Intermediary asset pricing:
Capital constraints and market power

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The presented views are those of the authors and not necessarily those of the Bank of Canada.
What moves asset prices?

- Intermediary asset pricing: equity capitalization of intermediaries (dealers)
  E.g., He and Krishnamurthy (2012, 2013); Brunnermeier and Sannikov (2014)

- Dealers are large banks, e.g., Bank of America, Deutsche Bank
  ① Face capital constraints
  ② Have market power
What moves asset prices?

- Intermediary asset pricing: equity capitalization of intermediaries (dealers)
  E.g., He and Krishnamurthy (2012, 2013); Brunnermeier and Sannikov (2014)

- Dealers are large banks, e.g., Bank of America, Deutsche Bank
  1. Face **capital constraints**
  2. Have market power
Basel III leverage ratio (SLR)

- Imposed to reduce systematic risk
- Requires banks to hold sufficient equity capital, even when holding safe assets
- "Major constraint on bank activity" (Jerome Powell)

**Leverage Ratio Runs Counter to Policy Objectives** (Wall Street Journal, 2016)


US banks push Fed for extension of Covid capital relief (Financial Times, 2021)

**Geithner stresses need for SLR reform** (Risk.net, 2022)
Motivation

What moves asset prices?

• Intermediary asset pricing: equity capitalization of intermediaries (dealers)
  E.g., He and Krishnamurthy (2012, 2013); Brunnermeier and Sannikov (2014)

• In practice, dealers (Bank of America, TD, Deutsche Bank,...)
  1 Face capital constraints
  2 Have market power, e.g., Hortaçsu et al. (2018); Allen and Wittwer (2020);
    Brancaccio and Kang (2022); Huber (2022); Pinter and Üslü (2022); Wallen (2022)
Do capital constraints affect asset demand/prices when dealers have market power?

1) **Model**
   - Capital-constrained dealers have market power à la Kyle (1989)

2) **Test and calibrate the model with data on Treasury auctions**
   - Why? Dealers submit demand curves and balance sheet information
   - How? Policy change of Basel III leverage ratio
Findings: Model predictions

Relax capital constraints

→ Price increases

→ Markups increase
Findings: Model predictions

Trade-off for primary market

→ Benefit: Lower funding costs for the issuer
→ Cost: Higher price distortion, which may reduce market efficiency
Findings: Model predictions

Trade-off for primary market
→ Benefit: Lower funding costs for the issuer
→ Cost: Higher price distortion, which may reduce market efficiency

Quantification
- Dealers face high (shadow) costs due to binding capital constraints
- If the shadow costs decrease by 1%
→ Market price and markups increase by $\approx 0.5\%$
Literature: Bird’s eye view

Theories on intermediary asset pricing (macro)
- Following He and Krishnamurthy (2012, 2013); Brunnermeier and Sannikov (2014)
  ⇒ This paper allows for market power

Theories on market power in financial markets (micro)
  ⇒ This paper introduces capital constraints
Road ahead

1 Model

2 Descriptive evidence in favor of the model

3 Structural estimation
Model

Goods
- Asset of supply $Q$, pays per unit return $R \sim N(\mu, \sigma)$
- Cash (numeraire)

Players
- $N > 2$ dealers
- Initially, dealer $i$ holds $z_i$ of the asset, capital $E_i$, and rest on its balance sheet
Model

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Players
• $N > 2$ dealers
• Initially, dealer $i$ holds $z_i$ of the asset, capital $E_i$, and rest on its balance sheet
Model: Simplest case

Aggregate uncertainty about $Q$, no private information/signals

Goods
- Asset of supply $Q \sim \mathcal{F}$, pays per unit return $R \sim N(\mu, \sigma)$ with $\mu \in \mathbb{R}^+, \sigma \in \mathbb{R}^+$
- Numeraire

Players
- $N > 2$ dealers
- Initially, dealer $i$ holds $z_i = 0$ of the asset, capital $E_i \in \mathbb{R}^+$ and rest $\in \mathbb{R}^+$
Model

Uniform price auction with a capital constraint

Period 1:

- Each dealer submits demand schedule $q_i(\cdot) : \mathbb{R} \to \mathbb{R}$ s.t. capital constraint
- Market clears at $p^*$ such that $\sum_i q_i(p^*) = Q$

