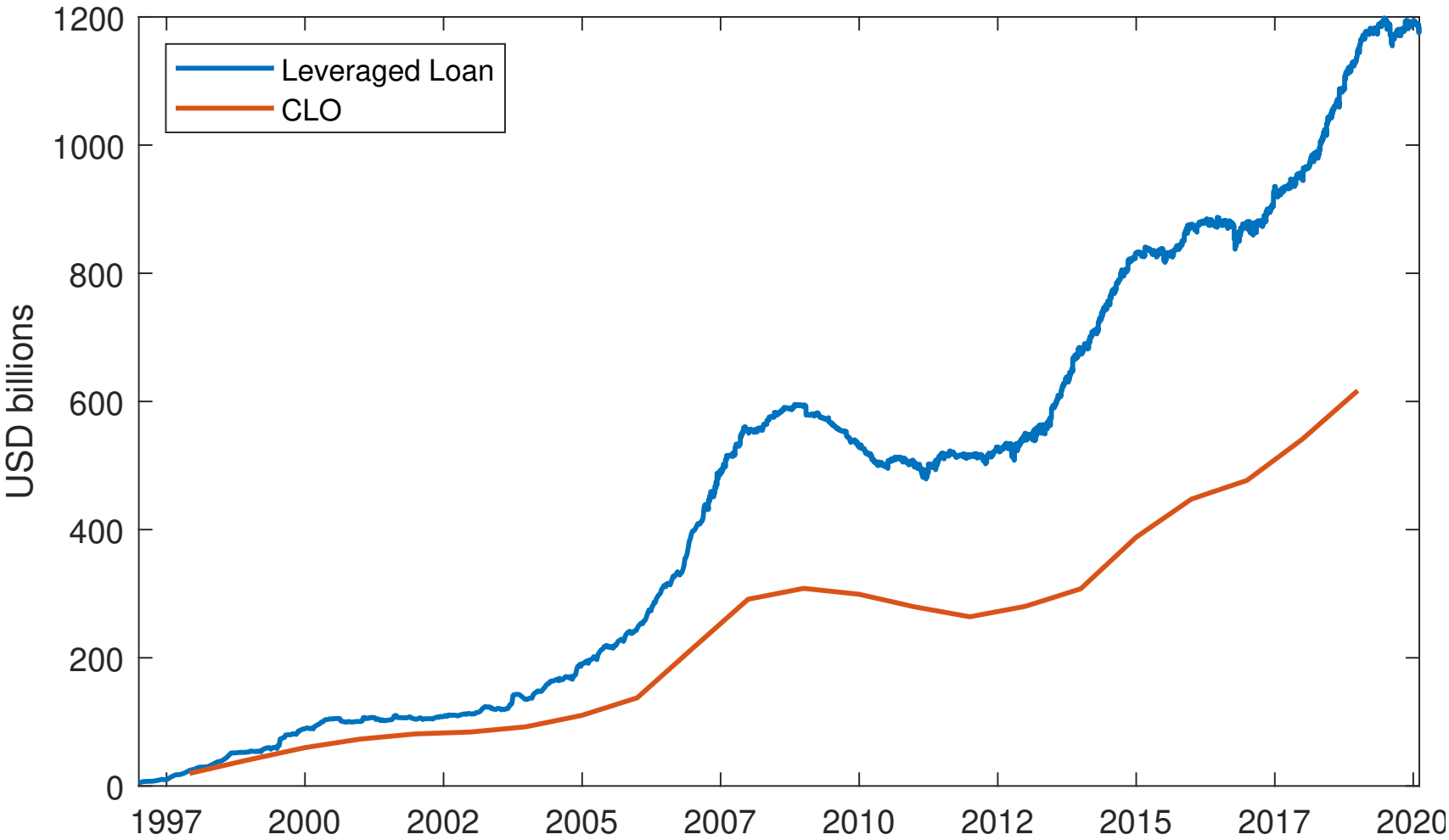
# Too Big to Diversify: A Stress Test on Collateralized Loan Obligations

