LASH Risk and Interest Rates

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Motivation

Liquidity crises increasingly common in the non-bank financial sector (e.g. pension funds, insurers)

- "Dash for Cash" in 2020
- Ukraine War-related commodity market turmoil in 2022
- UK LDI crisis in autumn 2022

Liquidity needs came from instruments often used for hedging (e.g. variation margin on swaps)
(Czech et al. 2023, Avalos & Huang 2024, Pinter 2023)

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This paper: *Liquidity After Solvency Hedging risk* ("LASH risk")

What We Do

1. **Definition:** *Liquidity After Solvency Hedging risk* ("LASH risk")
   - Liquidity risk due to hedging solvency risk...
   - ... Liquidity worsens at the same time as solvency improves

Example of a pension fund:

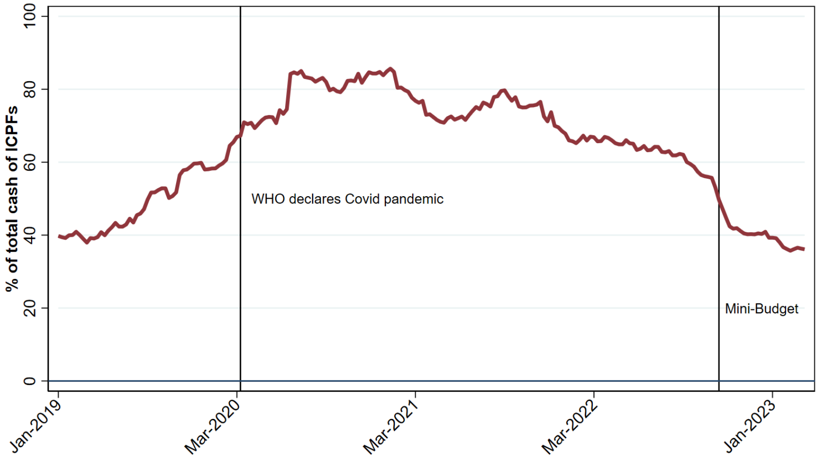
- Solvency ↓ when rates ↓
- Pension fund can hedge with interest rate swap
- If rates ↑: solvency ↑ but liquidity ↓

What We Do

1. **Definition:** *Liquidity After Solvency Hedging risk* ("LASH risk")

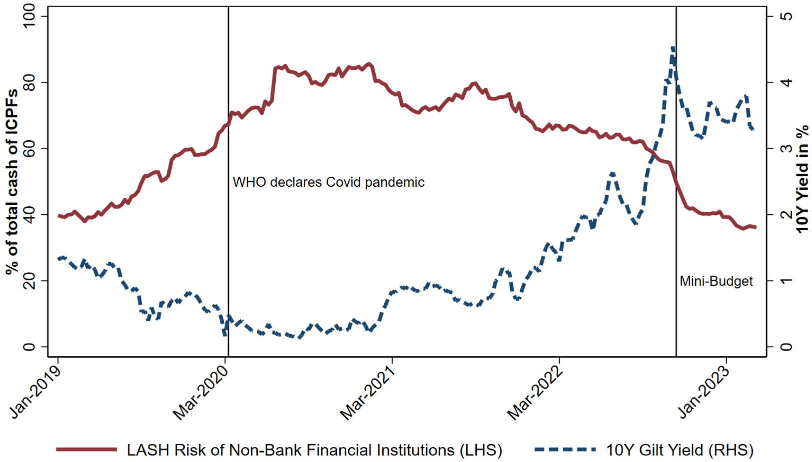
2. **Measurement:** LASH risk for non-banks and sterling interest rates (repos + swaps)
   - LASH risk is large
   - Negatively correlated with interest rates
   - Concentrated in pension fund and insurance sector

LASH Risk is Large ...



Units: liquidity need after 100bps rise in interest rates relative to total cash of ICPFs (%)

LASH Risk is Large and Moves with Interest Rates



Units: liquidity need after 100bps rise in interest rates relative to total cash of pension funds (%)

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2. **Measurement:** LASH risk for non-banks and sterling interest rates (repos + swaps)

3. **Causes:** Low interest rates and high LASH risk
   - Document causal link between LASH risk and low rates

Proposed mechanism: funds choose hedging to balance liquidity vs. solvency risk

- Rates $\downarrow \Rightarrow$ solvency $\downarrow \Rightarrow$ demand for hedging $\uparrow$

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3. **Causes:** Low interest rates and high LASH risk
4. **Consequences:** Backlash during crises
   - LASH predicts institution-level sales and yield spikes during LDI crisis

Outline

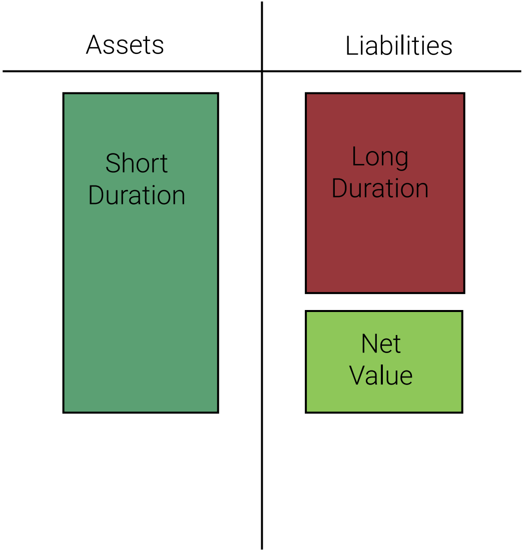
Definition of LASH Risk

Measurement: LASH Risk for Non-Banks and Sterling Rates

Consequences: Backlash During Crises

Discussion & Conclusion

Conceptualising LASH Risk (I) Model



Fund with long-term liabilities vs assets:

- Rate rises improve solvency
- Rate falls worsen solvency

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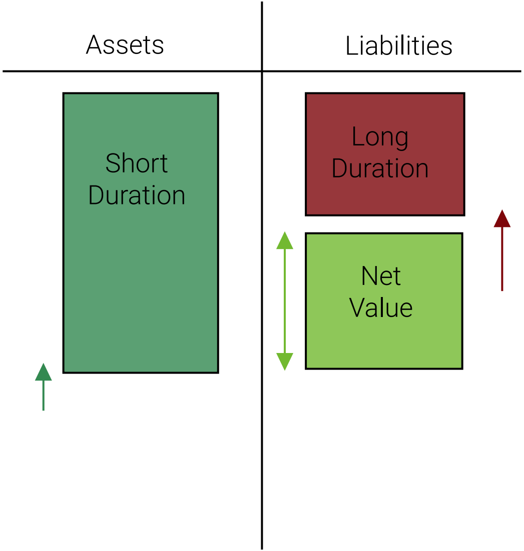

Fund with long-term liabilities vs assets:

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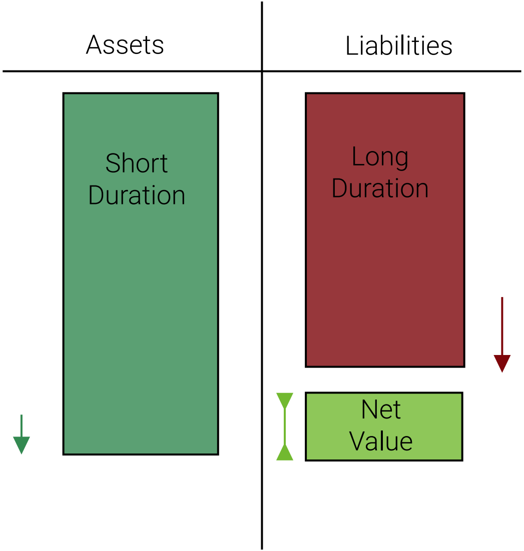

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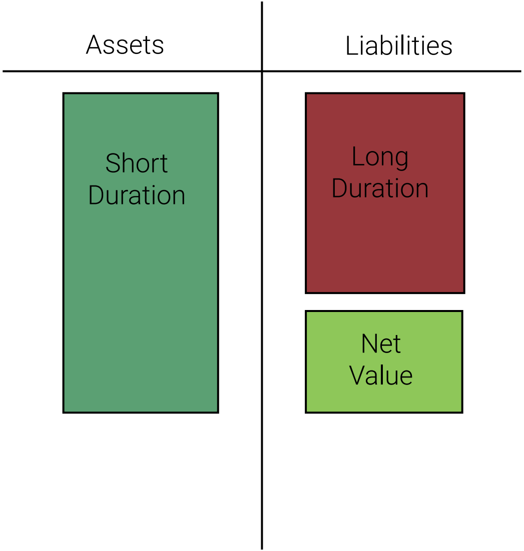

Fund with long-term liabilities vs assets:

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How can the fund hedge rate risk?

- It could buy a swap

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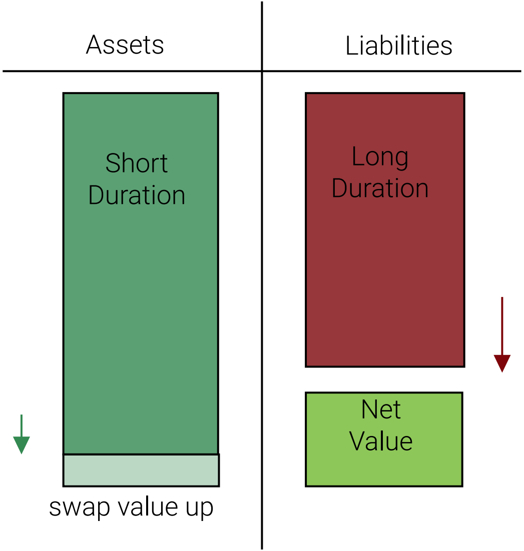

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  - Pays out when rates fall + eliminates solvency risk

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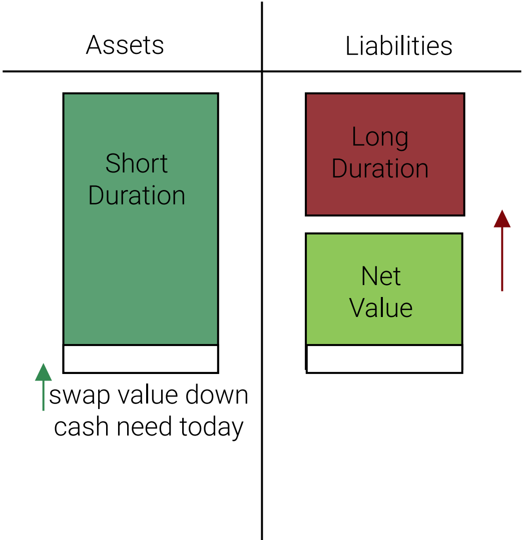

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How can the fund hedge rate risk?

