Liquidity and Prices in Over-the-Counter Markets with Almost Public Information

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Motivation

Many assets are traded over-the-counter:

- residential and commercial real estate
- private equity
- derivatives
- mortgage-backed securities
- bank loans
- corporate and municipal bonds
- sovereign dept

Motivation

In decentralized markets:

- search for a counter party takes time (search friction)
- price is negotiated bilaterally and the negotiation takes time (bargaining friction)

Important to distinguish the bargaining friction:

- the uncertainty about asset quality operates through negotiation delays
  - trade delay is a natural screening/signaling device
- existing literature views the search friction as a reduced form for both frictions
  - but do they operate similarly?
  - if not, does it affect policy implications (effect of transparency on the market liquidity)

This study

A tractable model of liquidity and asset prices in decentralized markets that captures both bargaining and search delays

This study

The approach is to look at the limit of almost public information (global games approach):

- agents get very precise signals about the asset quality, but the public information about the quality is crude;
- negotiation delays still arise, and depend on the amount of public information.

This study

- Intensive (negotiation delay) vs extensive (traded or not) trade margins
- Intensive margin: Liquidity is U-shaped in the asset quality conditional on public info
  - differs from the adverse selection story (decreasing relation)
- Extensive margin: Search delays operate differently from bargaining delays
  - dark and bright side of transparency
- Asset substitutability
  - gradual transparency policies hurt market liquidity, flights-to-liquidity
- Asset price decomposition, clearly separates effect of liquidity premium, market liquidity, and market thickness

Related Literature

- Search-and-bargaining models of OTC markets: Duffie, Gârleanu, and Pedersen (2005, 2007), Lagos and Rocheteau (2007, 2009), Vayanos and Weill (2008), Weill (2008)
- Asset trading with adverse selection: Guerrieri and Shimer (2014), Chang (2014), Kurlat (2013)
- Theoretical search-and-bargaining: Rubinstein and Wolinsky (1985), Satterthwaite and Shneyerov (2007), Lauermann and Wolinsky (2014), Atakan and Ekmekci (2014)

Plan

1. Model
2. Asset and Market Liquidity
3. Flights-to-Liquidity and Transparency
4. Asset Prices
5. Conclusion

Model

- Continuum of agents of mass $a > 1$.
- Continuum of asset qualities θ in $[0, 1]$ each in unit supply.
    - Initially, assents are randomly distributed among agents.
    - Since $a > 1$, not all agents hold an asset.
- Time is continuous, and agents discount at common rate r.
- Two observable types of agents: buyers and sellers.
- Buyer's flow payoff from asset θ is $k\theta$.
- Seller's flow payoff from asset θ is $k\theta - \ell$.
    - $k > 0$ is asset heterogeneity.
    - $\ell > 0$ is holding cost.

Model

- Agents are hit by a liquidity shock with Poisson intensity y_d and recover from it with Poisson intensity y_u.
- Shocks and recoveries are independent across agents.
- Agents are restricted to hold at most one asset.

Search Stage

- Agents can trade in the market with the search friction.
- Matches are independent across agents and time.
- Buyers of mass m_b contact sellers of mass m_s with intensity $\lambda m_b m_s$.
  - contact intensity λ reflects the search friction.
  - smaller $\lambda \implies$ greater search friction.

Bargaining Stage

- Both sides condition strategies on types and on the quality θ.
  - interpretation: get noisy private signals about θ, look at the limit as the precision goes to ∞.
- After the match is found:
  - all sellers agree to bargain (wlog);
  - buyers decide whether to proceed to the bargaining stage or continue the search.
- The strategy of the buyer $\sigma_\theta \in [0, 1]$ gives the probability with which the buyer participates in the bargaining stage conditional on θ.
- After agents proceed to the bargaining stage:
  - do not participate in search (prices are only good 'as long as the breath is warm');
  - only leave the match if one of the types switches or trade occurs (wlog).

Screening Bargaining Solution

- The buyer and the seller play the following continuous-time bargaining game.
  - The buyer makes increasing price offers p_t^B and the seller makes decreasing price offers p_t^S.
  - Bargaining stops when one of the parties accepts the opponent's offer and trade happens at this price.

