Risk Topography for Non-Banks

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Motivation: risk topography

> *The financial crisis of 2007–2008 dramatically revealed that it is time to rethink the measurement of economic activity. In particular, because of derivative securities, off-balance sheet vehicles, and other financial innovations, traditional measures of aggregate risk, such as leverage, are inadequate. It is imperative that we build an economy-wide risk topography, and submaps of different financial sectors of the economy.*

Brunnermeier, Gorton and Krishnamurthy (2012)

- Technological and organizational innovation in financial intermediation poses new challenges to market players and regulators.
- Traditional measures of aggregate risk become insufficient when leverage, liquidity demand and exposures move off balance sheet through derivatives, repos and specialized vehicles.

Why a New Risk Topography?

Structural changes in modern financial intermediation

- Systemic vulnerabilities migrate outside banks. In May 2026 the ECB High-Level Task Force therefore calls for a stronger *macroprudential lens* for NBFIs: leverage, liquidity mismatch and derivatives exposures can amplify shocks through asset sales, margin calls and interconnectedness with banks.

The nature of liquidity crises has changed

- (BoE CP 5/26 Modernising the liquidity policy framework) Advances in digital banking, payments and communication technologies have accelerated the speed of liquidity shocks and runs. Institutions may lack the operational readiness to monetise assets or mobilise collateral quickly enough.
- Prudential policy is therefore shifting from static liquidity buffers toward **liquidity preparedness**: the ability to meet large margin calls and funding needs under stress through robust contingency planning and collateral management.

Today talk

- We adopt a **bottom-up approach** to identify relevant "coordinates" of the emerging risk topography.
- The point of departure is the analysis of **Liability-Driven-Investment vehicles** and their behavior during the UK **gilt crisis**.

Main takeaway

- Forward looking measures can properly account for the liquidity demand contingent on external (interest rate) shocks at the level of individual activities.
- A new entity-based framework is needed to clarify the challenges posed by the institutional configuration of non-banks and a proper definition of liquidity preparedness.
- New tools are needed to produce a quantitative description of the liquidity risks within this broader context and to discipline regulator's intervention.

Organization of the presentation

1. **Empirical analysis**
   - Activity-based analysis: derivatives and forward-looking synthetic leverage.
   - Entity-based analysis: financial frictions, liquidity preparedness and balance-sheet response.
2. **A synthetic LDI fund**
   - Contingency plans to reduce liquidity and solvency risk.
   - Determinants of the liquid price of an illiquid security.
3. **The way forward**
   - Monitoring entity-level preparedness.
   - System-wide stress testing and price impact in thin markets.
   - Operational criteria for central bank and public intervention.

Synthetic Leverage

Consider a receive-fixed/pay-floating IRS

$$\text{Swap position} = \text{Long fixed-rate bond} - \text{Short-term funding}$$

interpret it in terms of a *synthetic balance sheet* of a financial intermediary:

$$A_t = PV_t^{\text{Fixed Bond}}, \qquad E_t = IM_t + VM_t,$$

where:

- A_t = value of the synthetic bond portfolio;
- E_t = liquid capital tied to the position (initial and variation margins).

Definition of Synthetic Leverage (Frazzini–Pedersen) $SL_t := \frac{\partial E_t}{\partial A_t}\frac{A_t}{E_t}$. For a swap, $\frac{\partial E_t}{\partial A_t} \simeq 1$ and $E_t \simeq F_t$ where F_t is the swap value. Hence:

$$\boxed{SL_t^{Swap} \simeq \frac{A_t}{F_t}}$$

Synthetic Leverage: forward looking measure

Assume a parallel yield-curve shock Δy_{t+1}. Then:

The liquidity demanded from the swap seller can be determined, to first order, by:

$$F_{t+1}^{\Delta y_{t+1}} - F_t = SL_{t+1}^{Swap} \times \frac{F_t}{A_t} \times (A_{t+1}^{\Delta y_{t+1}} - A_t) \simeq -\boxed{MD^{Fixed} A_t} \Delta y_{t+1} + O\left((\Delta y_{t+1})^2\right),$$

where MD^{Fixed} denotes the modified duration of the fixed leg of the swap position.

