that has at least a matching term.
- Revised Capital Adequacy Ratio (CAR): larger minimum of equity and reserves as a percentage of risk-weighted assets.
- Leverage Ratio (LR), maintain a quantity of stock and cash equal to at least 3% (5% for G-SIBs) of assets.

Dodd-Frank Act, Volcker Rule (full compliance by Jul 2015)

- Prohibits banks from engaging in proprietary trading of risky securities.
  - Market making is excepted, but the distinction is blurry.
  - Reports of measures as proxies for the underlying trading motive.

back

Electronification eased agency trading

Two main venues for corporate bond trading

1. Voice trading: customer-dealers sequential contacts.
2. Electronic trading platforms: customers send request-for-quotes (RFQ) on buy/sell orders to selected dealers who (may) reply with execution prices.

Electronic customer-dealer shares in the corp. bond mkt growth:

- IG (HY): '10: 6% (0.5%), '17: 17% (5%), 19': 23% (9%).

O'Hara and Zhou (2021) show that electronification eases matching:

- $RPT^{v}_{i,t,s,d} = \alpha + \beta \times E.Share_{i,t,s,d} + \gamma \times X_{i,t} + \mu_t + \mu_s + \mu_d + \epsilon_{i,t,s,d}$

Table 4
Electronic trading and riskless principal trades.

	I Bond level evidence	II Bond level evidence: Controlling for time fixed effects	III Bond-dealer level evidence	IV Bond-dealer level evidence: matched sample
E-Share	0.149***	0.138***	0.234***	0.138***
	(52.11)	(51.25)	(50.77)	(43.84)
Log(Amount Out)	−0.007***	−0.009***	0.002***	
	(−14.35)	(−17.32)	(11.70)	
Time to Maturity	−0.002***	−0.002***	−0.001***	
	(−15.72)	(−15.35)	(−27.75)	
Credit Rating FE	Yes	Yes	Yes	No
Industry FE	Yes	Yes	Yes	No
Size FE	Yes	Yes	Yes	No
Day FE	No	Yes	Yes	No
Dealer FE	No	No	Yes	Yes
Bond-Day-Size FE	No	No	No	Yes
Observations	10,484,065	10,484,065	17,777,860	10,743,569
R^2	0.12	0.12	0.5	0.65

For Columns I and II, the dependent variable is $RPTShare^{v}_{i,t,s}$, which is the share of RPT trade volume out of total voice trade volume, calculated at the bond-day-trade size level. For Columns III and IV, the dependent variable is $RPTShare^{v}_{i,t,s,d}$, which is the share of riskless principal trade (RPT) volume out of total voice trade volume, calculated at the bond-day-trade size-dealer level. *E-Share* is the share of dealer-customer trade volume that occurs on MarketAxess. It is calculated at the same frequency as the dependent variable. Controls include the log of the total par amount outstanding (*Log(Amount*

back

Flow Bellman Equation

Analytical expressions for expectations

$$V_i(a) = \bar{U}_i^{\kappa}(a) + \hat{\kappa}\big[(1-\hat{\delta})\max\left\{V_i^P(a), V_i^A(a)\right\} + \hat{\delta}\sum_j \pi_j \max\left\{V_j^P(a), V_j^A(a)\right\}\big]$$

where

$$\begin{aligned}
V_i^P(a) &= V_i(a_i^P) - p(a_i^P - a) - p\theta|a_i^P - a|, \\
V_i^A(a) &= \bar{U}_i^{\beta}(a) + \hat{\beta}[\bar{V}_i^A - p(\bar{a}_i^A - a)], \\
\bar{U}_i^{\nu}(a) &= \left[(1-\hat{\delta}_\nu)u_i(a) + \hat{\delta}_\nu \sum_j \pi_j u_j(a)\right]\frac{1}{r+\nu}, \\
\bar{V}_i^A &= (1-\hat{\delta}_\beta)V_i(a_i^A) + \hat{\delta}_\beta \sum_j \pi_j V_j(a_j^A), \\
\bar{a}_i^A &= (1-\hat{\delta}_\beta)a_i^A + \hat{\delta}_\beta \sum_j \pi_j a_j^A, \\
\hat{\kappa} &= \frac{\kappa}{r+\kappa}, \quad \hat{\beta} = \frac{\beta}{r+\beta}, \quad \hat{\delta}_\nu = \frac{\delta}{r+\delta+\kappa}, \quad \nu = [\kappa, \beta] \quad \kappa = \alpha(1-\eta).
\end{aligned}$$