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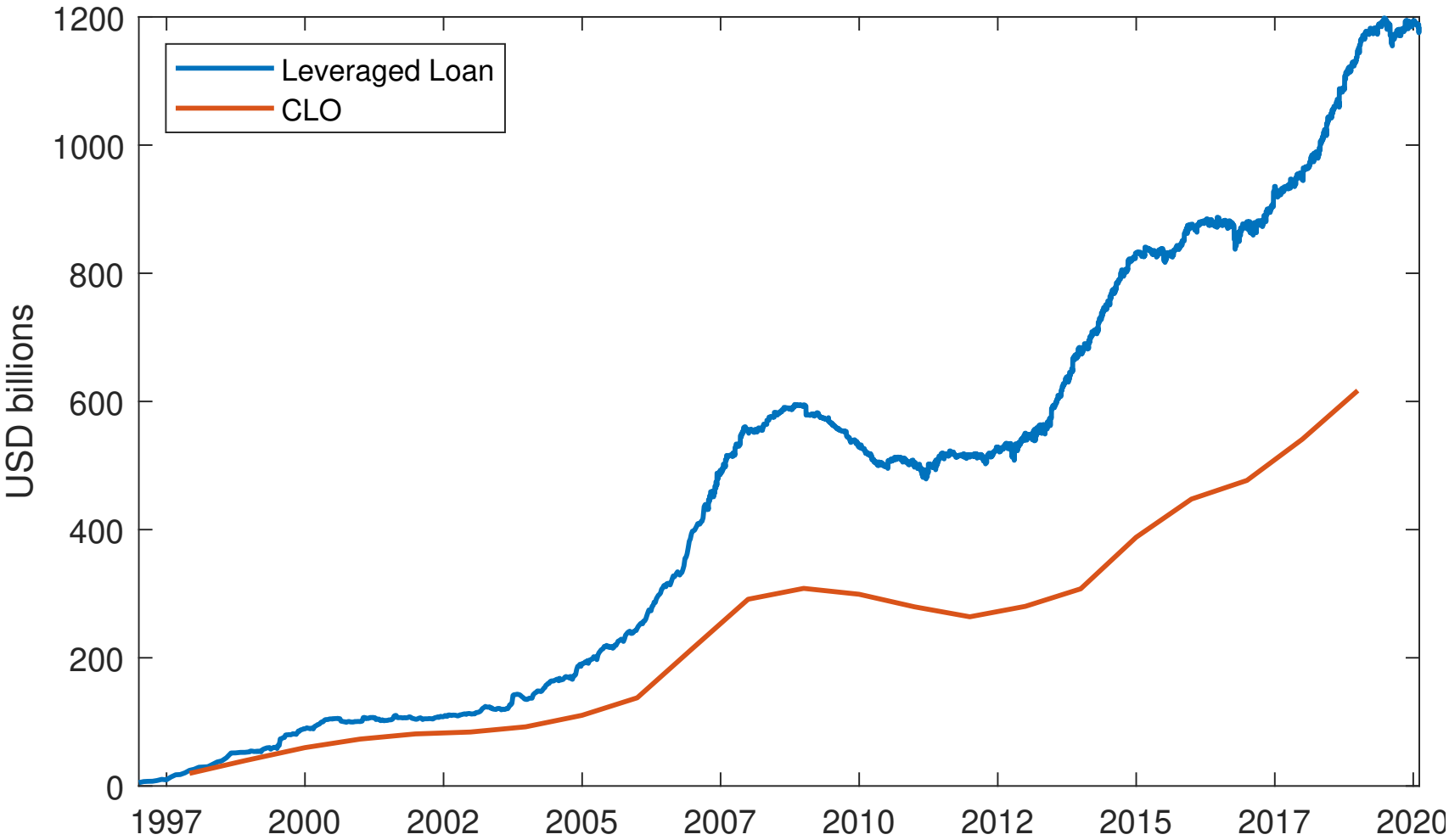
# Growth of Collateralized Loan Obligations and Leveraged Loan Market




Source: Refinitive Leveraged Loan Monthly (Leveraged Loan) and SIFMA (CLO)

# Growth of Collateralized Loan Obligations and Leveraged Loan Market

Shocks to some leveraged loan borrowers $\Rightarrow$ CLOs $\Rightarrow$ Other borrowers.




Source: Refinitive Leveraged Loan Monthly (Leveraged Loan) and SIFMA (CLO)

# What We Do

1. Stress tests on CLOs:
   - What happens if large borrowers default for idiosyncratic reasons?
   - Use CLO's loan holdings data to examine how this hypothetical shock spreads across CLOs.
   - Study the effect of the shocks on CLO's leverage.

2. Fire sale by constrained CLOs
   - To relax leverage constraints, CLOs sell loans downgraded to CCC.
   - Collective action to sell inflicts price impact on CCC-rated loans.

$\Rightarrow$ Systemic risk on the leverage loan market

# Data

CLO-i data from Acuris company:

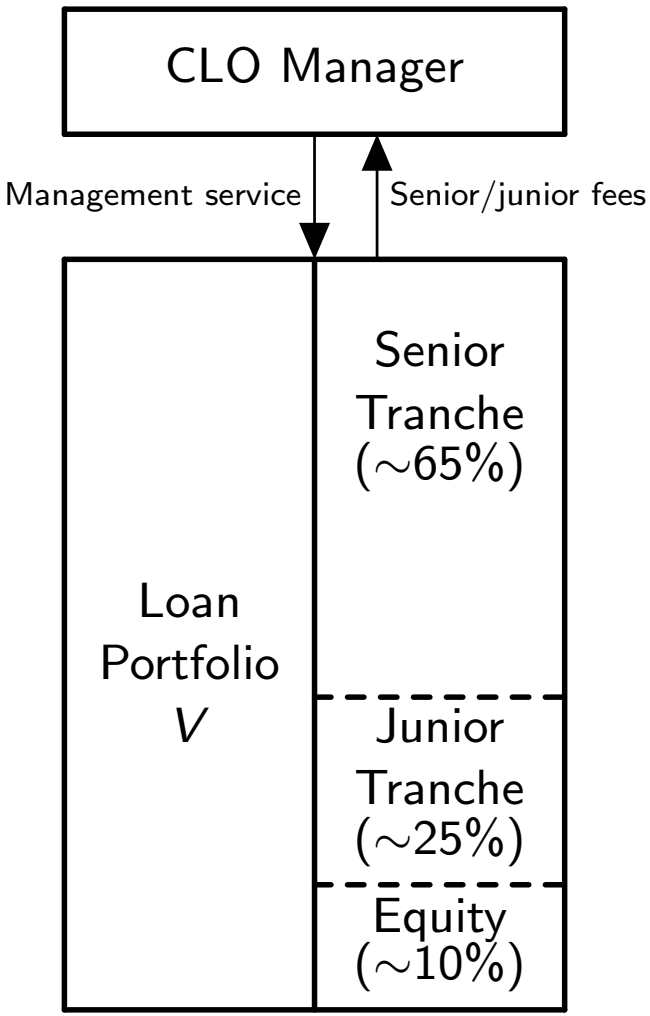
- Gather information in monthly trustee reports from January 2007 to March 2020.
- Loan-level holdings data including borrower's credit rating.
- CLO's transaction data including price and volume.
- Constraints imposed on CLOs (OC test results).
- Data coverage (in terms of asset under management) is about 80% in 2018.