- It could buy a swap
  - Pays out when rates fall + eliminates solvency risk
  - But generates liquidity needs when rates rise

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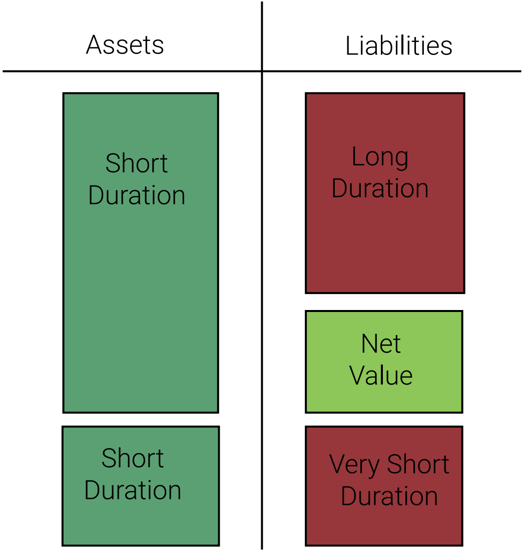

Fund with long-term liabilities vs assets:

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How can the fund hedge rate risk?

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- It could borrow short and lend long (repo)...

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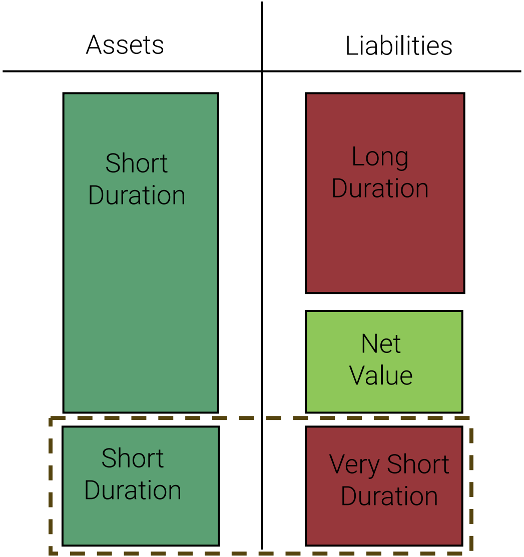

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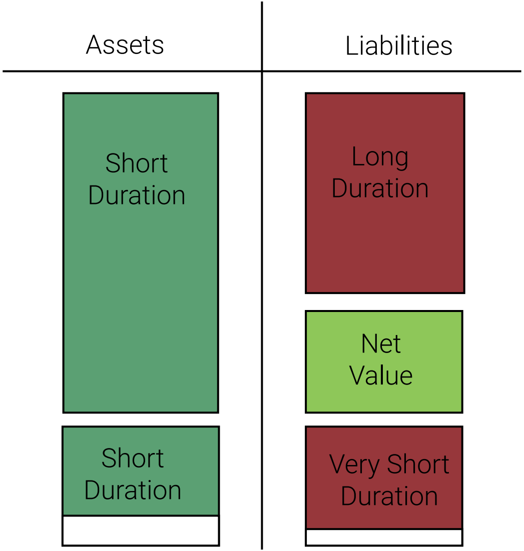

Fund with long-term liabilities vs assets:

- Rate rises improve solvency
- Rate falls worsen solvency

How can the fund hedge rate risk?

- It could buy a swap
- It could borrow short and lend long (repo)...
- ...or take a stake in an equivalent fund.
- Again:
  - Reduces solvency risk if rates fall
  - But increases liquidity needs if rates rise

Comparison with traditional measures
Comparison with liquidity spiral

Pension Funds' Funding Ratios and Gilt Yields

- Left Panel: Aggregate funding ratio (total assets/total liabilities) of UK pension funds
- Right Panel: Yields of UK government bonds (gilts) at different maturities

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Measurement: LASH Risk for Interest Rates

- **LASH Risk**: **liquidity needs** derived from sensitivity of net present value of hedging contract to changes in the **hedged instrument** (FX, inflation or interest rates)

LASH risk for contract i at time t (from e.g. interest rates, R_t):

$$LASH_{i,t} \approx \Lambda_i \times \frac{\partial NPV_{i,t}}{\partial R_t}$$

- $NPV_{i,t}$ is the combined net present value of the hedging strategy
- For simplicity, think of upward shift in yield curve
- Λ captures liquidity needs per unit of NPV change
  - $\Lambda_i \approx 1$
- No margin spirals, abstract from $\frac{d\Lambda_i}{dR_t}$

Measurement across markets

Measurement: Mechanical versus Discretionary

- Aggregate LASH risk $\sum_i Q_{i,t}\text{LASH}_{i,t}$ affected by interest rates for two reasons:
  1. Mechanical — lower interest rate raises $\text{LASH}_{i,t}$ for individual contract
  2. Discretionary — institutions raise quantity $Q_{i,t}$ of contract with higher $\text{LASH}_{i,t}$

→ Effect of interest rates on discretionary component is important

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→ Effect of interest rates on discretionary component is important

- We measure discretionary component of LASH risk with a standard first-order decomposition:

$$\overbrace{\Delta \sum_i Q_{i,t} \text{LASH}_{i,t}}^{\text{aggregate change}} = \underbrace{\sum_i Q_{i,t} \Delta \text{LASH}_{i,t}}_{\text{mechanical change}} + \overbrace{\sum_i \text{LASH}_{i,t-1} \Delta Q_{i,t}}^{\text{discretionary change}}$$

Main Data Sources

- Universe of gilt transactions (MiFID II Database)
- Universe of gilt repo transactions (Sterling Money Market Database)
- Universe of pound sterling interest rate swap positions (EMIR Trade Repositories)

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- Hand collected data on UK pension funds
  - Source: pension fund reports scraped from company websites
  - Information: total asset value, total liability value, cash, derivatives, equity + bond holdings...
  - Coverage: over 100 pension funds — approx. 40% of total pension fund assets in the UK

Constructing LASH

- Sample period: Jan 2019 to April 2023
- All transactions in UK gilt market (approx. 6m observations)
- Daily repo (borrowing) positions, with info on gilt collateral
- Weekly stock of interest rate swap positions, where at least one counterparty is a UK entity:
  - Covers approx 87% of global GBP swap market by daily turnover

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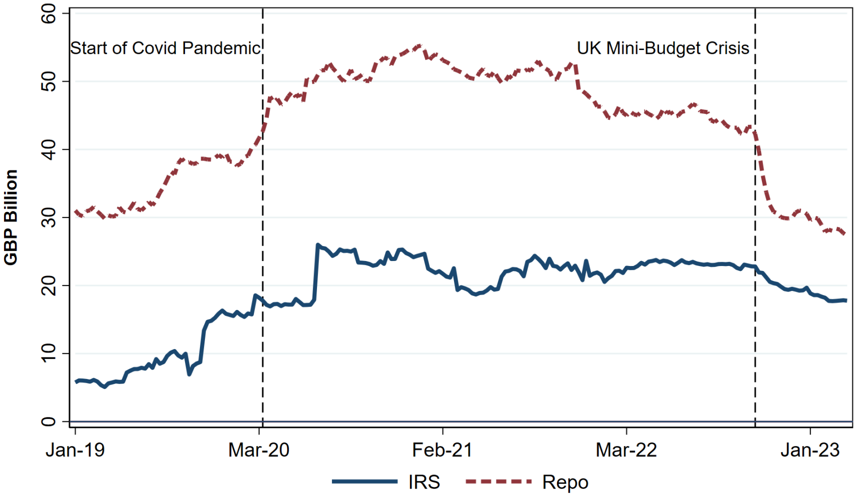
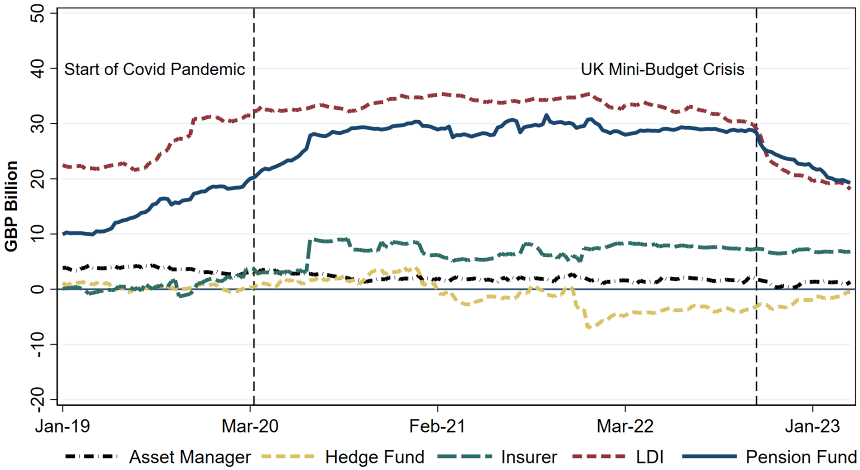
- LASH risk - impact of a 100 bps increase in interest rates on liquidity needs of a contract (Bardoscia et al., 2021)
  - for repos: based on the modified duration of underlying collateral (akin to DV01)
  - for IRS: based on expected cash flows of swapping fixed vs. floating
  - aggregate: merge repo and IRS LASH risk at individual institution level

LASH Risk: Concentrated in Repo



LASH Risk: Concentrated in Wider Pension Fund Sector



▸ Summary stats net positions ▸ Summary stats LASH risk

Stylized Facts: Summary

1. LASH Risk is large, and higher when interest rates are low
2. Movements in LASH Risk are largely due to discretionary rather than mechanical reasons
3. LASH Risk is concentrated in the pension fund sector
4. LASH Risk is large for both interest rate swaps and repo contracts

Do Interest Rates Cause High LASH Risk?