Period 2: Asset pays out return and all transactions take place
Dealers maximize expected CARA utility from wealth s.t. capital constraint:

$$
E \left[ 1 - \exp^{-\rho \omega_i(q_i, p)} \right] \quad \text{with} \quad \omega_i(q_i, p) = q_i(R - p), \quad \rho > 0
$$

subject to: $\kappa \leq \frac{\text{equity capital}}{\text{total exposure}}$
Dealers maximize expected CARA utility from wealth s.t. capital constraint:

\[ E \left[ 1 - \exp^{-\rho \omega_i(q_i, p)} \right] \text{ with } \omega_i(q_i, p) = q_i(R - p), \rho > 0 \]

subject to: \( \kappa \leq \frac{E_i}{pq_i + \text{rest}} \) \( \Rightarrow \) Lagrange multiplier: \( \lambda_i \)
Model: Equilibrium

There exists a unique linear equilibrium in which dealer $i$ chooses $q_i(p)$ at $p$ is s.t.:

\[ \text{marginal utility} = \text{marginal disutility} \]

No capital constraint & perfect competition:

\[ \mu - \sigma \rho q_i(p) = p \]
Model: Equilibrium

There exists a unique linear equilibrium in which dealer $i$ chooses $q_i(p)$ at $p$ is s.t.:

$$\text{marginal utility} = \text{marginal disutility}$$

With capital constraint & perfect competition

$$\mu - \rho \sigma q_i(p) = (1 + \lambda_i \kappa) p$$
There exists a unique linear equilibrium in which dealer $i$ chooses $q_i(p)$ at $p$ is s.t.:

$$\text{marginal utility} = \text{marginal disutility}$$

With capital constraint & market power

$$\mu - \rho \sigma q_i(p) = (1 + \lambda_i \kappa)[p + \Lambda_i(\bar{\lambda})q_i(p)]$$
Model: Proposition

When the capital constraint is relaxed, e.g., $\kappa \downarrow$

(1) demand $q_i(\cdot)$ becomes flatter, and market price $p^*$ increases

Figure: $q_i(p)$
When the capital constraint is relaxed, e.g., $\kappa \downarrow$

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Figure: $q_i(p)$
When the capital constraint is relaxed, e.g., $\kappa \downarrow$

1. demand $q_i(\cdot)$ becomes flatter, and market price $p^*$ increases
2. price impact $\Lambda_i(\vec{\lambda})$ increases for all dealers $i$.

**Figure: Residual Supply$_i(p)$**
When the capital constraint is relaxed, e.g., $\kappa \downarrow$

1. demand $q_i(\cdot)$ becomes flatter, and market price $p^*$ increases

2. price impact $\Lambda_i(\bar{\lambda})$ increases for all dealers $i$.

*Figure: Residual Supply $i(p)$*
Model: IPV environment

**IPV environment**
- Dealers are ex-ante identical
- Have iid private information about their inventory positions or the asset’s return

**There exists a symmetric equilibrium with analogous properties**
- In uniform price auction
- In discriminatory price auction under additional assumptions
Empirical application
Environment: Canada’s Primary Market for Government Bonds

Attractive market features

- Dealers submit entire demand curves
- Dealer demand can be linked to balance sheet infos

Challenges

- Auction format is discriminatory price
- Demand is a step-function as in Kastl (2011)
- There are different types of bidders, not only dealers
- Bids may be updated until auction closure as in Hortaçsu and Kastl (2012)
Data

Bidding data of all regular Treasury auctions (01/01/2015–02/01/2021)

- Who bids (ID), winning and losing bids
Data

Bidding data of all regular Treasury auctions (01/01/2015–02/01/2021)
- Who bids (ID), winning and losing bids

Balance sheet information of 8 dealers at bank level
- Quarterly Basel III Leverage Ratio (LR) = \( \frac{\text{Tier 1 capital}}{\text{Total leverage exposure}} \geq 3\% \)
- Quarterly institution-specific capital threshold

Volatility and price data
- Market Volatility Index
- Trade prices of the secondary market
Testing model predictions: Demand effect

- 04/2020–12/2021: Treasuries exempted from LR constraint
- Some banks $i$ faced stricter capital $threshold_{ik}$ than others

**Figure:** Time series of LR for an average bank
Testing model predictions: Demand effect

- 04/2020–12/2021: Treasuries exempted from LR constraint
- Some banks $i$ faced stricter capital $\text{threshold}_i$ than others

→ Test if their demand became flatter relative to others:

$$slope_{iqs} = \alpha + \sum_{k=-K}^{K} \gamma_k D_k \text{threshold}_i + \zeta_{qs} + \epsilon_{iqs}$$

- $slope_{iqs}$ is the avg. slope in $i$’s demand for security $s$ in quarter $q$
- $D_k$ is an indicator for quarter $k$, $\zeta_{qs}$ is a quarter-security fixed effect
**Figure:** Change in the slope of demand

