Market-making with Search and Information Frictions

Benjamin Lester
Philadelphia Fed

Ali Shourideh
Carnegie Mellon University

Venky Venkateswaran
NYU Stern

Ariel Zetlin-Jones
Carnegie Mellon University

October 2021

The Question

- Many assets trade in dealer-intermediated over-the-counter (OTC) markets
    - corporate & muni bonds, CDS, repos, swaps, FX contracts...

The Question

- Many assets trade in dealer-intermediated over-the-counter (OTC) markets
  - corporate & muni bonds, CDS, repos, swaps, FX contracts...
- These markets are undergoing significant changes

The Question

- Many assets trade in dealer-intermediated over-the-counter (OTC) markets
  - corporate & muni bonds, CDS, repos, swaps, FX contracts...

- These markets are undergoing significant changes
  - some changes have arguably **reduced trading frictions**
    - migration from voice-based to electronic trading ▸ more

    ⇒ faster/easier for traders to contact dealers, see bid/ask quotes

The Question

- Many assets trade in dealer-intermediated over-the-counter (OTC) markets
  - corporate & muni bonds, CDS, repos, swaps, FX contracts...

- These markets are undergoing significant changes
  - some changes have arguably **reduced trading frictions**
    - migration from voice-based to electronic trading ▸ more

    $\Rightarrow$ faster/easier for traders to contact dealers, see bid/ask quotes
  - other changes have arguably **increased trading frictions**
    - post-crisis regulations on large dealer-banks

    $\Rightarrow$ fewer, less active dealers $\Rightarrow$ harder for traders to contact dealers

The Question

- Many assets trade in dealer-intermediated over-the-counter (OTC) markets
  - corporate & muni bonds, CDS, repos, swaps, FX contracts...

- These markets are undergoing significant changes
  - some changes have arguably **reduced trading frictions**
    - migration from voice-based to electronic trading ▸ more
    - $\Rightarrow$ faster/easier for traders to contact dealers, see bid/ask quotes
  - other changes have arguably **increased trading frictions**
    - post-crisis regulations on large dealer-banks
    - $\Rightarrow$ fewer, less active dealers $\Rightarrow$ harder for traders to contact dealers

- **How should we expect these changes to affect ...**

The Question

- Many assets trade in dealer-intermediated over-the-counter (OTC) markets
  - corporate & muni bonds, CDS, repos, swaps, FX contracts...

- These markets are undergoing significant changes
  - some changes have arguably **reduced trading frictions**
    - migration from voice-based to electronic trading ▸ more
    - ⇒ faster/easier for traders to contact dealers, see bid/ask quotes
  - other changes have arguably **increased trading frictions**
    - post-crisis regulations on large dealer-banks
    - ⇒ fewer, less active dealers ⇒ harder for traders to contact dealers

- **How should we expect these changes to affect ...**
  - **market liquidity?** (bid-ask spreads, price impact, volume, ...)
  - **consumer surplus/welfare?**?

Two frictions

- Two canonical sources of illiquidity
  1. **Trading (search) frictions**: investors trade infrequently, dealers have market power
     - As in, e.g., Duffie-Garleanu-Pedersen (2005)
     - Prediction: more frequent contact with dealers, more competition $\Rightarrow$ spreads $\downarrow$

Two frictions

- Two canonical sources of illiquidity
  1. **Trading (search) frictions**: investors trade infrequently, dealers have market power
     - As in, e.g., Duffie-Garleanu-Pedersen (2005)
     - Prediction: more frequent contact with dealers, more competition $\Rightarrow$ spreads $\downarrow$
  2. **Information frictions**: investors know more about asset than dealers
     - As in, e.g., Glosten-Milgrom (1985)
     - Ascribes a central role to dealers *learning* over time

Two frictions

- Two canonical sources of illiquidity
  1. **Trading (search) frictions**: investors trade infrequently, dealers have market power
     - As in, e.g., Duffie-Garleanu-Pedersen (2005)
     - Prediction: more frequent contact with dealers, more competition $\Rightarrow$ spreads $\downarrow$
  2. **Information frictions**: investors know more about asset than dealers
     - As in, e.g., Glosten-Milgrom (1985)
     - Ascribes a central role to dealers *learning* over time

- **Do Δ trading frictions mitigate or exacerbate informational frictions?**
  - Predictions from model with only search frictions true when both frictions are present?

Two frictions

- Two canonical sources of illiquidity
  1. **Trading (search) frictions**: investors trade infrequently, dealers have market power
     - As in, e.g., Duffie-Garleanu-Pedersen (2005)
     - Prediction: more frequent contact with dealers, more competition $\Rightarrow$ spreads $\downarrow$
  2. **Information frictions**: investors know more about asset than dealers
     - As in, e.g., Glosten-Milgrom (1985)
     - Ascribes a central role to dealers *learning* over time
- **Do Δ trading frictions mitigate or exacerbate informational frictions?**
  - Predictions from model with only search frictions true when both frictions are present?
- Challenge: existing lit studies two frictions in isolation, need unified framework...

