Segmented Arbitrage

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Motivation

When analyzing the behavior of intermediaries, it is common to assume:

1. **A representative balance sheet (balance sheet integration)**
   - Marginal balance sheet cost of a trade is the same across all institutions

2. **A limited number of constraints**
   - E.g., a single balance sheet constraint on leverage

3. **Trades of equal risk are funded from the same source (funding integration)**
   - E.g., Equity and Treasury spot-futures arbitrage are funded at equal rates

Implications of Canonical Models

Policy:

- Liquidity support to any intermediary/market has the same aggregate effect
- All spreads are equally informative about the health of the sector

Pricing:

- Consistent risk pricing in markets where intermediaries are active
- Low dimensional factor structure for arbitrage spreads
  - Single leverage constraint → perfect correlation, irrespective of demand

Today: How reasonable is the standard view of intermediaries?

This paper

- Characterize frictions based on the dynamics of (nearly) **riskless arbitrage**
  - 32 trades spanning 7 strategies (all U.S.)

- Several reasons why studying arbitrage is useful:
  - Intermediated (Haddad and Muir, 2021)
  - Expected returns are nearly observable, so higher powered tests
  - Agency problems should be relatively weak (riskless trades)

- Arbitrage dynamics suggest the financial sector is highly segmented
  - Why? Arbitrage funding is fragmented and balance sheets are specialized

32 Arbitrage Trades (Dodd-Frank Era, 2010-2020)

1. **Foreign exchange (FX):** Covered interest parity (CIP) bases (Du et al., 2018)
   - G-10 countries minus Denmark and Norway

2. **Equity spot-futures**: S&P 500, Dow, and Nasdaq 100

3. **Equity options**: Put-call parity or "box spreads" (van Binsbergen et al., 2019)
   - 6m, 12m, and 18m S&P 500 index options.

4. **CDS-bond**: Aggregate individual bases into IG and HY indices

5. **TIPS-Treasury:** Treasury + Inflation Swap vs TIPS (2, 5, 10, and 20 year)

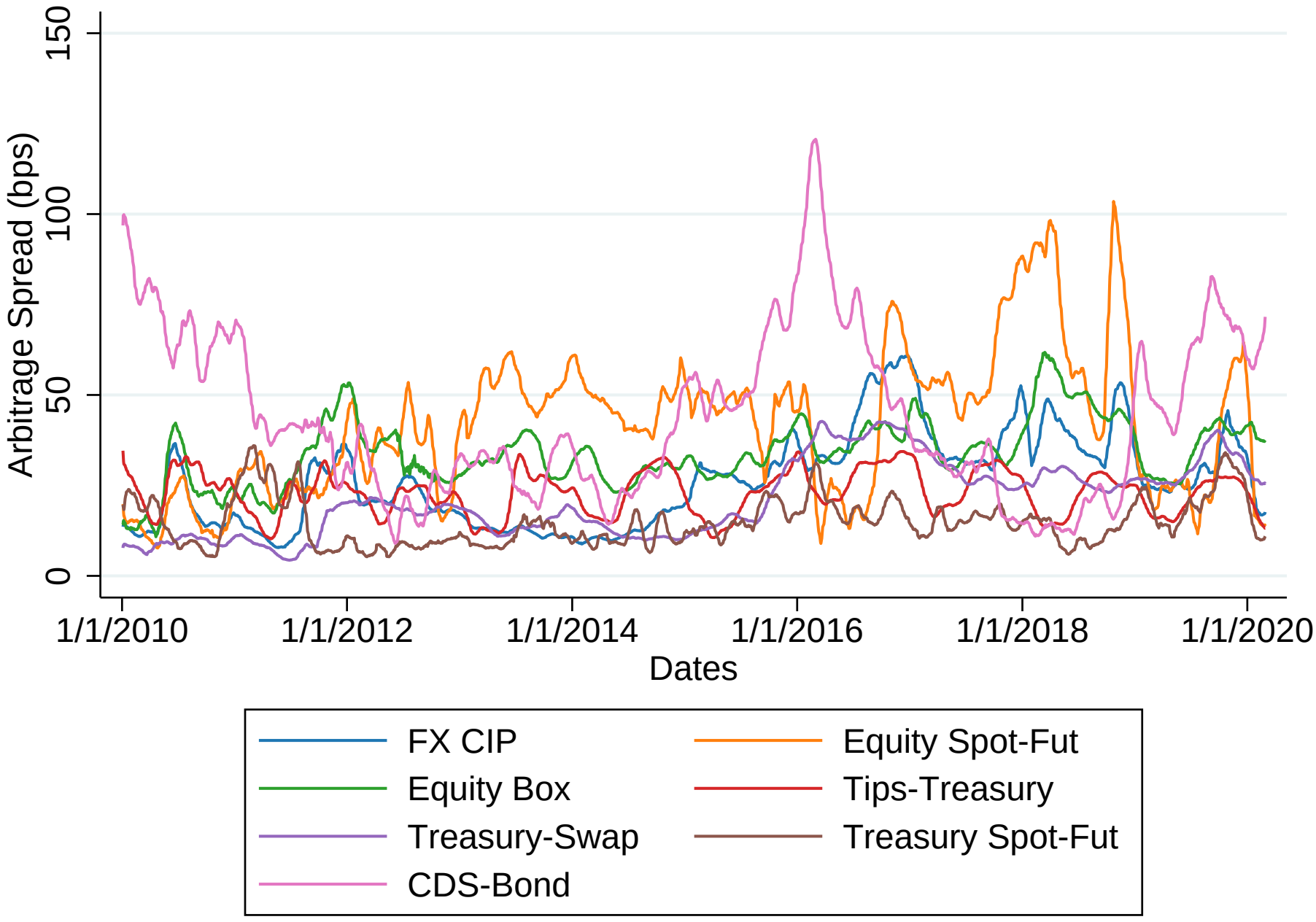
6. **Treasury-swap spread**: 1, 2, 3, 5, 10, 20, and 30 year

7. **Treasury spot-futures**: first-deferred futures on the 2, 5, 10, 20, and 30 year

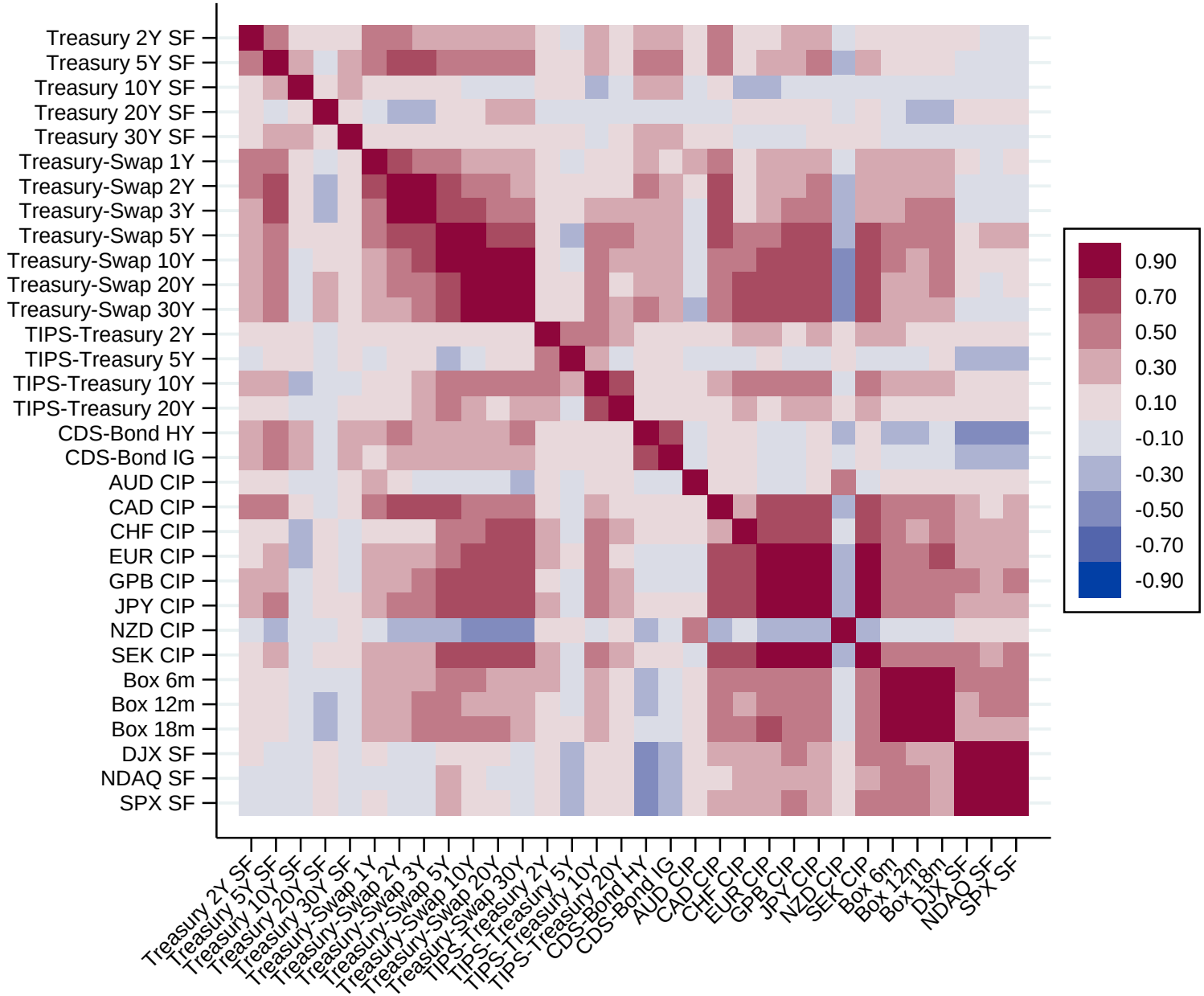
For each, we compute implied riskless rates (r) and arbitrage spreads (s)

