Corporate Bond Multipliers: Substitutes Matter

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Motivation

- The price impact of demand shifts in the bond market is an important input to answering a wide range of questions
  - Impact of QE/QT, mutual fund flows etc
  - Welfare loss in models with pecuniary externalities

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- The price impact of demand shifts in the bond market is an important input to answering a wide range of questions
  - Impact of QE/QT, mutual fund flows etc
  - Welfare loss in models with pecuniary externalities
- Existing literature has used both reduced-form and structural methods to provide quantitative answers to such questions (Ellul et al. 2011; Manconi et al. 2012; Bretscher et al. 2022...)
- Current methods often (implicitly) treat all securities as equally good substitutes

Introduction

- Corporate bonds' salient characteristics (rating and maturity) imply clear heterogeneous patterns in substitutability
  - Apple's (AA+) 10-year bond is a great substitute for Google's (AA+) 10-year bond, but a bad substitute for Ford's (BB+) 3-year bond

- Theory suggests that price impact crucially depends on the availability of close substitutes

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- Theory suggests that price impact crucially depends on the availability of close substitutes

- **This paper**: measure how much corporate bond prices respond to demand shocks by introducing rich heterogeneity in the substitution patterns
  - Mis-specified substitution structure leads to biased estimates

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- Allow bonds with similar characteristics to be better substitutes with each other than the rest of the bonds
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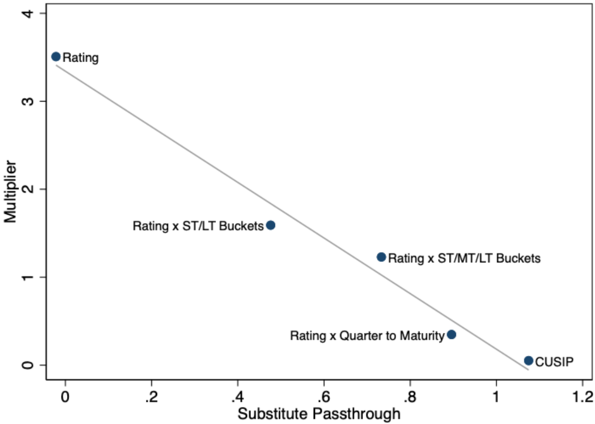
- Allow bonds with similar characteristics to be better substitutes with each other than the rest of the bonds
- The security level multiplier is near-zero
  - Much smaller than estimates ignoring heterogeneous substitutability
- Substitute passthrough ($\tilde{M}$), defined as the $\uparrow$ in price due to its close substitutes' prices $\uparrow$ 1%, is close to 1

...however price impact is rising in aggregation

- For portfolios, the multiplier monotonically increases with the aggregation level, while the substitute passthrough decreases



Fully flexible substitution $\implies$ inestimable equation

- Log linearizing investor i's demand for N risky assets,

$$\underbrace{\mathbf{q}_{i,t}}_{N\times 1} = \underbrace{\Gamma}_{N\times N} \underbrace{\mathbf{p}_t}_{N\times 1} + \underbrace{\hat{\mathbf{u}}_{i,t}}_{N\times 1} + \underbrace{\hat{\nu}_{i,t}}_{N\times 1}$$

where $\mathbf{q}_{i,t}$ log quantity, $\mathbf{p}_t$ log price, $\hat{\mathbf{u}}_{i,t}$ observed demand shocks, $\hat{\nu}_{i,t}$ unobserved demand shocks, $\Gamma_{j,j} = \frac{\partial q_j}{\partial p_j}$ and $\Gamma_{j,k} = \frac{\partial q_j}{\partial p_k}$.