This paper

- Develop a unified framework to study a dynamic asset market with:
  - **asymmetric information**
  - **trading frictions**

  where
  - dealers **learn over time** from market-wide trading activity
  - traders' behavior affected by **frequency of trading opportunities**

This paper

- Develop a unified framework to study a dynamic asset market with:
  - **asymmetric information**
  - **trading frictions**

  where
  - dealers **learn over time** from market-wide trading activity
  - traders' behavior affected by **frequency of trading opportunities**

- **Key result: more frequent trading opportunities slows down dealers' learning**

  ⇒ speeding up trading does not necessarily improve market liquidity
  - e.g., bid-ask spreads can $\uparrow$ or $\downarrow$

  ⇒ the value of speed depends on severity of info frictions
  - e.g., trading speed more valuable for investment grade vs. high yield bonds

Literature

Market-making with asymmetric information

- "Small" informed traders, dealers learn from individual trades: Glosten-Milgrom(1985), ...
- "Large" informed trader, dealers learn from aggregate trade: Kyle(1985),...
- This paper: "small" informed traders, dealers learn from aggregate trade, search & market power

Market-making with search frictions

- Full info: Duffie, Garleanu & Pedersen(2005), Lagos & Rocheteau(2009)...
- Private info, private values: Spulber(1996), Lester, Rocheteau & Weill (2015)...
- This paper: private information about common values (adverse selection), learning

Decentralized trading with adverse selection

- Idiosyncratic: Inderst(2005), Guerrieri-Shimer-Wright(2010), Camargo & Lester(2014), Lauermann & Wolinsky(2016), Kim (2017)...
- Aggregate: Wolinsky(1990), Blouin & Serrano(2001), Duffie, Malamud & Manso(2009), Golosov, Lorenzoni & Tsyvinski(2014)...
- This paper: Learning from market-wide activity, effect of info frictions on bid-ask spread

the economic environment

Agents and Assets

- Discrete time, infinite horizon
- A market for a single asset, quality (state of the world) is either l or h
- A continuum of **traders**
  - can hold $q \in \{0, 1\}$ units of the asset
  - with probability $1 - \delta$ in each period, asset matures (game ends)
  - traders have private info about asset quality + their own preferences
- A continuum of **dealers**
  - can hold unrestricted positions (long or short)
  - less informed (ex ante) about asset quality, but learn from trading activity

Preferences

Given state of world $j \in \{l, h\}$,

- **trader** i who owns an asset receives:
  - flow payoff $\omega_t + \varepsilon_{i,t}$ per period
  - terminal payoff c_j upon maturity, with $c_h > c_l$

  with
  - $\omega_t \sim F(\omega)$ = market-wide liquidity shock, mean zero, iid over time
  - $\varepsilon_{i,t} \sim G(\varepsilon)$ = idiosyncratic liquidity shock, mean zero, iid over time

- For each unit he holds, **dealer** receives:
  - payoff v_j at maturity, with $v_h > v_l$
  - no liquidity shocks

Search, Prices, and Trade

- Each period, trader meets a dealer with probability π

- Dealer offers to buy at bid price B_t, sell at ask price A_t
  1. Monopolist case: single dealer makes a take-it-or-leave-it-offer
  2. Competitive case: two or more dealers engage in Bertrand competition
  3. Mixed case: probability α_m of monopolist meeting, $\alpha_c = 1 - \alpha_m$ comp meeting

Search, Prices, and Trade

- Each period, trader meets a dealer with probability π
- Dealer offers to buy at bid price B_t, sell at ask price A_t
  1. Monopolist case: single dealer makes a take-it-or-leave-it-offer
  2. Competitive case: two or more dealers engage in Bertrand competition
  3. Mixed case: probability α_m of monopolist meeting, $\alpha_c = 1 - \alpha_m$ comp meeting
- Trader accepts or rejects
  - if she rejects, no trade occurs in that period

Information and Learning

After trades occur in each period, dealers observe total trading volume

Two sources of uncertainty for dealers:

1. asset quality: common value
2. aggregate liquidity shock: private value

$\Rightarrow$ volume is a noisy signal about asset quality

Information and Learning

After trades occur in each period, dealers observe total trading volume

Two sources of uncertainty for dealers:

1. asset quality: common value
2. aggregate liquidity shock: private value

$\Rightarrow$ volume is a noisy signal about asset quality

Dealers are informationally small and all have common beliefs

- Beliefs summarized by $\mu_t \equiv \text{Prob}_t(j = h)$

characterizing equilibrium

Outline

We need to characterize:

- Traders' behavior: when to buy/sell
- Dealers' behavior: optimal bid and ask prices
- Evolution of dealers' beliefs
- Distribution of assets across traders & dealers

Traders' Optimal Behavior

- $W^q_{j,t} \equiv$ value of owning $q \in \{0,1\}$ units of quality $j \in \{l,h\}$ asset at t
- Given bid and ask prices (B_t, A_t) and shocks $(\varepsilon_{i,t}, \omega_t)$,
  - Owner should sell if $\varepsilon_{i,t}$ sufficiently small, hold otherwise:

$$B_t + W^0_{j,t+1} \geq \varepsilon_{i,t} + \omega_t + W^1_{j,t+1}$$

  - Non-owner should buy if $\varepsilon_{i,t}$ sufficiently large, do nothing otherwise:

$$-A_t + \varepsilon_{i,t} + \omega_t + W^1_{j,t+1} \geq W^0_{j,t+1}$$

Traders' Optimal Behavior

- $W_{j,t}^{q} \equiv$ value of owning $q \in \{0,1\}$ units of quality $j \in \{l,h\}$ asset at t
- Given bid and ask prices (B_t, A_t) and shocks $(\varepsilon_{i,t}, \omega_t)$,
  - Owner should sell if $\varepsilon_{i,t}$ sufficiently small, hold otherwise:

$$B_t + W_{j,t+1}^{0} \geq \varepsilon_{i,t} + \omega_t + W_{j,t+1}^{1}$$

  - Non-owner should buy if $\varepsilon_{i,t}$ sufficiently large, do nothing otherwise:

$$-A_t + \varepsilon_{i,t} + \omega_t + W_{j,t+1}^{1} \geq W_{j,t+1}^{0}$$

- $R_{j,t} = W_{j,t}^{1} - W_{j,t}^{0} \equiv$ reservation value at t when quality is $j \in \{l,h\}$