First Key Result: Low correlations

Evidence from Time Series



Key Result: $\overline{\rho} = 0.22$



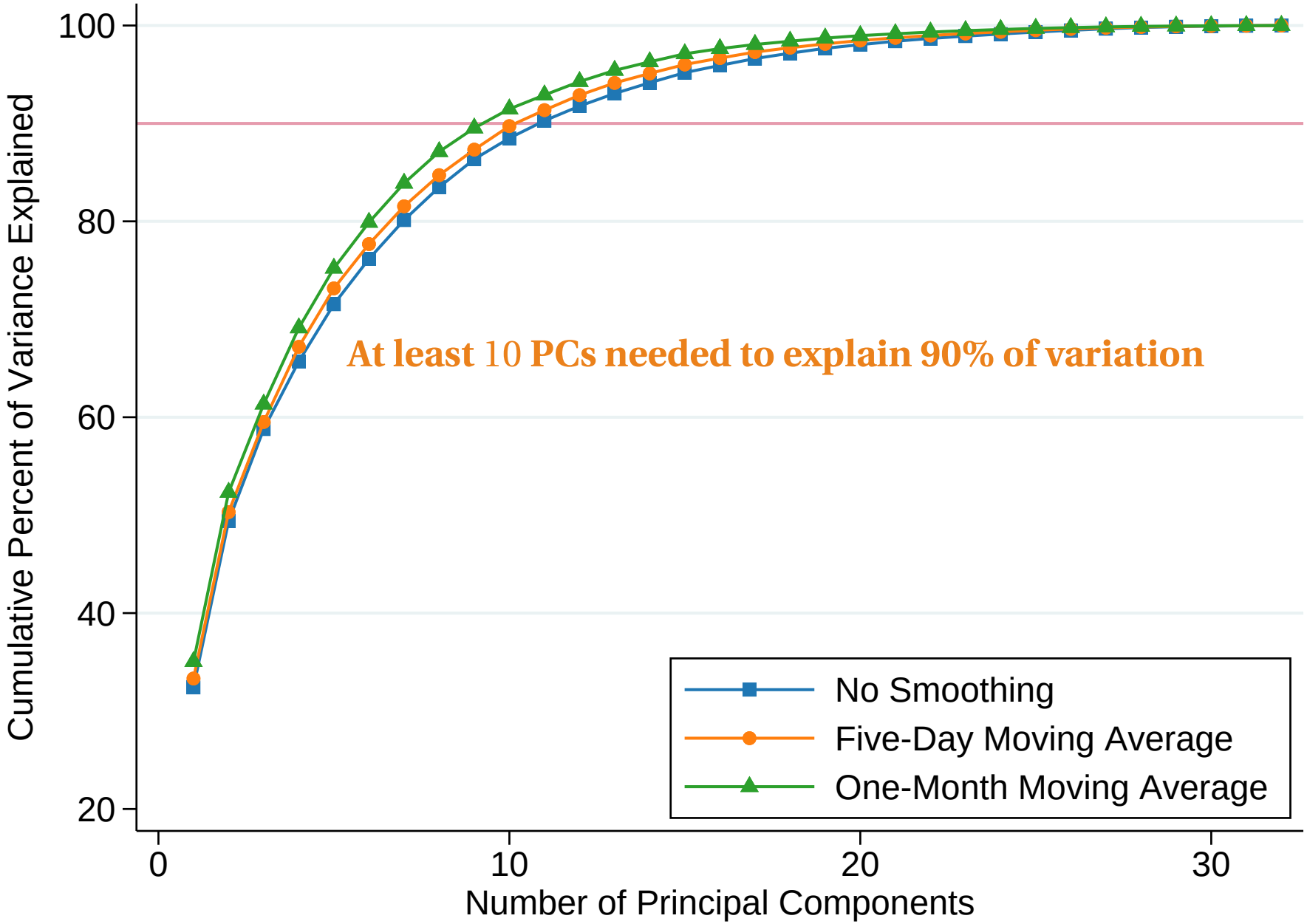
Interpreting Low Measured Correlations

In principle, low correlations may be driven by:

1. **Convergence/noise-trader risk**
   - Unlikely, since $\overline{\rho}$ is low in trades with short tenors

2. **Measurement error** (e.g., execution-related)
   - Results are robust to smoothing
   - Variance of measurement error would need to be large
   - Correlations are low after cleaning out measurement error using IVs

Results Robust to Smoothing



Funding Segmentation

What drives the high-dimensional factor structure?

- Low correlations imply at least one of the following conditions holds:
  1. Funding for arbitrage is segmented
  2. Balance sheets are segmented
  3. Integrated intermediary faces a high-dimensional constraint set

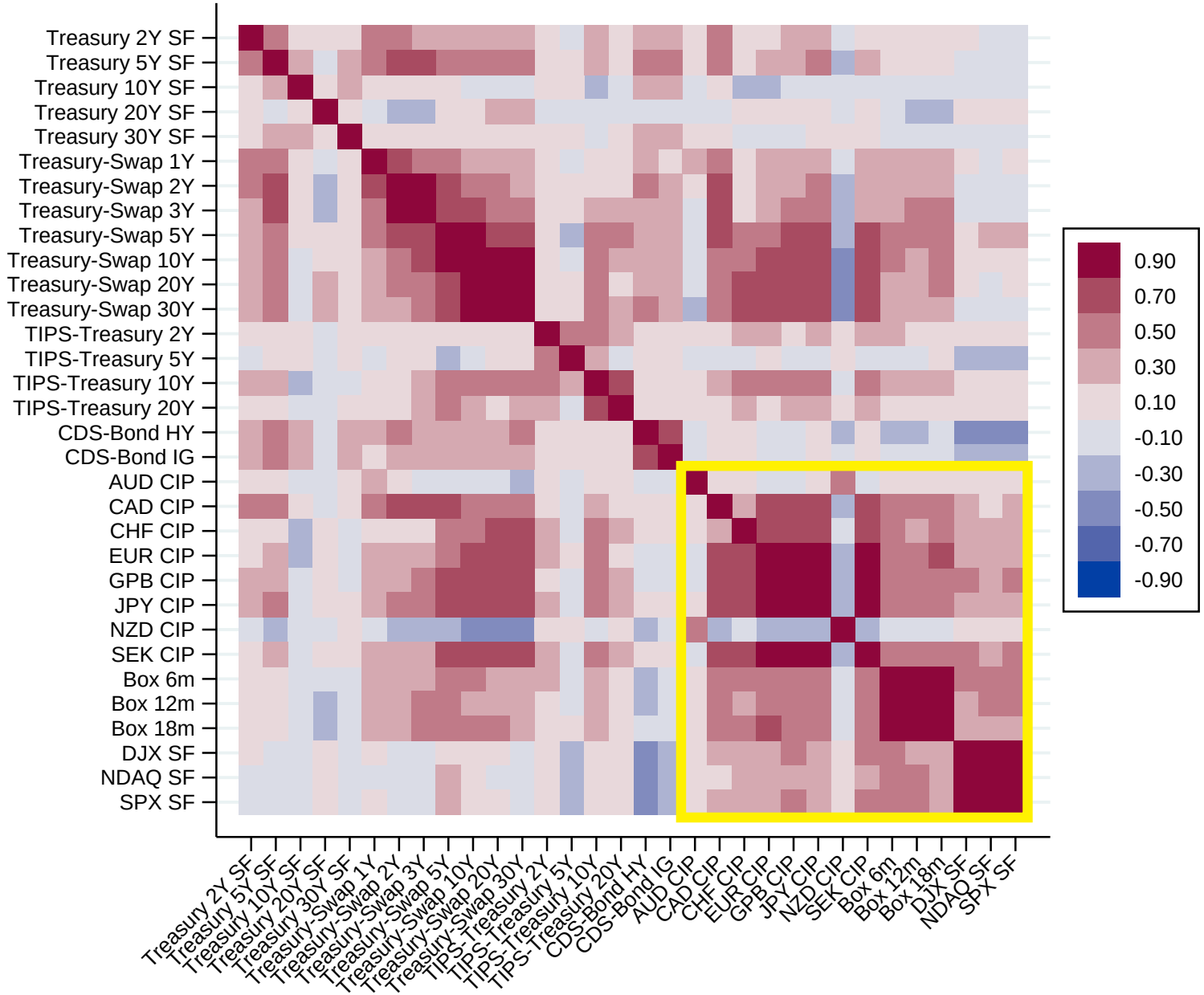
- We now show evidence ruling in both funding and balance segmentation

Funding Segmentation: Margin Requirements

		Margin Requirement (%)		
Arbitrage	Collateral	p10	Median	p90
Treasury S-F	Treasuries	2	2	2
Treasury-Swap	Treasuries	2	2	2
TIPS-Treasury	Treasuries	2	2	2
IG CDS-Bond	IG Corporate Bond	3	5	8
HY CDS-Bond	HY Corporate Bond	3	8	15
Equity Box	Equities	5	8	15
Equity S-F	Equities	5	8	15
CIP	Foreign Currency	6	6-12	12

- CIP, equity spot-futures, and box require more **unsecured** funding
- Label as "unsecured" trades and label the rest "**secured**" trades

Correlation of Secured vs Unsecured Trades



Arbitrage-Implied Riskless Rates and Funding Conditions

- Unsecured trades should be sensitive to unsecured funding conditions
- Test using OLS regressions:

$$\Delta r_{i,j,t} = \alpha_{i,j} + \beta_1 \Delta y_{i,t} + \beta_2 \Delta TED_t + \varepsilon_{i,j,t}$$

	Dep Variable: Δ Implied RF	
	Unsecured	Secured
Δ Treasury	0.88**	0.93**
	(9.37)	(51.70)
Δ TED	0.49**	0.07
	(4.57)	(1.34)
R^2	0.23	0.66
N	1,694	2,136