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- Taking changes and applying market clearing, asset j return,

$$\underbrace{\Delta p_{j,t}}_{1\times 1} = \underbrace{M_j}_{1\times 1} \underbrace{u_{j,t}}_{1\times 1} + \underbrace{\tilde{M}_j^{\top}}_{1\times(N-1)} \underbrace{\Delta p_{j,t}^{sub}}_{(N-1)\times 1} + \underbrace{\nu_{j,t}}_{1\times 1}$$

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- Fully general, but too many $\Gamma \implies$ not estimable......**need restrictions on substitution**

Imposing structure on substitution for feasible estimation

- If we assume homogeneous substitution (single-layered demand),

$$\Delta p_{j,t} = Mu_{j,t} + M_{mkt} \Delta p_t^{mkt} + \nu_{j,t}$$

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- If within-group substitution is different from cross-group substitution (double-layered demand),

$$\Delta p_{j,t} = Mu_{j,t} + \tilde{M}\Delta p_{g(j),t} + M_{mkt}\Delta p_t^{mkt} + \nu_{j,t}$$

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- *Mis-specifying the double-layer system as single-layer leads to positive omitted variable bias in M*

Demand shocks $u_{j,t}$

- Remove the predictable components and common factors from quarterly mutual fund flows to get fund-level shocks $\epsilon_{i,t}$ Details Robustness

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- Bond j's demand shock $u_{j,t}$: sum of $\epsilon_{i,t}$ weighted by fund's lagged market share of bond j, $S_{i,j,t-1}$ (Coval and Stafford, 2007; Lou, 2012; Gabaix and Koijen, 2021...)
  - 1:1 passthrough assumption Robustness

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- Identification assumption: unobserved shocks are not correlated with past shares, i.e. $\nu_{j,t} \perp S_{i,j,t-1}$ for all i, t (Goldsmith-Pinkham et al., 2020; Chaudhry, 2022...)
  - Pooled exogenous exposure design Longer lagged shares

$\Rightarrow$ $u_{j,t} \perp \nu_{j,t}$

Estimation

- Homogeneous substitution
  - Estimate using OLS with time fixed effects

$$\Delta p_{j,t} = Mu_{j,t} + \text{Time FE} + \nu_{j,t}$$

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$$\Delta p_{j,t} = Mu_{j,t} + \text{Group-Time FE} + \nu_{j,t}$$

  - Estimate 2SLS, instrumenting $\Delta p_{g(j),t}$ with $u_{g(j),t}$

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  - *Baseline group: bonds with the same detailed rating*

Estimates on individual securities

$$\Delta p_{j,t} = M u_{j,t} + \text{Time FE} + \nu_{j,t}$$

	Homo. OLS	OLS			First-stage	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)
Shock	0.39***	0.02	0.05	0.07		0.05
	(0.06)	(0.05)	(0.05)	(0.04)		(0.05)
Substitute return						1.07***
						(0.06)
Group Shock					2.61***	
					(0.30)	
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Group x Quarter FE	No	Yes	Yes	Yes	No	No
ST/LT x Quarter FE	No	No	No	Yes	No	No
Drop Crisis	No	No	Yes	Yes	Yes	Yes
N	333,537	333,537	314,534	314,534	314,534	314,534
R^2	0.21	0.39	0.36	0.40	0.62	
First-stage F-statistic						72.49

Standard errors in parentheses

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Portfolios with different levels of aggregation

Asset	Substitute	M	$\tilde{M}$
CUSIP	Bonds with same Det. rating	0.05 (0.05)	1.07*** (0.06)
Det. rating × Quarter-to-maturity	Bonds with same Det. rating	0.35*** (0.1)	0.9*** (0.05)
Rating × ST/MT/LT Buckets	Bonds with same rating	1.23* (0.48)	0.73*** (0.13)
Rating × ST/LT Buckets	Bonds with same rating	1.59** (0.58)	0.48** (0.15)
Rating	IG v.s. HY	3.51*** (0.87)	-0.02 (0.31)

Details

Conclusion

- It is important to account for the correct substitution set when estimating multipliers
- The price multiplier and substitution effect depend on the aggregation level
- Future line of work
  - How to robustly model different levels of substitution? Can we use information in investor holdings to identify close vs. distant substitutes?
  - How to map the multipliers and substitute passthroughs to model primitives? What are the connections of these estimates within and across asset classes?

Literature

- Demand estimation using logit-demand system: Koijen and Yogo (2019), Bretscher, Schmid, Sen, and Sharma (2022), Darmouni, Siani, and Xiao (2023)...

