Market-making with Search and Information Frictions

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Liquidity in Financial Markets

OTC markets are changing: reduced trading frictions & increased transparency

- policy: OTC markets $\rightarrow$ centralized exchanges, required disclosure of trades (TRACE)
- technology: faster/easier for traders to receive quotes & dealers to aggregate information

How will these changes impact liquidity?

A common metric for liquidity: **Bid-ask spreads**

- More generally, non-linear pricing or the price impact of trade

Asymmetric Information + Search

Two prominent theories provide stark predictions:

1. **Asymmetric information**: investors know more about asset than dealers
   - See, e.g., Glosten-Milgrom
   - Prediction: more transparency $\Rightarrow$ narrower spreads
2. **Search frictions**: dealers have market power, investors trade infrequently
   - See, e.g., Duffie-Garleanu-Pedersen
   - Prediction: faster trading $\Rightarrow$ narrower spreads

Do changes in trading frictions mitigate or exacerbate informational frictions?

Are these stark predictions true when both frictions are present?

Challenge: existing literature (theory & empirical) studies two frictions **in isolation**

Hard to answer without a **unified framework**

This Paper

Develop a unified framework of a dynamic asset market with:

1. search frictions and market power
2. asymmetric information

where dealers *learn over time* from market-wide trading activity

Show that interaction $\Rightarrow$ conventional wisdom does not hold

Focus: reducing search frictions can lead to wider bid-ask spreads

- Static effect: search frictions $\downarrow$ $\Rightarrow$ intertemporal competition $\uparrow$ $\Rightarrow$ spreads $\downarrow$ (DGP)
- Dynamic effect: **search frictions $\downarrow$ $\Rightarrow$ learning slows** $\Rightarrow$ spreads eventually $\uparrow$ (GM)

Additional contributions:

- New tradeoffs shed light on ambiguous empirical findings effects of reduced trading frictions
- Model useful for anticipating impact of regulations that reduce info or trading frictions

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
  - measure N_q^e of new traders with q assets enter each period
  - all traders exit market with probability $1 - \delta$ in each period
  - traders have private info about asset quality + their own preferences
- A continuum of **dealers**
  - can hold unrestricted positions (long or short)
  - don't know 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 exit, 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, with $v_h > v_l$
  - no liquidity shocks

Search, Prices, and Trade

Each period, trader meets stochastic number $n \in \{0, 1, 2\}$ of dealers

Prob(meet $n \geq 1$ dealer) $= \pi$

Conditional on meeting at least one dealer,

- Prob(meet $n = 1$ dealer) $= \alpha_m$ ("monopolist meeting")
- Prob(meet $n = 2$ dealer) $= \alpha_c$ ("competitive meeting")

Dealers observe number of competing dealers but not asset quality/trader preferences

- offer to buy at bid price B_t^k, sell at ask price A_t^k for $k \in \{c, m\}$
- 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

Dealers are informationally small and all have common beliefs

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

Interpretation via Interdealer Market

optimal behavior and equilibrium

Traders' Optimal Behavior

Let

- $W^q_{j,t} \equiv$ value of owning $q \in \{0,1\}$ units of quality $j \in \{l,h\}$ asset at t
- $R_{j,t} = W^1_{j,t} - W^0_{j,t} \equiv$ reservation value at t when quality is $j \in \{l,h\}$

Given bid and ask prices (B^k_t, A^k_t), $k \in \{m,c\}$, and shocks $(\varepsilon_{i,t}, \omega_t)$,

- Owner should sell if $\varepsilon_{i,t}$ sufficiently small, hold otherwise:

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

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

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

Traders' Optimal Behavior

- Owner i sells in a k meeting iff

$$\epsilon_{i,t} \leq \underline{\epsilon}_{j,t}^{k} \equiv B_t^k - R_{j,t} - \omega_t$$

- Non-owner i buys in a k meeting iff

$$\epsilon_{i,t} \geq \bar{\epsilon}_{j,t}^{k} \equiv A_t^k - R_{j,t} - \omega_t$$

