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Quantitative and Macro Research Division



LASH RISK

Liquidity after Solvency Hedging risk

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Abstract

Liquidity After Solvency Hedging (LASH) risk arises when non-bank financial institutions hedge long-duration liabilities with derivatives that improve solvency but create short-term liquidity needs through margining and collateral requirements. This paper develops a stylized model of a pension fund or insurer that chooses between (i) a liquid short-term bond that carries a liquidity premium, (ii) a medium-duration bond that is costly to liquidate, and (iii) interest-rate swaps that hedge duration risk but generate variation margin outflows when rates rise. The model delivers three predictions: funds hedge interest-rate risk only partially; optimal hedging increases when interest rates are low; and sufficiently large rate increases trigger forced sales of medium-duration assets even when net worth improves, generating fire-sale dynamics in solvent states. We then describe how to map the model to UK data sources, including MiFID II gilt transactions, sterling repo transactions (SMMD), and EMIR swap positions, and outline a measurement approach in which contract-level LASH is proxied by interest-rate sensitivity (DV01) under near one-for-one margin pass-through. Together, the framework clarifies why low-rate environments can build up latent liquidity fragility that materializes during rapid rate increases.

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1 Introduction

This project investigates a distinct form of financial vulnerability known as Liquidity After Solvency Hedging or LASH risk. This phenomenon primarily affects non-bank financial institutions, such as pension funds and insurers, which typically hold portfolios characterized by long duration liabilities and shorter duration assets. Due to this duration mismatch, these institutions face solvency risks when interest rates fall, prompting them to hedge using derivative contracts like interest rate swaps. In particular, LASH risk materializes specifically when the institution's solvency improves due to rising interest rates as, while the fund's fundamental health strengthens, the value of their hedging swap falls, triggering immediate liquidity needs. Consequently, if interest rates rise sharply, the immediate cash obligations can exceed the institution's available liquid holdings, forcing costly asset sales and potentially amplifying a liquidity crisis even as the institution's solvency technically improves.

The emergence of LASH risk is driven by four empirical constraints that will be examined in depth further in the paper:

- institutions face costly penalties for insolvency, driving the desire to hedge;
- institutions can only hedge duration risk using derivatives that require margin and generate liquidity risk;
- holding liquid assets to cover these margins comes with a premium, preventing full self-insurance against the risk;
- the fund can hold medium-duration assets, which have a higher return than liquid assets but incur a liquidity cost when sold.

2 The environment of the fund

In our model, we consider the investment problem of a non-bank financial institution (fund), e.g., a life insurer or pension fund. Time runs from $t = 0, 1, \dots, \infty$. Furthermore, the fund is endowed with a fixed, perpetual liability, l , that must be paid by the fund every period.

In our model the assets the fund can hold are priced by an investor who is risk neutral, competitive, and discounts the future at rate R_t^{-1} , which is the interest rate at time t .

The fund can hold three types of assets:

1. One-period bond

The bond is purchased at time t and pays the coupon a_t at time $t + 1$. The investor values the liquidity service provided by the one-period bonds at η , which is non-pecuniary. The fund does not share this non-pecuniary value. Therefore, the price of a one-period bond is:

$$q_t^a = R_t^{-1}(1 + \eta) \quad (1)$$

2. Medium-duration asset

In the model this asset is represented as a geometrically decaying multi-period bond, with the decay rate $\delta \in (0, 1)$. The fund in time t holds b_t units of the bond, which pays a coupon b_t in the period $t + 1$. The passive equation of the bond, according

to which it evolves overtime is: $b_{t+1} = \delta b_t$. The price of the bond is determined according to the following equation:

$$q_t^b = \mathbb{E}_t \left[\sum_{j=0}^{\infty} \delta^j \prod_{s=0}^j R_{t+s}^{-1} \right] \quad (2)$$

Importantly the fund also faces a significant cost of liquidation of the bond, which is represented by a constant share c of the value of the bond, which the investor disregards.