- Holding shorter duration assets implies higher capital losses, and hence greater solvency risk, when interest rates fall
- Low asset duration investors should disproportionately increase LASH risk when r decreases
- **Identification** — cross-sectional variation
  - Investor level j: quarterly portfolio rebalancing, taking into account the initial modified duration of investor j's assets at the beginning of sample ($\omega_{j,i,t=0} \times AD_{i,t}$)

$$\Delta LASH_{j,t}^{Discretionary} = \alpha + \alpha_j + \alpha_t + \beta_1 \Delta Yield_t^{10Y} + \beta_2 (\Delta Yield_t^{10Y} (\sum_i^I \omega_{j,i,t=0} \times AD_{i,t})) + \epsilon_{j,t}$$

Causality: Interest Rates and LASH

	(1)	(2)	(3)	(4)
		$\Delta LASH^{Discretionary}$		
$\Delta Yield^{10Y}$	-1.33***			
	(0.37)			
$\Delta Yield^{10Y}$ × Duration	0.89**	0.95**	1.08***	0.87**
	(0.37)	(0.35)	(0.35)	(0.37)
Observations	4657	4657	4657	4657
R squared	0.016	0.024	0.040	0.063
Time FE	no	yes	yes	yes
Institution FE	yes	yes	yes	yes
Institution-Yield Level FE	no	no	yes	no
Institution-Yield Slope FE	no	no	no	yes

- 100bps quarterly decrease in the gilt yield index: 133% increase in discretionary LASH Risk
- Interaction: Effect reduced to a 44% increase if initial asset duration increases by one SD

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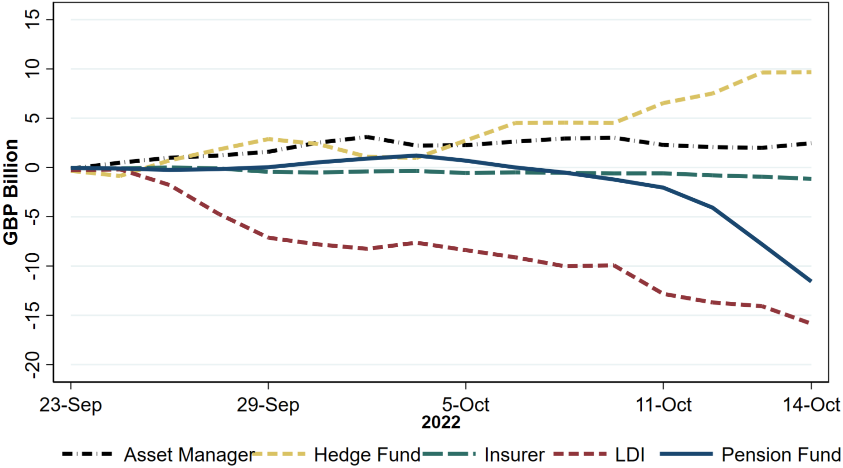
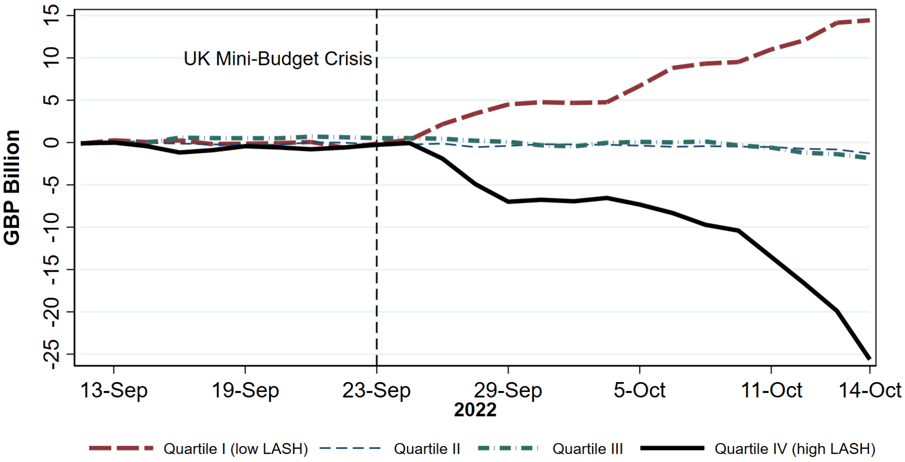
Did LASH Risk Contribute to the 2022 Gilt Market Crisis?

- Mini budget announcement: 23 September 2022
- Fire sale window: 16 trading days (September 23 - October 14)
  - 30-year gilt yield jumped by 140bps in the first three days
- BoE intervention: September 28
  - Intervention: Buy up to £5bn of 20y or longer-term gilts daily, ending on October 14 (13 trading days)
  - First day after intervention: 30-year gilt yield dropped by 100bps, but rose again after
- Yields fully reached pre-crisis level once uncertainty around fiscal policy resolved
- LASH risk materialized when yields jumped ⇒ can pre-crisis LASH exposures predict gilt selling and yield spikes?

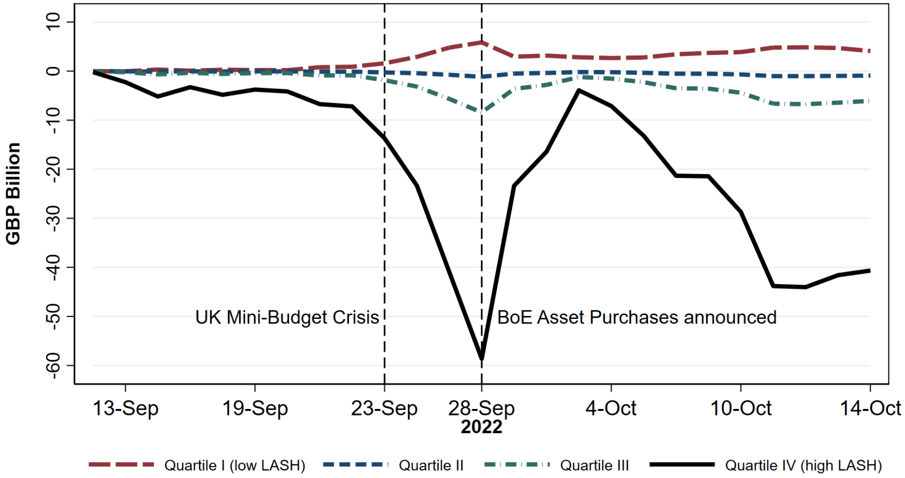
Cumulative Gilt Trading Volumes by Investor Type



Cumulative Gilt Trading Volumes by Pre-crisis LASH Exposure



Change in the Value of Repo Collateral by Pre-crisis LASH Exposure



LASH and Net Gilt Trading During the Gilt Market Crisis

- Specification at time t for institution j in sector s: $Vol_{j,t} = \alpha + \alpha_{s,t} + \beta_1 LASH_{j,t=0} + \varepsilon_{j,t}$

	(1)	(2)	(3)	(4)
	Net Volume		Sell Volume	
LASH combined	-0.21***		0.15***	
	(0.04)		(0.02)	
LASH Repo		-0.16***		0.12***
		(0.04)		(0.02)
LASH IRS		-0.13*		0.08***
		(0.05)		(0.02)
Observations	8875	8875	8875	8875
R squared	0.035	0.035	0.045	0.046
Sector-Day FE	yes	yes	yes	yes

- 1 SD increase in pre-crisis LASH risk associated with 15% higher daily sell volumes during crisis

LASH and Sources of Illiquidity

	(1)	(2)	(3)	(4)	(5)	(6)
				Sell Volume		
LASH	0.15***	0.14***	0.13***	0.20***	0.14***	0.12**
	(0.02)	(0.01)	(0.01)	(0.05)	(0.02)	(0.03)
LASH × Swap-only		0.15***				0.17**
		(0.04)				(0.06)
LASH × High Spread Exposure			0.12**			0.13***
			(0.04)			(0.03)
LASH × Segregated LDI Fund				-0.08		-0.00
				(0.06)		(0.04)
LASH × Pooled LDI Fund					0.93***	0.93***
					(0.02)	(0.06)
Observations	8875	8875	8875	8875	8875	8875
R squared	0.046	0.047	0.047	0.047	0.050	0.052
Sector-Day FE	yes	yes	yes	yes	yes	yes

- Effect driven by repo market frictions (lack of access & dealer constraints) & “pooled” LDI funds

LASH and Bond-level Liquidation Choices

- Specification at bond level b : $Sell\ Vol_{j,b,t} = \alpha + \alpha_{s,t} + \alpha_{b,t} + \beta_1 \left(LASH_{j,0} \times Bond\ Char_b \right) + \varepsilon_{j,b,t}$

	(1)	(2)	(3)	(4)
	Sell Volume			
LASH	0.05***	0.04***	0.04***	0.04***
	(0.00)	(0.00)	(0.00)	(0.00)
LASH × Frequent Collateral Use		0.01*		
		(0.00)		
LASH × Low Duration			0.01	
			(0.01)	
LASH × High Duration			0.01*	
			(0.00)	
LASH × Inflation-linked				0.02**
				(0.01)
Observations	42481	42382	41667	42481
R squared	0.115	0.115	0.114	0.115
Bond-Day FE	yes	yes	yes	yes
Sector-Day FE	yes	yes	yes	yes

- Selling pressure concentrated in for high-duration gilts, gilts frequently used as repo collateral + index-linked gilts