SL follows a mean reverting dynamics with mean reversion determined by the modified duration and by the size of the shock

$$\frac{1}{SL_{t+1}^{Swap}} - \frac{1}{SL_t^{Swap}} \simeq -MD_t^{Fixed} \Delta y_{t+1} \left(1 - \frac{1}{SL_t^{Swap}}\right) \tag{1}$$

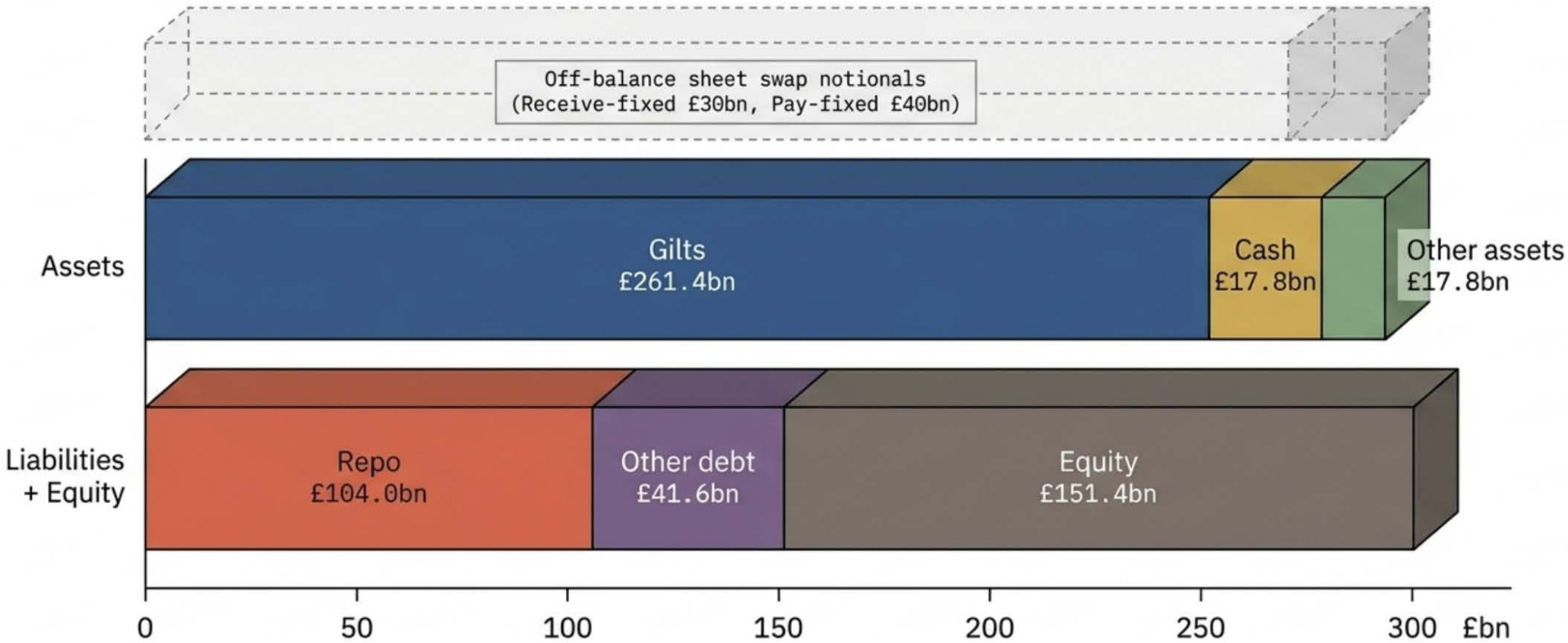
Empirical analysis: where it fits in the risk topography

The empirical section uses GBP-denominated LDI funds as a laboratory for the non-bank risk-topography problem. Three empirical questions organize the discussion:

1. Does synthetic leverage measured at a point in time forecast vulnerability?
2. Does the forward-looking component, $MD_i \times Size_i$, forecast valuation losses?
3. Do liquidity-demand predictors also forecast Gilt sales, or do entity frictions and preparedness break that link?

Anatomy of the Gilt Crisis: The Pre-Shock Setup

LDI Sector Aggregated Balance Sheet (Sept 2, 2022). Highly sensitive, thinly buffered.
Long-duration safe assets funded by short-term repo, amplifed by off-balance-sheet swaps.



Data and identification strategy

- Data combine Irish-authorised investment-fund returns with bond-duration information from ECB sources and external vendors.
- The sample focuses on GBP-denominated LDI funds around the September–October 2022 Gilt stress.
- Funds are classified by their use of direct bond exposure and synthetic swap exposure.
- Controls include fund characteristics, financial leverage through repos, bond-portfolio duration, cash buffers and subscription flows.