# Part I:

# Stress Tests on CLOs

# Structures and Constraints on CLOs

1. Diversification requirements [ASSET]
2. Leverage constraints [LIABILITY]




- Leverage of a CLO is measured by the Overcollateralization (OC) ratio.
- Senior OC ratio:

$$OC(S) = \frac{V}{D(S)}$$

e.g.

$$OC(S) = \frac{100}{65} \approx 154\%$$

- Junior OC ratio:

$$OC(J) = \frac{V}{D(S) + D(J)}$$

e.g.

$$OC(J) = \frac{100}{65 + 25} \approx 111\%$$

# Overcollatralization Ratio

Determinants of the OC ratio:

- Shocks to asset value $V$
- Initial leverage and repayment of CLO's debt

Shocks to CLO's asset

- CLOs evaluate their loan holdings at book value unless:
  - A loan is in default
  - Total holdings of CCC loans (rated CCC or below, but not in default) are more than 7.5% of assets
    $\Rightarrow$ The excess is evaluated at fair value.

OC ratio test: Test if the OC ratio remains above the pre-specified threshold.
$\Rightarrow$ If a CLO fails the OC ratio test, then it must take actions:

- If the CLO is in the reinvestment period, the CLO has to divert cash flows from equity / junior tranches to purchase more collaterals or pay down senior tranches.
- If the CLO is in the amortization period, the CLO has pay down senior tranches.

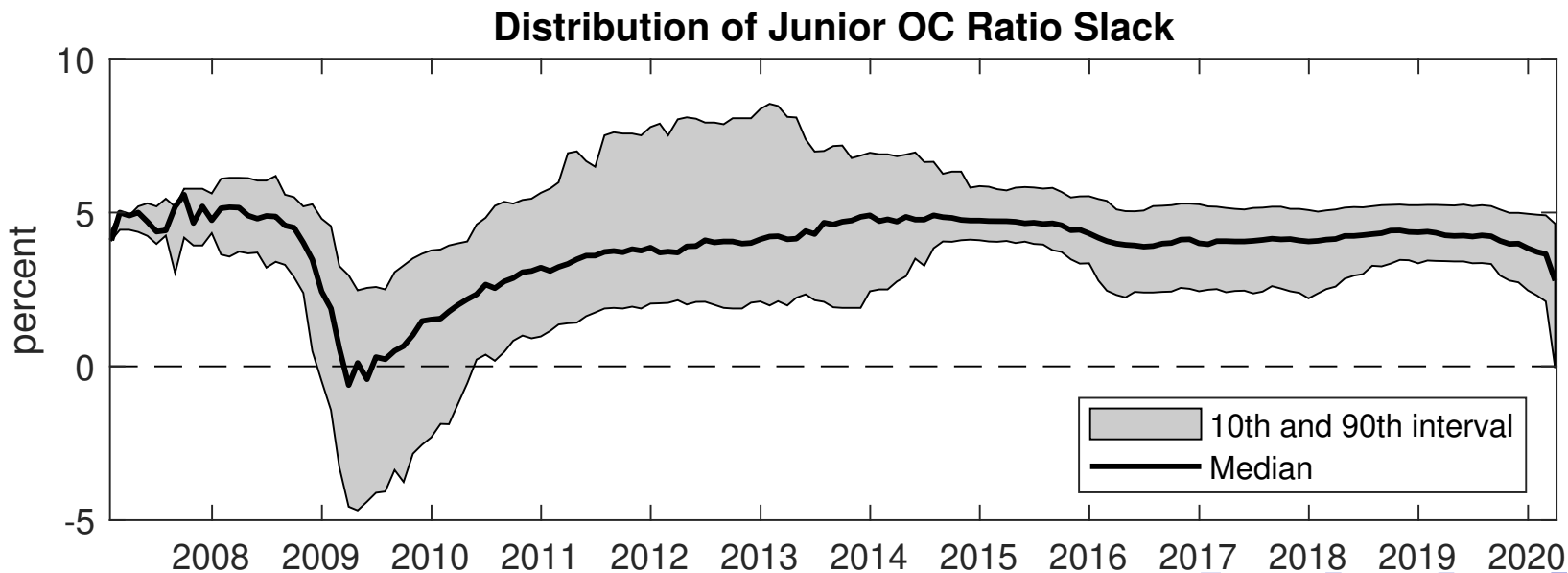
# Failing an OC Ratio Test

Failure in an OC ratio test leads to negative consequences on the CLO manager:

- No junior management fee
- Downgrading for CLO senior/junior tranches, lower returns on equity tranches
  $\Rightarrow$ Hurt reputation of the manager, making it more difficult to launch new CLOs in the future.

In practice, failing OC ratio tests has been rare since 2011.

Hypothesis: A CLO manager with a low OC ratio may take pre-emptive actions to prevent the OC ratio from falling.



# Stress Test on the Aggregate CLO Market

We consider three stress scenarios on the aggregate CLO market.

1. Top 10 borrowers (defined by the total borrowing from the CLOs as a whole) default
2. The 95% Value-at-Risk
3. The 99% Value-at-Risk

Assumptions:

- LGD=50% (the average recovery for senior secured loan (1st lien) during recessions (1992, 2002, 2008, and 2009) is 56.8%)
- Rise of covenant-lite loans

Additional assumptions for VaR:

- Asset returns for borrower $b$ follows a one-factor model:

$$R_b = \sqrt{\rho} W + \sqrt{1-\rho} Z_b$$

  where $W$ and $Z_b$ are normal random variables, and $\rho = 0.24$.
- Loss for CCC excess loans upon downgrading is 11.25% (the average market price).
- The borrower defaults if $R_b < \underline{R}$, where $\underline{R}$ is backed out from Moody's historical default probability.