**Take away:** Demands of banks s.t. stricter capital thresholds were flatter
Testing model predictions: Price effect

Quantifying effect on market price is difficult

- Must use variation across time instead of banks
- Endogeneity concern

⇒ Leverage structural model
Model calibration

Parameters

- Shadow cost of capital \( \lambda_t \kappa \)
- Risk aversion \( \rho_t \)

Identifying assumptions per auction \( t \)

- Dealer \( i \) draws private info \( \zeta_{ti} \sim \mathcal{H}_t \) about her true \( \text{value}_{ti}(q) \) for amount \( q \)
- \( \text{value}_{ti}(q) = \zeta_{ti} - \beta_t q \) with \( \beta_t = \frac{\rho_t \sigma_t}{1 + \lambda_t \kappa} \)
- Everyone bids as in equilibrium of Hortaçsu and Kastl (2012)'s auction game
Model calibration

**Estimation procedure**

1) Back out $\hat{value}_{tik}$ at each submitted step $k$ as in Allen et al. (2022)

2) Fixed-effect regression using bids of dealers who submit more than 1 step:

$$\hat{value}_{tik} = \zeta_{ti} - \beta_{tq_{tik}} + \epsilon_{ti}$$
Model calibration: Warm up

**Figure:** Distribution of $\frac{\hat{\beta}_t}{\sigma_t}$ with volatility $\sigma_t$

$$\frac{\hat{\beta}_t}{\sigma_t} = \rho_t \text{ during exemption; } \frac{\hat{\beta}_t}{\sigma_t} = \frac{\rho_t}{1 + \lambda_t \kappa} \text{ otherwise}$$
Point estimates: Policy change 1

- Assume $\rho_t = \rho$ and $\lambda_t \kappa = \lambda \kappa$ during a quarter
- Compare $\frac{\hat{\beta}_t}{\sigma_t}$ in auctions in 2020q1 and 2020q2 around exemption

<table>
<thead>
<tr>
<th></th>
<th>2020q1-2020q2</th>
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</thead>
<tbody>
<tr>
<td>$\rho$</td>
<td>+1.52/10^4</td>
<td>(0.033/10^4)</td>
</tr>
<tr>
<td>$\lambda \kappa$</td>
<td>+0.965</td>
<td>(0.168)</td>
</tr>
<tr>
<td>N</td>
<td>23,074</td>
<td></td>
</tr>
</tbody>
</table>

Estimate of $\hat{value}_{tik} = \zeta_{ti} + \rho \times exempt_t \sigma_t q_{tik} + \frac{\rho}{1 + \lambda \kappa} \times (1 - exempt_t) \sigma_t q_{tik} + \epsilon_{tik}$, values are in yields to maturity in %, quantities in million C$, standard errors in parentheses

- Risk aversion per unit of the asset, $\rho$, is small $\approx 0$
- The shadow cost of capital, $\lambda \kappa$, is large
Point estimates: Policy change 2

- Assume $\rho_t = \rho$ and $\lambda_t \kappa = \lambda \kappa$ during a quarter
- Compare $\frac{\hat{\beta}_t}{\sigma_t}$ in auctions in 2021q4 and 2022q1 around reintroduction

<table>
<thead>
<tr>
<th></th>
<th>2020q1-2020q2</th>
<th>2021q4-2022q1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho$</td>
<td>+1.52/10^4</td>
<td>+3.96/10^4</td>
</tr>
<tr>
<td>$\lambda \kappa$</td>
<td>+0.965</td>
<td>+0.302</td>
</tr>
<tr>
<td>$\sigma_t q_{tik}$</td>
<td>(0.033/10^4)</td>
<td>(0.155/10^4)</td>
</tr>
<tr>
<td>$\rho(1+\lambda \kappa)$</td>
<td>(0.168)</td>
<td>(0.115)</td>
</tr>
<tr>
<td>$N$</td>
<td>23,074</td>
<td>12,894</td>
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Estimate of $\hat{\text{value}}_{tik} = \zeta_{ti} + \rho \times \text{exempt}_t \sigma_t q_{tik} + \frac{\rho}{1+\lambda \kappa} \times (1-\text{exempt}_t) \sigma_t q_{tik} + \epsilon_{tik}$, values are in yields to maturity in %, quantities in million C$, standard errors in parentheses

- Risk aversion per unit of the asset, $\rho$, is small $\approx 0$
- The shadow cost of capital, $\lambda \kappa$, is large
When demand functions are linear

- Decreasing the capital cost $\lambda\kappa$ by 1%,
  - Increases the market price
  - Increases markups
    - I.e., difference btw. price that would arise if dealers were price takers and actual price