Static synthetic leverage is not itself a sufficient forward-looking indicator.

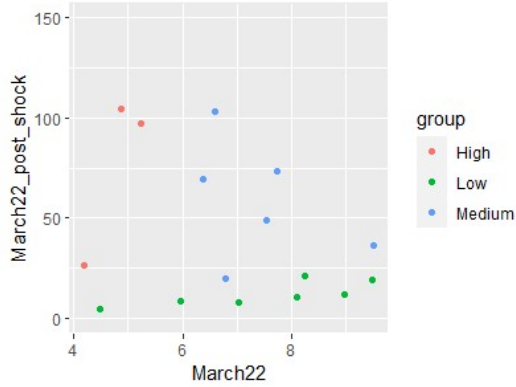


Figure: Synthetic leverage of funds before and after a 65 basis point interest rate shock. Sample of swap-only funds. Elements of terciles corresponding to funds with high-medium-low levels of duration terciles are respectively identified by red-green-blu color bullets. The shock sensitivity is governed by duration, consistent with the derivative-replica formula. Source: MMMIF Return, Central Bank of Ireland; Datastream; Authors' calculations

Forward-looking liquidity demand predicts NAV losses

Regression specification:

$$y_i = \beta_1 MD_i^{Fixed} + \beta_2 Size_i + \beta_3 (MD_i^{Fixed} \times Size_i) + \gamma X_i + \varepsilon_i.$$

Table: Valuation changes to end-Sept. 2022

	Monthly change		
Variable	(1)	(2)	(3)
MD_i	-0.002	-0.003	-0.004
	(0.004)	(0.004)	(0.004)
$Size_i$	0.008	0.019	0.017
	(0.027)	(0.026)	(0.022)
$MD_i \times Size_i$	-0.005**	-0.003	-0.007***
	(0.003)	(0.003)	(0.002)
Fund char.	No	Yes	Yes
Portfolio	No	No	Yes
N	344	344	344
Adj. R^2	0.035	0.140	0.382

Table: Valuation changes to end-Sept. 2022

	Quarterly change		
Variable	(4)	(5)	(6)
MD_i	0.002	0.001	0.000
	(0.003)	(0.003)	(0.002)
$Size_i$	-0.023	-0.025	-0.031**
	(0.020)	(0.019)	(0.014)
$MD_i \times Size_i$	-0.006***	-0.005***	-0.009***
	(0.002)	(0.002)	(0.001)
Fund char.	No	Yes	Yes
Portfolio	No	No	Yes
N	341	341	341
Adj. R^2	0.114	0.263	0.587

Notes: standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

But liquidity-demand predictors do not explain Gilt sales

Table: Gross Gilt sales

Variable	(7)	(8)	(9)
MD_i	-0.003	-0.001	-0.001
	(0.003)	(0.002)	(0.002)
$Size_i$	-0.021	0.000	-0.023
	(0.034)	(0.026)	(0.026)
$MD_i \times Size_i$	-0.001	-0.001	0.001
	(0.004)	(0.003)	(0.003)
Fund char.	No	Yes	Yes
Portfolio	No	No	Yes
N	301	301	301
Adj. R^2	0.005	0.491	0.537

Table: Net Gilt sales

Variable	(10)	(11)	(12)
MD_i	-0.003	-0.003	-0.002
	(0.002)	(0.002)	(0.002)
$Size_i$	0.024	0.022	0.006
	(0.026)	(0.027)	(0.026)
$MD_i \times Size_i$	-0.001	0.000	0.002
	(0.003)	(0.003)	(0.003)
Fund char.	No	Yes	Yes
Portfolio	No	No	Yes
N	301	301	301
Adj. R^2	0.000	0.013	0.189

- Interpretation: the valuation loss is predictable; the cash-equivalent value of Gilt liquidation is not.
- This points to the missing object in the risk topography: state- and entity-specific liquidity weights $\lambda_{\omega}^{A,L}$.