In this case a risk-free perpetuity, that is, a bond paying 1 every period is:

$$q_t^l = \mathbb{E}_t \left[\sum_{j=0}^{\infty} \prod_{s=0}^j R_{t+s}^{-1} \right] \quad (3)$$

3. Interest rate swaps

The fund hold s_t amount of swaps, and its value can be both positive and negative. A swap lasts for one period only, and is priced fairly. The swap has 2 legs a fixed and floating leg. The fixed leg is $\mathbb{E}(R_{t+1}^{-1})$, which is payed by the buyer when the swap contract settles in period $t + 1$. The floating leg is: R_{t+1}^{-1} , which the buyer recievs when the contract settles in period $t + 1$. Therefore, the realized cash flow from an interest rate swap in period $t + 1$ is:

$$R_{t+1}^{-1} - \mathbb{E}(R_{t+1}^{-1}) \quad (4)$$

If the cash flow is positive, that is, there is an unexpected rise in the interest rate, the fund gets payed. However, if it is negative and there is an unexpected decrease in interest rates the fund must pay the absolute value of the cash flow. This loss is called variation margin.

Additionally, the fund in our model cannot short bonds, therefore, it must be true that $a_t \geq 0$ and $b_t \geq 0$.

3 Constraints: Net Wealth and Liquidity

The evolution of the net wealth (or net asset value) of the fund, after accounting for liquidity costs at time t , is given by:

$$\begin{aligned} w_t = & a_{t-1} + b_{t-1} - l + q_t^b(\delta b_{t-1}) \\ & + s_{t-1}(R_t^{-1} - \mathbb{E}_{t-1}[R_t^{-1}]) \\ & - c q_t^b \max\{0, \delta b_{t-1} - b_t\} - q_t^l l. \end{aligned} \quad (5)$$

where:

- w_t : net wealth (net asset value) of the fund at time t .
- a_{t-1} : holdings of short-term (one-period) bonds from the previous period, which pay total coupon of a_{t-1} in t .
- δb_{t-1} : value of bond holdings b_t , where: b_{t-1} : holdings of medium-duration bonds at $t - 1$, with coupons b_{t-1} in t ; δ : decay rate of the medium-duration bond ($0 < \delta < 1$).
- l : fixed perpetual liability payment each period.
- q_t^b : price of the geometrically decaying medium-duration bond.
- s_{t-1} : position in interest rate swaps (positive if receiving fixed, paying floating).
- $R_t^{-1} - \mathbb{E}_{t-1}[R_t^{-1}]$: unexpected movement in the inverse of the interest rate between $t - 1$ and t .
- c : proportional cost of liquidating the medium-term bond (liquidity cost parameter).
- q_t^l : price of a perpetuity paying one unit each period, representing the discounted value of liabilities.

The first three terms represent the inflows from bond holdings and liability payments. The fourth term, $q_t^b(\delta b_{t-1})$, accounts for the change in value of the medium-term bond. The fifth term, $s_{t-1}(R_t^{-1} - \mathbb{E}_{t-1}[R_t^{-1}])$, captures the profit or loss from the previous-period interest rate swap: it is positive when rates fall (hedge payoff) and negative when rates rise (margin call). The sixth term represents liquidation costs from selling medium-term bonds and the last term deducts the continuation value of the long-term liabilities.

The fund faces the following liquidity constraint:

$$(1 - c)q_t^b \max\{0, \delta b_{t-1} - b_t\} \geq -\min[m_t, 0], \quad (6)$$

where

$$m_t = a_{t-1} + b_{t-1} + s_{t-1}(R_t^{-1} - \mathbb{E}_{t-1}[R_t^{-1}]) - l \quad (7)$$

m_t denotes the liquid resources available to the fund. If $m_t < 0$, the fund must sell medium-term assets to raise liquidity, incurring the proportional cost c .

When interest rates fall, the liability value rises, worsening solvency, but the swap value increases, improving net wealth. When interest rates rise, the swap loses value, requiring margin payments, liquidity deteriorates even as solvency improves. This interaction embodies the core of LASH risk, where hedging strategies create liquidity needs precisely when solvency strengthens.

4 Assumptions

The following are the primitives and restrictions that deliver an interior hedging choice and the three model predictions.