Screening Bargaining Solution

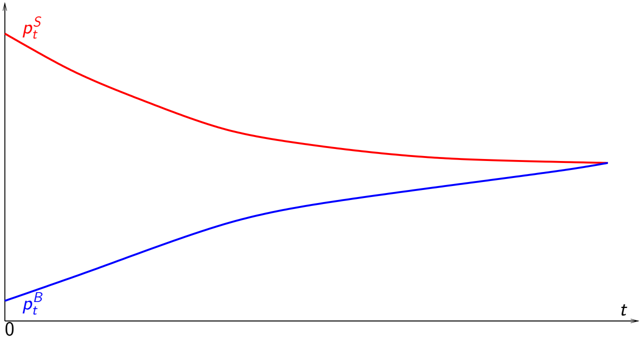

Figure: The buyer makes continuously increasing offers p_t^B and the seller makes continuously decreasing offers p_t^S.

Screening Bargaining Solution

- The outcome of the pure-strategy Nash equilibrium of this game can be described by (p_θ, t_θ).
  - Outcome (p_θ, t_θ) depends on the choice of price offers p_t^B and p_t^S .
  - Suppose that price paths p_t^B and p_t^S are chosen so that in equilibrium, p_θ splits trade surplus between the buyer and the seller in proportion α and $1-\alpha$ where $\alpha \in (0,1)$.
  - This pins down uniquely t_θ. Call this outcome (p_θ, t_θ) SBS.

Microfoundations

- Microfoundation (Tsoy, 2015):
  - agents get noisy private signals about asset quality that determine their values (global games information structure)
  - agents alternate making price offers (as in Rubinstein, 1982)
- The SBS outcome is the limit of a sequence of equilibria in the bargaining game as the noise goes to zero and offers become frequent
- Why delay?
  - Despite precise signals, the public information about the quality is crude
  - Public info determines the bargaining delays

Details

Equilibrium

- M is the distribution of assets among agents

Definition

A tuple (σ_θ, M) *constitutes an* equilibrium if

- *the buyer's strategy* σ_θ *is optimal given* M*,*
- M *is the steady-state distribution of assets generated by* σ_θ*.*

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Intensive Margin: U-shaped Liquidity

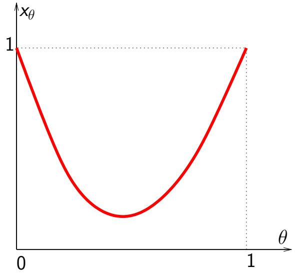
- Liquidity of asset θ – real costs of trade delay t_θ:

$$x_\theta \equiv e^{-\rho t_\theta}, \text{ where } \rho \equiv r + y_u + y_d.$$

  - In equilibrium, x_θ is an increasing function of an asset turnover ($x_\theta \approx$turnover when r is small relative to $y_u + y_d$).

Theorem

Liquidity x_θ is U-shaped in quality θ.



Intensive Margin: U-shaped Liquidity

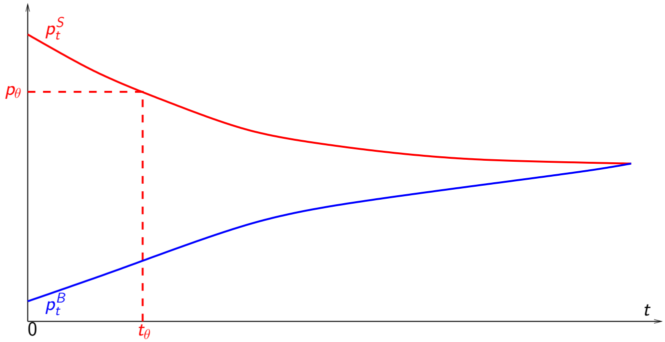


Figure: For relatively high asset qualities, the buyer of asset θ prefers to accept price offer of the seller p_θ at time t_θ rather than any other price offer.

Intensive Margin: U-shaped Liquidity

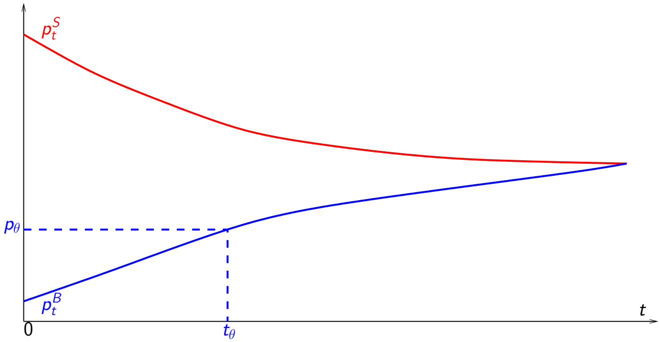


Figure: For relatively low asset qualities, the seller of asset θ prefers to accept price offer of the buyer p_θ at time t_θ rather than any other price offer.