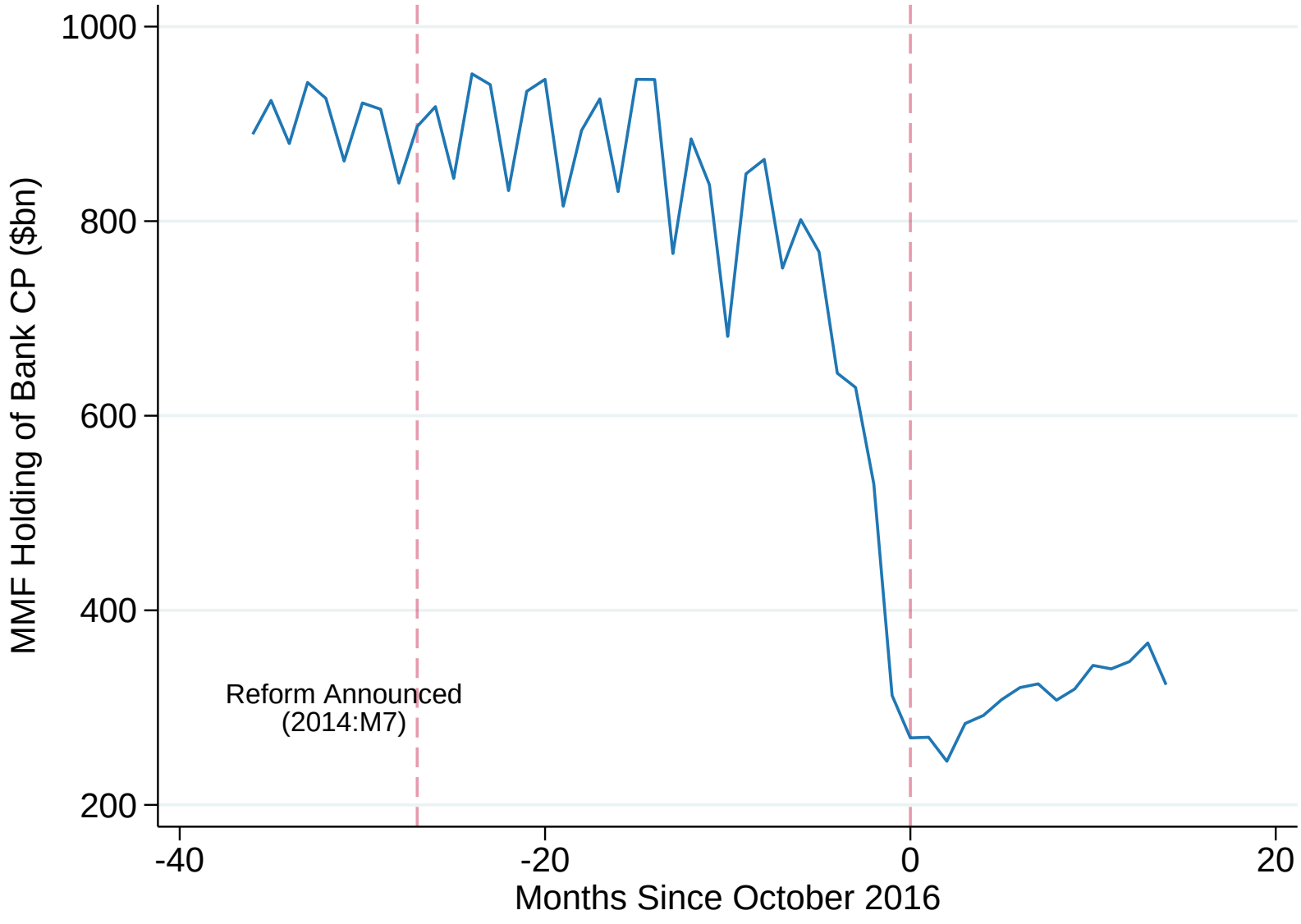
Isolating Funding Shocks

- Are funding conditions *causing* spreads to move?
- Or are spreads and TED rising because bank balance sheets are tightening?
- Isolate funding shocks using 2016 money market fund (MMF) reform

2016 MMF Reform

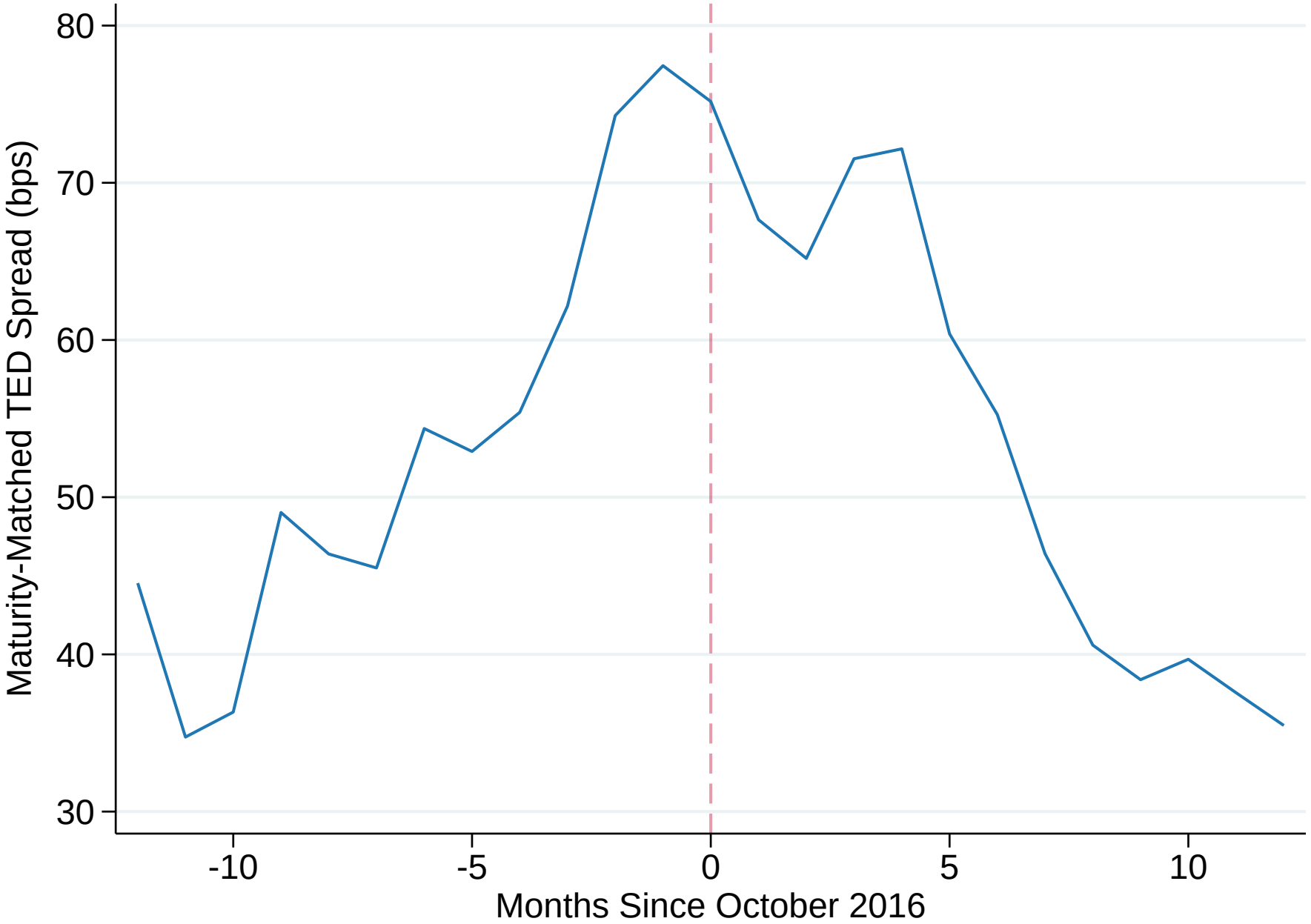
- Modified SEC Rule 2a-7 and required prime MMFs to use floating NAVs
- Government funds not affected by the reform
- To accommodate clients, many prime funds converted to gov't funds
- Prime funds were large unsecured lenders to banks, so reform plausibly represents a funding shock that is distinct from bank balance sheet shocks