Liquidity preparedness is endogenous

Table: Cash as % of NAV

Variable	(1)	(2)	(3)
MD_i	-0.010	-0.008	-0.004
	(0.007)	(0.007)	(0.006)
$Size_i$	-0.110***	-0.115***	-0.074**
	(0.041)	(0.042)	(0.035)
$MD_i \times Size_i$	0.019***	0.018***	0.016***
	(0.004)	(0.004)	(0.003)
Fund char.	No	Yes	Yes
Portfolio	No	No	Yes
N	344	344	344
Adj. R^2	0.067	0.067	0.355

Table: Net subscriptions as % of NAV

Variable	(1)	(2)	(3)
MD_i	0.002	0.002	0.003
	(0.004)	(0.004)	(0.020)
$Size_i$	0.022	0.015	0.028
	(0.024)	(0.022)	(0.035)
$MD_i \times Size_i$	-0.000	-0.000	0.010**
	(0.002)	(0.002)	(0.005)
Fund char.	No	Yes	Yes
Portfolio	No	No	Yes
N	344	344	344
Adj. R^2	0.001	0.251	0.552

- Funds with higher duration-driven synthetic exposure entered the crisis with larger cash buffers.
- Subscriptions are less robust, but become significant for $MD_i \times Size_i$ once portfolio controls are included.
- This endogenous preparedness helps explain why synthetic leverage is not a robust predictor of Gilt sales.

Why Activity-Based Analysis is Not Enough

Key limitation: The replication argument assumes frictionless access to funding markets.

The synthetic intermediary representation implicitly assumes:

- no borrowing constraints;
- immediate access to contingent liquidity.
- positions obtained from the algebraic decomposition of portfolio strategies are tradable at fair price

Under these assumptions, there is no reason to retain cash.

Liquidity demand can be measured, liquidity preparedness cannot.

Liquidity Mismatch Index and the Entity Perspective

The Liquidity Mismatch Index of Brunnermaier et al. (2012) is defined as

$$LMI_i^{\omega} = \Lambda_A^{\omega} - \Lambda_L^{\omega},$$

with

$$\Lambda_A^{\omega} = \lambda_A^{\omega} CF_A^{\omega}, \qquad \Lambda_L^{\omega} = \lambda_L^{\omega} CF_L^{\omega}.$$

where

- CF_A^{ω} and CF_L^{ω} are asset and liability cash flows;
- λ_A^{ω} and λ_L^{ω} are state-contingent liquidity weights.

The LMI measures the difference between

- market liquidity of assets;
- funding liquidity of liabilities.

LMI is only meaningful at the *entity level* since it depends on the contingent liquidity sources!

A non-bank risk topography.

The non-bank framework is much more heterogeneous and the relevant question becomes:

> Which contingent liquidity sources can be mobilised quickly?

Examples:

- cash buffers;
- subscriptions;
- repo capacity;
- committed funding lines;
- internal transfers of collateral and liquidity;
- equity recapitalization procedures.

Balance-Sheet Segmentation

Two similar institutional configurations:

Insurance company
Liabilities and hedging positions reside on the same balance sheet.

Pension Fund + LDI Vehicle
The pension liabilities remain in the pension fund. The LDI vehicle has short-term liabilities.

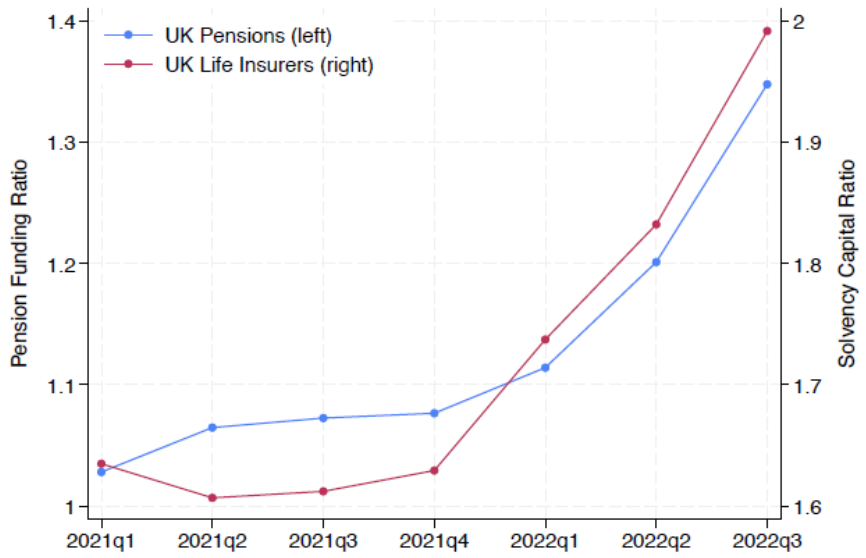
Why did insurers not experience a similar crisis?