  ⇒ Our approach is close to a *nested-logit* demand system

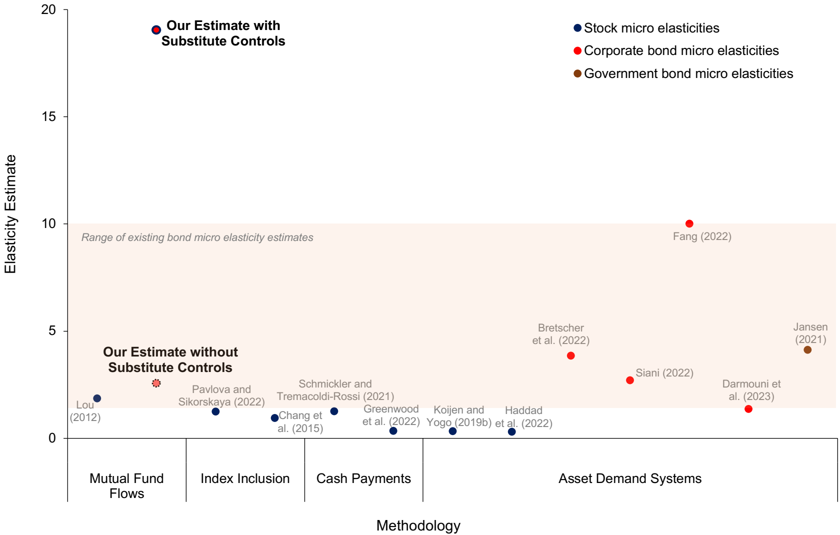
- Flow induced trading: Lou (2012), Coval and Stafford (2007), Li (2021)...

  ⇒ We account for close-substitute portfolio's return to correct for omitted variable bias

- One-time demand shocks: Shleifer (1986); Harris and Gurel (1986); Wurgler and Zhuravskaya (2002); Pavlova and Sikorskaya (2022)...

  ⇒ Our approach can analyze multipliers for portfolios at different aggregation level

Comparison with Existing Estimates



Details on the Demand System

- For fund i, assume demand for N risky assets as

$$\underbrace{\mathbf{q}_{i,t}}_{N\times 1} = \underbrace{\Gamma}_{N\times N} \underbrace{\mathbf{p}_t}_{N\times 1} + \underbrace{\mathbf{u}_{i,t}}_{N\times 1} + \underbrace{\nu_{i,t}}_{N\times 1} \quad (1)$$

  - $\mathbf{q}_{i,t}$: log quantity
  - $\mathbf{p}_t$: log price
  - $\mathbf{u}_{i,t}$: observed demand shocks
  - $\nu_{i,t}$: unobserved demand shocks
  - $\Gamma_{j,j} = \frac{\partial q_j}{\partial p_j}$ and $\Gamma_{j,k} = \frac{\partial q_j}{\partial p_k}$

- Log-linearization of any generic demand function

Details on the Demand System

- For asset j, apply market clearing, and log-linearize around previous period prices

$$\Delta p_{j,t} = \underbrace{M_{0,j}}_{=-\frac{1}{\Gamma_{j,j}}} u_{j,t} + \underbrace{M_{1,j}}_{=-\frac{\sum_{k\neq j}\Gamma_{j,k}}{\Gamma_{j,j}}} \Delta p^{sub}_{j,t}(\mathbf{u}_t) + \underbrace{\nu_{j,t}}_{\text{Unobserved demand shocks}} \tag{2}$$

where

$$u_{j,t} \equiv \sum_i S_{i,j,t-1} u_{i,t} \tag{3}$$

$$\Delta p^{sub}_{j,t} \equiv \frac{\sum_{k\neq j}\Gamma_{j,k}\Delta p_{k,t}}{\sum_{k\neq j}\Gamma_{j,k}} \tag{4}$$

- **Issue**: (i) cross-elasticities $\Gamma_{j,k}$ are not observed $\therefore$ we cannot construct $\Delta p^{sub}_{j,t}$, and (ii) too many $M_{0,j}$ and $M_{1,j}$ to estimate

Details on the Demand System

- Typical single-layered demand assumes homogeneous substitution,

$$\Gamma_{j,k} = \begin{cases} \gamma^o & \text{if} \quad j = k \\ \gamma^d w_k & \text{if} \quad j \neq k \end{cases}$$

where w_k is the market share, and γ^o, and γ^d are constants.