Intensive Margin: U-shaped Liquidity

- In contrast to the decreasing relationship in adverse selection models (e.g. Guerrieri and Shimer, 2014).
  - primary markets: adverse selection (asym info b/w originator and buyers).
  - secondary markets: both sides have private information.

Extensive Margin: Shopping for Liquidity

- Intensive margin: asset liquidity x_θ
- Extensive margin
  - Liquid assets: $\theta \in \Theta_L \iff \sigma_\theta = 1$
  - Illiquid assets: $\theta \in \Theta_I \iff \sigma_\theta = 0$
- Market thickness: Λ_s and Λ_b equilibrium intensities of contact for sellers and buyers, resp.
- Average liquidity:

$$\bar{x} \equiv \mathbb{E}[x_\theta | \theta \in \Theta_L]$$

Theorem

In equilibrium, there is a threshold $\underline{x} \equiv \frac{\Lambda_b}{\rho+\Lambda_b}\bar{x}$ *such that*

$$x_\theta > \underline{x} \implies \theta \in \Theta_L,$$

$$x_\theta < \underline{x} \implies \theta \in \Theta_I.$$

Extensive Margin: Shopping for Liquidity

- Buyers have the outside option of finding another asset in the market $\Longrightarrow$ shop for the most liquid assets
  - non-trivial search in equilibrium
- Asset qualities in the middle of the distribution may be rejected by buyers

Theorem

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Extensive Margin: Shopping for Liquidity

- Even when observable search and negotiation delays are relatively short (e.g. corp. bonds), does not mean they don't matter:
  - extensive margin leads to illiquidity of assets

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Bargaining vs Search Friction

Define market liquidity $L \equiv |\Theta_L|$ to be the mass of assets accepted by buyers ($\sigma_\theta = 1$).

Theorem

Market liquidity L is

- *decreasing in the asset heterogeneity k,*
- *decreasing in the contact intensity λ.*

Average liquidity $\overline{x}$ is decreasing in k and increasing in λ.

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The severity of the bargaining friction is linked to k.

- If there is no difference in payoffs $(k = 0)$, then there is no bargaining delays.
- Higher differences in payoffs $(\uparrow k) \implies$ the highest and the lowest price offers are farther apart $\implies$ trade delays higher $(\uparrow t_\theta) \implies$ buyers are willing to accept fewer assets $(\downarrow L)$.

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Difference between Treasuries and housing markets.

- Greater heterogeneity conditional on public information $\implies$ longer negotiation delays.

Liquidity during periods of heightened market uncertainty.

- Public information (e.g. credit ratings) becomes less accurate $\implies$ less liquid markets.

Bargaining Friction (k)

y_u	y_d	λ	$r(\%)$	α	a	k	ℓ
70	.2	1500	12	.7	1.5	.01	4

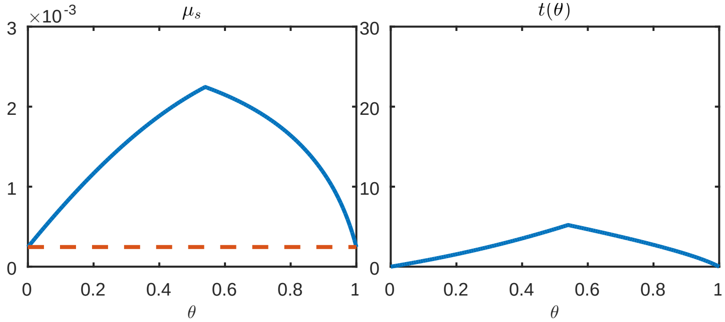

Figure: Mass of sellers holding asset quality θ and delay t_θ.