back

Inflow-Outflow Equations

$$n_{[a_i^{P,b},i,\omega_1]}: \quad \delta\pi_i \sum_{j\neq i} n_{[a_i^{P,b},j,\omega_1]} + \alpha \sum_{a\in Buy_i^P} n_{[a,i,\omega_1]} = n_{[a_i^{P,b},i,\omega_1]}\left[\delta[1-\pi_i] + \alpha \mathbf{1}_{[a_i^{P,b}\notin NoT_i^P]}\right]$$

$$n_{[a_i^{P,s},i,\omega_1]}: \quad \delta\pi_i \sum_{j\neq i} n_{[a_i^{P,s},j,\omega_1]} + \alpha \sum_{a\in Sell_i^P} n_{[a,i,\omega_1]} = n_{[a_i^{P,s},i,\omega_1]}\left[\delta[1-\pi_i] + \alpha \mathbf{1}_{[a_i^{P,s}\notin NoT_i^P]}\right]$$

$$n_{[a_i^{A},i,\omega_1]}: \quad \delta\pi_i \sum_{j\neq i} n_{[a_i^{A},j,\omega_1]} + \beta \sum_{a\in \mathcal{A}^*} n_{[a,i,\omega_2]} = n_{[a_i^{A},i,\omega_1]}\left[\delta[1-\pi_i] + \alpha \mathbf{1}_{[a_i^{A}\notin NoT_i^P]}\right]$$

$$n_{[a,i,\omega_1]}: \quad \delta\pi_i \sum_{j\neq i} n_{[a_j,j,\omega_1]} = n_{[a_j,i,\omega_1]}\left[\delta[1-\pi_i] + \alpha \mathbf{1}_{[a_j\notin NoT_i^P]}\right], \quad a \in \cup_{j\neq i}\{a_j^{P,b}, a_j^{P,s}, a_j^{A}\}$$

$$n_{[a,i,\omega_2]}: \quad \delta\pi_i \sum_{j\neq i} n_{[a_i,j,\omega_2]} + \alpha n_{[a_i,i,\omega_1]} \mathbf{1}_{[a_i\in\Gamma_i^A]} = n_{[a_i,i,\omega_2]}\left[\delta[1-\pi_i] + \beta\right], \quad a \in \mathcal{A}^*$$

back

Solution Method

1. Set an initial guess for the equilibrium price p.
    1.1 Set an asset holdings grid and an initial guess for $V_i(a)$
    1.2 Compute optimal asset holdings $\{a_i^P(a), a_i^A\}_{i=1}^I$ using eq. (4) and eq. (6).
    1.3 Compute trading mechanism choice for each pair $\{i, a\}$, using indifference condition.
    1.4 Fix $\{a_i^P(a), a_i^A\}_{i=1}^I$, and iterate h times the following steps:
        1.4.1 Update $V_i(a)$ using eq. (1).
        1.4.2 Compute trading mechanism choice for each pair $\{i, a\}$, using indifference condition
    1.5 Update $V_i(a)$ using eq. (1) until convergence with initial guess of step (a).
2. Define trading mechanism sets $\{\Gamma_i^P, \Gamma_i^A\}_{i=1}^I$ using thresholds.
3. Compute transition matrix T using inflow-outflow equations.
4. Set vector n_0 and obtain $n = \lim_{k \to K} n_0 T^k$, with K sufficiently large to reach convergence.
5. Compute total demand and update p until excess demand in market clearing equations converges towards zero.