Traders' Optimal Behavior

- Owner i sells iff

$$\varepsilon_{i,t} \leq \underline{\varepsilon}_{j,t} \equiv B_t - R_{j,t+1} - \omega_t$$

- Non-owner i buys iff

$$\varepsilon_{i,t} \geq \overline{\varepsilon}_{j,t} \equiv A_t - R_{j,t+1} - \omega_t$$

- Reservation values satisfy

$$R_{j,t} = (1-\delta)c_j + \delta\mathbb{E}\left[R_{j,t+1}\right] + \delta\pi\mathbb{E}\left[\underbrace{\Omega_{j,t+1}}_{\text{Net option value}}\right]$$

where

$$\Omega_{j,t} = \underbrace{\max\{B_t - R_{j,t+1} - \omega_t - \varepsilon_{i,t}, 0\}}_{\text{option to sell}} - \underbrace{\max\{-A_t + R_{j,t+1} + \omega_t + \varepsilon_{i,t}, 0\}}_{\text{option to buy}}$$

Aggregate Positions

$N^q_{j,t}$ = measure of traders holding $q \in \{0,1\}$ units of asset when quality is $j \in \{l,h\}$

$$N^1_{j,t+1} = \left\{ N^1_t \left[\underbrace{1-\pi}_{\text{no meeting}} + \underbrace{\pi \left(1 - G(\underline{\varepsilon}_{j,t})\right)}_{\text{meeting, no sell}} \right] + N^0_t \underbrace{\pi \left(1 - G(\overline{\varepsilon}_{j,t})\right)}_{\text{meet \& buy}} \right\}$$

$$N^0_{j,t+1} = \left\{ N^1_t \pi G(\underline{\varepsilon}_{j,t}) + N^0_t \left[1 - \pi + \pi G(\overline{\varepsilon}_{j,t})\right] \right\}.$$

Dealers observe past volume

$\Rightarrow$ they know N^q_t when setting (B_t, A_t).

Monopolist Dealer's Prices

Dealer chooses (A_t, B_t) to maximize

$$\mathbb{E}_{j,\omega}\left[\frac{N_t^0}{N_t^0+N_t^1}\left(1-G(\overline{\varepsilon}_{j,t})\right)\left(A_t-v_j\right)+\frac{N_t^1}{N_t^0+N_t^1}G(\underline{\varepsilon}_{j,t})(v_j-B_t)\right]$$

Monopolist Dealer's Prices

Dealer chooses (A_t, B_t) to maximize

$$\mathbb{E}_{j,\omega}\left[\frac{N_t^0}{N_t^0+N_t^1}\left(1-G(\overline{\varepsilon}_{j,t})\right)(A_t-v_j)+\frac{N_t^1}{N_t^0+N_t^1}G(\underline{\varepsilon}_{j,t})(v_j-B_t)\right]$$

Notice pricing problem is **static** and separable

- No dynamic inventory considerations
  - dealers can hold unrestricted positions, have deep pockets

Monopolist Dealer's Prices

Dealer chooses (A_t, B_t) to maximize

$$\mathbb{E}_{j,\omega}\left[\frac{N_t^0}{N_t^0+N_t^1}\left(1-G(\overline{\varepsilon}_{j,t})\right)(A_t-v_j)+\frac{N_t^1}{N_t^0+N_t^1}G(\underline{\varepsilon}_{j,t})(v_j-B_t)\right]$$

Notice pricing problem is **static** and separable

- No dynamic inventory considerations
  - dealers can hold unrestricted positions, have deep pockets
- No motive for experimentation
  - continuum of traders & dealers
  - support of shocks is "large enough"
  - shocks are uncorrelated with state of the world

▸ No Experimentation

Monopolist Dealer's Prices (given beliefs μ_t)

As a result, optimal prices satisfy:

$$A_t = \mathbb{E}_j v_j + \underbrace{\frac{1 - \mathbb{E}_{j,\omega}\left[G\left(\overline{\varepsilon}_{j,t}\right)\right]}{\mathbb{E}_{j,\omega}\left[g\left(\overline{\varepsilon}_{j,t}\right)\right]}}_{\text{market power}} + \underbrace{\mu_t(1-\mu_t)(v_h - v_l)\frac{\mathbb{E}_{\omega}\left[g\left(\overline{\varepsilon}_{h,t}\right) - g\left(\overline{\varepsilon}_{l,t}\right)\right]}{\mathbb{E}_{j,\omega}\left[g\left(\overline{\varepsilon}_{j,t}\right)\right]}}_{\text{asymmetric information}}$$

$$B_t = \mathbb{E} v_j - \frac{\mathbb{E}_{j,\omega}\left[G\left(\underline{\varepsilon}_{j,t}\right)\right]}{\mathbb{E}_{j,\omega}\left[g\left(\underline{\varepsilon}_{j,t}\right)\right]} - \mu_t(1-\mu_t)(v_h - v_l)\frac{\mathbb{E}_{\omega}\left[g\left(\underline{\varepsilon}_{l,t}\right) - g\left(\underline{\varepsilon}_{h,t}\right)\right]}{\mathbb{E}_{j,\omega}\left[g\left(\underline{\varepsilon}_{j,t}\right)\right])}.$$