MMF Holdings of Bank Commercial Paper

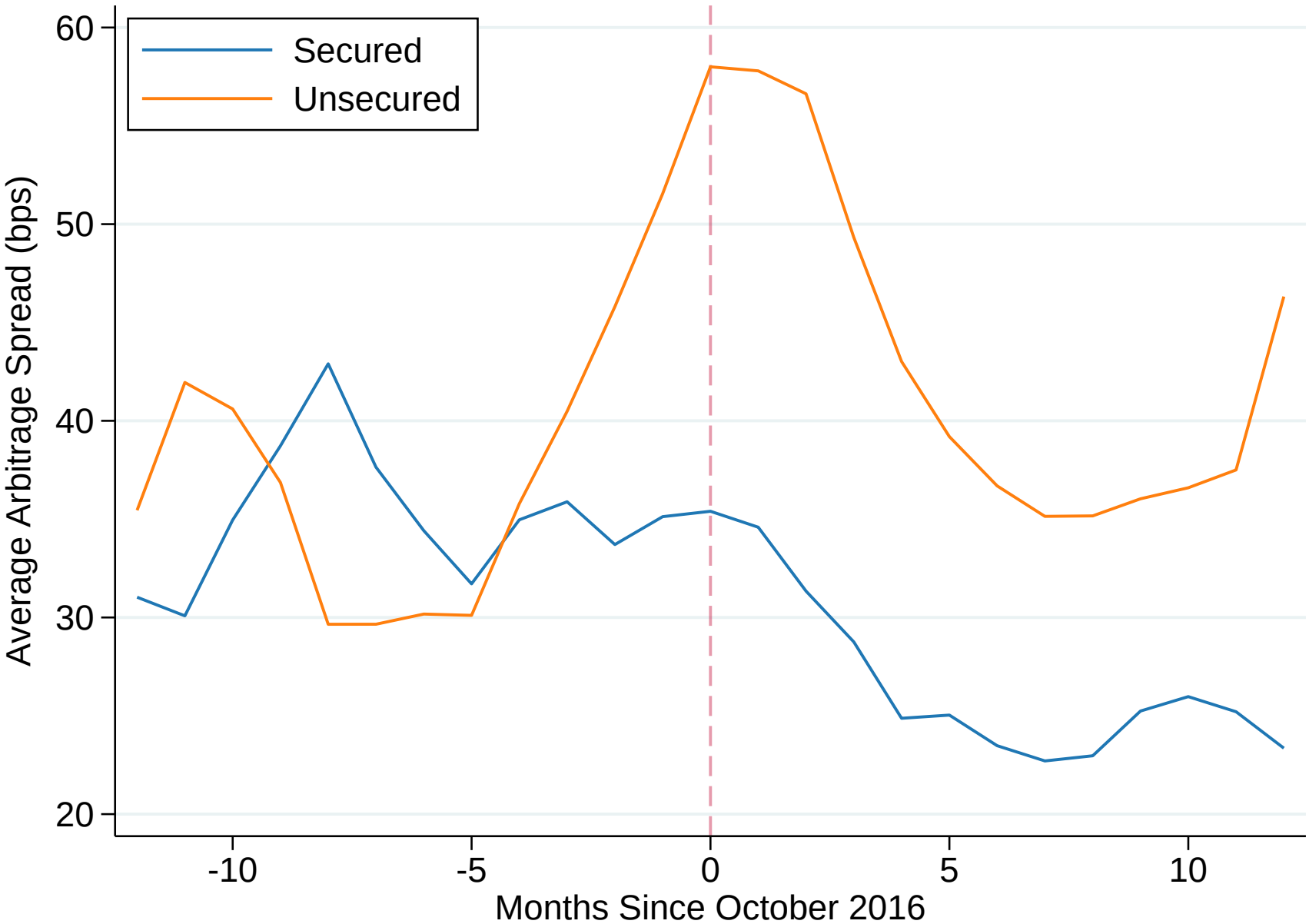


$550 billion drop in unsecured funding

TED Spread Rises



And Unsecured Spreads Rise



Why is Arbitrage Segmented?

- Low correlation between arbitrages is partly due to funding segmentation

- Some arbitrage trades are exposed to local funding supply shocks
  - Unsecured vs Secured trades
  - Equity Spot-Futures and Fidelity

- Next: low correlations are also driven by balance sheet segmentation
  - Intermediaries specialize in certain trades
  - When their firm-specific constraints tighten, spreads rise

Balance Sheet Segmentation

JP Morgan and Equity Spot-Futures Arbitrage

- Coalition Greenwich (S&P subsidiary) reports JPM has had largest share of equity derivatives market since 2015

- According to regulatory filings, JPM held the most equities in its trading books among U.S. bank holding companies
  - 37% over full sample and 56% in 2010

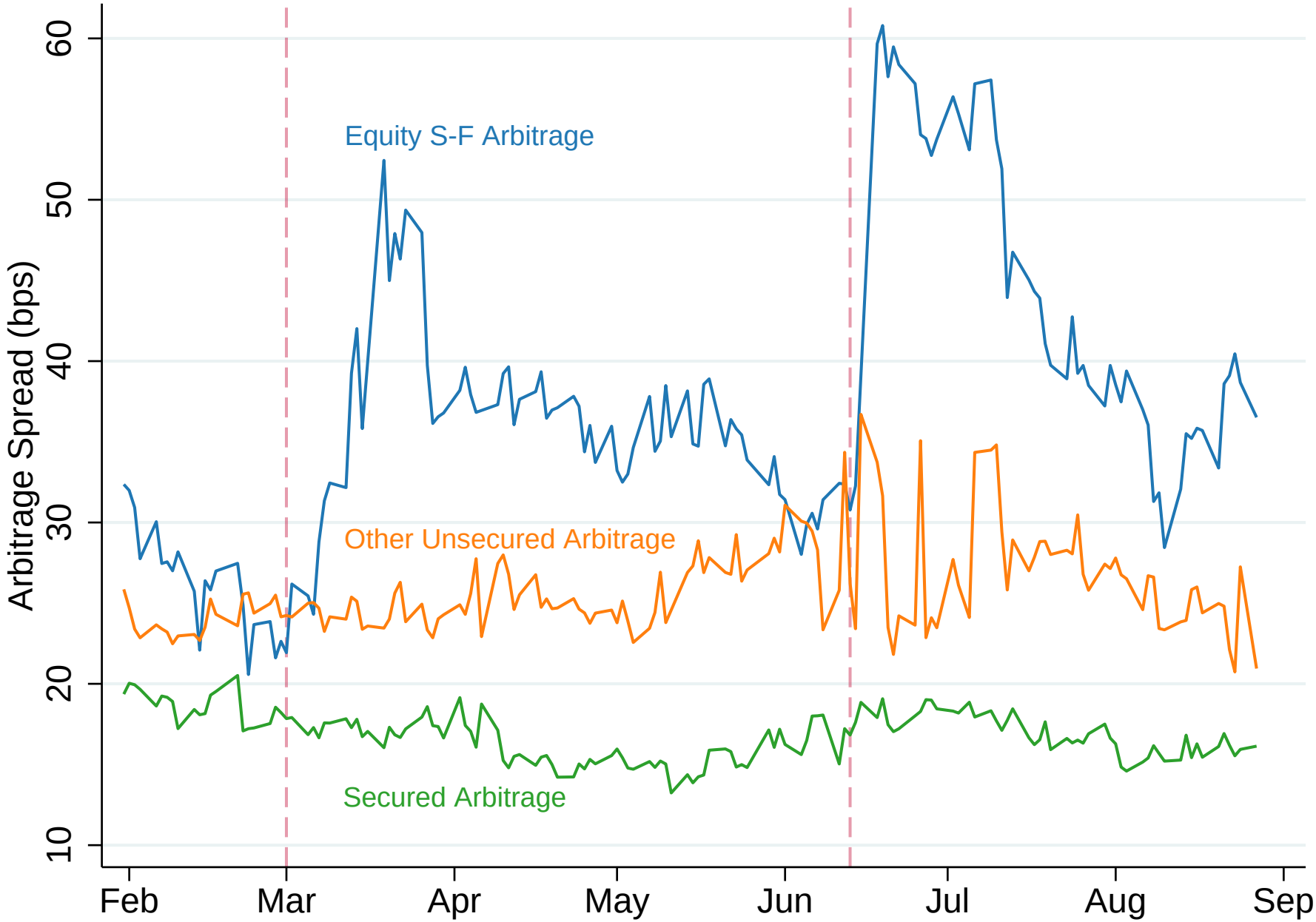
- Seems plausible that JPM is marginal in Equity S-F arbitrage

- Study how a balance sheet shock to JPM impact Equity S-F arbitrage

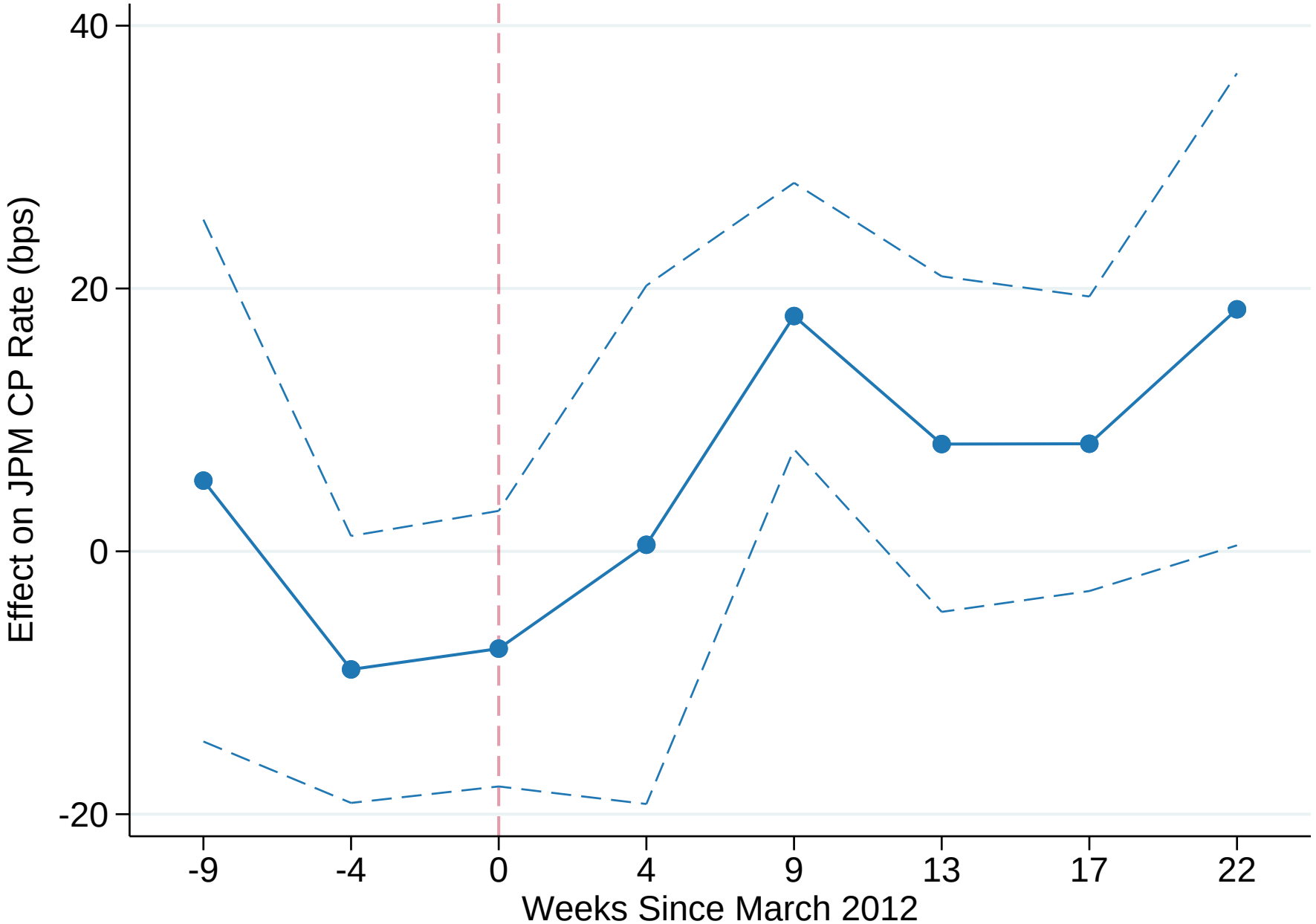
The London Whale: Background

- JPM's CIO tasked with hedging credit risk in the bank's lending portfolio
- The firm aimed to reduce hedges at onset of 2012
- Initially offset credit protection it had bought by selling credit protection
  - But rogue trader (the "whale") sold much more CDS than required
  - At peak, JPM was one of largest CDS sellers in the market
- Rising CDS spreads caused positions to lose over $6 billion
- Two key moments:
  - Mar. 2012: Risk limits are breached + losses of $550 million (75% of YTD losses)
  - June 13, 2012: CEO Jamie Dimon testified before Congress and announced that significant additional losses were to be expected