Note: Our Bellman operator is a contraction mapping with modulus $\hat{\kappa}$ and operates in a complete normed vector space

back

Discussion on Inventory Costs calibration

Inventory Costs θ:

- Suppose we want to capture the regulations-induced inventory costs.
- Greenwood et. al. (2017), Duffie (2018), Fed stress test (2019): Leverage Ratio Requirement as most important constraint for U.S. banks
  $\rightarrow$ LR: hold extra capital when including assets in inventory: 3% to 5%/
- LR cost $= p[a' - a][e^{zm} - 1]x\%$, where bank face $x\%$ of capital requirement and $z\%$ opportunity costs for such capital, and offload position after m days.
- Model cost $= 2\theta p[a' - a]$. $\implies \theta = [e^{zm} - 1]x\%/2$
- Take $z = r$ as the opportunity cost.
- Goldstein and Hotchkiss (2020), TRACE 02-11, $m = 10.6$ days.
- During sample period, 2016-2019, $x\% = 5\%$ for GSIB banks.

  $\implies \theta = 0.44 b.p.$.

My estimated $\hat{\theta} = 0.89 b.p.$, so arguably adding other cost on top of LR.

back

Empirical moments details I

Data Sources

- TRACE Academic: US dealers corporate bond transactions.
  - Dealers with anonymous identifiers.
  - 2016m1 - 2019m12.
  - Standard filters: error cleaning + literature basics [1].
  - IG Bonds
- FISD (bond characteristics)

Principal-Agency classification.

- Keep only customer-dealer trades.
- Agency: trades that share the same dealer-bond executed within a 15 min.
  - $\geq$ 50% vol if partial match.
  - Competing trades sorted by time distance and volume.
- Principal trades: non-agency trades.

back

[1] Among the most significant filters, I follow the literature and drop preferred, convertible or exchangeable, yankee bonds, bonds with sinking fund provision, variable coupon, with time to maturity $<$ 1 year, or issued $<$ 2 months)

Empirical moments details II

1) $\mathcal{S}$, Vol Weighted Transaction costs

- Remove micro trades ($\leq$\$100k)
- For each trade, compute Choi, Huh and Shin (2023)'s Spread1:

$$s_{i,b,d} = Q \times \left(\frac{p_{i,b,d} - p^{DD}_{b,d}}{p^{DD}_{b,d}}\right) \quad , \quad p^{DD}_{b,d} = \frac{\sum_{i \in DD_{b,d}} vol^{DD}_{b,d,i} p^{DD}_{b,d,i}}{\sum_{i \in DD_{b,d}} vol^{DD}_{b,d,i}}$$

  where i=trade, b=bond, d=day, $Q = 1$ (-1) if customer buys (sells).
- $\mathcal{S}^P_b = \sum_{i,d}(s_{i,b,d} \times vol^P_{i,b,d}) / \sum_{i,d} vol^P_{i,b,d}$
- $\mathcal{S}^A_b = \sum_{i,d}(s_{i,b,d} \times vol^A_{i,b,d}) / \sum_{i,d} vol^A_{i,b,d}$

2) $\mathcal{T}$, Monthly Turnover

- $k_b =$ numbers of days between offering and maturity, within the period sample.
- $iao_b =$ the average amount outstanding of bond during k_b days.
- $\mathcal{T}_b = \left(\sum_i vol_{i,b}/iao_b\right)/\left(k_b/30.5\right)$.

back

Empirical moments details III

3) γ, Transaction cost-Size slopes

- $s_{i,d,b} = \alpha + \beta FE + \gamma(vol^P_{i,d,b}/iao_b) + \epsilon_{i,d,b}$, with $FE = [dealer, bond, day]$.
- $\hat{\gamma}^P$ and $\hat{\gamma}^A$ are OLS estimates over corresponding subsamples.
- SE clustered by bond-day.