Price Impact of LASH Selling Pressure

- Endogeneity problem: price impact $\longleftrightarrow$ asset sales?
- We follow Czech et al. (2022) and construct LASH-Induced-Trading (LASH-IT) variable to mitigate these concerns:
  - Bond-level exposure to LASH risk
  - Definition: $LASH\text{-}IT_b = \frac{\Sigma_j LASH_{j,t=0} \times w_{j,b,t=0}}{Amount\ Outstanding_{b,t=0}}$
  - where $LASH_{j,t=0}$ is the estimated pre-crisis LASH exposure of investor j, and $w_{j,b}$ is the weight of bond b in investor's j pre-crisis repo collateral portfolio
  - $\Rightarrow$ Exogenous variation in LASH-induced selling pressure
- We then examine extent to which LASH-IT affects gilt yields:
  - Specification: $\Delta Yield_{b,t} = \alpha + \alpha_{m,t} + \alpha_{g,t} + \beta_1 \times LASH\text{-}IT_b + \varepsilon_{b,t}$
  - where $\alpha_{g,t}$ denotes day-bond type FE (nominal or index-linked gilt) and $\alpha_{m,t}$ denotes day-maturity bucket FE

Price Impact of LASH Selling Pressure

- Specification: $\Delta Yield_{b,t} = \alpha + \alpha_{m,t} + \alpha_{g,t} + \beta_1 \times LASH\text{-}IT_b + \varepsilon_{b,t}$

	(1)	(2)	(3)	(4)
	$\Delta Yield_{b,t}$			
LASH-IT	9.29***	9.72***	3.21**	4.13**
	(0.91)	(1.06)	(1.49)	(1.60)
Observations	1253	1253	1253	1253
R squared	0.261	0.321	0.616	0.649
Day FE	yes	-	-	-
Day × Type Gilt FE	no	no	yes	yes
Day × Maturity Bucket FE	no	yes	no	yes

- 1 SD increase in LASH-IT associated with 4.1bps daily increase in gilt yields
- Roughly 66bps over entire 16-day crisis period

  ⇒ LASH-induced trading accounts for around two thirds of the yield spike during the LDI crisis

Discussion: Implications of LASH Risk

What are the implications of LASH risk?

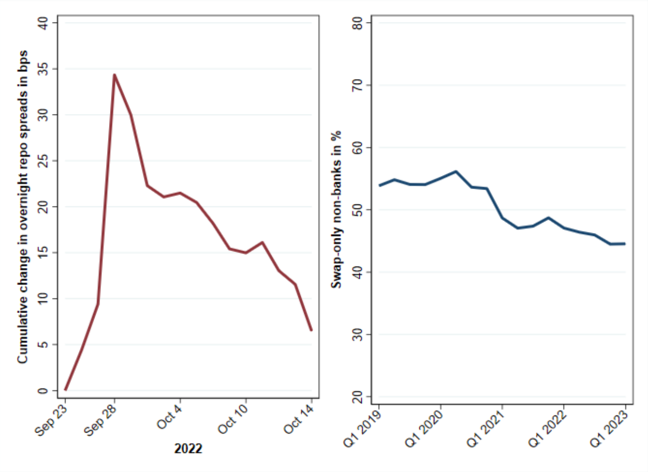
- LASH risk materializes precisely when solvency improves
- "Responsible" institutions exposed to LASH risk due to hedging solvency risk

⇒ LASH risk not associated with moral hazard from risky investments

⇒ ... but still leads to pecuniary externalities

- Policy: Implications for liquidity support after crises

Discussion: Why Not Borrow in the Repo Market?



- Left Panel: Overnight repo rates spiked by more than 30bps during the crisis
- Right Panel: Only around 50% of non-banks routinely access repo market

Conclusion

1. **LASH risk:** “Liquidity risk arising from hedging solvency risk”
   - Method to measure LASH risk in real time using regulatory data

2. **Model and Measurement:** LASH risk for non-banks and sterling interest rates (repos + swaps)
   - LASH risk is (i) large, (ii) concentrated in pension funds and LDIs, (iii) comoves with interest rates

3. **Causes:** Low interest rates and high LASH risk
   - We document causal link between LASH and interest rates

4. **Consequences:** Backlash during crises
   - LASH risk predicts institution-level sales and yield spikes during LDI crisis

Appendix

Related Literature

Forms of liquidity risk *and why LASH risk is different*

- Demandability + run risk (e.g. Diamond & Dybvig 1983, Kashyap et al 2002, Goldstein & Pauzner 2005

  Many non-banks do not issue demandable claims

- Rollover risk (e.g. Calvo 1983)

  Liquidity risk even with long term hedging instruments

- Funding liquidity (e.g. Brunnermeier & Pedersen 2009) i.e. solvency ↓, liquidity needs ↑
- In our case: *Solvency ↓, liquidity needs ↓*

More Literature

1. Non-bank intermediaries (Campbell and Sigalov, 2022; Khetan et al., 2023; Becker and Ivashina, 2015; Aramonte et al., 2022; Pinter and Walker, 2023; Jansen et al., 2022)
2. Monetary policy, interest rates and financial stability (Stein, 2012; Adrian and Shin, 2020; Jiménez, et al., 2014; Ioannidouet al., 2015; Adrian et al., 2019; Greenwood et al., 2022; Acharya et al., 2023; Grimm, Jorda et al., 2023; Fahri and Tirole, 2012)
3. Financial stability and pension funds (Lucas and Zeldes, 2009; Jansen et al., 2023; Koijen and Yogo, 2022; Czech et al., 2023)
4. Crises (Kindleberger, 1978; Froot et al., 1993; Brimm et al., 2023; Ma, Xiao and Zeng, 2022; Pinter, 2023; Cesa-Bianchi et al., 2023)

Different Liquidity Risks: Comparisons and Distinctions

"A liquid asset's salient property is that it is widely accepted as a means of payment without major capital loss, a property that Menger (1892) labeled salability" (Calvo, 2012)

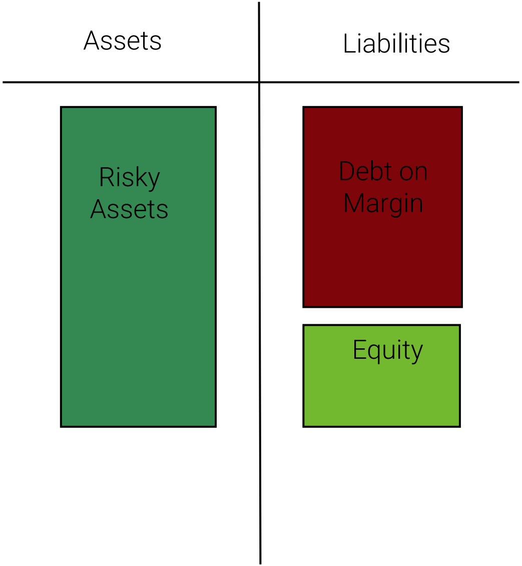
- Holmstrom and Tirole (1998): liquidity risk broadly defined shocks to cash need imperfectly correlated with solvency

Typical sources (and why LASH is different):

1. Demandability/Maturity Transformation (Poole, 1968; Kashyap et al., 2002): customer withdrawal needs generate immediate need for cash independent of asset returns
    - BUT: most NBFIs don't issue demandable claims. Open ended funds an exception
2. Run risk (Diamond and Dybvig, 1983; Rochet and Vives, 2004): creditors face coordination issues and can attempt to recall funding
    - BUT: most NBFI trading is with a small number of counterparties
3. Rollover risk (Calvo 1988, AER): short term debt can generate belief driven crises
    - BUT: liquidity risk arises from contracts at term

Back

Comparison with Liquidity Spiral (Brunnermeier-Pedersen, 2009)



Fund has leveraged bet on a risky asset with margin requirement

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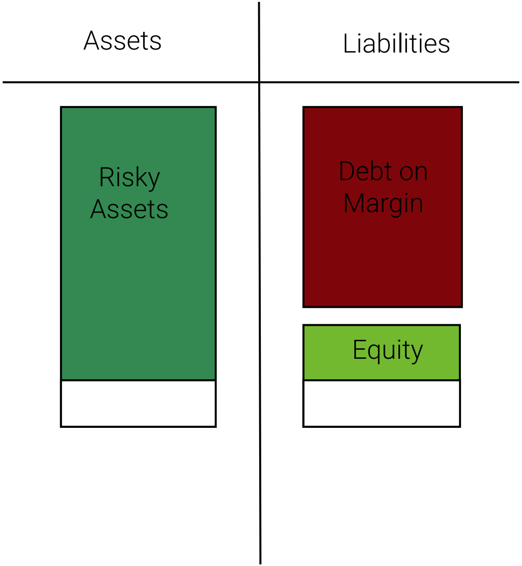
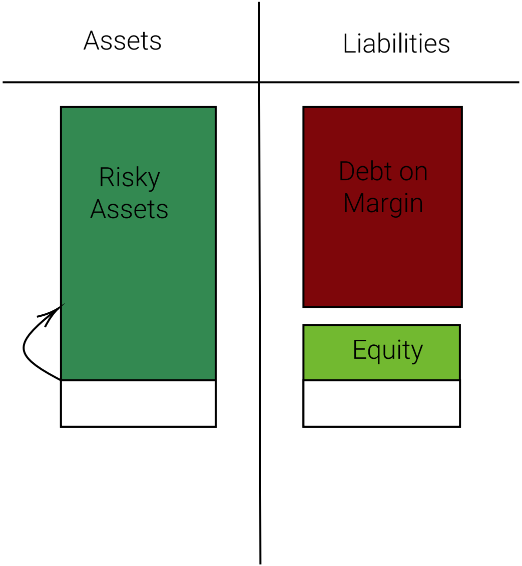


Fund has leveraged bet on a risky asset with margin requirement

- Initial loss wipes out some of bank assets/net worth
- Leads to margin calls...