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y_u	y_d	λ	$r(\%)$	α	a	k	ℓ
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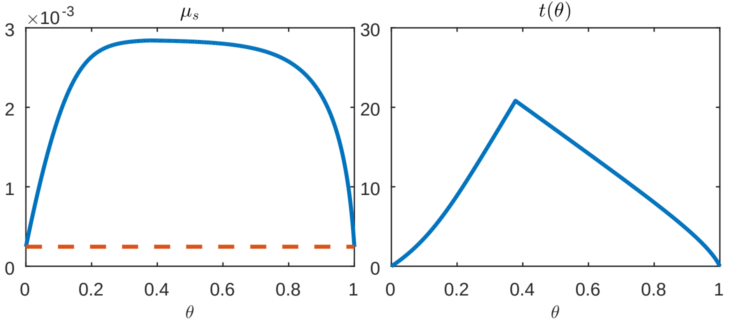

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Bargaining Friction (k)

y_u	y_d	λ	$r(\%)$	α	a	k	ℓ
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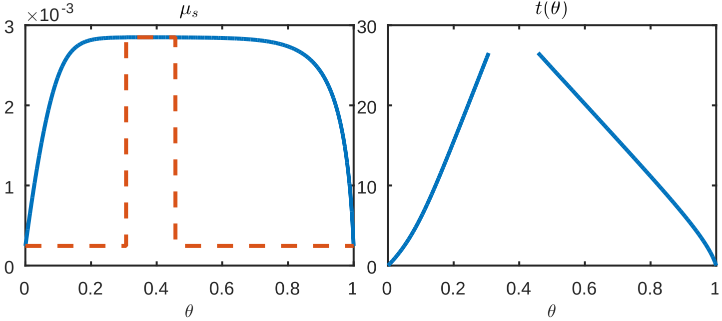

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Average liquidity $\overline{x}$ is decreasing in k and increasing in λ.

- The search friction increases the market liquidity L.
  - Harder to find a counter-party ($\downarrow \lambda$) $\Longrightarrow$ buyers' outside option of continuing search decreases $\Longrightarrow$ buyers are willing to accept a wider range of assets for trade ($\uparrow L$).

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y_u	y_d	λ	$r(\%)$	α	a	k	ℓ
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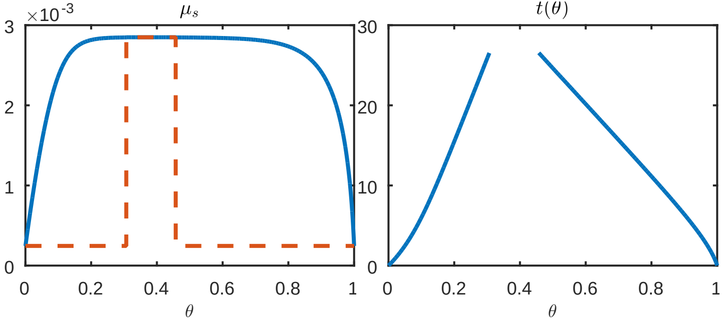

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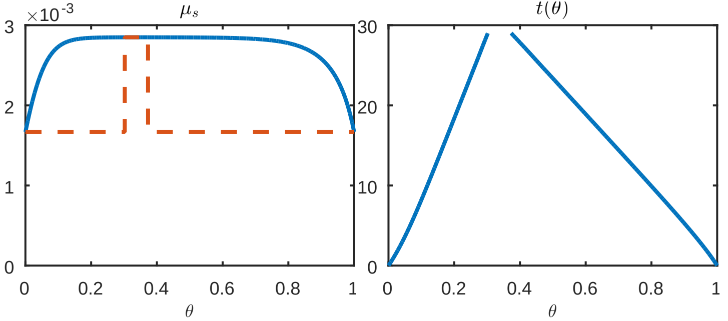

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Bright and Dark Sides of Transparency

- Bright side: $\uparrow$transparency (credit ratings, benchmarks, quotes) $\implies \uparrow$public info $\implies \downarrow$bargaining friction $\implies \uparrow$market liquidity
- Dark side: $\uparrow$transparency (trading platform, post-trade) $\implies \downarrow$search friction $\implies \downarrow$market liquidity
  - Transparency ($\uparrow \lambda$) increases the aggregate welfare through shorter search times, but this is not a Pareto-improvement
  - Fewer assets are actively traded ($\downarrow L$) and owners of assets that become illiquid are worse off

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Flights and Transparency

Theorem

Market liquidity L is increasing in the mass of agents a.