Dependent Variable:	Transaction Cost (bp)	
	Principal	Agency
Trade size (pp)	1.45***	0.61***
	(0.13)	(0.12)
Dealer FE	Yes	Yes
Bond FE	Yes	Yes
Day FE	Yes	Yes
Observations	1,505,133	97,305
R^2	0.111	0.019

Clustered (Bond & Day) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

back

Theoretical moments details

1) $\mathcal{S}$, Vol Weighted Transaction costs

$$\mathcal{S}^P = \sum_{i\in\mathcal{I}} \sum_{a\in\Gamma_i^P} \frac{n_{[a,i,\omega_1]}|a_i^P - a|}{\sum_{i\in\mathcal{I}} \sum_{a\in\Gamma_i^P} n_{[a,i,\omega_1]}|a_i^P - a|} \frac{\phi_{a,i}^P}{|a_i^P - a|p}$$

$$\mathcal{S}^A = \sum_{i\in\mathcal{I}} \sum_{a\in\Gamma_i^A} \frac{n_{[a,i,\omega_1]} rav_{a,i}}{\sum_{i\in\mathcal{I}} \sum_{a\in\Gamma_i^A} n_{[a,i,\omega_1]} rav_{a,i}} \frac{\phi_{a,i}^A}{rav_{[a,i]}p}$$

where realized agency volume $rav_{a,i} = (1-\hat{\delta})|a_i^A - a| + \hat{\delta}\sum_{j\in\mathcal{I}} \pi_j |a_j^A - a|$

2) $\mathcal{T}$, Monthly Turnover

$$\mathcal{T} = \sum_{i\in\mathcal{I}} \alpha\Big[\sum_{a\in\Gamma_i^P} n_{[a,i,\omega_1]}|a_i^P - a| + \sum_{a\in\Gamma_i^A} n_{[a,i,\omega_1]} rav_{a,i}\Big]$$

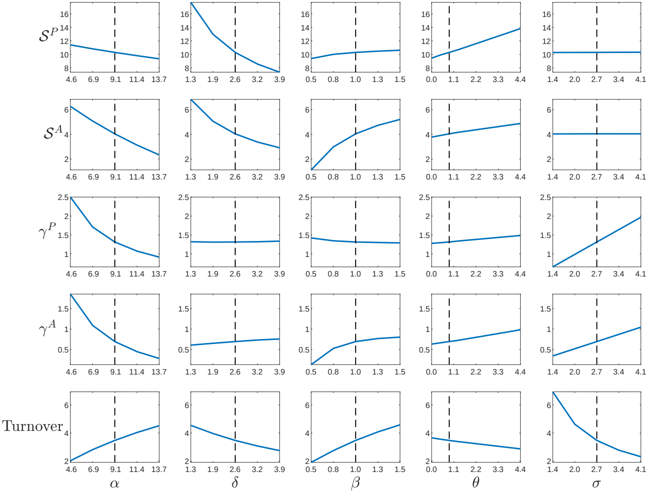
3) γ, Transaction cost-Size slopes

$$\hat{\gamma}^P = \frac{cov(\phi^P/(|a^P - a|p), |a^P - a|)}{var(|a^P - a|)} \quad , \quad \hat{\gamma}^A = \frac{cov(\phi^A/(rav * p), rav)}{var(rav)}$$

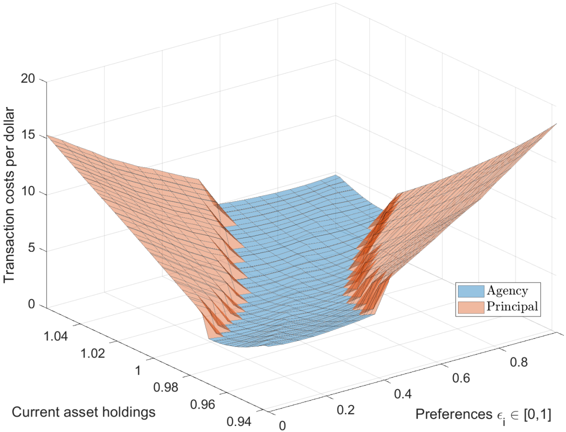
back

Sources of Identification

Theoretical moments as parameters change around $\hat{\upsilon}$



Transaction Costs per dollar: $\dfrac{\phi_i(a)}{|a' - a|}\dfrac{10000}{p}$



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Transaction Costs Decomposition: Principal Trades

$$\mathcal{S}^P = \sum_{i\in\mathcal{I}} \sum_{a\in\Gamma_i^P} \underbrace{\frac{n_{[a,i,\omega_1]}|a_i^P - a|}{\sum_{i\in\mathcal{I}}\sum_{a\in\Gamma_i^P} n_{[a,i,\omega_1]}|a_i^P - a|}}_{\text{steady state vol weight}} \underbrace{\frac{\phi_{a,i}^P}{|a_i^P - a|p}}_{\text{transaction cost per dollar}}$$