In the aggregate, both sectors are effectively negative duration institutions but:

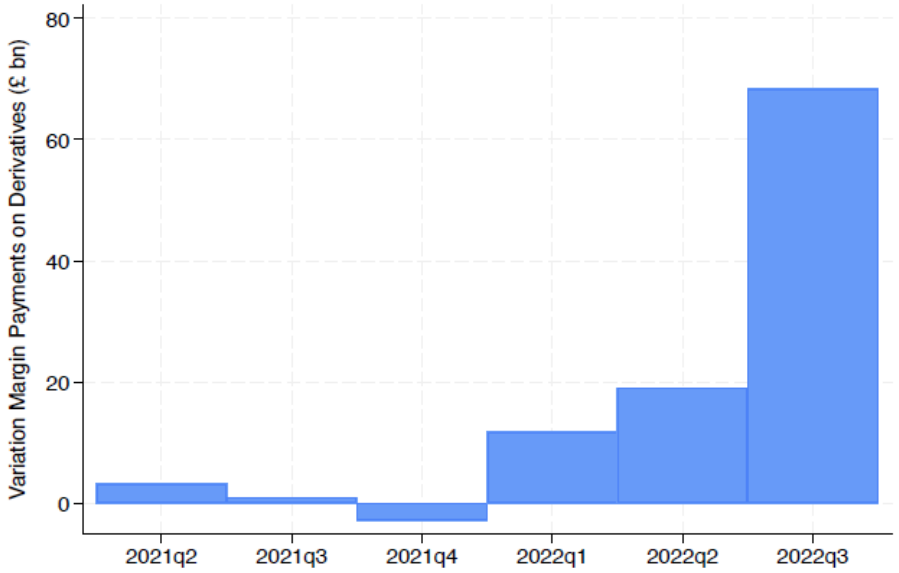
- liquidity demand emerges inside the LDI;
- capital resides outside the LDI;
- transfers require operational and governance processes.

Pension vs Insurers sector

(a) Solvency



(b) Liquidity Needs



Liquidity mismatch is not additive across entities.

Ex-ante, the two institutional configurations are economically equivalent.

$$LMI_{LDI} + LMI_{PF} = LMI_{Life}$$

Life insurer

- Assets and liabilities remain on the same balance sheet.
- Liability values fall more than asset values.

$$\Delta LMI_{\omega}^{Life} > 0$$

Pension fund + LDI

- Pension fund liquidity improves:

$$\Delta LMI_{\omega}^{PF} > 0$$

- LDI vehicle suffers liquidity stress:

$$\Delta LMI_{\omega}^{LDI} < 0$$

Institutional segmentation breaks the additivity of liquidity mismatch:

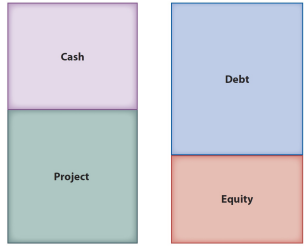
$$\Delta LMI_{\omega}^{LDI} + \Delta LMI_{\omega}^{PF} \neq \Delta LMI_{\omega}^{Life} \tag{9}$$

LMI for an LDI

Key question: *How does balance-sheet liquidity determine the liquid price of an otherwise safe but temporarily illiquid asset?*

Technical challenge: *Compute the LMI index for the LDI vehicle.*

A model inspired by the analysis of Bolton Chen Wang (2024) for non-financial corporations.



A Stylized LDI Balance Sheet and liquidity preparedness

LDI funds (over)simplified balance-sheet structure:

$$\text{Assets} = \underbrace{\ell_0}_{\text{cash}} + \underbrace{h_0}_{\text{Long-Duration illiquid Gilts}}$$

$$\text{Liabilities} = \underbrace{d_0}_{\text{debt (Repo Financing)}} + \underbrace{e_0}_{\text{equity}}$$

Central variable, the liquidity ratio:

$$z_0 = \frac{\ell_0}{h_0}$$

which measures liquid resources relative to illiquid holdings. Low z_0 means low liquidity preparedness. Even small margin calls may force asset sales.