# Summary Statistics for the Overall CLO Market

| Year | N(CLO) | N(B) | Total Holdings ($ bil.) | Avg. N(CLO) per brwrs | Avg. N(CLO) (Top 10) | Avg. N(B) per CLO |
|---|---|---|---|---|---|---|
| 2007 | 19 | 1,076 | 6.8 | 4.2 | 14.9 | 237.0 |
| 2008 | 143 | 2,123 | 54.6 | 13.3 | 106.6 | 196.8 |
| 2009 | 163 | 2,193 | 62.4 | 13.8 | 136.6 | 186.2 |
| 2010 | 219 | 2,340 | 84.5 | 17.1 | 183.0 | 182.8 |
| 2011 | 235 | 2,310 | 91.1 | 18.1 | 196.7 | 178.3 |
| 2012 | 221 | 2,222 | 85.7 | 16.9 | 173.0 | 169.6 |
| 2013 | 244 | 2,270 | 91.8 | 17.3 | 175.7 | 161.2 |
| 2014 | 354 | 2,303 | 133.1 | 24.8 | 228.4 | 161.2 |
| 2015 | 428 | 2,273 | 159.0 | 32.0 | 299.7 | 170.0 |
| 2016 | 421 | 2,100 | 154.0 | 38.4 | 289.7 | 191.4 |
| 2017 | 493 | 2,089 | 223.4 | 56.2 | 380.2 | 238.0 |
| 2018 | 535 | 1,695 | 259.6 | 83.0 | 441.4 | 262.9 |
| 2019 | 607 | 1,641 | 262.5 | 98.8 | 479.5 | 267.1 |

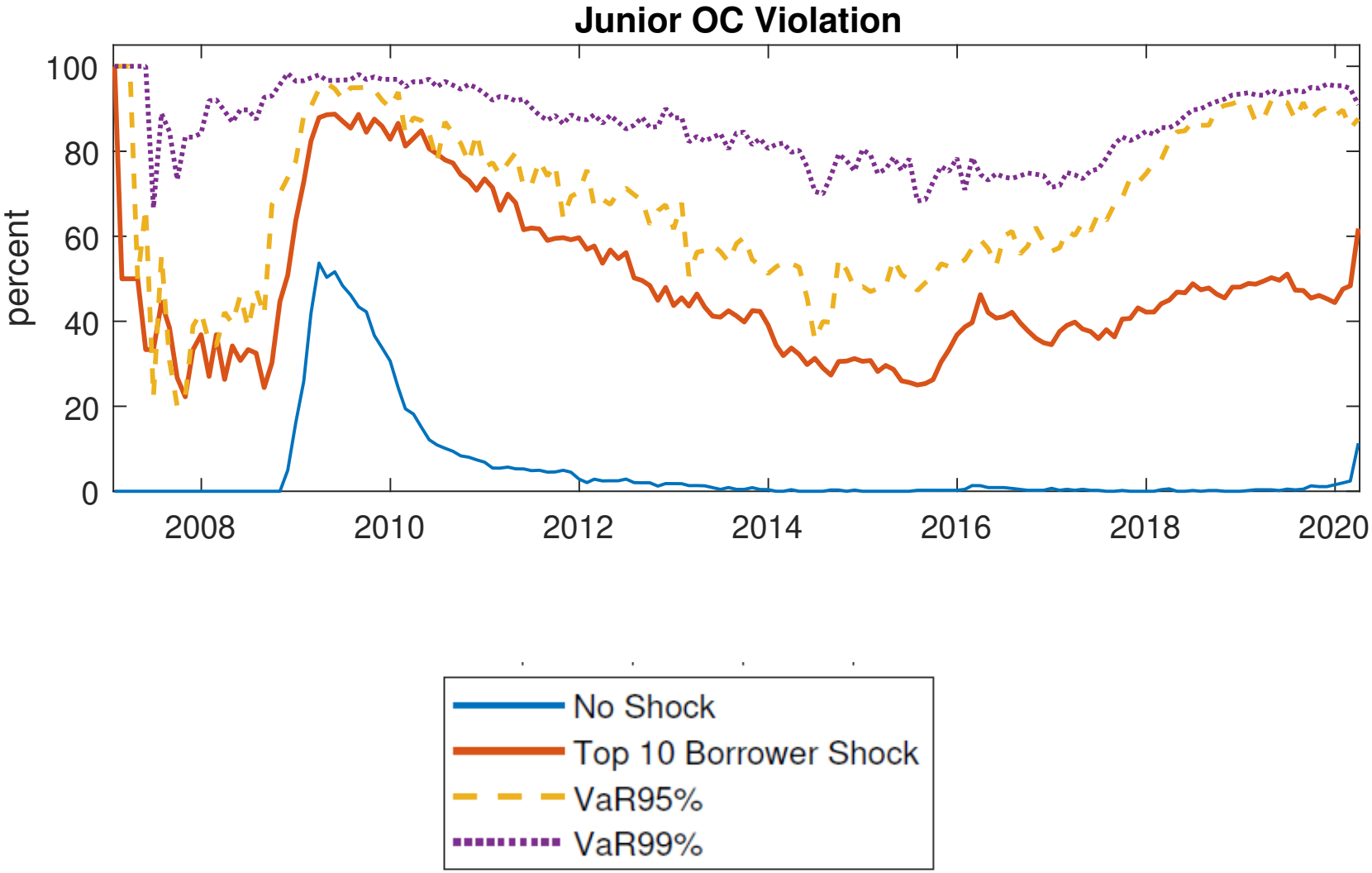
# Summary Statistics of CLO Loan Holdings