Transaction cost decomposition: consider change in parameter $q \in \{0, 1\}$

$$\mathcal{S}^P(q=0) = \mathcal{S}^{P,0}_{P^0,P^1} \times w^{P,0}_{P^0,P^1} + \mathcal{S}^{P,0}_{P^0,A^1} \times w^{P,0}_{P^0,A^1} + \mathcal{S}^{P,0}_{P^0,NT^1} \times w^{P,0}_{P^0,NT^1}$$
$$\mathcal{S}^P(q=1) = \mathcal{S}^{P,1}_{P^0,P^1} \times w^{P,1}_{P^0,P^1} + \mathcal{S}^{P,1}_{A^0,P^1} \times w^{P,1}_{A^0,P^1} + \mathcal{S}^{P,1}_{NT^0,P^1} \times w^{P,1}_{NT^0,P^1}$$

$$\Delta\mathcal{S}^P = \underbrace{\mathcal{S}^{P,1}_{P^0,P^1} \times w^{P,1}_{P^0,P^1} - \mathcal{S}^{P,0}_{P^0,P^1} \times w^{P,0}_{P^0,P^1}}_{\text{ongoing principals}}$$
$$\underbrace{+\mathcal{S}^{P,1}_{A^0,P^1} \times w^{P,1}_{A^0,P^1}}_{\text{agency} \to \text{principal}} \underbrace{+\mathcal{S}^{P,1}_{NT^0,P^1} \times w^{P,1}_{NT^0,P^1}}_{\text{no trader} \to \text{principal}}$$
$$\underbrace{-\mathcal{S}^{P,0}_{P^0,A^1} \times w^{P,0}_{P^0,A^1}}_{\text{principal} \to \text{agency}} \underbrace{-\mathcal{S}^{P,0}_{P^0,NT^1} \times w^{P,0}_{P^0,NT^1}}_{\text{principal} \to \text{no trader}}$$

Back

Transaction Cost Decomposition: Agency Trades

$$\mathcal{S}^A = \sum_{i\in\mathcal{I}} \sum_{a\in\Gamma_i^A} \frac{n_{[a,i,\omega_1]} rav_{a,i}}{\sum_{i\in\mathcal{I}} \sum_{a\in\Gamma_i^A} n_{[a,i,\omega_1]} rav_{a,i}} \frac{\phi^A_{a,i}}{rav_{[a,i]} p}$$

where $rav_{a,i}$ accounts for realized agency volume:

$$rav_{a,i} = (1-\hat{\delta})|a_i^A - a| + \hat{\delta} \sum_{j\in\mathcal{I}} \pi_j |a_j^A - a|$$

Transaction cost decomposition:

$$\begin{aligned}
\Delta\mathcal{S}^A = & \underbrace{\mathcal{S}^{A,1}_{A^0,A^1} \times w^{A,1}_{A^0,A^1} - \mathcal{S}^{A,0}_{A^0,A^1} \times w^{A,1}_{A^0,A^1}}_{\text{ongoing agency traders}} \\
& + \underbrace{\mathcal{S}^{A,1}_{P^0,A^1} \times w^{A,1}_{P^0,A^1}}_{\text{principal} \to \text{agency}} + \underbrace{\mathcal{S}^{A,1}_{NT^0,A^1} \times w^{A,1}_{NT^0,A^1}}_{\text{no traders} \to \text{agency}} \\
& - \underbrace{\mathcal{S}^{A,0}_{A^0,P^1} \times w^{A,0}_{A^0,P^1}}_{\text{agency} \to \text{principal}} - \underbrace{\mathcal{S}^{A,0}_{A^0,NT^1} \times w^{A,0}_{A^0,NT^1}}_{\text{agency} \to \text{no traders}}
\end{aligned}$$