Comparison with Liquidity Spiral (Brunnermeier-Pedersen, 2009)



Fund has leveraged bet on a risky asset with margin requirement

- Initial loss wipes out some of bank assets/net worth
- Leads to margin calls...
- ...leading to asset sales...
- ...pushing down asset prices...
- ...raising margin requirements...
- ...add causing further asset sales

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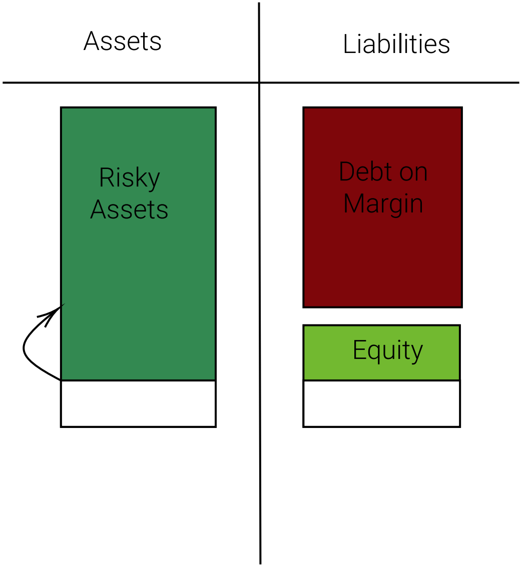

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$\Rightarrow$ A "liquidity spiral". Fundamental difference:

- In our case, there are no losses, solvency improves.

Back

Measurement Across Markets

- **Repo**
  - Short dated contracts with long maturity bonds as collateral
  - LASH risk: via change in bond prices and hence need to provide additional collateral

$$LASH^{Repo}_{i,t} = \frac{Q_{i,t}}{100} \times \underbrace{\frac{\sum_{k=1}^{K}(1+r_t)^{-k_b} \cdot CF_{b,k} \cdot k_b}{P_{b,t}} \times \left(1+\frac{YTM_{b,t}}{c_b}\right)^{-1}}_{\text{Modified duration of bond } b} \tag{1}$$

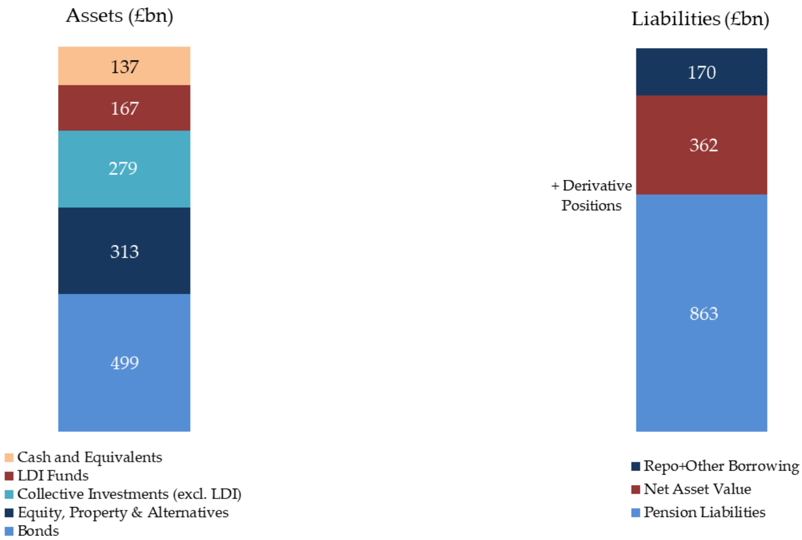
  - Contract i, net borrowing amount Q, with bond collateral b of maturity m evaluated at time t
  - $P_{b,t}$ - market price of bond b, YTM - yield to maturity, assuming coupons are paid c times a year
- **Interest rate swaps**
  - Long dated contracts based on a fixed and floating leg
  - LASH risk: via cash flow sensitivity to changes in interest rates

$$LASH_{i,m,t} = \frac{1}{c}\frac{Q_{it}}{100} \times \sum_{k=1}^{c \times m} e^{-r_{j,t} \cdot (T_j - t)} \tag{2}$$

  - Contract i, net notional Q (receiving fixed rate), with maturity m evaluated at time t

Back

Aggregate Balance Sheet of Private UK Defined Benefit Funds



Summary Statistics: Average Net Positions and LASH Risk

	Repo net borrowing (£bn)					IRS net receive fixed (£bn)				
Sector	2019	'20	'21	'22	'23	2019	'20	'21	'22	'23
Pension fund	38	64	74	69	48	65	96	101	132	112
LDI	99	121	130	113	73	17	37	40	38	23
Insurer	0	0	0	0	0	10	23	27	72	60
Hedge Fund	-7	11	-3	-34	-15	59	82	-14	-108	-81
Fund	9	7	7	4	4	23	21	11	18	15
Other financial	7	20	18	10	5	-8	-11	-3	-9	-14
	Repo discretionary LASH (£bn)					**IRS discretionary LASH (£bn)**				
Sector	2019	'20	'21	'22	'23	2019	'20	'21	'22	'23
Pension fund	8	15	18	16	11	5	11	12	12	10
LDI	22	28	30	26	17	2	5	5	5	3
Insurer	0	0	0	0	0	0	6	6	8	7
Hedge Fund	0	1	-1	-3	-1	1	0	-1	-1	-1
Fund	2	1	1	1	1	2	1	1	0	0
Other financial	2	4	3	2	1	-2	-2	-1	-1	-1

Summary Statistics: Cross-sectional Variation

	Repo net borrowing (£m)				Repo discretionary LASH (£m)		
Sector	N	Mean	Median	Std dev	Mean	Median	Std dev
Pension fund	273	259.3	144.3	388.3	59.4	31.5	89.3
LDI	337	360.6	113.6	1275.5	82.6	25.5	300.6
Insurer	16	45.2	36.7	205.3	6.3	3.6	43.4
Hedge Fund	284	-59.7	-0.6	561.4	-4.0	0.0	65.6
Fund	203	117.6	3.7	626.6	22.9	0.6	143.7
Other financial	13	-10.5	0.0	116.7	-1.1	0.0	21.1
	IRS net receive positions (£m)				**IRS discretionary LASH (£m)**		
Sector	N	Mean	Median	Std dev	Mean	Median	Std dev
Pension fund	450	297.9	32.0	1372.2	29.9	2.6	183.9
LDI	231	199.3	48.2	477.1	24.9	3.0	72.6
Insurer	76	971.4	17.0	4034.6	139.2	0.2	691.3
Hedge Fund	149	-231.0	10.0	19493.3	-7.4	0.0	186.4
Fund	869	54.2	0.8	565.0	2.6	0.0	29.4
Other financial	217	-148.8	-6.5	1266.4	-14.1	-0.2	107.3

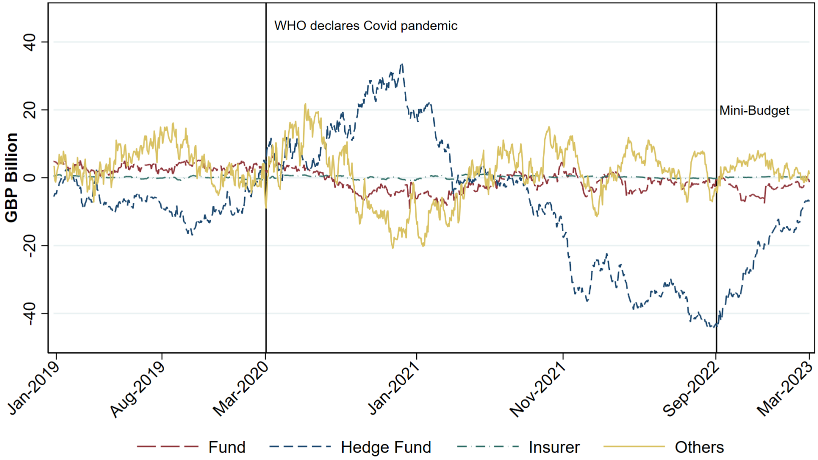
Summary Statistics: Pension Fund Balance Sheets

	2017	2018	2019	2020	2021	2022	2023
N	10	22	50	65	68	69	10
Total assets (£bn)	115.0	553.7	801.3	1046.9	956.5	876.9	55.1
Total liabilities (£bn)	117.2	560.7	815.2	1099.9	900.0	807.9	50.8
Actuarial assets (£m)							
Min	907	933	179	62	145	177	916
Mean	11501	25170	15711	15863	14066	12709	5513
Median	3600	4360	3767	3676	3611	3029	2364
Max	60000	358175	395867	444167	463022	406597	23500
Std deviation	18973	75692	55560	55490	56579	49732	7605
Actuarial liabilities (£m)							
Min	1074	1044	193	95	125	162	835
Mean	11724	25485	15985	16665	13235	11709	5078
Median	3673	4501	3499	3642	3511	2960	2195
Max	67500	368981	404974	475130	418665	366574	20300
Std deviation	20615	78046	56894	59416	51396	45031	6659

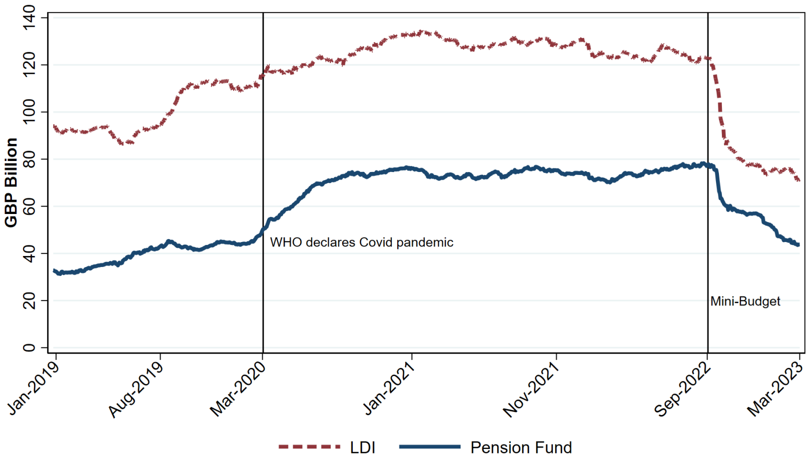
Summary Statistics: Pension Fund Funding Ratios