| | Mean | Percentiles | | | | |
|---|---|---|---|---|---|---|
| | | 5% | 25% | 50% | 75% | 95% |
| *Diversification across industry:* | | | | | | |
| Top 1 industry share (%) | 12.9 | 8.2 | 10.0 | 11.8 | 13.7 | 22.0 |
| Top 3 industry share (%) | 29.8 | 21.8 | 25.3 | 28.9 | 32.0 | 43.1 |
| Herfindahl index $\times 100$ | 6.9 | 4.4 | 5.2 | 5.9 | 6.7 | 12.8 |
| Exposure to 10 largest borrowers (%) | 8.1 | 1.2 | 5.6 | 8.2 | 10.6 | 14.5 |
| *Share of loans by credit ratings (%)*: | | | | | | |
| IG | 3.7 | 0.0 | 0.6 | 1.7 | 5.1 | 12.3 |
| BB | 19.0 | 4.8 | 14.4 | 19.1 | 24.3 | 31.2 |
| B | 64.4 | 38.7 | 58.7 | 67.8 | 73.3 | 79.9 |
| CCC | 7.3 | 1.9 | 4.4 | 6.2 | 8.5 | 16.2 |
| Monthly loan turnover (%) | 6.2 | 0.3 | 2.2 | 4.3 | 7.0 | 17.9 |

# Results of the Stress Tests

| $\Delta Slack/V$ | Mean | Percentiles | | | | | %(< 0) |
|---|---|---|---|---|---|---|---|
| | | 5% | 25% | 50% | 75% | 95% | |
| Panel A. Slack without shocks | | | | | | | |
| $OC(J)$ | 3.5 | 0.5 | 2.5 | 3.3 | 4.0 | 7.7 | 3.1 |
| $OC(S)$ | 9.3 | 4.3 | 5.9 | 6.5 | 9.2 | 25.5 | 0.0 |
| *Def* | 21.1 | 13.6 | 18.3 | 20.3 | 22.0 | 33.0 | 0.0 |
| Panel B. Top 10 borrowers default | | | | | | | |
| $OC(J)$ | 0.0 | -4.2 | -1.4 | 0.0 | 1.3 | 4.5 | 46.0 |
| $OC(S)$ | 5.7 | -0.2 | 2.3 | 3.7 | 5.8 | 20.6 | 5.4 |
| *Def* | 17.6 | 9.4 | 14.5 | 16.9 | 19.0 | 29.2 | 0.0 |
| Panel C. VaR95% shock | | | | | | | |
| $OC(J)$ | -3.5 | -7.8 | -5.2 | -3.7 | -2.0 | 1.8 | 81.2 |
| $OC(S)$ | 1.8 | -4.3 | -1.9 | -0.2 | 2.7 | 16.9 | 47.0 |
| *Def* | 13.8 | 6.4 | 10.9 | 12.9 | 15.4 | 25.1 | 0.0 |
| Panel D. VaR99% shock | | | | | | | |
| $OC(J)$ | -11.2 | -17.1 | -14.0 | -11.8 | -8.7 | -3.8 | 88.7 |
| $OC(S)$ | -6.0 | -13.8 | -10.7 | -8.0 | -3.7 | 10.4 | 77.8 |
| *Def* | 6.0 | -2.0 | 2.3 | 4.8 | 8.4 | 18.7 | 9.3 |

# Fraction of CLOs (%) That Would Fail the OC Tests Under Stress



# Summary of Stress Test Results

Idiosyncratic default of large borrowers can increase the fraction of constrained CLOs from 3.1% to 46.2%.

Diversification requirement on CLOs causes them to choose similar loans to each other.

$$\Rightarrow \textbf{“Too big to diversify”}.$$

The original shocks are not as large as a “tail event” as quantified by VaR.

- Our VaR results depend on normally-distributed shocks, and likely underestimate the true tail risk.
- The magnitude of shocks from top 10 borrower default is even smaller.

Next question: What happen to constrained CLOs?

# Part II:

# Systemic Risk of the Underlying Leveraged Loan Market

# OC Ratio and Sales of Loans

Consider a CLO with $OC^{Pre} = A/D$ sells its loan holdings, and repay senior tranches with the proceeds.

1. The loan is valued at the book value (i.e. loans rated B or above).
2. The loan is marked-to-market (excess CCC loans, defaulted loans).

**Case I:** The OC ratio after the transaction changes to,

$$OC^{Post} = \frac{A - 100}{D - P}. \tag{1}$$

and the OC ratio improves upon transactions (i.e. $OC^{Post} > OC^{Pre}$) if and only if,