Minimal Model of Optimal LDI Allocation

Objective

- Develop a stylized model of an LDI fund facing a trade-off between:
  - expected return and leverage,
  - liquidity risk and liquidation costs.
- The portfolio contains:
  - a liquid financing leg (cash/debt),
  - an illiquid long-duration asset (Gilts),
  - leverage obtained through short-term funding.
- Illiquid assets cannot be freely liquidated and require a *liquidity discount*.
- Liquidity is summarized by

$$z = \frac{l_0}{h_0},$$

  where l_0 denotes liquid resources and h_0 the illiquid asset position.

Key friction: bringing liquidity onto the balance sheet is costly and generates an endogenous valuation adjustment.

Optimal Allocation and Liquidity Pricing

The fund solves a joint min-max problem. Maximizes mean–variance problem of the pension fund equityholder while minimizing the cost of gilt relative illiquidity:

$$\max_{x_A} \min_{rp_B} \left\{ x_A(\sigma rp_A) + x_B(\beta_A^H \sigma rp_A + \eta\bar{\rho}\, rp_B) - \frac{1}{2}\gamma_{Lev}\sigma^2 x_A^2 + \frac{1}{2\Gamma_{Liq}}(\eta\bar{\rho}\, rp_B)^2 \right\}.$$

First-order conditions

$$x_A^* = \frac{\alpha - r_f}{\gamma_{Lev}\sigma^2},$$

$$\eta\bar{\rho}\, rp_B^* = \Gamma_{Liq}\, x_B.$$

- Optimal leverage depends on the usual risk-return trade-off.
- The liquidity discount rp_B^* increases with the size of the illiquid position.
- Less liquid portfolios require larger valuation haircuts.

Main Analytical Result: Liquidity Fixed Point

Define

$$K^*(z) = \frac{l_0}{l_0 + h_0^{liq,*}},$$

the equilibrium share of liquid wealth.

The FOC imply a fixed-point condition for $K^*(z)$. The unique economically relevant solution is

$$K^*(z) = 1 - \frac{1 + r_f}{2z\Gamma_{Liq}} \left[\sqrt{4z\frac{\Gamma_{Liq}}{1 + r_f} + (1 + z)^2} - (1 + z) \right].$$

- $1 - K^*(z) \to \infty$ when liquidity is exhausted.
- $1 - K^*(z) \to 0$ when liquidity becomes abundant.
- Liquidity conditions endogenously determine the valuation of illiquid assets.

Liquidity Preparedness and Gilt Valuation

The liquid value of the gilt portfolio is

$$p^{Liq} = \frac{h_0^{liq}}{h_0} = \frac{1 + r_f}{1 + r_f + \eta\bar{\rho}\, rp_B}.$$

Using the optimality condition

$$\eta\bar{\rho}\, rp_B^* = \Gamma_{Liq}(1 - K^*(z)),$$

the equilibrium liquid price becomes a function of liquidity preparedness

$$\lambda^{Gilt}(z) = \frac{1}{1 + \frac{\Gamma_{Liq}}{1+r_f}(1 - K^*(z))}.$$

Main implication

Higher (Lower) liquidity preparedness $z = l_0 / h_0$ reduces (increases) the liquidity discount, raises the liquid price of gilts, and mitigates (accelerates) fire-sale losses!

Way forward: Implications for the 2022 LDI Crisis

Model prediction:

$$\Delta y > 0 \Longrightarrow \text{Margin calls} \Longrightarrow z \downarrow \Longrightarrow \lambda^{Gilts} \downarrow$$

Empirical evidence:

- Repo top-ups and variation margin generated large liquidity outflows.
- LDI funds sold Gilts to restore liquidity.
- Fire-sale discounts rose from 0% to roughly 9% within 3 days.

$$d_t = \{0,\ -2.8\%,\ -6.9\%,\ -9.3\%\}$$

Main takeaway

The (demanded) liquid price of an illiquid asset is jointly determined by liquidity preparedness, leverage and liquidation costs.

Way forward: Conclusions and open (policy) problems

- The above discussion highlights that liquid-value of illiquid securities is entity-based, i.e. it critically depends depends on the contingent liquidity plans of financial intermediaries
- The conventional signal of a (possibly systemic) liquidity crisis for a financial institution, i.e. $LMI < 0$, seems to be ineffective in this framework, due to the non-linear accelerating dynamics of fire sales.