- Two asset classes indexed by $i = 1, 2$ each of mass 1, a mass $a > 2$ of agents.
- For each class i, flow payoffs of the buyer and seller are parametrized by k_i.
- The mass $a_i \geq 1$ of agents trading assets in each class i is determined in equilibrium so that $a_1 + a_2 = a$.

Definition

A tuple $(\sigma_\theta^i, M^i, a_i)_{i=1,2}$ is a multi-class equilibrium *if (σ_θ^i, M^i) is the equilibrium of the baseline model with mass of agents a_i and the following condition holds*

$$\begin{cases} \underline{x}^1 = \underline{x}^2, & \text{if } a - 1 > a_1 > 1, \\ \underline{x}^1 \leq \underline{x}^2, & \text{if } a_1 = 1, \\ \underline{x}^1 \geq \underline{x}^2, & \text{if } a_1 = a - 1. \end{cases}$$

Flights-to-Liquidity

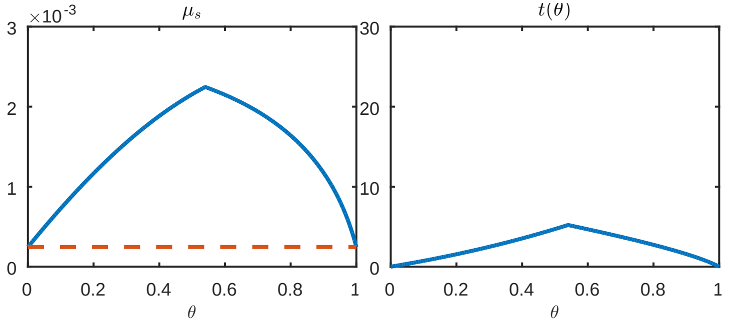
- Consider a model with two classes: class 1 ($k_1 > 0$) and class 2 ($k_2 = 0$).
  - AAA securities and Treasuries: flights-to-liquidity exacerbate drop in liquidity from the increase in the bargaining friction
  - High-yield and investment-grade bonds: post-trade transparency was introduced gradually at first covering only investment-grade bonds $\Longrightarrow$ hurt liquidity of high yield bonds (Asquith et al., 2013)

Theorem

Suppose the range of asset payoffs k_1 in class 1 increases to $\tilde{k}_1$. Then the set of liquid assets in class 1 decreases to $\tilde{L}_1 < L_1$ and agents migrate from trading assets in class 1 to trading assets in class 2 ($a_1 < \tilde{a}_1$ and $a_2 > \tilde{a}_2$).

Flights-to-Liquidity

y_u	y_d	λ	$r(\%)$	α	a	k	ℓ	a_1
70	.2	1500	12	.7	3.52	.01	4	1.49



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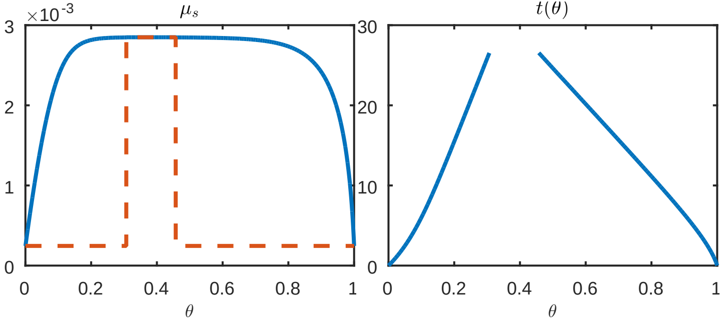
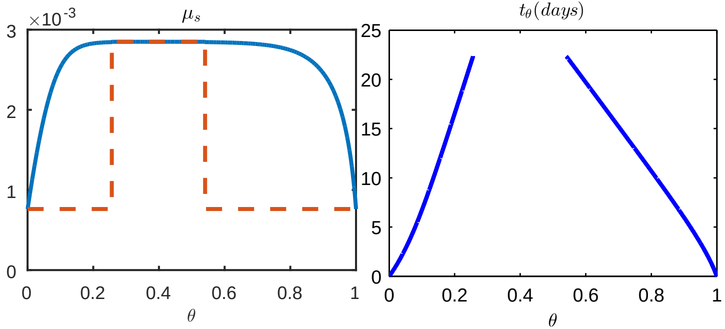


Figure: Mass of sellers holding asset quality θ and liquidity t_θ.