Monopolist Dealer's Prices (given beliefs μ_t)

As a result, optimal prices satisfy:

$$A_t = \mathbb{E}_j v_j + \underbrace{\frac{1-\mathbb{E}_{j,\omega}\left[G\left(\overline{\varepsilon}_{j,t}\right)\right]}{\mathbb{E}_{j,\omega}\left[g\left(\overline{\varepsilon}_{j,t}\right)\right]}}_{\text{market power}} + \underbrace{Cov\left(\frac{g\left(\overline{\varepsilon}_{j,t}\right)}{\mathbb{E}_{j,\omega}\left[g\left(\overline{\varepsilon}_{j,t}\right)\right]}\ ,\ v_j\right)}_{\text{asymmetric information}}$$

$$B_t = \mathbb{E}_j v_j - \frac{\mathbb{E}_{j,\omega}\left[G\left(\underline{\varepsilon}_{j,t}\right)\right]}{\mathbb{E}_{j,\omega}\left[g\left(\underline{\varepsilon}_{j,t}\right)\right]} - Cov\left(\frac{g\left(\underline{\varepsilon}_{j,t}\right)}{\mathbb{E}_{j,\omega}\left[g\left(\underline{\varepsilon}_{j,t}\right)\right]}\ ,\ v_j\right)$$

Competitive Prices

Bertrand competition ⇒ zero profits (*a la* Glosten-Milgrom)

$$A_t = \frac{\mathbb{E}_{j,\omega}\left[v_j\left(1 - G(\overline{\varepsilon}_{j,t})\right)\right]}{\mathbb{E}_{j,\omega}\left[\left(1 - G(\overline{\varepsilon}_{j,t})\right)\right]}$$

$$B_t = \frac{\mathbb{E}_{j,\omega}\left[v_j G(\underline{\varepsilon}_{j,t})\right]}{\mathbb{E}_{j,\omega}\left[G(\underline{\varepsilon}_{j,t})\right]}$$

Competitive Prices

Bertrand competition ⇒ zero profits (*a la* Glosten-Milgrom)

$$A_t = \mathbb{E}_t v_j + \underbrace{Cov\left(\frac{1-G\left(\bar{\varepsilon}_{j,t}\right)}{\mathbb{E}_{j,\omega}\left[1-G\left(\bar{\varepsilon}_{j,t}\right)\right]}\ ,\ v_j\right)}_{\text{asymmetric information}}$$

$$B_t = \mathbb{E}_t v_j - \underbrace{Cov\left(\frac{G\left(\underline{\varepsilon}_{j,t}\right)}{\mathbb{E}_{j,\omega}\left[G\left(\underline{\varepsilon}_{j,t}\right)\right]}\ ,\ v_j\right)}_{\text{asymmetric information}}$$

Monopoly vs. Competitive (Ask) Prices

$$A_t^m = \mathbb{E}_j v_j + \underbrace{\frac{1 - \mathbb{E}_{j,\omega}\left[G\left(\overline{\varepsilon}^m_{j,t}\right)\right]}{\mathbb{E}_{j,\omega}\left[g\left(\overline{\varepsilon}^m_{j,t}\right)\right]}}_{\text{market power}} + \underbrace{Cov\left(\frac{g\left(\overline{\varepsilon}^m_{j,t}\right)}{\mathbb{E}_{j,\omega}\left[g\left(\overline{\varepsilon}^m_{j,t}\right)\right]}, v_j\right)}_{\text{asymmetric information}}$$

$$A_t^c = \mathbb{E}_t v_j + \underbrace{Cov\left(\frac{1 - G\left(\overline{\varepsilon}^c_{j,t}\right)}{\mathbb{E}_{j,\omega}\left[1 - G\left(\overline{\varepsilon}^c_{j,t}\right)\right]}, v_j\right)}_{\text{asymmetric information}}$$

Two key differences:

1. Competitive price has no markup/market power term.
2. PDF vs. CDF:
   - Monopolist's optimal price depends on mass of *marginal* investors
   - Competitive price requires equal profits *on average*

Evolution of Beliefs

Information: Dealers see volume at end of t (buys and sells), or equivalently

$$\underline{\varepsilon}_t = B_t - R_{t+1} - \omega_t \qquad \text{or} \qquad \bar{\varepsilon}_t = A_t - R_{t+1} - \omega_t$$

where $R_{t+1} = R_{j,t+1}$ if asset is of quality j

Evolution of Beliefs

Information: Dealers see volume at end of t (buys and sells), or equivalently

$$\underline{\varepsilon}_t = B_t - R_{t+1} - \omega_t \qquad \text{or} \qquad \bar{\varepsilon}_t = A_t - R_{t+1} - \omega_t$$

where $R_{t+1} = R_{j,t+1}$ if asset is of quality j

Since prices known, as if dealers see a signal $S_t = R_{t+1} + \omega_t \Rightarrow$ signal extraction problem

Evolution of Beliefs

Information: Dealers see volume at end of t (buys and sells), or equivalently

$$\underline{\varepsilon}_t = B_t - R_{t+1} - \omega_t \qquad \text{or} \qquad \bar{\varepsilon}_t = A_t - R_{t+1} - \omega_t$$

where $R_{t+1} = R_{j,t+1}$ if asset is of quality j

Since prices known, as if dealers see a signal $S_t = R_{t+1} + \omega_t$ $\Rightarrow$ signal extraction problem

Updating: what would ω_t have to be in state $\iota \in \{l, h\}$ to generate S_t?