	2017	2018	2019	2020	2021	2022	2023
N	13	23	52	70	76	74	11
Underfunded PFs	0.62	0.52	0.56	0.60	0.33	0.27	0.27
Pension fund funding ratios							
Min	0.81	0.78	0.81	0.65	0.80	0.91	0.91
Mean	0.98	1.02	1.00	0.98	1.04	1.06	1.07
Median	0.94	1.00	0.99	0.98	1.04	1.05	1.07
Max	1.31	1.39	1.40	1.49	1.54	1.42	1.23
Std deviation	0.13	0.12	0.11	0.12	0.10	0.10	0.09

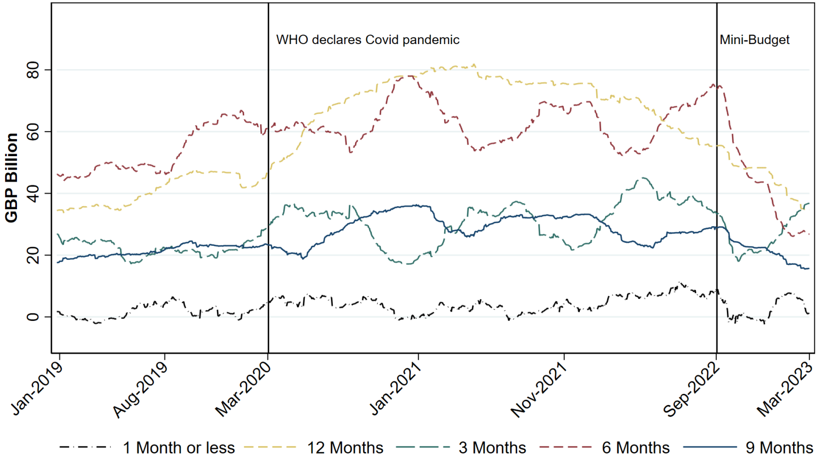
NBFI Repo Borrowing



PFLDI Repo Borrowing



PFLDI Repo Borrowing by Maturity



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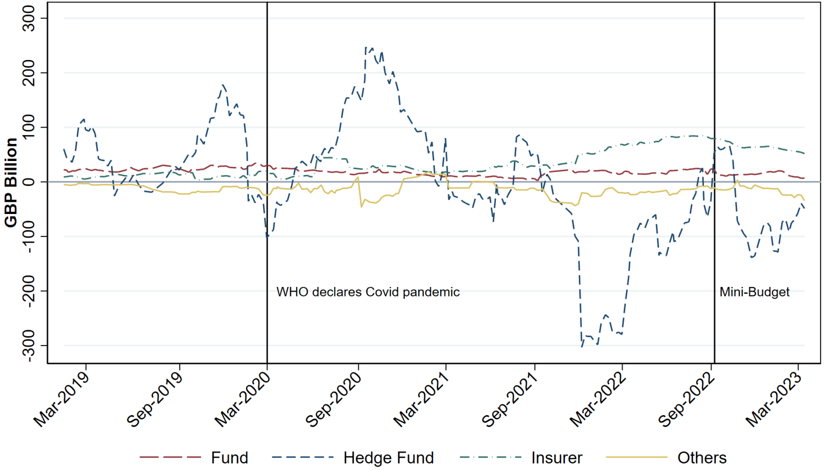

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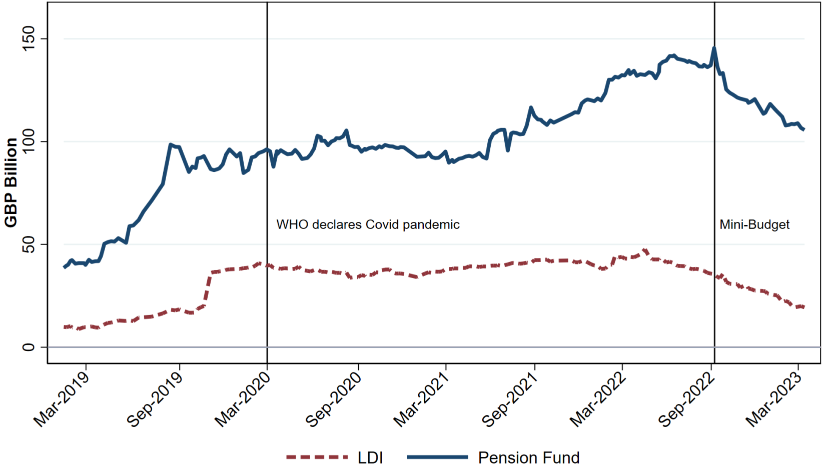

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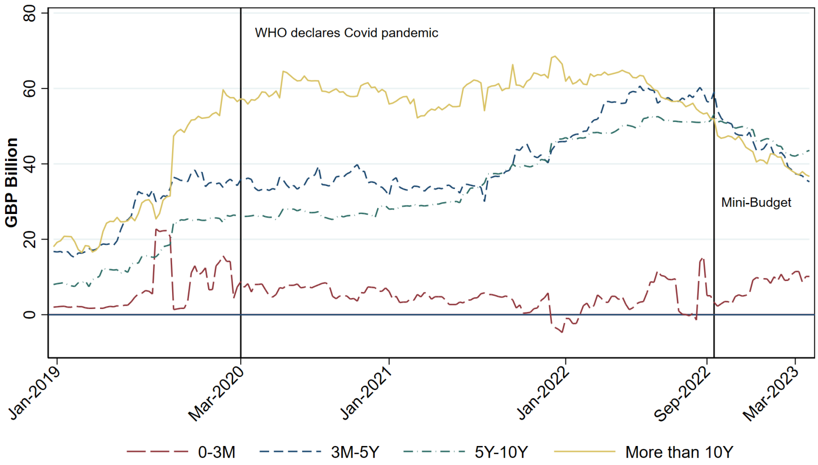
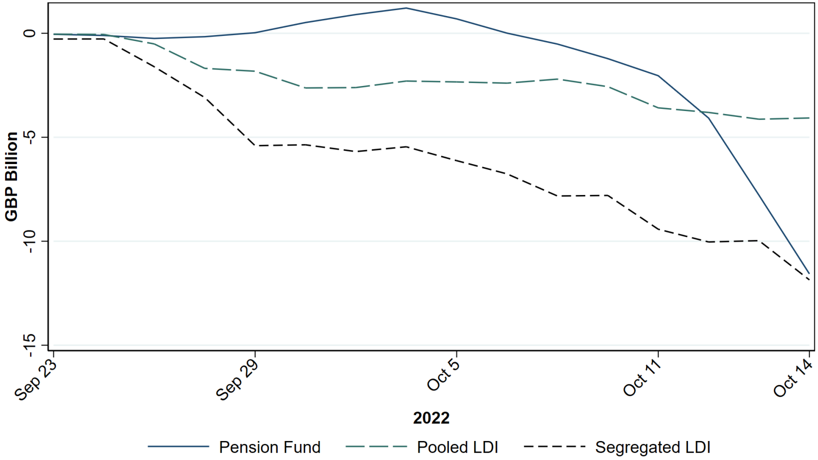
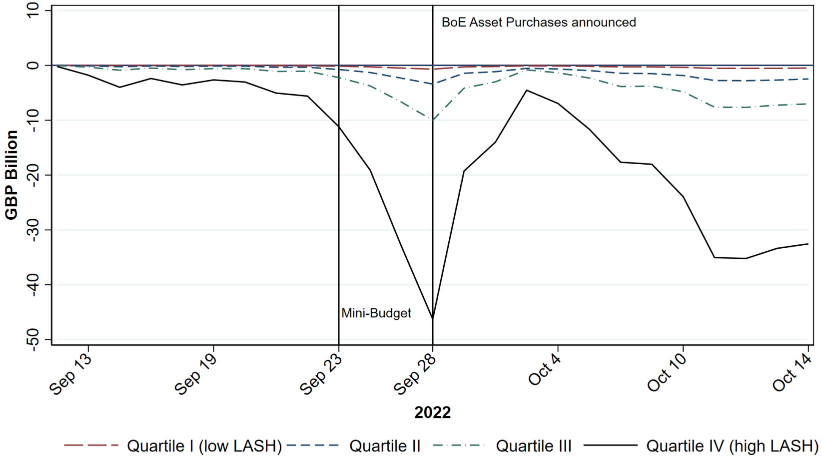


PFLDI Cumulative Gilt Trading Volumes



PFLDI Change in Repo Collateral Value by Pre-crisis LASH Exposure



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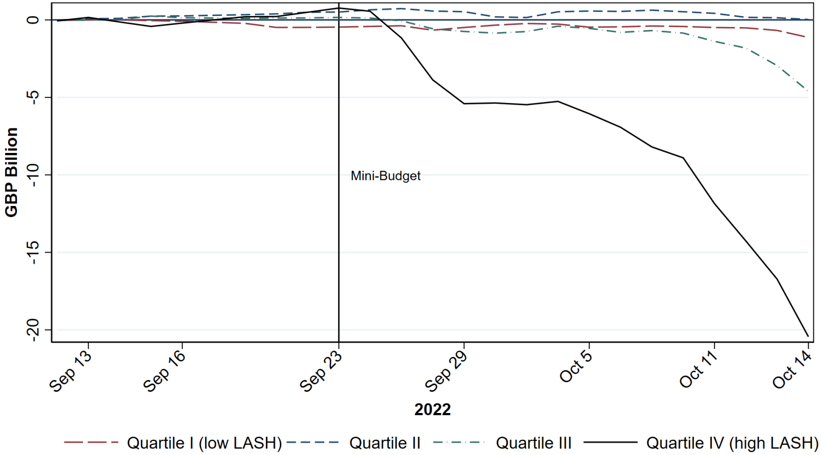
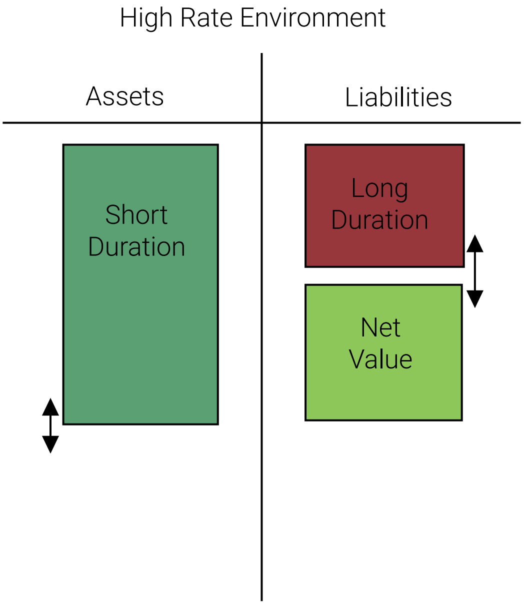