The London Whale: Large and Persistent Impact on Equity S-F



The London Whale: No Relative Impact on JPM's CP Rates



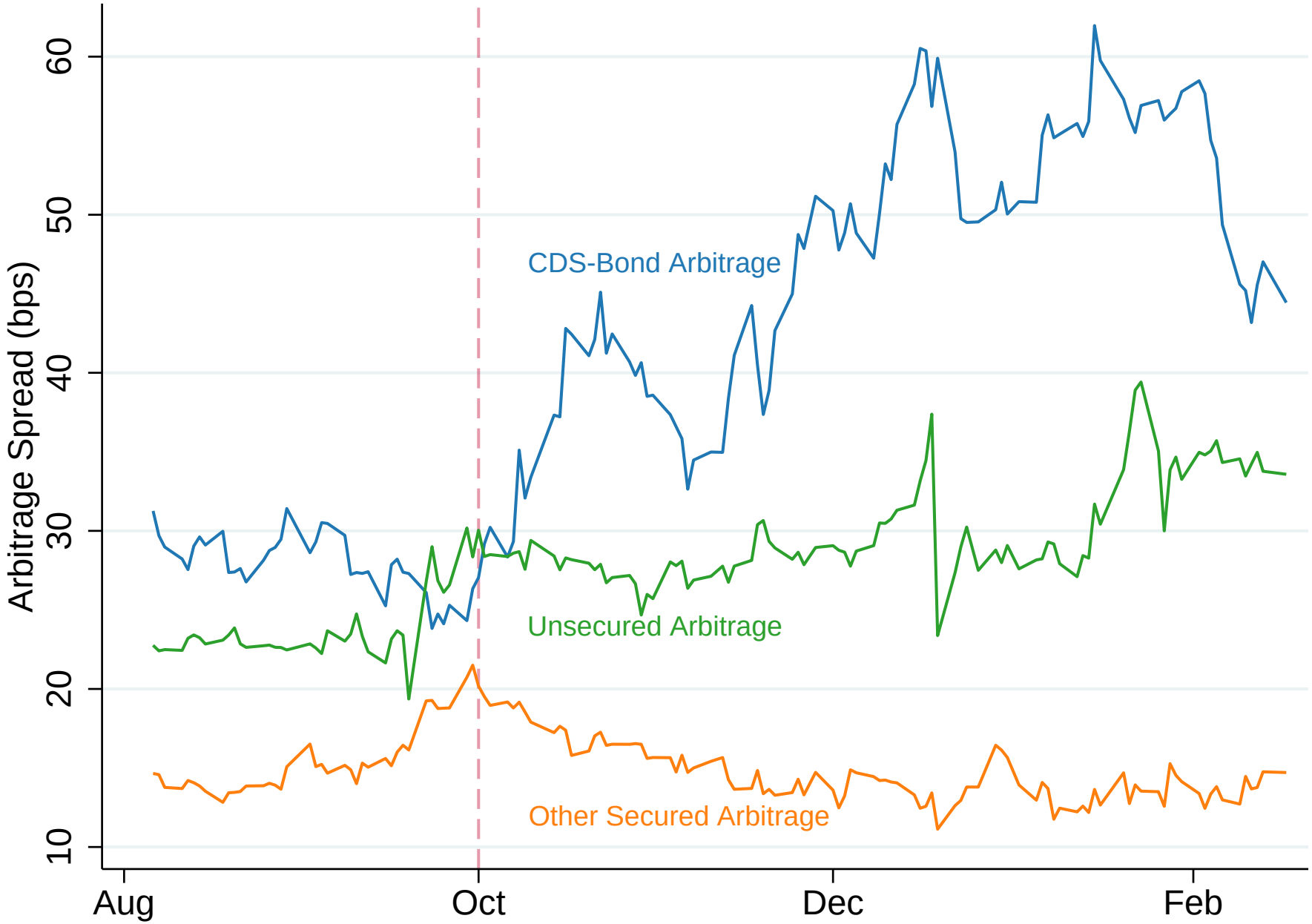
Another Example of Balance Sheet Segmentation

- In late 2014, Deutsche Bank (DB) exited the CDS market (Wang et al., 2021)

- DB had a large presence in the market
  - 2013 annual report: $2 trillion in CDS notional outstanding

- Exact timing of DB's exit is unknown, but known to be in fall of 2014
  - Sept. 2014: Sold large portion of CDS portfolio to Citi (Bloomberg)
  - Nov 17, 2014: Publicly announced exit from CDS market
  - Dec. 2014: $1.4 trillion in CDS outstanding (2014 annual report)

CDS-Bond Bases Rise with DB exit



Hedge Funds and Balance Sheet Segmentation

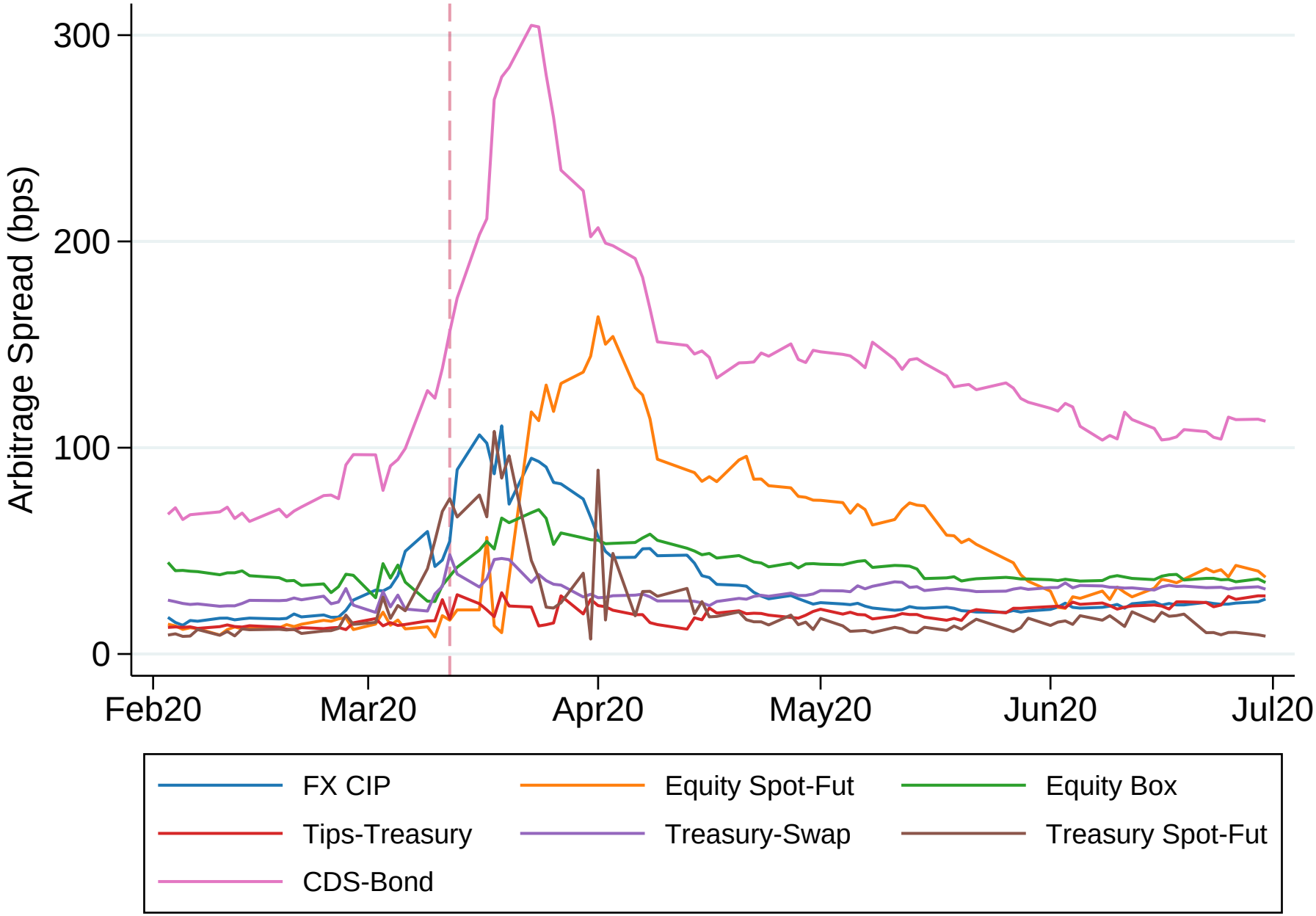
- HFs appear active in Treasury spot-futures arbitrage (Barth and Kahn, 2021)
- Check if low HF returns (tighter constraints) are followed by spread increases
- Measure HF returns using Barclay's Aggregate Fixed Income Arbitrage Index