$$\omega^{\star}_{\iota,t} = S_t - R_{\iota,t+1}$$

Evolution of Beliefs

Information: Dealers see volume at end of t (buys and sells), or equivalently

$$\underline{\varepsilon}_t = B_t - R_{t+1} - \omega_t \qquad \text{or} \qquad \bar{\varepsilon}_t = A_t - R_{t+1} - \omega_t$$

where $R_{t+1} = R_{j,t+1}$ if asset is of quality j

Since prices known, as if dealers see a signal $S_t = R_{t+1} + \omega_t \Rightarrow$ signal extraction problem

Updating: what would ω_t have to be in state $\iota \in \{l, h\}$ to generate S_t?

$$\omega^\star_{\iota,t} = S_t - R_{\iota,t+1}$$

Beliefs then evolve according to

$$\mu_{t+1} = \frac{\mu_t f\left(\omega^\star_{h,t}\right)}{\mu_t f\left(\omega^\star_{h,t}\right) + (1-\mu_t) f\left(\omega^\star_{l,t}\right)} = \frac{\mu_t}{\mu_t + (1-\mu_t)\frac{f\left(\omega_t + R_{j,t+1}(\mu_{t+1}) - R_{l,t+1}(\mu_{t+1})\right)}{f\left(\omega_t + R_{j,t+1}(\mu_{t+1}) - R_{h,t+1}(\mu_{t+1})\right)}}$$

Evolution of Beliefs

Information: Dealers see volume at end of t (buys and sells), or equivalently

$$\underline{\varepsilon}_t = B_t - R_{t+1} - \omega_t \qquad \text{or} \qquad \bar{\varepsilon}_t = A_t - R_{t+1} - \omega_t$$

where $R_{t+1} = R_{j,t+1}$ if asset is of quality j

Since prices known, as if dealers see a signal $S_t = R_{t+1} + \omega_t \Rightarrow$ signal extraction problem

Updating: what would ω_t have to be in state $\iota \in \{l, h\}$ to generate S_t?

$$\omega^{\star}_{\iota,t} = S_t - R_{\iota,t+1}$$

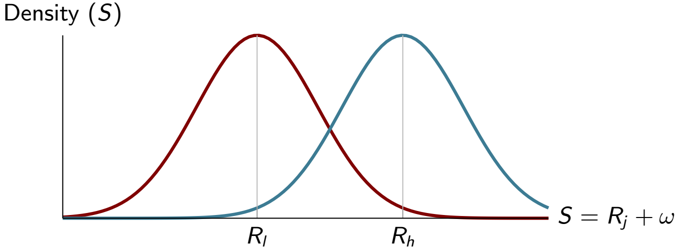
Beliefs then evolve according to

$$\mu_{t+1} = \frac{\mu_t f\left(\omega^{\star}_{h,t}\right)}{\mu_t f\left(\omega^{\star}_{h,t}\right) + (1-\mu_t) f\left(\omega^{\star}_{l,t}\right)} = \frac{\mu_t}{\mu_t + (1-\mu_t)\frac{f\left(\omega_t + R_{j,t+1}(\mu_{t+1}) - R_{l,t+1}(\mu_{t+1})\right)}{f\left(\omega_t + R_{j,t+1}(\mu_{t+1}) - R_{h,t+1}(\mu_{t+1})\right)}}$$

Learning process depends on $R_{h,t+1} - R_{l,t+1}$

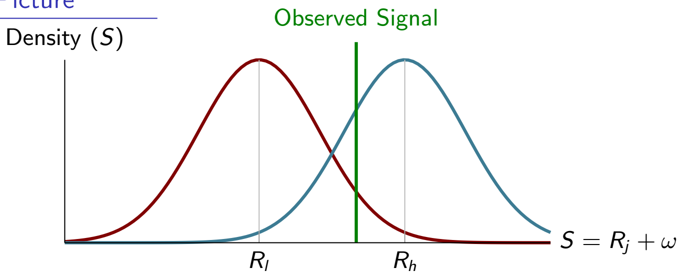
- Trading typically more informative when the reservation values are very different

Learning: Picture



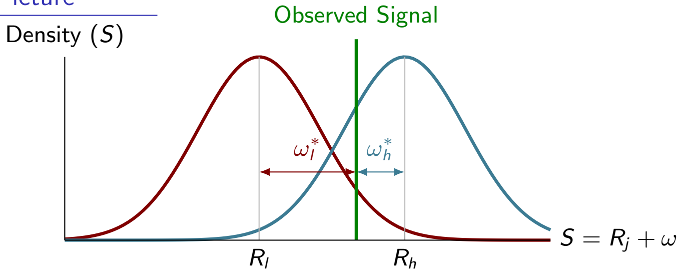
- Belief evolution depends on basic signal extraction

Learning: Picture



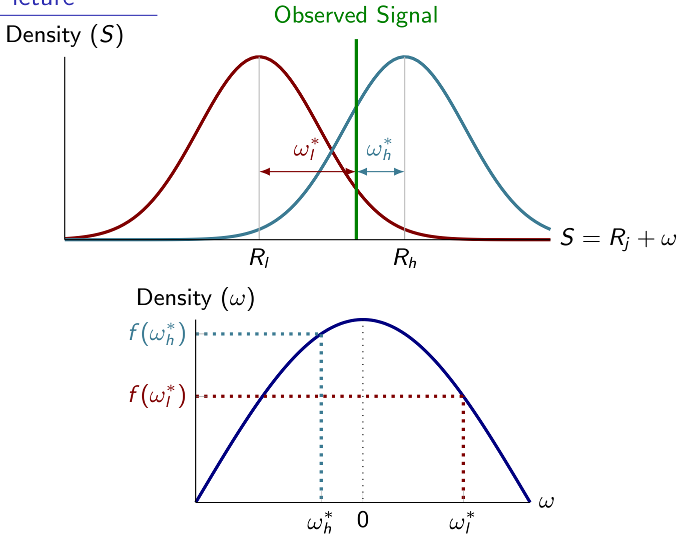
- Belief evolution depends on basic signal extraction