$$OC^{Pre} > \frac{100}{P}. \tag{2}$$

**Case II:** The OC ratio changes to,

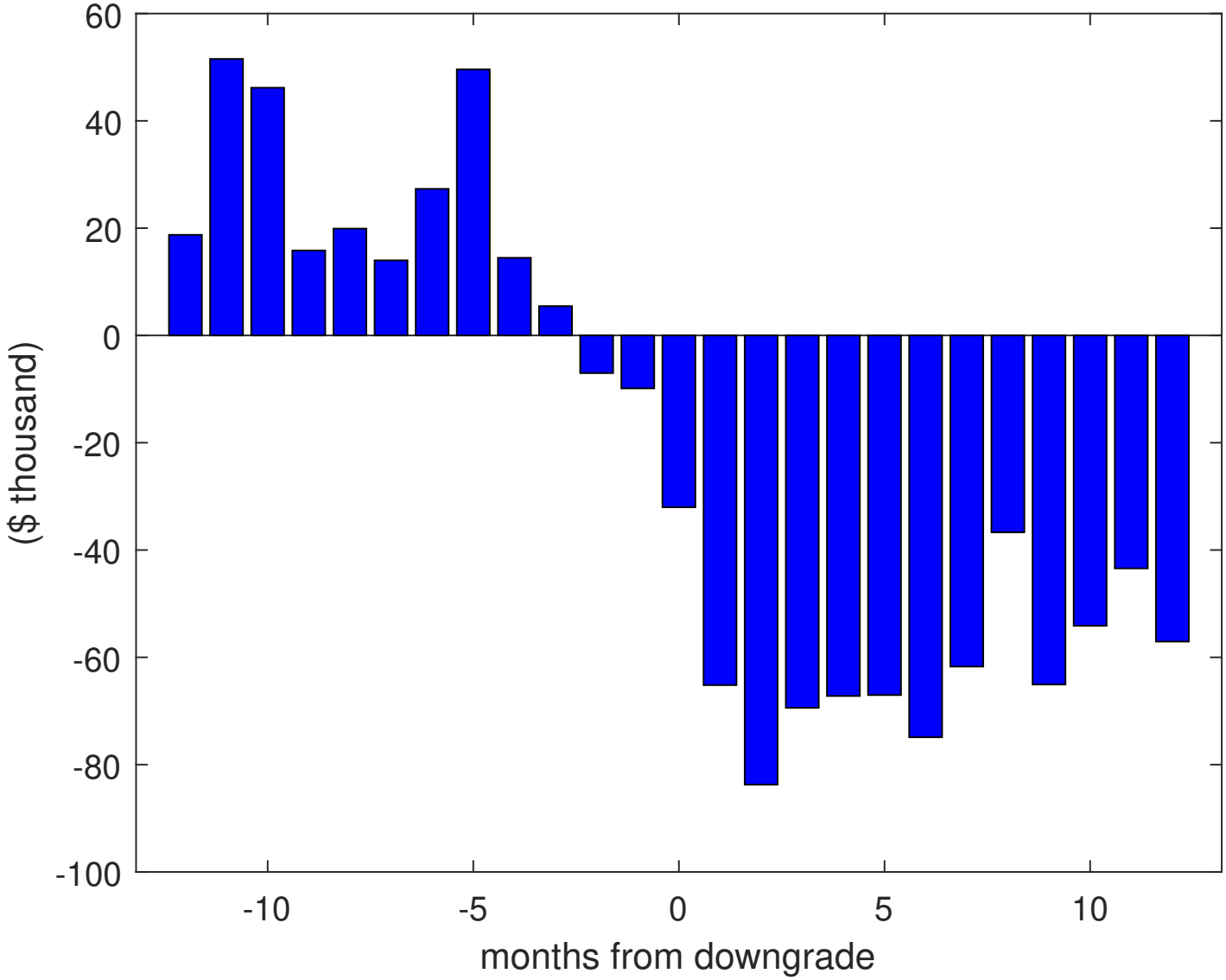
$$OC^{Post} = \frac{A - P}{D - P}. \tag{3}$$