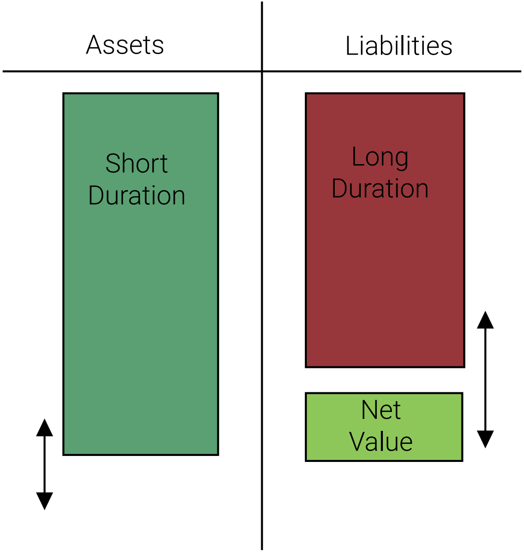
Framework: Interest Rates and LASH Risk Model



Why should low rates raise LASH risk?

Framework: Interest Rates and LASH Risk Model

Low Rate Environment



Why should low rates raise LASH risk?

- A basis point change in rates leads to a bigger impact on valuations when rates are lower (convexity)
  - Mechanical
  - Hedging more valuable
- Net asset values are lower

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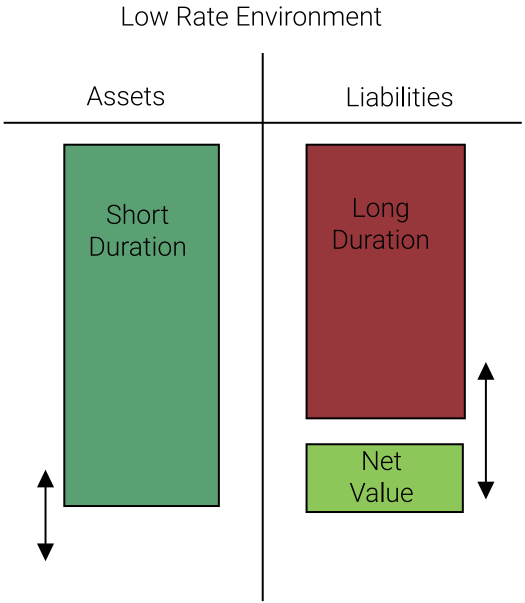

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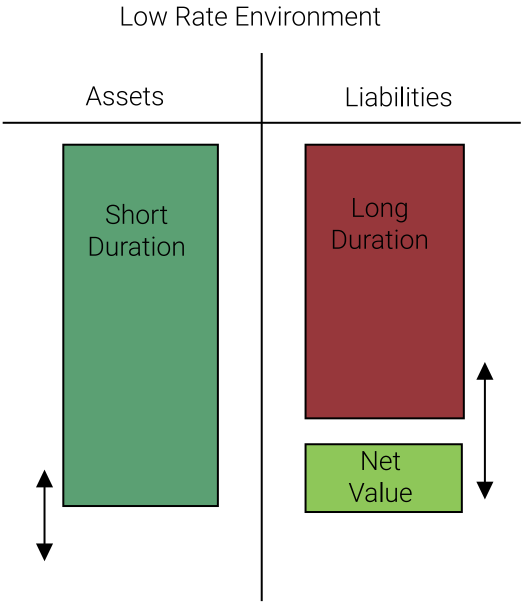

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  - Mechanical
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- Net asset values are lower
  - Kink in payoff around zero NAV
  - Institutional reasons
  - Behavioral (Lian et al., 2021)
  - Effective risk aversion up

Pension Funds' Funding Ratios and Gross Asset Duration

- Is gross asset duration a valid proxy for net duration, i.e. the duration gap?
- We regress pension funds' funding ratios on changes in the 10Y gilt yield, and plot the fund-specific coefficients against their gross asset duration (both standardized)

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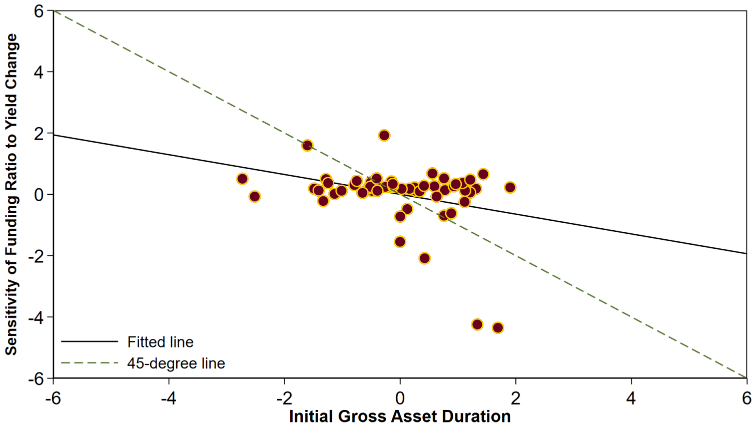

A Model: Net Asset Values and Hedging Demand

- Interest rate risk management problem of a non-bank financial institution (fund), e.g. pension fund or an insurer: Exogenous perpetual liability covered with a portfolio of assets

1. **Asymmetric payoffs:** Reducing a deficit by $1 is more beneficial than increasing a surplus by $1 (e.g. regulatory penalty) → kink in the objective of the fund: effective risk aversion and that motivates the hedging of interest rate risk
2. **Duration mismatch:** Fund only has access to financial assets of shorter duration (Perpetual liability cannot be hedged by a perpetual bond). Derivatives can be used to hedge → fund will choose to the hedge interest rate risk partly through the use of derivatives
3. **Liquid assets are expensive:** Self insure against liquidity needs by holding short duration assets is costly (convenience premium)
4. **Illiquidity of the long duration asset:** Selling the long duration asset requires paying a proportional liquidation cost. → Liquidity needs generated by the hedge cannot be offset without a cost: hold expensive liquid assets or run the risk of liquidating a portion of its long duration portfolio

- Liquidity-solvency trade-off: fund is imperfectly hedged + lower rates worsen the funds financial position
- This pushes the fund closer to the kink in its objective function which, in turn, raises effective risk aversion
- Higher risk aversion raises hedging demand and encourages the fund to take more liquidity risk

Environment

- Investment problem of a non-bank financial institution ("the fund"); $t = 0, 1, \ldots, \infty$.
- Fund's liabilities: perpetuity that require paying a fixed l in every period. Invest in:
  1. one period bond, a_t
  2. a geometrically decaying multi-period bond, b_t, with decay rate δ: i.e. the bond has a coupon b_t in $t+1$ with passive equation of motion $b_{t+1} = \delta b_t$
  3. interest rate swap s_t
- Can't short bonds: $a_t \geq 0$ and $b_t \geq 0$, but the swap position, s_t, can be positive or negative
- Assets are priced by a deep pocketed marginal investor active in the bond and swap markets
  * Investor is competitive, risk neutral and discounts the future at rate R_t^{-1}; evolves according to a first order Markov process, $F(R'|R)$ (also to discount liabilities); R_t^{-1} as i.i.d with mean $\bar{R}^{-1}$
- The marginal investor values the liquidity service from one period bond at rate η (non-pecuniary)

Asset Prices

- q_t^b: price of the geometric bond. The investor values the bond at $q_t^b = \mathbb{E}_t\left[\sum_{j=0} \delta^j \prod_{s=0}^j R_{t+s}^{-1}\right]$
  - i.i.d. case: price equal to $q_t^b = \left(1 - \delta \bar{R}^{-1}\right)^{-1} R_t^{-1}$
- q_t^l: price of a perpetuity paying one every period: $q_t^l = \sum_{j=0}^{\infty} \prod_{s=0}^j \mathbb{E}_t\left[R_{t+s}^{-1}\right]$
  - i.i.d case, price: $q_t^l = \left(1 - \bar{R}^{-1}\right)^{-1} R_t^{-1}$
- Liquidity service implies, price of the short term bond: $q_t^a = R_t^{-1}(1+\eta)$
- Interest rate swaps are priced fairly and have a fixed leg $\mathbb{E}_t\left[R_{t+1}^{-1}\right]$ and floating leg R_{t+1}^{-1}: buying the swap means paying fixed and receiving floating
  - Cashflows from the realised swap position are given by $s_t\left(R_{t+1}^{-1} - \mathbb{E}_t\left[R_{t+1}^{-1}\right]\right)$
- The geometric bond is costly to sell; the fund bears a liquidation cost $q_t^b c$ per unit sold; marginal investor does not discount the value of the bond due to the liquidation cost

Fund Value

- Net asset value of the fund: $w_t = q_t^a a_t + q_t^b b_t - q_t^l l$
- Accounting for liquidity costs, w_t:

$$w_t = a_{t-1} + b_{t-1} - l + q_t^b \delta b_{t-1} + s_{t-1}\left(R_t^{-1} - \mathbb{E}_{t-1}\left[R_t^{-1}\right]\right) - cq_t^b \underbrace{\max\left\{0, \delta b_{t-1} - b_t\right\}}_{\text{sales of geometric bond}} - q_t^l l$$