Back

Counterfactual Measures

Composition-free avg. transaction cost under parametrization $q \in \{0, 1\}$:

- Only those customers who would not migrate when q changes.

$$\tilde{\mathcal{S}}^P(q) \equiv \mathcal{S}^{P,q}_{P^0,P^1},$$
$$\tilde{\mathcal{S}}^A(q) \equiv \mathcal{S}^{A,q}_{A^0,A^1}.$$

Composition-free avg. transaction cost changes:

- Change in costs fixing the set of customers to those non-migrants.

$$\Delta\tilde{\mathcal{S}}^P \equiv \mathcal{S}^{P,1}_{P^0,P^1} - \mathcal{S}^{P,0}_{P^0,P^1},$$
$$\Delta\tilde{\mathcal{S}}^A \equiv \mathcal{S}^{A,1}_{A^0,A^1} - \mathcal{S}^{A,0}_{A^0,A^1},$$

Composition effect bias:

- Percentage difference between avg and composition-free measures.

$$CE^P \equiv (\Delta\mathcal{S}^P - \Delta\tilde{\mathcal{S}}^P)/\Delta\mathcal{S}^P,$$
$$CE^A \equiv (\Delta\mathcal{S}^A - \Delta\tilde{\mathcal{S}}^A)/\Delta\mathcal{S}^A.$$

Quantitative Exercises Robustness Checks

I compute the composition effect (CE) in both quantitative exercises using:

- Alternative preference distribution, $\pi_i \sim Beta(\lambda, \lambda)$. Baseline: $\lambda = 1$.
- Alternative dealer's bargaining power η. Baseline: $\eta = 0.95$.

		Composition Effect					
		λ			η		
		0.2	1	5	0.91	0.95	0.99
$\Delta\theta$	CE^P	18.49	32.19	28.65	25.99	32.19	34.58
	CE^A	-0.20	-1.19	0.42	0.50	-1.19	-16.78
$\Delta\beta$	CE^P	79.64	89.54	101.38	74.71	89.54	105.18
	CE^A	-1.14	-1.03	0.26	-1.09	-1.03	-4.08

The parameters not affected are kept at their baseline calibration value

$$CE^P \equiv (\Delta\mathcal{S}^P - \Delta\tilde{\mathcal{S}}^P)/\Delta\mathcal{S}^P,$$
$$CE^A \equiv (\Delta\mathcal{S}^A - \Delta\tilde{\mathcal{S}}^A)/\Delta\mathcal{S}^A.$$

Back

Balance sheet costs seem linear + constraint.

Duffie et al. (2023)

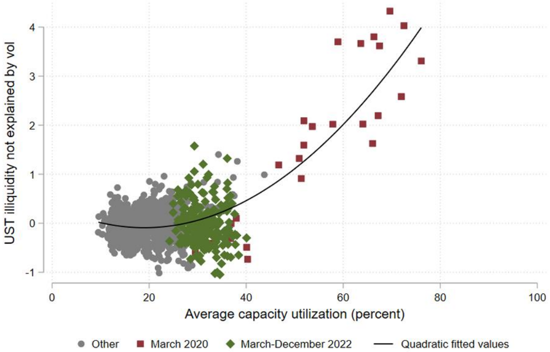

Figure 5. Relationship between US Treasury market illiquidity not explained by yield volatility and average dealer capacity utilization. A scatter plot of the residual illiquidity that remains after controlling for average swaption-implied volatility (the residuals associated with the fitted relationship in Figure 4) and average dealer capacity utilization. The average capacity utilization is the average of the dealer capacity utilization measures based on dealer gross positions, dealer net positions, gross dealer-to-customer volume, and net dealer-to-customer volume. The plotted ordinary-least-squares fit, for July 10, 2017 to December 31, 2022, is the second-order polynomial $y = 0.363 - 0.048x + 0.0013x^2$, with $R^2 = 43.6\%$. All three coefficient estimates have p-values of less than 1% using Newey-West standard errors.

back