and the OC ratio improves upon sale if and only if,

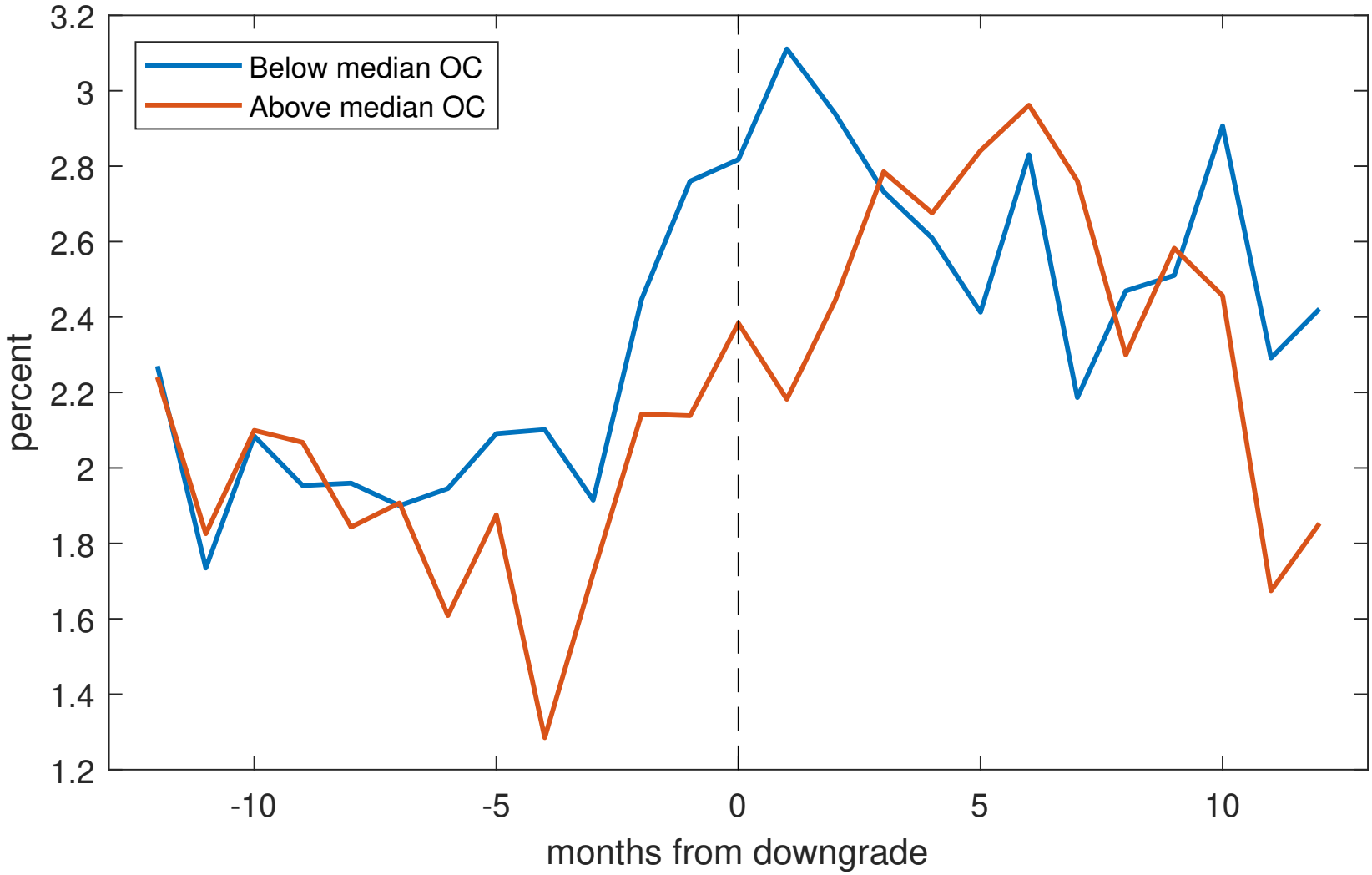
$$OC^{Pre} > 1. \tag{4}$$

# Net Purchases of Loans Downgraded to CCC or Below by CLOs

CCC-Rated loans above threshold level are marked to market.



# Average Probability of Selling Downgraded Loans Around Downgrading Months



# Logit Regression of Loan Sales on OC Ratio Slack

Do constrained CLOs sell downgraded loans more than unconstrained CLOs do, after controlling for loan/CLO characteristics?

Use a dummy variable for CLO $i$'s sale for loan $j$ between months $m_0$ and $m_1$.

$$D^{SELL}_{i,j,m_0\to m_1} = f\left(b\frac{Slack(J)_{i,m_0-1}}{A_{i,m_0-1}} + \gamma_0 X_{j,m_0-1} + \gamma_1 Y_{i,m_0-1} + \gamma_2 FE_{q_1} + \varepsilon_{i,j,m_0\to m_1}\right).$$

- $X_{j,m_0-1}$: Rating before downgrade, loan time to maturity.
- $Y_{i,m_0-1}$: CLO time to reinvestment date, log CLO size, CLO manager's age, log CLO manager's size, CCC loan ratio.

# Determinants of Sales of Downgraded Loans

| | Months -1 to 1 | | Months -3 to -2 | | Months 2 to 3 | |
|---|---|---|---|---|---|---|
| | $b$ | $m(b)$ | $b$ | $m(b)$ | $b$ | $m(b)$ |
| $Slack(J)/A$ | -5.72 | -0.41 | -6.71 | -0.27 | -3.24 | -0.18 |
| | (-3.25) | (-3.26) | (-2.58) | (-2.59) | (-1.54) | (-1.54) |
| $Rtg$ | 3.09 | 0.22 | 4.16 | 0.17 | -7.10 | -0.38 |
| | (2.03) | (2.03) | (2.01) | (2.01) | (-3.66) | (-3.68) |
| $LoanMat$ | 4.27 | 0.31 | -8.85 | -0.35 | 4.34 | 0.23 |
| | (0.94) | (0.94) | (-1.93) | (-1.94) | (0.90) | (0.90) |
| $CLOMat$ | 1.12 | 0.08 | 3.08 | 0.12 | -1.43 | -0.08 |
| | (0.71) | (0.71) | (1.46) | (1.46) | (-0.75) | (-0.75) |
| log $CLOSize$ | 17.55 | 1.26 | 7.26 | 0.29 | -9.63 | -0.52 |
| | (1.95) | (1.95) | (0.60) | (0.60) | (-0.90) | (-0.90) |
| $MgrAge$ | -4.55 | -0.33 | -3.92 | -0.16 | -8.74 | -0.47 |
| | (-5.63) | (-5.66) | (-3.82) | (-3.84) | (-8.09) | (-8.28) |
| log $MgrSize$ | 16.84 | 1.21 | 18.41 | 0.74 | 45.66 | 2.47 |
| | (4.26) | (4.29) | (3.61) | (3.64) | (9.02) | (9.40) |
| $CCCRatio$ | 0.29 | 0.02 | 0.35 | 0.01 | 0.48 | 0.03 |
| | (0.48) | (0.48) | (0.43) | (0.43) | (0.71) | (0.71) |
| Time FE | Yes | | Yes | | Yes | |
| $\bar{R}^2$ | 2.86 | | 3.61 | | 3.75 | |
| $N$ | 25,225 | | 21,494 | | 19,769 | |

# Cumulative Abnormal Returns Upon Downgrade

Sale of a downgraded loan by an individual CLO may not affect the loan price.

However, collective action of many constrained CLOs may matter.