- 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

$$\Omega_{j,t} = \sum_{k=c,m} \alpha^k \left[\underbrace{\max\{B_t^k - R_{j,t+1} - \omega_t - \varepsilon_{i,t}, 0\}}_{\text{option to sell}} - \underbrace{\max\{-A_t^k + R_{j,t+1} + \omega_t + \varepsilon_{i,t}, 0\}}_{\text{option to buy}}\right]$$

Aggregate Positions

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

$$N^1_{j,t+1} = \delta \left\{ N^1_t \left[\underbrace{1-\pi}_{\text{no meeting}} + \underbrace{\pi \left(1 - \sum_{k=c,m} \alpha^k G(\underline{\varepsilon}^k_{j,t}) \right)}_{\text{meeting, no sell}} \right] + \underbrace{N^0_t \, \pi \left(1 - \sum_{k=c,m} \alpha^k G(\overline{\varepsilon}^k_{j,t}) \right)}_{\text{meet \& buy}} \right\} + N^e_1$$

$$N^0_{j,t+1} = \delta \left\{ N^1_t \pi \sum_{k=c,m} \alpha^k G(\underline{\varepsilon}^k_{j,t}) + N^0_t \left[1 - \pi + \pi \sum_{k=c,m} \alpha^k G(\overline{\varepsilon}^k_{j,t}) \right] \right\} + N^e_0.$$

Dealers observe past volume and (know N^e_q)

$\Rightarrow$ they know N^q_t when setting (B^k_t, A^k_t).

Monopolist Dealer's Prices

Dealer with a captive customer chooses (A_t^m, B_t^m) to maximize

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

Why? we find conditions s.t. no motive for experimentation, no benefit to waiting

- Pricing decision is static
- Sell (buy) choice unaffected by ask (bid) $\Rightarrow$ separates the bid/ask problems
- Aggregate positions known $\Rightarrow$ irrelevant for pricing, only beliefs μ_t matter

No Experimentation

Key assumptions:

- Both traders and dealers are small, so take future beliefs as given
- Dealers can hold unrestricted positions, have deep pockets
- Support of shocks "large enough"

Under these conditions: market-wide info dominates learning from an individual meeting

Monopolist Dealer's Prices (given beliefs μ_t)

As a result, optimal monopoly prices satisfy:

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

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

Monopolist Dealer's Prices (given beliefs μ_t)

As a result, optimal monopoly prices satisfy:

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

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

Competitive Prices

Bertrand competition $\Rightarrow$ zero profits (*a la* Glosten-Milgrom)

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

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

Competitive Prices

Bertrand competition $\Rightarrow$ zero profits (*a la* Glosten-Milgrom)

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

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

Monopoly vs. Competitive (Ask) Prices

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

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

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

$$\underline{\epsilon}_t^k = B_t^k - R_t - \omega_t \qquad \text{or} \qquad \bar{\epsilon}_t^k = A_t^k - R_t - \omega_t$$

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

Since prices known, as if dealers see a signal $S_t = R_t + \omega_t$ $\Rightarrow$ signal extraction problem