Assumption 1 (Primitives: assets, prices, frictions) *Time is $t, t+1$. The fund holds a one-period short bond a_t , a geometric medium-duration bond b_t with passive law $b_{t+1} = \delta b_t$ for $\delta \in (0, 1)$, and a one-period interest-rate swap s_t . Bond shorting is not allowed ($a_t, b_t \geq 0$); $s_t \in \mathbb{R}$. The short bond carries a liquidity premium $\eta > 0$. Selling the medium bond is costly: liquidating $\Delta b_t > 0$ incurs proportional cost $c \in (0, 1)$. Swaps are fairly priced and fully variation-margined; realized P&L at $t+1$ is $s_t(R_{t+1}^{-1} - {}_t[R_{t+1}^{-1}])$. Prices for the marginal investor are*

$$q_t^b = {}_t \left[\sum_{j \geq 0} \delta^j \prod_{s=0}^j R_{t+s}^{-1} \right], \quad q_t^l = {}_t \left[\sum_{j \geq 0} \prod_{s=0}^j R_{t+s}^{-1} \right], \quad q_t^a = R_t^{-1}(1 + \eta).$$

Assumption 2 (Interest-rate process) *The one-period discount factor follows*

$$R_{t+1}^{-1} = R_t^{-1} + \varepsilon_{t+1}, \quad \varepsilon_{t+1} \in [\varepsilon_\ell, \varepsilon_h],$$

with mean zero, bounded support whose density vanishes at the bounds, and $R_{t+j} = \bar{R}$ for $j \geq 2$ (risk confined to $t+1$). Under this process, $q_{t+1}^b(\varepsilon) = \frac{\varepsilon + R_t^{-1}}{1 - \delta \bar{R}^{-1}}$ and $q_{t+1}^l(\varepsilon) = \frac{\varepsilon + R_t^{-1}}{1 - \bar{R}^{-1}}$.

Assumption 3 (Objective and horizon) *The manager is risk-neutral with a shortfall penalty $\kappa > 0$ and chooses (a_t, b_t, s_t) to*

$$\max E_t[(1 + \kappa \mathbf{1}\{w_{t+1} < 0\}) w_{t+1}]$$

subject to the wealth recursion and liquidity constraint from Sections 2–3, with a one-step horizon $T = t+1$.

Assumption 4 (Interior solvency region & small liquidation cost) *Define the unhedged continuation value*

$$y_{t+1}(\varepsilon) \equiv b_t - l + q_{t+1}^b(\varepsilon) \delta b_t - q_{t+1}^l(\varepsilon) l.$$

Require: (i) $y_{t+1}(0) > 0$ and $y_{t+1}(\varepsilon_h) < 0$ (solvent at expected rates, insolvent after a large rate fall); (ii) $c < \frac{y_{t+1}(0)}{y_{t+1}(0) - y_{t+1}(\varepsilon_h)}$ (optimal liquidations never induce insolvency).

Assumption 5 (Restrictions used for predictions) *(i) The liquidity premium η on the short asset is sufficiently high (self-insurance via a_t is limited). (ii) The upper-tail realization of the rate increase is sufficiently large; a convenient sufficient bound is*

$$\varepsilon_\ell < \frac{b_t - l}{y_0/\varepsilon_h + y_1}, \quad \text{for } y(\varepsilon) = y_0 + y_1 \varepsilon, \quad y_0 > 0, \quad y_1 < 0,$$

ensuring a positive threshold shock that triggers $m_{t+1} < 0$ while w_{t+1} exceeds its level at $\varepsilon = 0$.

5 Objective function of the fund and its optimization problem

A fund manager is in charge of the fund until an exogenous period T . The fixed investment horizon is helpful for tractability. When the model horizon is infinite, the manager discounts the future and is compensated in proportion to the fund's current value; every period delivers results similar to those in the finite-horizon case. Additionally, the manager is risk neutral, does not enjoy limited liability, and receives compensation in period T (that is negligible to the value of the fund) proportional to:

$$\pi_T = (1 + \kappa \mathbf{1}\{w_T < 0\})w_T. \quad (8)$$

The fund manager maximizes their objective function (9) by choosing holdings of swaps, short and medium-term bonds $\{s_t, a_t, b_t\}_{t=0}^T$ subject to the law of motion for net worth, which is the equation specifying the evolution of the fund's value (6), the liquidity constraint of the fund (8), and the no-shorting requirement, meaning $a_t, b_t \geq 0$. Moreover, the marginal value to the fund manager of increasing wealth is linear, and the marginal value of greater wealth when the fund is in deficit because $\kappa > 0$.