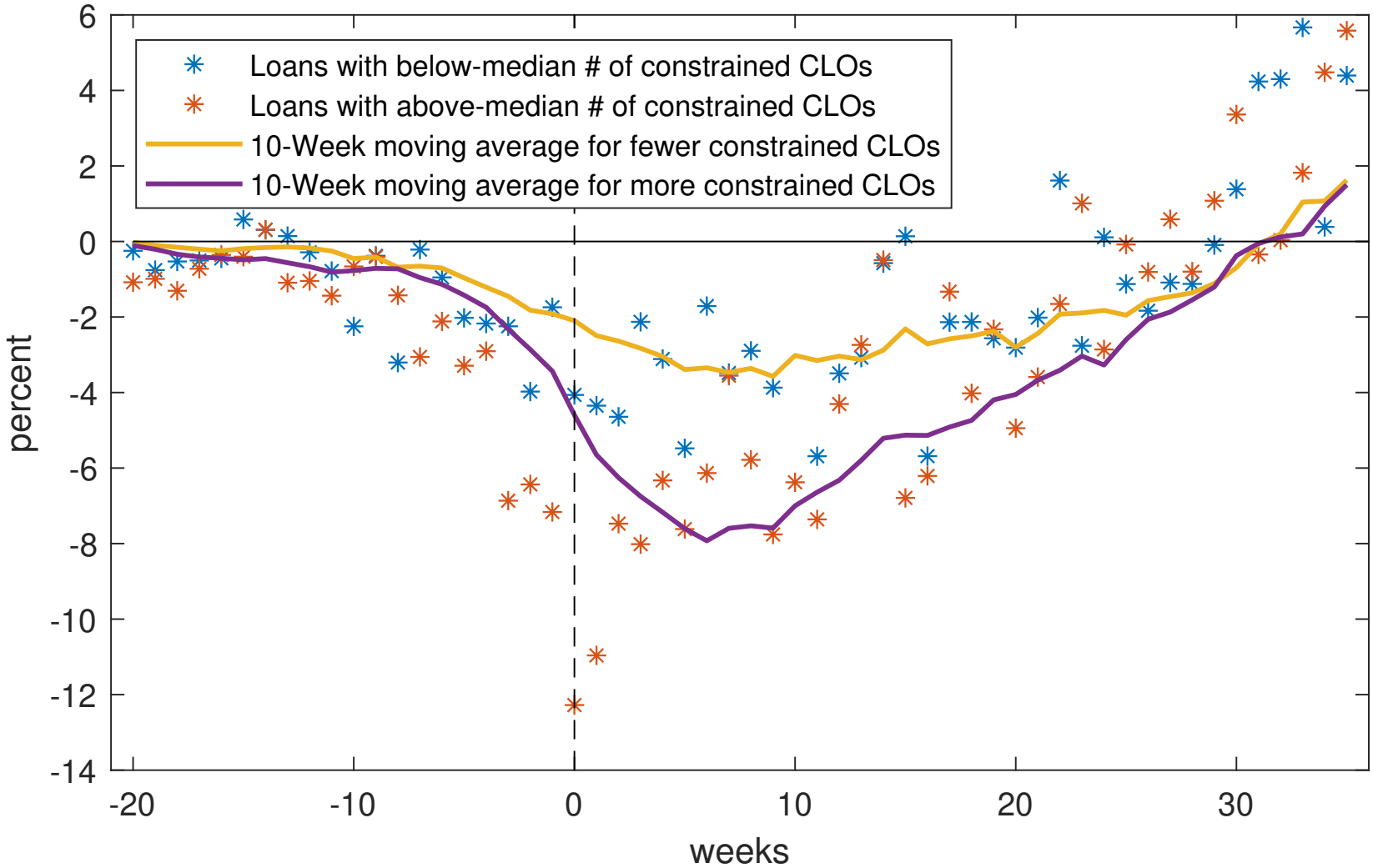
Abnormal returns on downgraded loan:
We run regressions of weekly returns on loan $i$:

$$\Delta \log P_{i,w+1} = \alpha + \beta IDX_{w+1} + \gamma_1 (S_{i,w+1} - S_{i,w}) + \gamma_2 (S_{i,w+1} \log Q_{i,w+1} - S_{i,w} \log Q_{i,w}) + \varepsilon_{i,w+1}.$$

- $IDX_{w+1}$ is a vector of benchmark returns (S&P LSTA Leveraged Loan Index, SPX, T-bill).
- $S_{i,w}$ is an indicator variable which is 1 (-1) when a CLO buys (sells) loan $i$.
- $Q_{i,w}$ is dollar volume of the transaction.
- Run separately for 4 groups based on i) rating before downgrade / ii) maturity.

Cumulate $\varepsilon$ from 20 weeks before the downgrade week.

# Moving-Average of Mean Cumulative Abnormal Returns Around the Downgrade Event



# Placebo Tests: Number of Unconstrained CLOs

$$CAR_{i\tau} = b_0 + b_1 N(CLO_{LowOC})_i + b_2 N(CLO_{HighOC})_i + \gamma Ctrl_i + u_i.$$

| $\tau$ | $N(CLO_{LowOC})$ | $N(CLO_{HighOC})$ | Maturity | Rating before downgrade | Year FE | $\bar{R}^2$ |
|---|---|---|---|---|---|---|
| -16 | -0.01 | 0.01 | -0.23 | -0.15 | YES | 0.02 |
| | (-0.15) | (0.46) | (-2.99) | (-0.75) | | |
| -1 | -0.25 | 0.05 | -0.70 | -0.52 | YES | 0.07 |
| | (-2.44) | (0.54) | (-3.02) | (-0.83) | | |
| 0 | -0.26 | 0.05 | -0.83 | -0.36 | YES | 0.11 |
| | (-2.26) | (0.53) | (-3.31) | (-0.55) | | |
| 5 | -0.21 | 0.07 | -0.52 | -0.89 | YES | 0.13 |
| | (-1.85) | (0.67) | (-1.67) | (-1.17) | | |
| 35 | -0.21 | 0.17 | -0.10 | -0.57 | YES | 0.14 |
| | (-1.19) | (1.10) | (-0.19) | (-0.53) | | |

# Conclusion: Increased Risk Amid the Pandemic

The impact of fire sale could be larger during the COVID-19 pandemic.

- Borrowers have difficulty refinancing.
- Banks are major investors in CLO senior tranches.
- Risk of downgrades and lower market prices.