$$\Delta s_{i,t} = \alpha + \beta f_{t-1} + \varepsilon_{i,t}$$

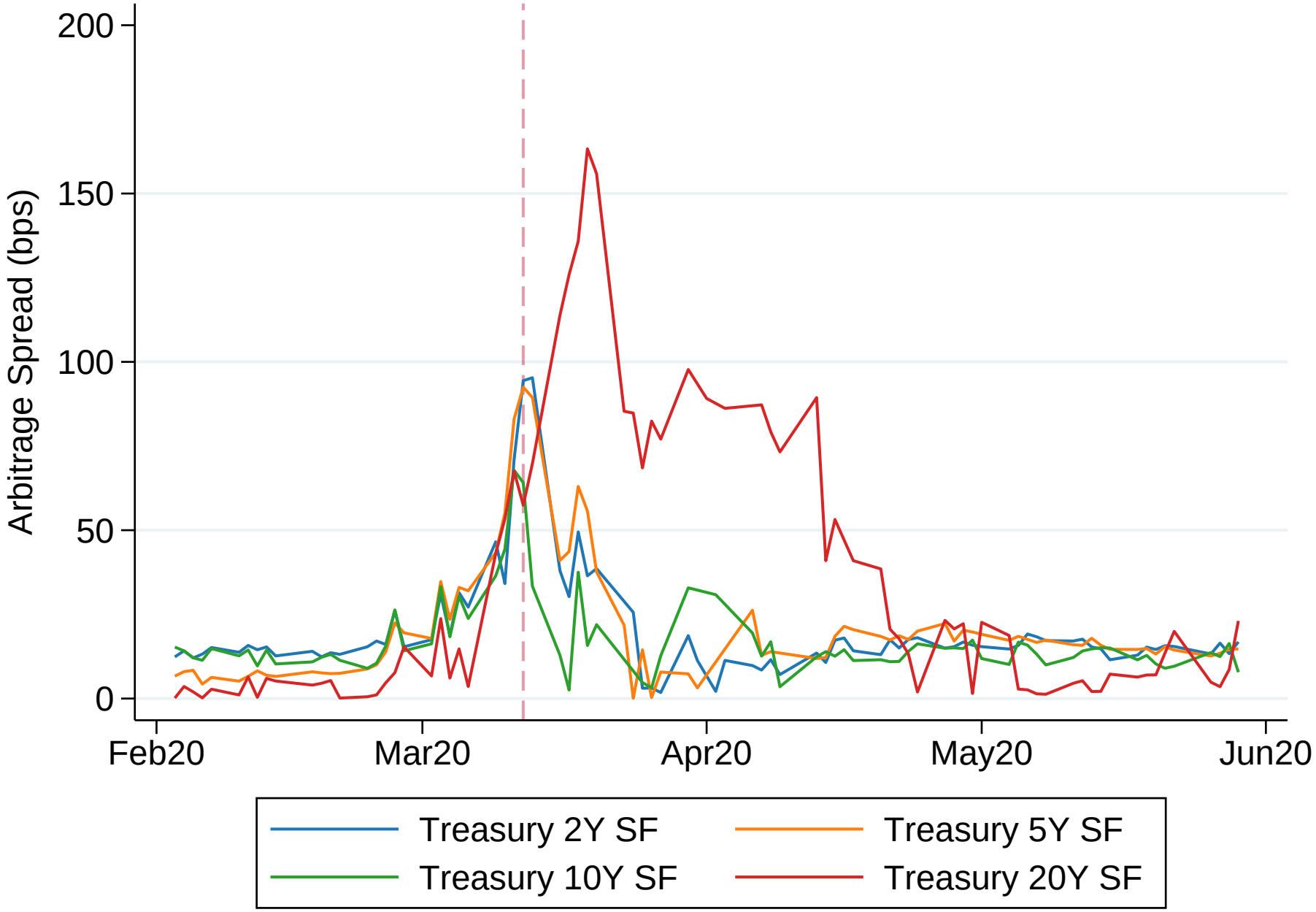
	Dep Variable: Δ Arbitrage Spread	
	Unsecured	Secured
FI Arb HF Return$_{t-1}$	0.01	-0.65**
	(0.03)	(-2.99)
R^2	0.00	0.01
N	1,694	2,136

Crisis Periods

Low Correlation of Arbitrage Spreads During Covid



Particularly Stark in Treasury-Futures Arbitrage



2008 Global Financial Crisis

Pre-crisis: Jan-2005 to June-2007

ρ_{ij}								p-value	
Mean	Sd	Min	p25	p50	p75	Max	N	$\overline{\rho} > 0.67$	$\rho_{ij} = \rho$
0.05	0.27	-0.68	-0.10	0.03	0.20	0.90	190	0.00	0.00

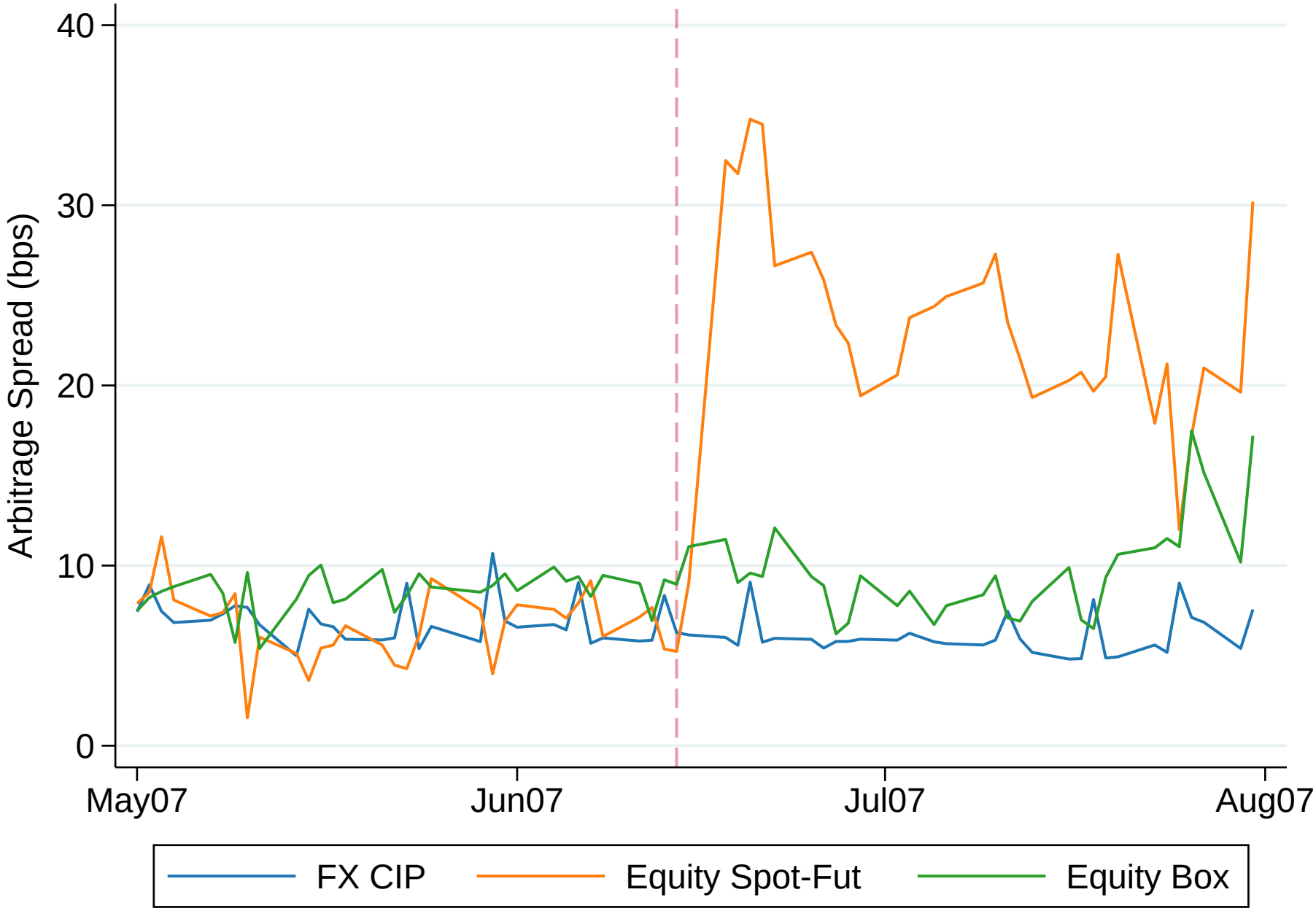
97% of pairs reject H_0: $\rho_{ij} > 0.67$