Learning: Picture



- Belief evolution depends on basic signal extraction

Learning: Picture



- Belief evolution depends on basic signal extraction
- Easy to see signal extraction problem more difficult if reservation values close together

Recursive Equilibrium

1. Traders buy and sell according to $R_j(\mu)$, $\underline{\varepsilon}_j(\mu, \omega)$, and $\overline{\varepsilon}_j(\mu, \omega)$
2. Dealers price according to $A(\mu)$ and $B(\mu)$
3. Beliefs evolve according to $\mu'(\mu, \omega)$
4. Demographics evolve according to $N_j^0(\mu, \omega)$ and $N_j^1(\mu, \omega)$

a tractable case

The Uniform-Uniform Model

Assumptions:

1. $v_j = c_j$ for $j \in \{l, h\}$
2. $\varepsilon_{i,t} \sim U(-e, e)$ and $\omega_t \sim U(-m, m)$
3. e and m are sufficiently large s.t. thresholds are always interior
4. $\alpha_c > 0$

Uniform distributions simplify both learning and pricing

- learning: dealers either learn nothing or everything
- pricing: linear demand and supply functions

Given simple rules for pricing, updating beliefs and prices, we can...

- characterize (unique) equilibrium
- study relationship between search frictions and learning
- explore implications for liquidity, gains from trade, ...

Learning in the Uniform-Uniform Model

Recall: updating equation depends on

$$\frac{f(\omega_l^\star)}{f(\omega_h^\star)} = \frac{f(S - R_l)}{f(S - R_h)}$$

Guess and verify

$$\mu'(\mu, S) = \begin{cases} 0 & \text{if } S \in \Sigma_l(\mu) \equiv [-m + R_l(0), -m + R_h(\mu)) \\ \mu & \text{if } S \in \Sigma_b(\mu) \equiv [-m + R_h(\mu), m + R_l(\mu)] \\ 1 & \text{if } S \in \Sigma_h(\mu) \equiv (m + R_l(\mu), m + R_h(1)] \,. \end{cases}$$

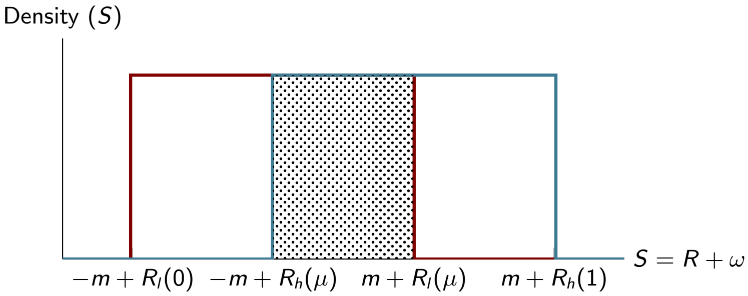
Learning in the Uniform-Uniform Model

Recall: updating equation depends on

$$\frac{f(\omega_l^\star)}{f(\omega_h^\star)} = \frac{f(S - R_l)}{f(S - R_h)}$$

Guess and verify

$$\mu'(\mu, S) = \begin{cases} 0 & \text{if } S \in \Sigma_l(\mu) \equiv [-m + R_l(0), -m + R_h(\mu)) \\ \mu & \text{if } S \in \Sigma_b(\mu) \equiv [-m + R_h(\mu), m + R_l(\mu)] \\ 1 & \text{if } S \in \Sigma_h(\mu) \equiv (m + R_l(\mu), m + R_h(1)]\,. \end{cases}$$



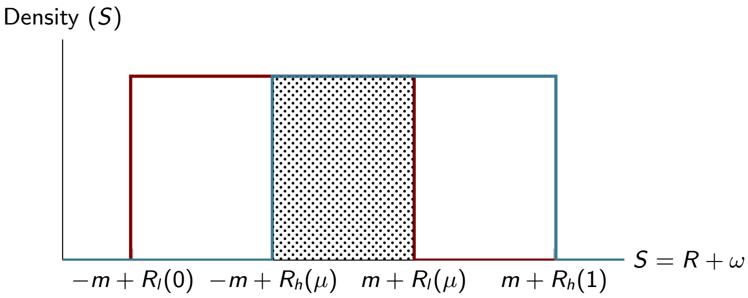
Learning in the Uniform-Uniform Model

In candidate eqm, learning process summarized by $\mathbb{P}$(quality revealed):

$$p(\mu) = \frac{R_h(\mu) - R_l(\mu)}{2m}.$$

Result

Time to learn, $\frac{1}{p(\mu)}$ *increases as* $(R_h - R_l) \downarrow$.



How does a higher π affect $R_h - R_l$?

$$R_h - R_l = (1-\delta)\,(c_h - c_l) + \delta\,\mathbb{E}[R_h' - R_l'] + \delta\pi\,\mathbb{E}(\Omega_h' - \Omega_l')$$

where Ω_j = option value of selling − option value of buying

Result

$R_h - R_l$ is decreasing in π.