- Both by $\eta = \left( \frac{1}{1+\lambda\kappa} - 1 \right) \%$
Model calibration: Trade off

In the data, demand functions are not linear, but approximately linear

→ We can approximate the trade off

<table>
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<th>2021q4-2022q1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta$</td>
<td>0.49%</td>
<td>0.23%</td>
</tr>
</tbody>
</table>

Implication

• Exempting Treasuries from the Basel III leverage ratio $\approx$ capital cost ↓ by 100%

→ Reduces bond yields, but increases markups by $\approx 49\%$
Conclusion

This paper

• Shows that dealer capitalization affects asset prices and market power—trade-off!
• Quantifies the effects with data on Treasury auctions

→ Helps inform ongoing policy debate about Basel III
→ Contributes to intermediary asset pricing literature thanks to micro-level data
  E.g., Adrian et al. (2014); He et al. (2017); Gospodinov and Robotti (2021)

Thank you!


Appendix
Empirical literature

Empirical intermediary asset pricing (macro)

• He et al. (2017); Du et al. (2018); Gospodinov and Robotti (2021); He et al. (2022)...
⇒ This paper uses micro-level to observe the link btw. demand and capitalization

Empirical studies on market power in Treasury auctions (micro)

• Hortaçsu (2002); Cassola et al. (2012); Hortaçsu and Kastl (2012); Hortaçsu et al. (2018)...
⇒ This paper introduces capital constraints
**Data:** Slope measure

**Conventions:** Draw demand curves with quantity on y-axis

Day $t$, security $s$, dealer $i$: $slope_{its} = -\frac{\max_k \{q_{itsk}\}}{\max_k \{p_{itsk}\}}$ in quantity-price space
**Data:** Slope measure

**Conventions:** Draw demand curves with quantity on y-axis

Day $t$, security $s$, dealer $i$: $\text{slope}_{its} = + \frac{\max_k \{q_{itsk}\}}{\min_k \{y_{itsk}\}}$ in quantity-yield space
(i) There exists a unique equilibrium in which dealer $i$ submits demand curve

$$q_i(p) = ((1 + \lambda_i \kappa)\Lambda_i + \sigma \rho)^{-1}(\mu - (1 + \lambda_i \kappa)p),$$

where

$$\Lambda_i = \beta_i \alpha_i \sigma \text{ with } \beta_i = \frac{2}{\alpha_i b - 2 + \sqrt{(\alpha_i b)^2 + 4}} \text{ and } \alpha_i = \frac{\rho}{1 + \lambda_i \kappa s},$$

with $b \in \mathbb{R}^+$ as unique positive solution to $1/2 = \sum_i (\alpha_i b + 2 + \sqrt{(\alpha_i b)^2 + 4})^{-1}$.

(ii) When dealers are identical ($z_i = z, E_i = E$), the demand curve simplifies to

$$q_i(p) = \left(\frac{N - 2}{N - 1}\right) \frac{1}{\rho \sigma} \left(\mu - \rho \sigma z - (1 + \lambda \kappa)p\right).$$

The price impact is $\Lambda = \frac{1}{N-2} \frac{\rho \sigma}{1 + \lambda \kappa}$ with $\lambda \geq 0$ for sufficiently high $\kappa$. 
IPV uniform price auction

Period 1:

- Each dealer observes $z_i \sim \mathcal{H}$ and $\sum_i z_i$
- Each dealer submits demand schedule $q_i(\cdot) : \mathbb{R} \to \mathbb{R}$ s.t. capital constraint
- Market clears at $p^*$ such that $\sum_i q_i(p^*) = Q$

Period 2:

- Dealer’s balance out total exposure so that each carries $\alpha - \beta p^*$, $\alpha \in \mathbb{R}, \beta > 0$
- Asset pays out return and all transactions take place
In equilibrium dealer $i$ submits

$$q_i(p) = (\Lambda + \sigma \rho)^{-1} \left( \mu + \alpha \kappa \Lambda \lambda - \sigma \rho z_i - (1 + 2 \beta \kappa \Lambda \lambda) p \right)$$

with $\Lambda = \frac{-(N - 2) + \sqrt{(N - 2)^2 + 8 \beta \kappa \lambda (N - 1) \rho \sigma}}{\sqrt{4 \beta \kappa \lambda (N - 1)}}$.

The equilibrium exists if $\lambda$ which solves $E - \kappa p^* \eta(p^*) = 0$ with $p^* : \sum_i a_i(p^*) = A$ is non-negative. This is the case when $\kappa$ is sufficiently high given all other parameters.