- No shorting constraint implies that the fund must have sufficient cash on hand from the payments it receives on its assets and bond liquidations to cover its swap position:

$$a_{t-1} + b_{t-1} - l + (1-c)q_t^b \max\left\{0, \delta b_{t-1} - b_t\right\} \geq s_{t-1}\left(\mathbb{E}_{t-1}\left[R_t^{-1}\right] - R_t^{-1}\right)$$

Fund Manager's Objective

- Fund manager is risk neutral, does not enjoy limited liability and receives period compensation (that is negligible compared to the value of the fund) proportional to:

$$\pi_t = w_t + \kappa \mathbf{1}(w_t < 0) w_t$$

- $\kappa > 0$ is a penalty term that incentivizes the manager to avoid deficits
- The fund manager discounts the future at a fixed rate β rather than R_t^{-1}

Fund Manager's Problem

- $\mathcal{S}_t = \{R_t, R_{t-1}\}$: the state of the world at time t. Fund manager's problem can be expressed recursively as:

$$\max_{a_t, b_t, s_t} V(a_{t-1}, b_{t-1}, s_{t-1}; \mathbb{S}_t) = (1 + \kappa \mathbf{1}[w_t < 0])\, w_t + \beta \mathbb{E}\left(V(a_t, b_t, s_t; \mathcal{S}_{t+1})\right)$$

subject to:

$$w_t = q_t^a a_t + q_t^b b_t - q_t^l l,$$

$$q_t^a a_t + q_t^b b_t = a_{t-1} + b_{t-1} - l + q_t^b \delta b_{t-1} + s_{t-1}\left(R_t^{-1} - \mathbb{E}_{t-1}\left[R_t^{-1}\right]\right) - c q_t^b \max\left\{0, \delta b_{t-1} - b_t\right\}$$

- No shorting condition on a_t implies cash flow constraint:

$$(1-c) q_t^b \max\left\{0, \delta b_{t-1} - b_t\right\} \geq \max\left\{s_{t-1}\left(\mathbb{E}_{t-1}\left[R_t^{-1}\right] - R_t^{-1}\right) - a_{t-1} - b_{t-1} + l, 0\right\} \quad (3)$$

- RHS: loss on the swap contract net of the liquidity available to the fund → when positive: the fund needs to liquidate long term assets
- LHS: proceeds from liquidations → when positive (LASH risk materialises) the fund is forced to sell assets at a cost to cover losses on its hedges

Fund Manager's Problem, cont'd

- Fund will only ever liquidate if it is forced to: equation (3) holds with equality
- Flow budget constraint:

$$q_t^a a_t + q_t^b b_t = a_{t-1} + b_{t-1} - l + q_t^b \delta b_{t-1} + s_{t-1}\left(R_t^{-1} - \mathbb{E}_{t-1}\left[R_t^{-1}\right]\right) - \\ - \frac{c}{1-c} \max\left\{s_{t-1}\left(\mathbb{E}_{t-1}\left[R_t^{-1}\right] - R_t^{-1}\right) - a_{t-1} - b_{t-1} + l, 0\right\}$$

1. Fund's exposure to interest rate risk
2. Optimal hedging strategy'
3. Level of interest rates affects the demand for hedging.

Analysis: 1. Funds' Exposure to Interest Rate Risk (Excluding Hedging)

- Fund never hedges ($s_t = 0$):

$$\frac{dw_t}{dR_t^{-1}} = b_{t-1}\frac{dq_t^b}{dR_t^{-1}} - l\frac{dq_t^l}{dR_t^{-1}}$$

- i.i.d. discount factor with unconditional mean $\bar{R}^{-1}$:

$$\frac{dq_t^b}{dR_t^{-1}} = \frac{1}{1-\delta\bar{R}^{-1}}$$

$$\frac{dq_t^l}{dR_t^{-1}} = \frac{1}{1-\bar{R}^{-1}} > \frac{dq_t^b}{dR_t^{-1}}$$

- Unless $w_t \gg 0$, $\frac{dw_t}{dR_t^{-1}} < 0$ (i.e. a fall in interest rates hurts the fund): fund tries to set $s_t > 0$

Analysis: 2.Optimal Hedging Strategy

- Fund's first order condition with respect to s_t:

$$\beta \mathbb{E}_t \left[\frac{d}{ds_t} \left(1 + \kappa \mathbf{1}\left[w_{t+1} < 0\right]\right) w_{t+1} \right] = 0$$

- Conditional expectations on the fund having a deficit, having to liquidate and being exposed to both (deficit and liquidation):

$$\mathbb{E}_t^{\oplus}[.] \equiv \mathbb{E}_t\left[.|w_{t+1} < 0\right],$$

$$\mathbb{E}_t^{\odot}[.] = \mathbb{E}_t\left[.|s_t\left(\mathbb{E}_t\left[R_{t+1}^{-1}\right] - R_{t+1}^{-1}\right) - a_t - b_t + l > 0\right],$$

$$\mathbb{E}_t^{\ominus}\left[.|s_t\left(\mathbb{E}_t\left[R_{t+1}^{-1}\right] - R_{t+1}^{-1}\right) - a_t - b_t + l > 0, w_{t+1} < 0\right]$$

- Define $p_t^{\oplus}$, $p_t^{\odot}$ and $p_t^{\ominus}$ the corresponding probabilities:

$$\frac{\beta c p_t^{\odot}}{1-c}\left(\mathbb{E}_t^{\odot}\left[R_{t+1}^{-1}\right] - \mathbb{E}_t\left[R_{t+1}^{-1}\right]\right) + p_t^{\oplus}\beta\kappa\left(\mathbb{E}_t^{\oplus}\left[R_{t+1}^{-1}\right] - \mathbb{E}_t\left[R_{t+1}^{-1}\right]\right) + \frac{p_t^{\ominus}\beta\kappa c}{1-c}\left(\mathbb{E}_t^{\ominus}\left[R_{t+1}^{-1}\right] - \mathbb{E}_t\left[R_{t+1}^{-1}\right]\right) = 0$$

Analysis: 2. Optimal Hedging Strategy, cont'd

- Absent liquidity costs, the fund would be perfectly hedged against interest rate risk and either set $p_t^{\obar} = 0$ or $\mathbb{E}_t^{\obar}\left[R_{t+1}^{-1}\right] = \mathbb{E}_t\left[R_{t+1}^{-1}\right]$

- $p_t^{\odot} > 0$, perfect hedging is not optimal: insuring all interest rate risk ignores the costs of liquidity risk

- Since the fund is imperfectly hedged, $\frac{dw_t}{dR_t^{-1}} < 0$ and s_t:

$$\left(\mathbb{E}_t^{\obar}\left[R_t^{-1}\right] - \mathbb{E}_t\left[R_t^{-1}\right]\right) > 0$$

- $\longrightarrow$ states of the world where the fund is in deficit are ones where the discount factor is higher than expected (rates lower than expected). Fund will have a liquidity deficit if:

$$s_t\left(\mathbb{E}_t\left[R_{t+1}^{-1}\right] - R_{t+1}^{-1}\right) - a_t - b_t + l > 0$$

$$\mathbb{E}_t^{\odot}\left[R_{t+1}^{-1}\right] - \mathbb{E}_t\left[R_{t+1}^{-1}\right] < 0$$

- Discount rate is low (interest rate high) when the fund faces a liquidity shortfall

Analysis: 2. Optimal Hedging Strategy, cont'd

- How about $p_t^{\ominus}$?
  - Fund faces a deficit and a liquidity shortfall at the same time
  - Only possible if the fund's initial deficit (i.e. $w_t \ll 0$) is so big that even a positive interest rate surprise, which causes a liquidity shortfall, still has the fund in deficit

$$\mathbb{E}_t^{\ominus}\left[R_{t+1}^{-1}\right] - \mathbb{E}_t\left[R_{t+1}^{-1}\right] < 0$$

- Case where $p_t^{\ominus} = 0$ (i.e. $w_t \approx 0$). Then the optimal hedging strategy sets:

$$p_t^{\oplus} \kappa \left(\mathbb{E}_t^{\oplus}\left[R_{t+1}^{-1}\right] - \mathbb{E}_t\left[R_{t+1}^{-1}\right]\right) = p_t^{\odot} \frac{c}{1-c} \left(\mathbb{E}_t\left[R_{t+1}^{-1}\right] - \mathbb{E}_t^{\odot}\left[R_{t+1}^{-1}\right]\right)$$

- The fund trades off the fact that a swap transfers cashflows to states of the world where the fund is in deficit, against the fact that the swap transfers cashflows away from states of the world where the fund has a liquidity shortfall

3. Low Rates and LASH Risk

- The unhedged cashflows generated by the fund are given by

$$a_{t-1} + b_{t-1} - l$$

- Independent of R_t:

$$w_t = q_t^a a_t + q_t^b b_t - q_t^l l$$

- $p_t^{\obar}$, the probability of a deficit, is more sensitive to rates than current cash flows
- Holding s_t fixed, a fall in rates raises $p_t^{\obar}$, (via lower w_t) but it does not have much impact on $p_t^{\odot}$
- LHS side of the hedging optimality condition rises more than the right hand side in response to a fall in rates
    - Fall in rates raises hedging demand

Parameterization Back

Parameter	Description	Value
c	Cost of liquidation	0.015
δ	Decay rate of long term bond	0.91
l	Fund payment to its members at each period	0.04
η	Short term bond premium	0.014
κ	Penalty for fund's deficit	0.3
β	Discount factor	0.96

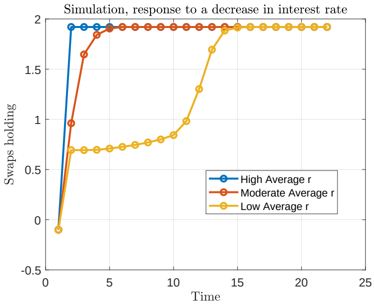

Figure Swap holdings response to a fall in interest rate across different average values for r