- Our two-layered demand allows for close and distant substitutes,

$$\Gamma_{j,k} = \begin{cases} \gamma^o & \text{if} \quad j = k \\ \gamma^c w_{k|g} + \gamma^d w_k & \text{if} \quad j \neq k; \text{ and } j, k \text{ in same group} \\ \gamma^d w_k & \text{otherwise} \end{cases}$$

where $w_{k|g}$ is the market share within group g, and γ^c is a constant.

Comparison with Nested-Logit Demand Model

In nested-logit demand

$$w(j \mid g) = \frac{exp(\delta(j,g))}{\sum_{j\in g} exp(\delta(j,g))} \quad (5)$$

$$w(g) = \frac{(\sum_{k\in g} exp(\delta(k,g)))^{\lambda}}{1 + \sum_{g'}(\sum_{k\in g'} exp(\delta(k,g')))^{\lambda}} \quad (6)$$

$$\delta(j,g) = \beta_g p_j + \beta X + u_j \quad (7)$$

Apply market clearing condition, we get

$$\Delta p_j = \underbrace{\frac{1}{(1-\beta_g)}}_{M} u_j + \underbrace{\frac{\beta_g}{(\beta_g - 1)}(1-\lambda)}_{\tilde{M}} \underbrace{\sum_{k\in g} w(k \mid g)\Delta p_k}_{\Delta p_j^g} + \underbrace{\lambda \frac{1}{(\beta_g - 1)} \sum_{g'} \sum_{k\in g'} \beta_{g'} w(k)\Delta p_k}_{\text{Time FE}} + \tilde{\nu}_j \quad (8)$$

If $\lambda = 1$, collapse to logit demand and Δp_j^g drops out.

Detailed Construction of Demand Shocks

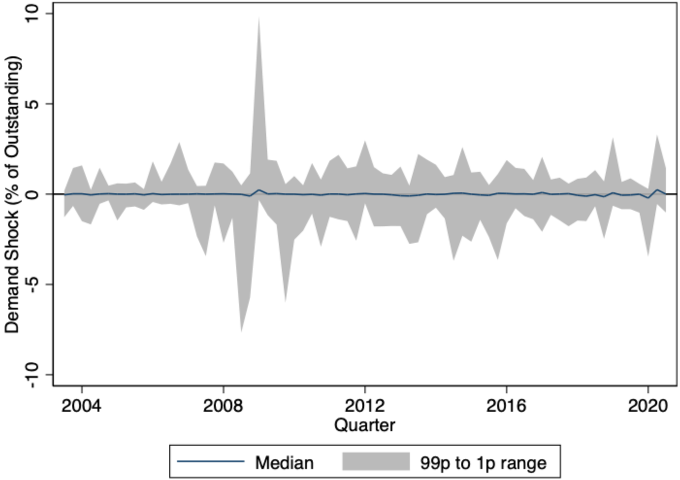
1. **Flow induced trading by mutual funds**: Morningstar data subset to corporate bond funds
2. **Remove predictable component**: estimate an AR(3) model with a time trend for each fund i

$$f_{i,t} = \rho_{i,0} + \sum_{k=1}^{3} \rho_{i,k} f_{i,t-k} + \delta_i t + \varepsilon_{i,t}$$

   demand shocks are scaled by $K_i = 1/(1 - \sum_{k=1}^{3} \rho_{i,k})$
3. **Remove common factors**: $\varepsilon_{i,t} = \alpha_i + \delta_t + u_{i,t}$
4. **Aggregate to asset j shock**: $u_{j,t} = \sum_j S_{i,j,t-1} K_i u_{i,t}$

Back

Distribution of Demand Shocks



Factor Structure of Flows

$$f_{i,t}(\text{or } \epsilon_{i,t}) = \delta_t + C'_{i,t}(\lambda\eta_t) + u_{i,t}$$

where $C_{i,t}$ is a vector of observable characteristics of fund i, including (lagged) log AUM of the firm, the share in high-yield bonds, and the average duration in the portfolio.