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

$$\omega_{\iota,t}^{\star} = S_t - R_{k,t}$$

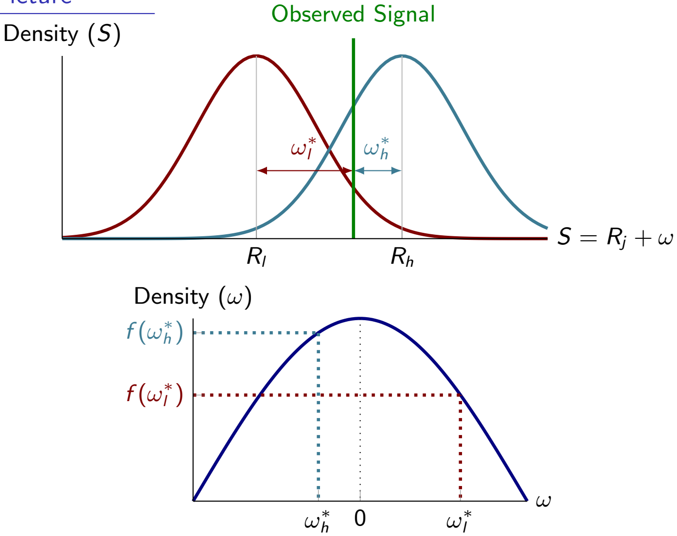
Beliefs then evolve according to

$$\mu' = \frac{\mu_t f\left(\omega_{h,t}^{\star}\right)}{\mu_t f\left(\omega_{h,t}^{\star}\right) + (1-\mu_t) f\left(\omega_{l,t}^{\star}\right)} = \frac{\mu_t}{\mu_t + (1-\mu_t)\frac{f\left(\omega_t + R_{j,t+1}(\mu') - R_{l,t+1}(\mu')\right)}{f\left(\omega_t + R_{j,t+1}(\mu') - R_{h,t+1}(\mu')\right)}}$$

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

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

Learning: Picture



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

Equilibrium

A recursive equilibrium is a collection of functions for

1. Reservation values: $R_j(\mu) \quad j \in \{h, l\}$
2. Thresholds: $\underline{\varepsilon}_j^k(\mu, \omega)$, $\overline{\varepsilon}_j^k(\mu, \omega) \quad k \in \{c, m\}$
3. Prices: $A^k(\mu)$, $B^k(\mu)$
4. Beliefs: $\mu'(\mu, \omega)$
5. Demographics: $N_j^0(\mu, \omega)$, $N_j^1(\mu, \omega)$

such that

1. Reservation values are consistent with future beliefs and prices
2. Given beliefs and prices, thresholds are optimal for traders
3. Given beliefs and thresholds, prices are optimal for dealers
4. Beliefs evolve according to Bayes' rule
5. Demographics evolve consistent with prices, thresholds

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

Together, these assumptions simplify both learning and pricing.

Given beliefs and prices, can characterize (unique) equilibrium

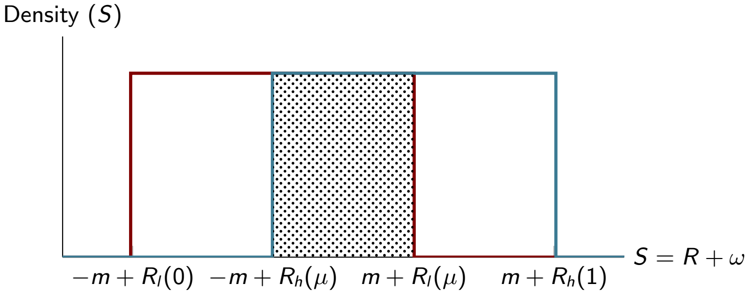
- Study relationship between search frictions, learning, and spreads...

Learning in the Uniform-Uniform Model

Recall: updating equation depends on

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

With bounded and uniform liquidity shocks, either j is revealed, or nothing is learned:



Learning in the Uniform-Uniform Model

Recall: updating equation depends on

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

Under uniform shocks, $f(\omega) = \frac{1}{2m}$ if $\omega \in [-m, m]$, zero otherwise

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

Then learning process summarized by $\mathbb{P}$(quality revealed):

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

Result

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

Pricing & Equilibrium in the Uniform-Uniform Model

Given simple learning process and linear demand/supply, prices easy to characterize.

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

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

Simple expression allows us to derive properties of spreads

Result (GM effect)

Spread is $\bigcap$-shaped in μ, maximized at $\mu = 1/2$.

Result (DGP effect)

Spread is decreasing in α_c.

Reservation Values and Search Frictions

How does a higher π affect spreads?

Crucial channel: effect of π on $R_h - R_l$:

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

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
- $\Rightarrow$ less adverse selection (given μ), but also *slower learning*

Search Frictions and Spreads

Result (Putting it all together)

1. *Spread big when uncertainty high ($\mu \approx 1/2$) (GM)*
2. $(R_h - R_l) \downarrow$ *as* $\pi \uparrow$
3. *Holding* $\mu \in (0, 1)$ *fixed, spread* $\downarrow$ *as* $\pi \uparrow$ *(Static)*
4. *Learning occurs slower when* $R_h - R_l$ *is small (Dynamic)*