Crisis: July-2007 to June-2009

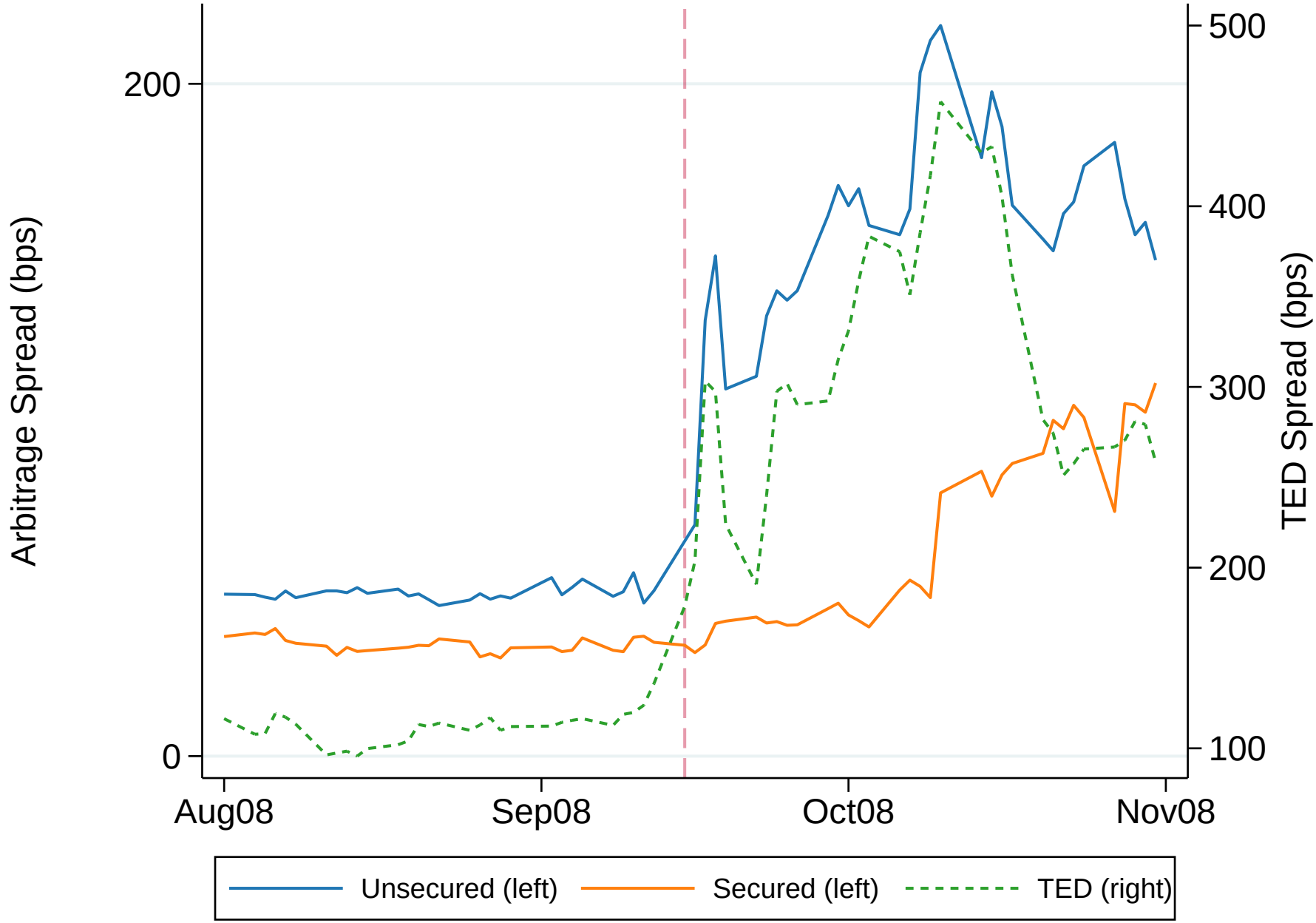
ρ_{ij}								p-value	
Mean	Sd	Min	p25	p50	p75	Max	N	$\overline{\rho} > 0.67$	$\rho_{ij} = \rho$
0.66	0.24	-0.04	0.55	0.72	0.83	0.99	190	0.21	0.00

28% of pairs reject H_0: $\rho_{ij} > 0.67$

Balance Sheet Segmentation in July 2007



Funding Costs and Unsecured Arbitrages After Lehman



Other Results in the Paper

More evidence on segmentation:

- Funding: Fidelity MMFs are dominant in equity repo (Hu et al., 2021) → their supply shocks uniquely impact equity S-F arbitrage
- Balance sheet: Different HF balance sheets matter for different secured trades

Supply vs Demand (new):

- Supply shocks (via SVAR) have low correlations, implying arbitrage segmentation
- Contribution of supply vs demand to covariance of spread levels (supply matters!)

Persistent/permanent segmentation (new):

- For many trades, segmentation exists over long horizons

Implications and Questions

Main Point: Arbitrage appears to be quite segmented

Implications:

- All spreads are not equally informative about health of financial system
- Fire sales need not have economy-wide effects
- Liquidity and capital injections must be carefully tailored

Questions:

- Which spreads reflect the health of the "core"?
- Can we use spreads to understand specific market dislocations?
- How much does each type of segmentation contribute to factor structure?
- Boundaries of the firm: what determines areas of specialization?

Thanks!

Interpreting Low Correlations

Distribution of Pairwise Correlations

ρ_{ij}								p-value	
Mean	Sd	Min	p25	p50	p75	Max	N	$\overline{\rho} > 0.67$	$\rho_{ij} = \rho$
0.22	0.30	-0.54	0.00	0.17	0.42	0.96	496	0.00	0.00

91% of pairs reject H_0: $\rho_{ij} > 0.67$

- Pairwise correlations are low on average ($\overline{\rho} = 0.22$)
- 75% of pairs have a correlation of less than 0.42
- Ten factors needed to capture 90% of total daily variation

Are Low Correlations Driven by Convergence Risk?

- Focus on trades with short tenors (CIP, Equity S-F, and Treasury S-F)
- Correlations are still low: $\overline{\rho} = 0.19$

ρ_{ij}								p-value	
Mean	Sd	Min	p25	p50	p75	Max	N	$\overline{\rho} > 0.67$	$\rho_{ij} = \rho$
0.19	0.32	-0.40	-0.02	0.15	0.35	0.89	120	0.00	0.00

87% of pairs reject H_0: $\rho_{ij} > 0.67$

Are Low Correlations Driven by Measurement Error?

- Any measurement error or noise will bias correlations down

- We address this possibility in three ways:
  1. Smoothing the data
  2. Measuring how large noise would need to be to generate $\overline{\rho} = 0.22$
  3. Directly estimating size of noise and adjusting correlations accordingly

- Main conclusion: measurement error isn't driving low correlations

Measured vs. True Correlations

- Suppose true spreads $s^*_{i,t}$ are observed with error:

$$s_{it} = s^*_{it} + \varepsilon_{it}$$

- Let n_i be the noise-to-signal variance ratio:

$$n_i = \frac{Var[\varepsilon_{it}]}{Var[s^*_{it}]}$$

- The measured correlation ρ_{ij} and true correlation ρ^*_{ij} are linked as follows:

$$\rho_{ij} = \frac{\rho^*_{ij}}{a_i a_j}$$

where correlation "adjustment factors" $a_i = \sqrt{1 + n_i} \geq 1$

How large would measurement error need to be?

- When $n_i = n$, then the wedge between ρ_{ij} and ρ^*_{ij} simplifies to:

$$\rho_{ij} = \frac{\rho^*_{ij}}{1+n}$$

- To observe $\overline{\rho} = 0.22$ when $\rho^*_{ij} = 1$, error variance would need to be **4x** the variance of the true spread ($n \approx 4$)

- Alternative framing: for $n < 0.5$ and $\rho^*_{ij} = 1$, we should observe $\rho_{ij} > 0.67$
  - Yet 91% of pairs reject the null that $\rho_{ij} > 0.67$

- **Main point:** Lots of noise needed to generate such low observed correlation

Directly measuring correlation adjustment factors

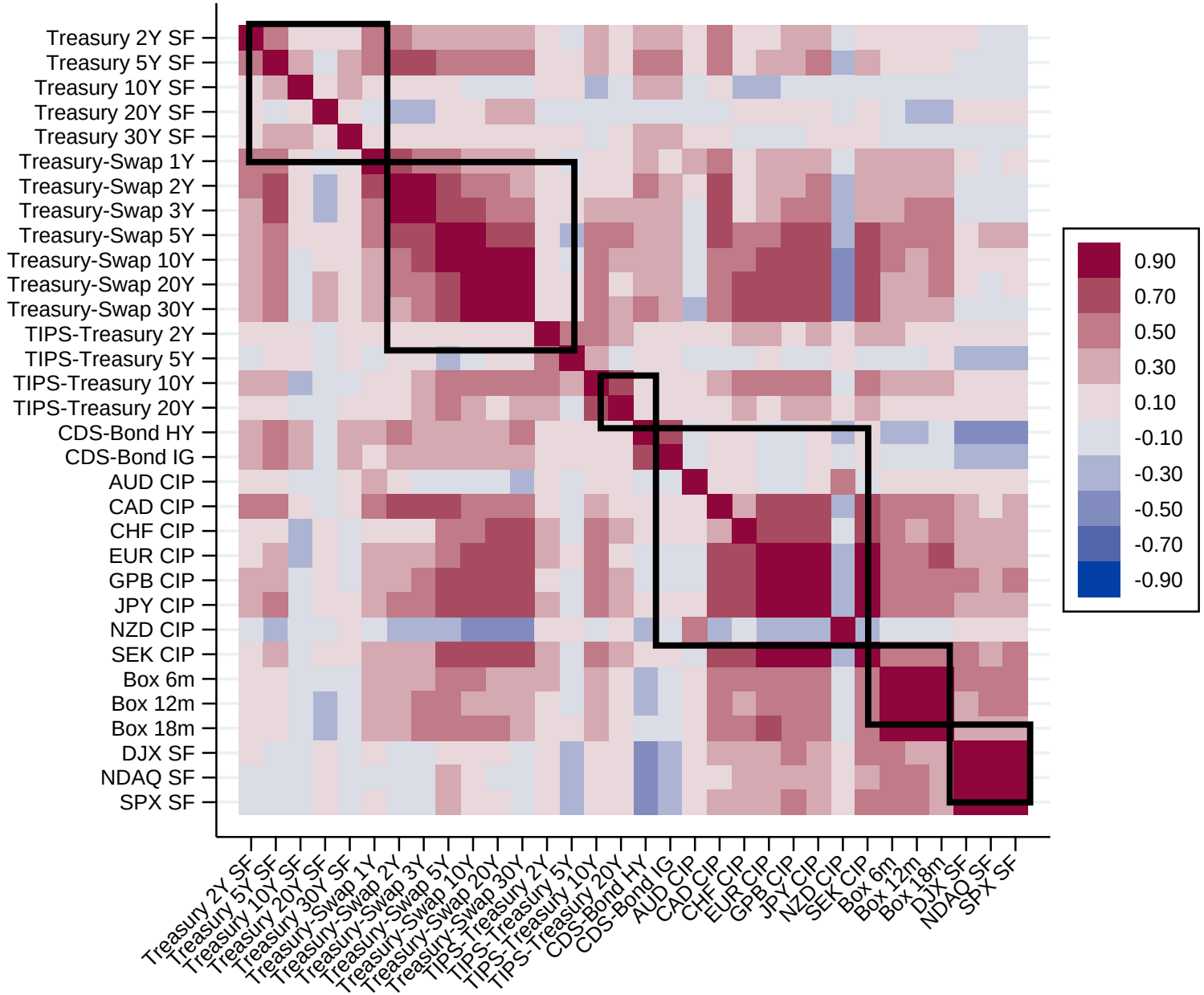
- Under certain conditions, correlation adjustment factors a_i can be inferred from instrumental variable regressions