Back

Alternative Flow Specification

	Bench.	Robustness						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Shock	0.33***	0.29**	0.32**	0.37***	0.26**	0.28***	0.21***	0.18
	(0.10)	(0.10)	(0.11)	(0.11)	(0.08)	(0.08)	(0.06)	(0.13)
AR lags	3	3	1	2	1	2	3	0
Time Trend	Yes	Yes	Yes	Yes	No	No	No	No
Factors	No	Yes	No	No	No	No	No	No
Quarter $\times$ Sub FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Drop Crisis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	77,387	77,387	77,387	77,387	77,387	77,387	77,387	77,387
R^2	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Back

Fund Passthrough

- Assuming MFs have downward sloping demands, we can estimate lower-bound passthrough coefficient β by running the regression,

$$\Delta q_{ijt} = \alpha + \beta f_{it} + \varepsilon_{ijt}$$

- We can find upper-bound multiplier estimates $\bar{M} = \hat{M}/\hat{\beta}$
- Even the upper bound multiplier estimates are much smaller than estimates assuming homogeneous substitutability.

	CUSIP		Det Rating x Q to Mat		Rating	
	(1)	(2)	(3)	(4)	(5)	(6)
Flows	0.51***	0.49***	0.58***	0.57***	0.94***	0.91***
	(0.02)	(0.01)	(0.01)	(0.01)	(0.04)	(0.05)
Time + Fund FE	No	Yes	No	Yes	No	Yes
N	4,861,780	4,861,779	1,193,197	1,193,177	163,515	163,502

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Back

Using Large Shocks Only — CUSIP

	Homo. OLS	OLS			First-stage	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)
Shock	0.35***	0.06	0.05	0.04		0.05
	(0.05)	(0.04)	(0.04)	(0.04)		(0.05)
Substitute return						1.18***
						(0.06)
Group Shock					2.54***	
					(0.28)	
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Group x Quarter FE	No	Yes	Yes	Yes	No	No
ST/LT x Quarter FE	No	No	No	Yes	No	No
Drop Crisis	No	No	Yes	Yes	Yes	Yes
N	166,749	166,747	157,247	157,247	157,248	157,248
R^2	0.20	0.40	0.37	0.39	0.61	0.17
First-stage F-statistic						79.08

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Back

Using Large Shocks Only — Baseline Portfolio

	Homo. OLS	OLS			First-stage	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)
Shock	0.80***	0.33***	0.28**	0.23*		0.27**
	(0.11)	(0.10)	(0.10)	(0.09)		(0.10)
Substitute return						0.97***
						(0.07)
Group Shock					2.76***	
					(0.32)	
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Group x Quarter FE	No	Yes	Yes	Yes	No	No
ST/LT x Quarter FE	No	No	No	Yes	No	No
Drop Crisis	No	No	Yes	Yes	Yes	Yes
N	39,324	39,323	37,086	37,086	37,086	37,086
R^2	0.25	0.51	0.47	0.49	0.51	0.24
First-stage F-statistic						71.62

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Back

One-Year Lagged Shares: CUSIP-level

	Homo. OLS	OLS		First-stage	2SLS
	(1)	(2)	(3)	(4)	(5)
Shock	0.39***	-0.03	0.01		0.02
	(0.07)	(0.06)	(0.05)		(0.06)
Substitute return					1.08***
					(0.04)
Group Shock				3.93***	
				(0.47)	
Quarter FE	Yes	Yes	Yes	Yes	Yes
Group x Quarter FE	No	Yes	Yes	No	No
Drop Crisis	No	No	Yes	Yes	Yes
N	277,336	277,336	261,144	261,144	261,144
R^2	0.21	0.40	0.37	0.62	
First-stage F-statistic					94.96

Standard errors in parentheses

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Back

One-Year Lagged Shares: Baseline Portfolios

	Homo. OLS	OLS		First-stage	2SLS
	(1)	(2)	(3)	(4)	(5)
Shock	1.04***	0.31**	0.33**		0.33**
	(0.15)	(0.12)	(0.12)		(0.12)
Substitute return					0.96***
					(0.04)
Group Shock				4.36***	
				(0.51)	
Quarter FE	Yes	Yes	Yes	Yes	Yes
Group x Quarter FE	No	Yes	Yes	No	No
Drop Crisis	No	No	Yes	Yes	Yes
N	81,866	81,866	77,387	76,348	76,348
R^2	0.22	0.47	0.41	0.48	
First-stage F-statistic					69.48