Flights-to-Liquidity

y_u	y_d	λ	$r(\%)$	α	a	k	ℓ	a_1
70	.2	1500	12	.7	3.52	.06	4	1.13



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Conclusion

Asset Price Decomposition

Theorem

In equilibrium, prices of assets in Θ_L are given by

$$p_\theta = \frac{1}{r}\left(k\theta - \frac{r+y_d}{r+y_d+y_u}\ell\right) + (1-\alpha)\frac{\ell}{\rho} + (1-\alpha)\frac{y_d}{r}\frac{\Lambda_s}{\rho+\Lambda_s}\frac{\ell}{\rho}x_\theta - \alpha\frac{\ell}{\rho}\frac{y_u}{r}\frac{\Lambda_b}{\rho+\Lambda_b}\bar{x}.$$

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- Fundamental-value = price if there were no market:
  - NPV of flow payoffs + surplus from trade to the seller.
- Higher quality ($\uparrow \theta$) $\Longrightarrow$ less costly to keep the asset during the search $\Longrightarrow$ $\uparrow$seller's outside option $\Longrightarrow \uparrow p_\theta$.

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- Liquidity-premium component:
  - more liquid asset ($\uparrow x_\theta$) $\implies$ conditional on finding a partner, the seller realizes gains from trade more quickly $\implies$ $\uparrow$seller's outside option $\implies \uparrow p_\theta$.
- Average-liquidity component:
  - higher average liquidity ($\uparrow \bar{x}$) $\implies$ conditional on finding a partner, the buyer is more likely to be matched to a seller of a more liquid asset $\implies$ $\uparrow$buyer's outside option $\implies \downarrow p_\theta$.

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- Market thickness measures (Λ_s and Λ_b) affect the sensitivity of price to liquidity and average-liquidity.
  - liquidity/average liquidity affect outside options only after agents find partners.

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- DGP ($x_\theta = \bar{x} = 1$) already have a liquidity component but its sign is ambiguous.
- The bargaining friction allows for further decomposition into non-ambiguous liquidity premium and average-liquidity components.

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- Longstaff, Mithal, Neis (2005) shows empirically that
  - corporate spreads can be decomposed into default and non-default components;
  - non-default component
    - varies with liquidity measures in the cross-section of assets (liquidity-premium component);
    - and depends on the market-wide liquidity in the time series analysis (average-liquidity component).

Conclusion

Tractable model of liquidity in OTC markets arising from negotiation delays.

- Intensive margin: U-shaped dependence of liquidity on asset quality conditional on public information.
- Extensive margin: bargaining and search frictions operate differently.
- Bright and dark side of transparency, credit ratings, and emergence of flights-to-liquidity.
- Asset price decomposition.

Directions for future research.

- U-shaped liquidity pattern is testable.
- Framework can accommodate various forms of asset-specific trade delay.
- The role of dealers that face bargaining friction.

Microfoundation for SBS

Sequential bargaining model with private correlated values.

- The buyer gets a signal θ_b about the quality and the seller gets a signal θ_s about the quality.

$$\begin{aligned}\theta_b &= \theta + \varepsilon_b,\\ \theta_s &= \theta + \varepsilon_s,\end{aligned}$$

where θ is distributed on $[0,1]$ and $\varepsilon_b, \varepsilon_s$ are conditionally independent with bounded support in $[\theta - \frac{\eta}{2}, \theta + \frac{\eta}{2}] \cap [0,1]$.

- The buyer's value is $v(\theta_b)$ and the seller's cost is $c(\theta_s)$, where v and c are strictly increasing functions.
- Players alternate making offers with the interval between offers Δ.
- Consider continuous-time limits of PBEs, i.e. $\Delta \to 0$.

Microfoundation for SBS

Consider continuous-time limits of equilibrium with two-sided screening dynamics, i.e.

- the buyer makes increasing offers irrespective of type,
- the seller makes decreasing offers irrespective of types,
- both sides gradually accept offers of each other.

Tsoy (2015) shows:

- For any η, there is a variety of continuous-time limits of equilibrium with two-sided screening dynamics.
- Under the support restriction on beliefs, the unique two-sided screening dynamics coinciding with SBS is selected as $\eta \to 0$.

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