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

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

Search Frictions and Spreads

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

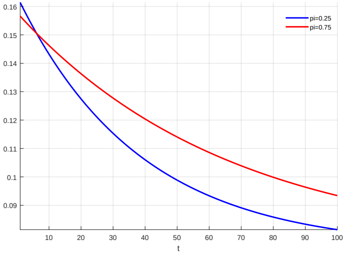


Figure: Average Spread Over Time

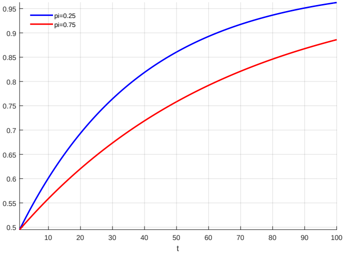


Figure: Average Beliefs Over Time

- $\pi \uparrow$ causes **static** fall in spread
- $\pi \uparrow$ causes slower learning, higher **"long-run"** spreads

Numerical Example

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

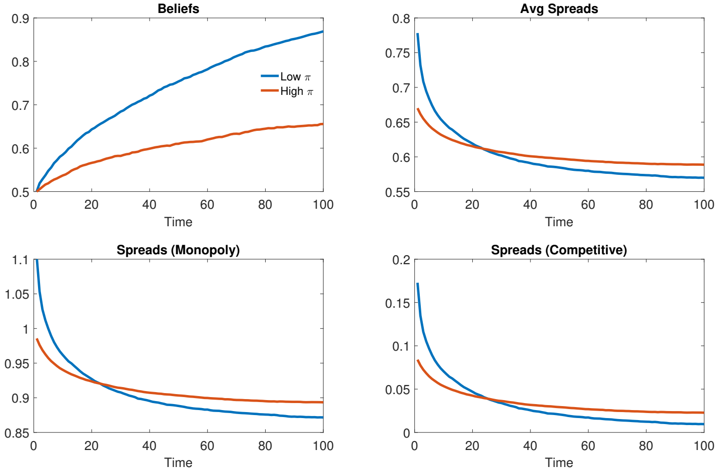
- Parameters approximate evidence from AAA-rated 5-year corporate bond evidence
- No gains to trade (on average) between dealers and traders ($\xi = 0$)
- Model period set to 1 week

Parameter	Value	Target	Source
$c_h - c_l$	\$1.16	Impact of Downgrade	Feldhutter (2012b)
μ_0	0.5	Probability of (AAA $\rightarrow$ AA) Downgrade	S&P
$\sigma_\omega^2 = \sigma_\epsilon^2$	0.16	Avg. Gains to Trade	Feldhutter (2012a)
π	0.55	Match Rates given Poisson	Feldhutter (2012a)
α	0.35		
δ	0.9	sensitivity	

- $\delta = 0.9$ implies trading horizon (conditional on no trade) of 10 weeks

The Normal-Normal Model

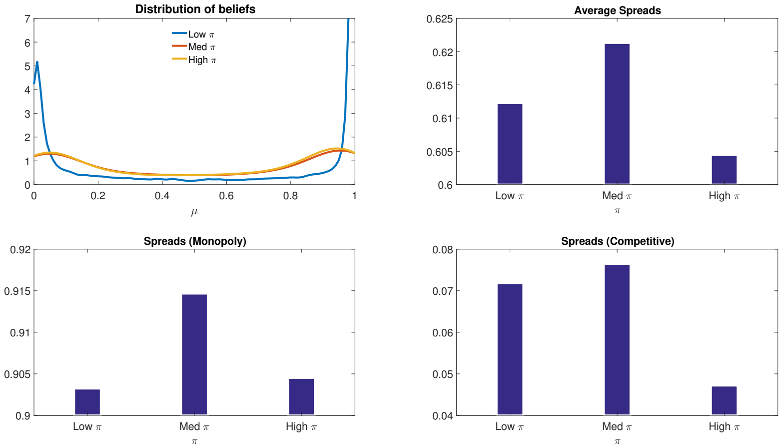
Effect of π (true state is $j = h$)



Higher π $\rightarrow$ Lower $(R_h - R_l)$ $\rightarrow$ Less learning $\rightarrow$ Wider spreads eventually

The Normal-Normal model: Stationary Version

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



Higher π $\rightarrow$ Lower $(R_h - R_l)$ $\rightarrow$ Less learning $\rightarrow$ Wider spreads

Search vs Info Frictions

Exercise: hit benchmark with shocks to π and v_l $\Rightarrow$ same Δ spread.