Standard errors in parentheses

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Back

Estimates for Baseline Portfolio

Define assets as portfolios formed by bonds with the same (detailed rating, quarter-to-maturity)

	Homo. OLS	OLS			First-stage	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)
Shock	0.95***	0.32**	0.33***	0.35***		0.35***
	(0.12)	(0.10)	(0.10)	(0.10)		(0.10)
Substitute return						0.90***
						(0.05)
Group shock					2.91***	
					(0.34)	
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Group x Quarter FE	No	Yes	Yes	Yes	No	No
ST/LT x Quarter FE	No	No	No	Yes	No	No
Drop Crisis	No	No	Yes	Yes	Yes	Yes
N	81,866	81,866	77,387	77,387	76,348	76,348
R^2	0.23	0.47	0.41	0.44	0.47	
First-stage F-statistic						69.85

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Back

Alternative Substitute Definitions

	(1)	(2)	(3)	(4)
Shock	0.35***	0.35***	0.31**	0.33**
	(0.10)	(0.10)	(0.11)	(0.11)
Detailed rating substitute return	0.90***	0.77***		
	(0.05)	(0.17)		
IG substitute return		0.18		
		(0.22)		
Coarse rating substitute return			0.79***	
			(0.08)	
Det rating x ST/LT substitute return				0.99***
				(0.08)
Quarter FE	Yes	Yes	Yes	Yes
Drop Crisis	Yes	Yes	Yes	Yes
N	76,348	76,348	76,296	76,348
First-stage F-statistic	69.85	3.37	18.19	107.94

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Back

Portfolios with different levels of aggregation

Table: Aggregate Portfolios

	Asset	Substitute Portfolio
CUSIP	Individual bonds	Other bonds in the same detailed rating category
Rating × Quarter to Maturity	Portfolios formed by detailed rating and quarter-to-maturity	Other bonds in the same detailed rating category
Rating × ST/MT/LT Buckets	Portfolios formed by coarse rating and three maturity groups $(\{[0,4),[4,10),[10,\infty)\})$	Other bonds in the same coarse rating category
Rating × ST/LT Buckets	Portfolios formed by coarse rating and two maturity groups $(\{[0,10),[10,\infty)\})$	Other bonds in the same coarse rating category
Rating	Portfolios formed by coarse rating categories	Other bonds in the same investment grade category

Back

Firm-level Portfolios

Portfolios formed by firm × quarter to maturity

	Homo. OLS	OLS			First-stage	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)
Shock	0.44***	0.10*	0.11*	0.12**		0.11*
	(0.06)	(0.05)	(0.04)	(0.04)		(0.05)
Substitute return						0.98***
						(0.05)
Group Shock					2.63***	
					(0.31)	
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Group x Quarter FE	No	Yes	Yes	Yes	No	No
ST/LT x Quarter FE	No	No	No	Yes	No	No
Drop Crisis	No	No	Yes	Yes	Yes	Yes
N	368,138	368,138	348,230	348,230	344,446	344,446
R^2	0.19	0.35	0.31	0.35	0.61	0.14
First-stage F-statistic						71.96

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Information Ratio of Arbitrage Strategies

- If $u_{j,t} > 0$, short asset j and buy the close substitute portfolio (and the market) in period t. Unwind in period $t+1$.
  - If $u_{j,t} < 0$, do the opposite

- Define arbitrage risk

$$ArbRisk_j \equiv std(\tilde{\nu}_{j,t} + Mu_{j,t}) \tag{9}$$

- Sharpe ratio

$$SR = \frac{M \times Mean(|u_{j,t}|)}{Mean(ArbRisk_j)} \tag{10}$$

- Sharpe ratio ranges from 0.006 at the CUSIP level to 0.28 at the rating-portfolio level

Information Ratios

The risks of engaging in these arbitrage activities are high relative to the average gain.