Reservation Values and Search Frictions

How does a higher π affect $R_h - R_l$?

$$R_h - R_l = (1-\delta)\,(c_h - c_l) + \delta\,\mathbb{E}[R_h' - R_l'] + \delta\pi\;\mathbb{E}(\Omega_h' - \Omega_l')$$

where Ω_j = option value of selling − option value of buying

Result

$R_h - R_l$ is decreasing in π.

- $\Omega_h' - \Omega_l' < 0$: Option to sell (buy) is worth less (more) when quality is high
- Higher π increases the weight of the net option value, bringing R_h and R_l closer
- Intuition: investors behave more alike in two states when more opportunities to trade

Key Result

Putting it together:

1. Time to learn ($\frac{1}{p(\mu)}$) is decreasing in $R_h(\mu) - R_l(\mu)$
2. $R_h(\mu) - R_l(\mu)$ is decreasing in trading frequency (π)

$\Rightarrow \frac{1}{p(\mu)}$ is increasing in π

Result

Ceteris paribus, dealers learn more slowly in markets with more frequent trading opportunities

Implication #1: Search Frictions and Bid-ask Spreads

Implied bid-ask spread σ given current beliefs $\mu \in (0, 1)$:

$$\sigma(\mu) = e - \alpha_c \sqrt{e^2 - 4Cov\left(r_j, v_j\right)}$$

where

$$r_j = p(\mu)R_j\left(\mathbf{1}_{j=h}\right) + (1 - p(\mu))R_j\left(\mathbf{1}_{j=l}\right).$$

Implication #1: Search Frictions and Bid-ask Spreads

Implied bid-ask spread σ given current beliefs $\mu \in (0, 1)$:

$$\sigma(\mu) = e - \alpha_c \sqrt{e^2 - 4Cov\left(r_j, v_j\right)}$$

where

$$r_j = p(\mu) R_j \left(\mathbf{1}_{j=h}\right) + (1 - p(\mu)) R_j \left(\mathbf{1}_{j=l}\right).$$

Result

1. *Spread is $\bigcap$-shaped in μ, maximized at $\mu = 1/2$.*
2. *Holding μ fixed, spread is decreasing in π.*

Therefore, two opposing effects on spread from decreasing search frictions ($\pi \uparrow$):

- **Static:** spread $\downarrow$ as competition $\uparrow$
- **Dynamic:** $(R_h - R_l) \downarrow \Rightarrow$ learning slows $\Rightarrow$ more uncertainty $\Rightarrow$ spread $\uparrow$

Numerical simulation: $j = h$, $\mu = 1/2$, $\pi \in \{0.25, .75\}$.

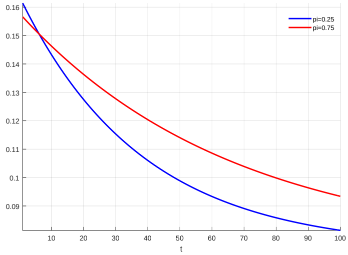


Figure: Average Spread Over Time

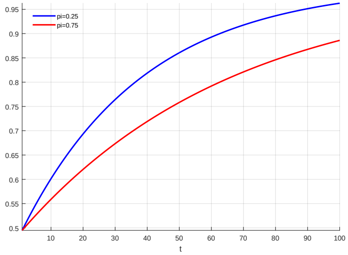


Figure: Average Beliefs Over Time

- $\pi \uparrow$ causes fall in spread in **current period**
- $\pi \uparrow$ causes slower learning, higher spreads in **future periods**

Implication #2: The Value of Trading Speed Across Assets

How much would customers pay (ex ante) to increase π? How does it depend on μ?

$$W^1 = \mu W_h^1(\mu) + (1 - \mu) W_l^1(\mu)$$

Result

When π and δ are sufficiently large, $\frac{\partial^2 W^1}{\partial \pi \partial \mu} > 0$ for $\mu \in [0.5, 1]$

- Trading speed can be more valuable for assets with less informational sensitivity
- Consistent with less migration of HY bonds to electronic platforms

numerical analysis

Generalized Version of Model

Relax previous assumptions on distributions, valuations:

- $\omega_t \sim N(0, \sigma_\omega^2) \qquad \varepsilon_{i,t} \sim N(0, \sigma_\varepsilon^2)$
- $v_j = c_j + \xi$

Additional, higher order terms complicate analysis

But, model easily solved computationally

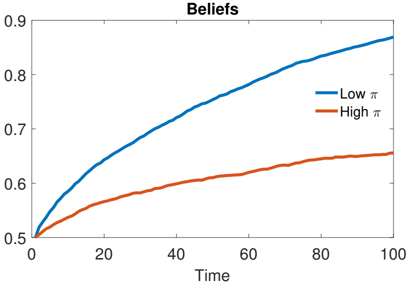
- Guess $R_j(\mu)$ for $j = l, h$
- Given R_j, determine dealers' evolution of beliefs μ^+
- Given future beliefs and R_j, compute $A(\mu)$ and $B(\mu)$
- Update guess of R_j until convergence

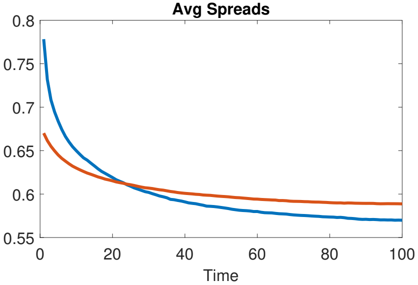
Parameterization

- Model period set to one week
- Distributions of shocks: $\omega_t \sim N(0, \sigma_\omega^2)$ $\varepsilon_{i,t} \sim N(0, \sigma_\varepsilon^2)$
- No gains from trade (on average) between dealers and investors ($v_j = c_j$)
- Remaining parameters approximate evidence from AAA-rated 5-year corporate bond