Question: are dynamic properties of spread *and* volume informative?

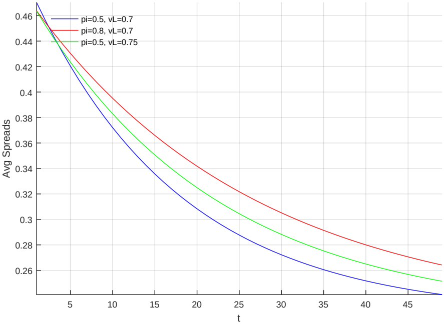


Figure: Spreads

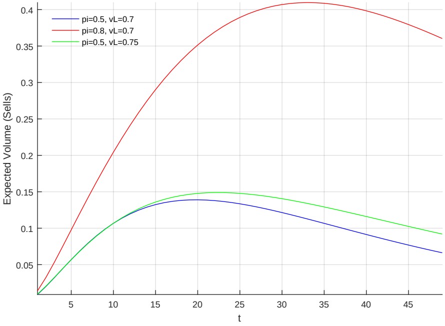


Figure: Volume

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

- Simulations suggest introduction of TRACE could widen spreads...
- disentangling the two frictions?....

Dealers

- Indexed by $i \in [0, 1]$
- They come into each period with $x_{i,t}$ units of the asset
- Payoff:
$$\sum_{s=t}^{\infty}(1-\delta)^{s-t}[-d_{i,t}P_t + q_{i,t}p_t + \delta v_j(x_{i,t} + d_{i,t} + q_{i,t})]$$
  where
$$d_{i,t} \in \{-1, 0, 1\}$$
$$P_t \in \{A_t, B_t\}$$
$$x_{i,t+1} = x_{i,t} + d_{i,t} + q_{i,t}$$
- p_t: price in the interdealer market; competitive

Dealers

- Conjecture that future bid and ask only a function of aggregate information and independent of individual positions.
- Radner: REE in the inter-dealer market $p_t = \mathbb{E}_t\left[v_j | \{d_{i,t}\}_{i\in[0,1]}\right]$.
- Dealers are small:

$$\mathbb{E}_t[v_j|p_t, d_{i,t}] = \mathbb{E}_t\left[v_j | \{d_{i,t}\}_{i\in[0,1]}\right]$$

- Act as if they are short-lived dealers and only care about $\mathbb{E}_t[v_j]$ where expectation is common across all dealers

Back

Experimentation

- From individual trader, dealer can learn at most $R_j + \omega + \epsilon$
- From market volume, dealer will learn $R_j + \omega$
- Implies 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 $R_j + \omega + \epsilon$

Back

Equilibrium

A recursive equilibrium is a set of functions: Start with a guess for Compute optimal prices: Update/verify the guess $R_j(\mu)$ $A(\mu)$ and $B(\mu)$ s.t. $\rightarrow$ beliefs

$$
\begin{aligned}
R_j &= (1-\delta)\, c_j + \delta\, \mathbb{E}[R_j(\mu_j')] + \delta\, \pi\ \ \Omega_j(\mu) \\
A &= \frac{\mathbb{E} v_j g(A - R_j(\mu_j') - \omega) + 1 - \mathbb{E} G(A - R_j(\mu_j') - \omega)}{\mathbb{E} g(A - R_j(\mu_j') - \omega)} \\
B &= \frac{\mathbb{E} v_j g(B - R_j(\mu_j') - \omega) - \mathbb{E} G(B - R_j(\mu_j') - \omega)}{\mathbb{E} g(B - R_j(\mu_j') - \omega)}
\end{aligned}
$$

where

$$
\mu_j' = \frac{\mu}{\mu + (1-\mu)\, \mathcal{L}_j(\omega, R_h(\mu_j') - R_l(\mu_j'))}
$$

$$
\Omega_j(\mu) = \mathbb{E}\left[\max(B(\mu) - R_j(\mu_j') - \omega - \epsilon, 0) \ - \ \max(R_j(\mu_j') + \omega + \epsilon - A(\mu), 0)\right]
$$

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