Assume that the capital constraint is relaxed so that $\lambda$ decreases. Then demand becomes flatter, the market price and price impact increase.
Let dealer $i$ have value $v_i(q) = \frac{\sigma \rho}{1+\lambda \kappa} [\mu - (z_i + q)]$ for amount $q$, with $z_i$ being drawn from iid across $i$ from a distribution with support $[\underline{z}, \overline{z}]$.

If winning quantities are drawn from a distribution with CDF $F_i(q) = 1 - \left( \frac{\nu_i + \xi q}{\nu_i} \right)^{-\frac{1}{\xi}}$ with $\xi \in (-\infty, -1]$, $\nu_i = -\xi \left( \frac{N(1-\xi)-1}{N(1-\xi)} \right)(\overline{z} - z_i) - \xi \left( \frac{Q}{N} \right)$, there exists an equilibrium in which dealer $i$ submits the demand curve

$$
q_i(p) = \left( \frac{N(1-\xi)-1}{N-1} \right) \frac{1}{\sigma \rho} (\mu_i - (1 + \lambda \kappa)p)
$$

with $\mu_i = \mu + \frac{\rho \sigma}{1-\xi} (\overline{z} - z_i) + \frac{\rho \sigma A}{N(1-\xi)-1}$ as long as $\mathbb{E}[\mu_i] \geq \frac{\rho \sigma A(N-1)}{N(N(1-\xi)-1)}$. 


Yield effect

Table: Correlation between yield and LR

<table>
<thead>
<tr>
<th></th>
<th>(OLS)</th>
<th>(FE1)</th>
<th>(FE2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LR</td>
<td>-0.360</td>
<td>-0.370</td>
<td>-0.245</td>
</tr>
<tr>
<td></td>
<td>(0.0362)</td>
<td>(0.0411)</td>
<td>(0.0521)</td>
</tr>
<tr>
<td>controls</td>
<td>—</td>
<td>—</td>
<td>✓</td>
</tr>
<tr>
<td>fixed effects</td>
<td>—</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Observations</td>
<td>2912</td>
<td>2912</td>
<td>2904</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.032</td>
<td>0.679</td>
<td>0.789</td>
</tr>
</tbody>
</table>

This shows results of $yield_d = \alpha + \beta LR_{qi} + \epsilon_{ti}$ in (OLS). In (FE1) we add dealer and year fixed effects; in (FE2) other control variables. Yield and LR are in %. Standard errors are in parentheses, clustered at the dealer level in (FE1) and (FE2).
Implied volatility index

- Measures the expected volatility of Treasury yields (in % per year)
- Based on option prices on interest rate futures (Chang and Feunou (2014))
- Similar to MOVE for US Treasuries, VIX for stocks
Sanity check

Use observed bids instead of estimated values:

<table>
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<tr>
<td>$\rho$</td>
<td>+0.686/10^4 (0.010/10^4)</td>
<td>+2.050/10^4 (0.046/10^4)</td>
</tr>
<tr>
<td>$\lambda_\kappa$</td>
<td>+0.844 (0.169)</td>
<td>+0.169 (0.076)</td>
</tr>
<tr>
<td>N</td>
<td>23,074</td>
<td>12,894</td>
</tr>
</tbody>
</table>

Tables shows the estimate of $\text{bid}_{tik} = \zeta_{ti} + \rho \times \text{exempt}_t \sigma_t q_{tik} + \frac{\rho}{1+\lambda_\kappa} \times (1-\text{exempt}_t) \sigma_t q_{tik} + \epsilon_{tik}$ with bids expressed as yields to maturity in %, quantities are in million C$, standard errors are in parentheses

Findings

- Both parameters are downward biased due to shading
- But magnitudes are roughly similar
Shading

Figure: Distribution of bid shading per step $k$
Supporting descriptive evidence

Follow Hortaçsu (2002) and check $R_t^2$ of

$$b_{t_1 t_k} = \zeta_{t_1 t_k} + \beta_t q_{t_1 t_k} + \epsilon_{t_1 t_k}$$

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>median</th>
<th>sd</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_t$</td>
<td>0.20</td>
<td>0.17</td>
<td>0.11</td>
</tr>
<tr>
<td>$R_t^2$</td>
<td>0.82</td>
<td>0.83</td>
<td>0.16</td>
</tr>
<tr>
<td>Adj. $R_t^2$</td>
<td>0.77</td>
<td>0.77</td>
<td>0.21</td>
</tr>
<tr>
<td>Within $R_t^2$</td>
<td>0.53</td>
<td>0.54</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Subsample: bidding-functions with at least 2 steps. Bids are in yields (bps) and quantities in % of supply.