Table: Arbitrage Risk and Portfolio Multipliers

	M	Arb. risk	Sharpe ratio
CUSIP	.052	.043	.006
Det. rating × Quarter to maturity	.348	.055	.026
Rating × ST/MT/LT	1.229	.037	.134
Rating × ST/LT	1.591	.048	.142
Rating	3.507	.043	.280

Arbitrage Risks and Multipliers

Use baseline portfolios formed by detailed rating and quarter-to-maturity

$$\Delta p_{j,t} = M_0 u_{j,t} + M_1 u_{j,t} \times ArbRisk_j + \tilde{M} \Delta p_{j,t}^{sub} + \tilde{\nu}_{j,t}$$

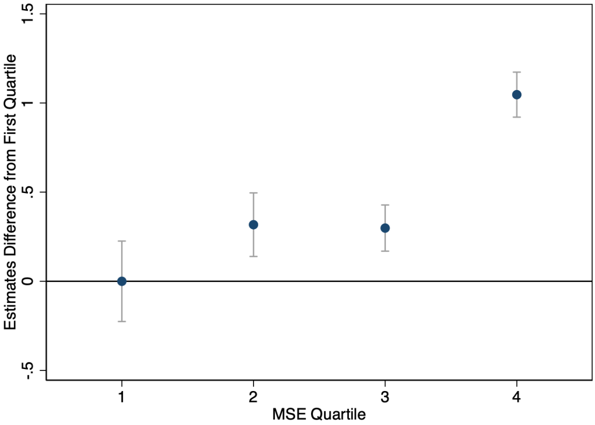
	(1)	(2)
Shock	0.35***	0.03
	(0.04)	(0.04)
ArbRisk x Shock		0.45***
		(0.03)
Substitute return	0.90***	0.91***
	(0.04)	(0.04)
Quarter FE	Yes	Yes
Drop Crisis	Yes	Yes
N	76,348	76,348
First-stage F-statistic	2544.04	2562.86

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

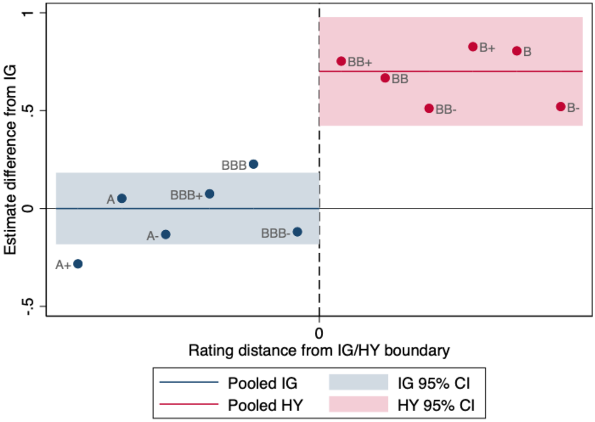
Arbitrage Risks and Multipliers

Sort portfolios into quartiles



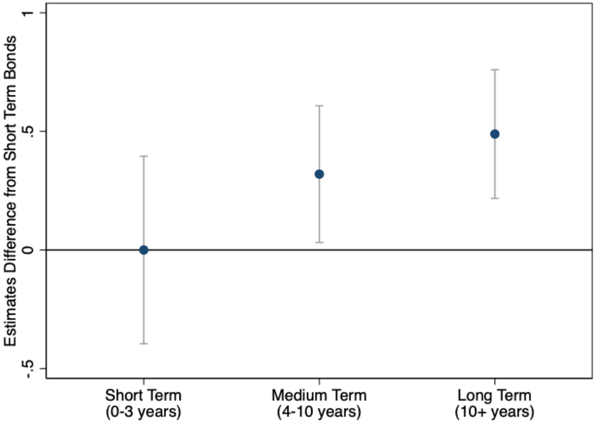
Heterogeneity in Rating

Figure: Heterogeneity in HY/IG



Heterogeneity in Maturity

Figure: Heterogeneity in Maturity



In the Case of Equity

Table: Multiplier estimates for stock markets

	Stock Return		
	(1)	(2)	(3)
Shock	0.380***	0.254***	0.252***
	(0.086)	(0.040)	(0.072)
Group x Quarter FE	None	FF3	Industry
Quarter FE	Yes	Yes	Yes
N	144,768	136,270	135,201
R^2	0.188	0.332	0.263

- The multiplier estimated is smaller once we allow for heterogeneous cross-elasticities, but the difference in magnitudes is not as large as that in the bond case