- Our instrument logic: any execution-induced error today should be uncorrelated with errors from the previous quarter

- Concretely, consider the Treasury spot-futures arbitrage today (9/19/2022):
  - Spread computed from first-deferred contract (expires Dec 2022)
  - Instrument based on spreads on Sept 2022 contract observed last quarter

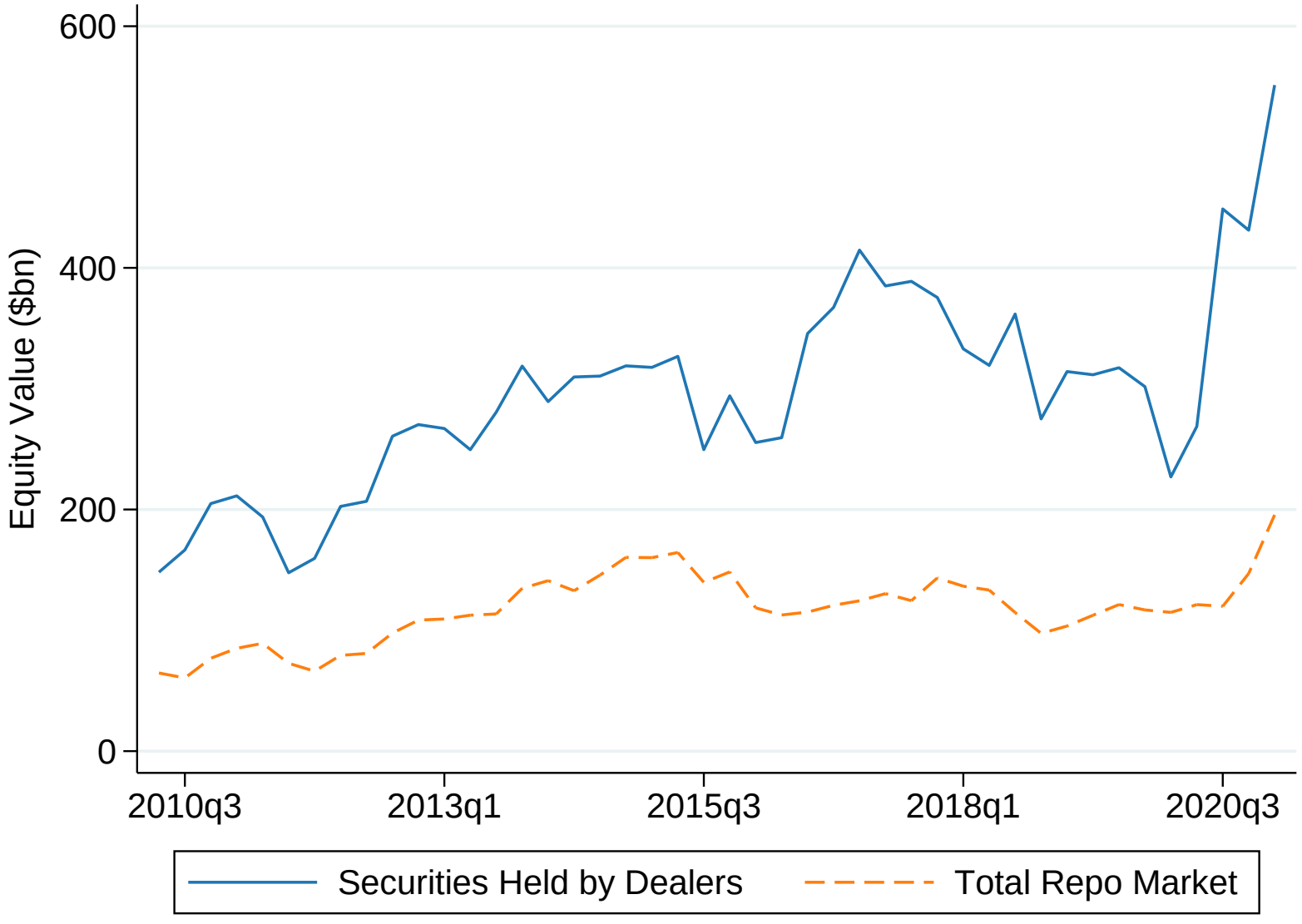
- **Main finding:** Average adjusted correlation is still low ($\overline{\rho} = 0.19$)

Correlations are High within Strategies



Additional Results on Funding Segmentation

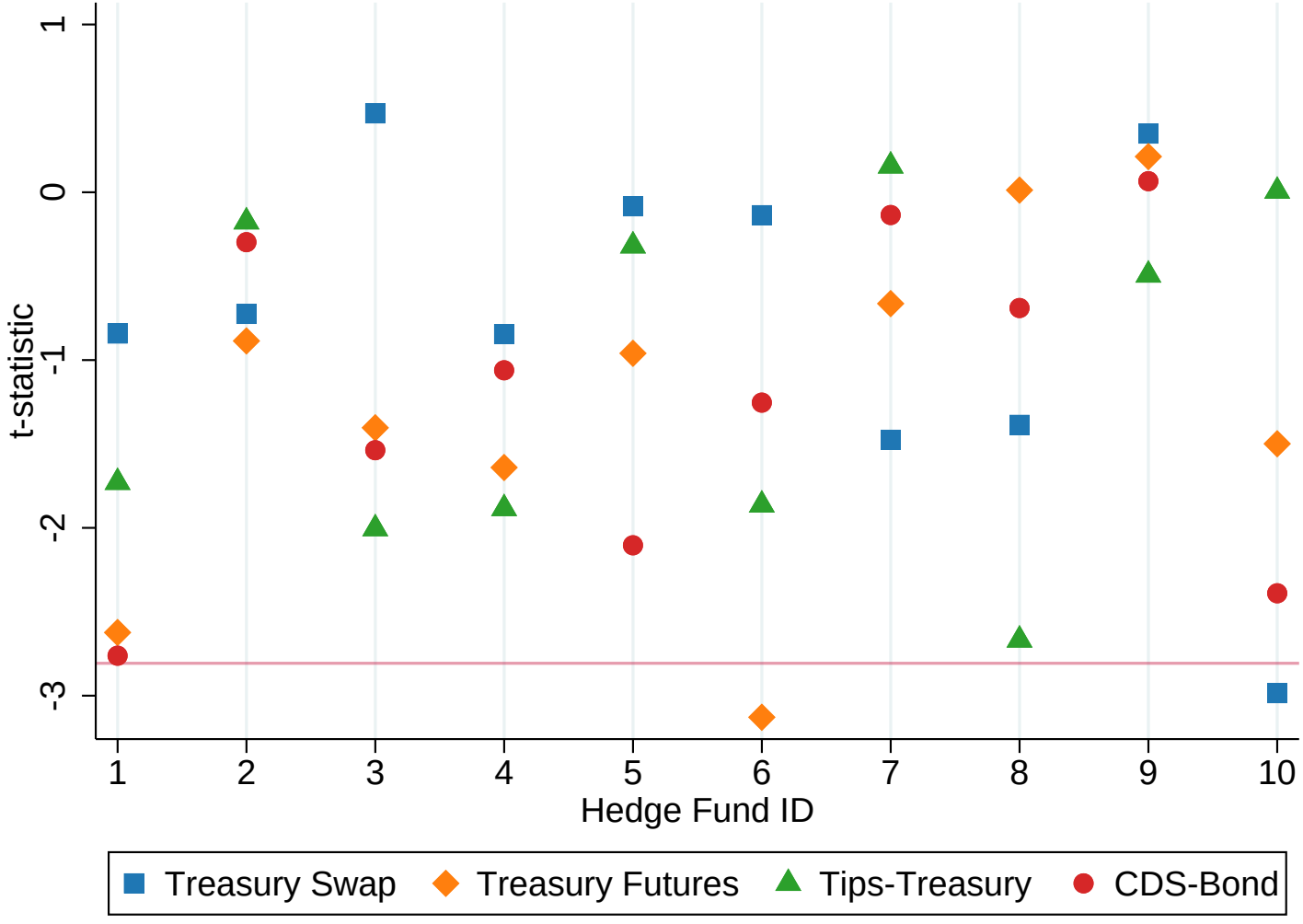
Equities: Dealer Holdings vs Repo Financing



Additional Results on Balance Sheet Segmentation

Evidence from 10 largest Fixed-Income Arbitrage HFs

Run predictive regressions for each of the 10 largest FI-arbitrage HFs (Preqin data)



Suggests different hedge funds matter for different secured trades

Appendix: Trade Details

1. **Foreign exchange (FX):** $(1 + OIS_t^{foreign})F_t^{FX} = (1 + OIS_t^{US} + z_t)S_t$
   - S_t is the spot rate, and F_t^{FX} is the forward rate in USD/foreign
2. **Equity spot-futures**: $F_t^{equity} = P_t^{equity}(1 - \delta_t + OIS_t^{US} + z_t)$
   - P_t^{equity} is the spot price, F_t^{equity} is the futures price, and δ_t is the expected dividend yield (from Bloomberg)
3. **Equity options**: $Put_t - Call_t = -P_t^{equity}(1 - \delta_t) + (1 + OIS_t^{US} + z_t)K$
   - K is the strike; estimate with regression across strikes
4. **CDS-bond**: $z_t = AssetSwap_{i,t} - \text{CDS}_{i,t}$
   - $AssetSwap_{i,t}$ is from Bloomberg
5. **TIPS-Treasury:** $z_t = y_{TIPS,t} + \pi_t - y_t$
   - $y_{TIPS,t}$ is the TIPS yield, y_t is the nominal yield, and π_t is the fixed rate on an inflation swap
6. **Treasury-swap spread**: $z_t = y_t - y_{\text{sw},t}$
   - $y_{sw,t}$ is the fixed rate on an OIS swap
7. **Treasury spot-futures**: $F_t^{Treasury} = P_t^{Treasury}(1 - c_t + OIS_t^{US} + z_t)$
   - c_t is the coupon; use first-deferred futures contract

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