Parameter	Value	Target	Source
$v_h - v_l$	\$0.95	Impact of rating downgrade	Feldhutter (2012b)
μ_0	0.5	Probability of (AAA $\rightarrow$ AA) downgrade	S&P
$\sigma_\omega^2 = \sigma_\varepsilon^2$	0.16	Avg. gains to trade	Feldhutter (2012a)
δ	0.9	sensitivity	

- Initial beliefs $\mu_0 = 0.5$ and true quality $j = h$

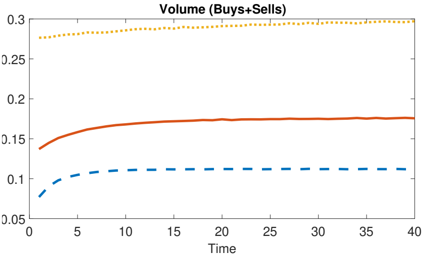


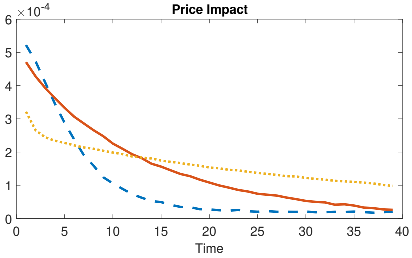


- $\pi \uparrow$ causes fall in spread in **current period**
- $\pi \uparrow$ causes slower learning, higher spreads in **future periods** spreads

Other measures of liquidity

Effect of π on volume and price impact (low π, med π, high π)



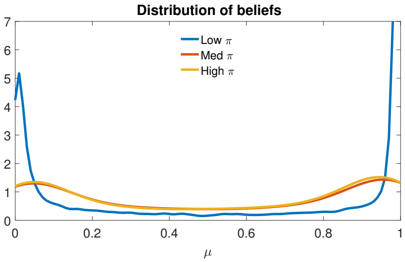


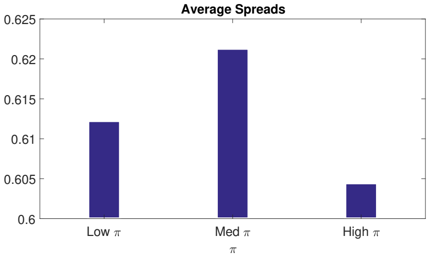
- Price impact behaves similarly to spreads, but not volume
- Note: spreads and volume can move in same direction, as in data

stationary version

Stationary Version

- Asset quality j changes over time (with probability $\rho = 0.05\%$)
- Other elements exactly the same as before
- $\Rightarrow$ Non-trivial belief distribution in the long run (stochastic steady state)





low π=0.55, med π= 0.75, high π = 0.95

Welfare

Reducing trading frictions causes:

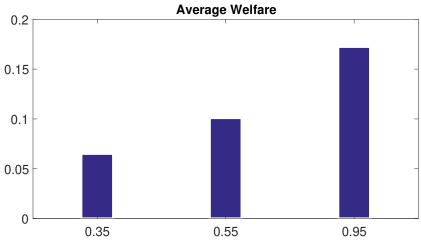
- more opportunities to trade (meetings)
- but potentially less trades per meeting

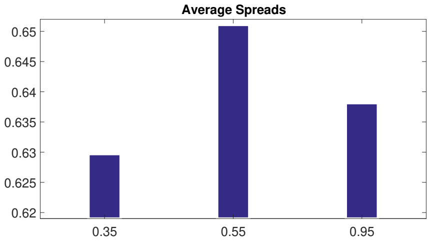
Welfare

Reducing trading frictions causes:

- more opportunities to trade (meetings)
- but potentially less trades per meeting

Under this calibration, first effect dominates second.





Wider spreads do not imply lower welfare

Conclusion

A dynamic model with two canonical frictions

- asymmetric information and infrequent trading opportunities/market power

Frictions interact in novel ways

- mitigating one could lead to wider spreads
- model helpful for understanding recent changes in OTC markets

Next steps

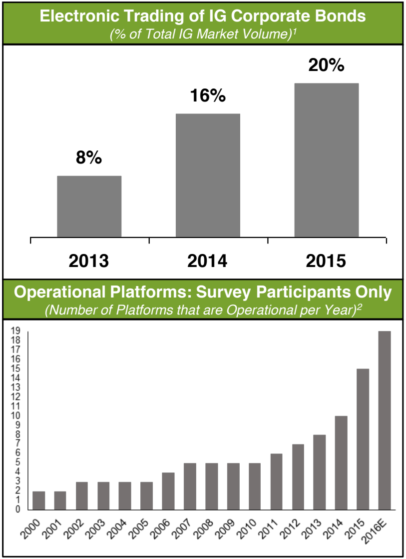
- Effects of reducing information frictions, increasing transparency?
- Empirically disentangling the two frictions?

Experimentation

- From individual trader, dealer can learn at most $R_{j,t} + \omega_t + \varepsilon_{i,t}$
- From market volume, dealer will learn $R_{j,t} + \omega$
- Since $\varepsilon_{i,t}$ independent of the state, j, information in market volume dominates information that can be learned from a single trade
  - dominates in sense that dealer unwilling to pay any cost to learn $R_{j,t} + \omega_t + \varepsilon$

Back

Corporate Bond Market (from SIFMA report)



Back