Define the risk of insolvency by $w_{t+1} < 0$ and the risk of illiquidity by $w_{t+1} > 0$. The paper's objective, therefore, is to represent the tradeoff between hedging against solvency risk and hedging against liquidity risk.

Full FOC:

$$P(w_{t+1} < 0) \mathbb{E}[\varepsilon_{t+1} \mid w_{t+1} < 0] = \frac{c}{1-c} P(m_{t+1} < 0) \mathbb{E}[-\varepsilon_{t+1} \mid m_{t+1} < 0]. \quad (9)$$

Equates the Marginal benefit of hedging against solvency with the marginal loss of hedging against solvency. Equates the benefit of putting one more unit into the swap trade with the loss of putting one more unit into the swap trade. Shows the fund's incentive to trade off solvency risk against liquidity risk.

LHS of the FOC:

$$\text{LHS} = \kappa P(w_{t+1} < 0) \mathbb{E}[\varepsilon_{t+1} \mid w_{t+1} < 0]. \quad (10)$$

The term before the equality is the marginal value of holding swaps in states of the world in which the fund has a negative solvency, hence $w_{t+1} < 0$. Therefore it shows the benefit of holding swaps, by reducing insolvency when rates fall.

- κ : parameter denoting the willingness of the manager to take extreme actions to avoid insolvency. The higher κ , the larger the swap positions, hence larger gains if rates don't rise.
- $P(w_{t+1} < 0)$: probability that next period's net worth is negative (insolvency likelihood). According to the paper, interest rates evolve stochastically $R^{-1}t + 1 = R^{-1}t + \varepsilon_{t+1}$, the fund's wealth depends on that shock $w_{t+1} = f(\varepsilon_{t+1})$. Therefore the MB of hedging against insolvency risk is greater, the greater the risk of insolvency is. This is the case since the hedge pays off in a larger set of states, following the higher probability of insolvency in more states.

- $\mathbb{E}[\varepsilon_{t+1} \mid w_{t+1} < 0]$: Expectation, conditional on insolvency in the future period of an interest rate shock. The question is: "given the fact that the fund is insolvent in the next period, what is the average interest rate shock that leads to this state?". And the greater the average shock is, the more the fund is going to benefit from it, since, as already stated, the wealth is decreasing in the rates.

RHS of the FOC:

When interest rates rise $R_{t+1} > R_t$, the fund has a loss position in the swap trade and therefore has to liquidate medium-term assets. We hereby, therefore, want to model the risk of overinvesting/misinvesting in the swap trade, hence the risk coming from overhedging.

$$\frac{c}{1-c} P(m_{t+1} < 0) \mathbb{E}[-\varepsilon_{t+1} \mid m_{t+1} < 0] \quad (11)$$

- $\frac{c}{1-c}$: Liquidation cost multiplier. When interest rates rise, the fund needs to liquidate short term assets, as it now holds a negative position in the swap trade. However, there are transaction costs associated to this operation, which are measured by the term.
- $P(m_{t+1} < 0)$: This term measures the probability that the fund goes illiquid in the next period. This risk is associated to the stochastic behavior of the interest rates $R_{t+1} > R_t$, where the term measures the probability of the event to occur hence that rates will rise in the next period.
- $\mathbb{E}[-\varepsilon_{t+1} \mid m_{t+1} < 0]$: Expectation of an interest rate shock, given that this has to cause illiquidity. It measures the average size of the interest rate shock in the states of the world where the fund goes illiquid.

6 Predictions derived from the FOC

Three main predictions can be derived from the first-order conditions previously described.

These predictions also require Assumption 1 to hold, the liquidity premium η on the short-run asset to be sufficiently high, and

6.1 Prediction 1

The fund will partially hedge interest rate risk: the fund will choose an optimal level of hedging $s_t > 0$, but solvency risk will remain positive, so that $\Pr(w_{t+1} < 0) > 0$.

This prediction implies that the fund only partially hedges interest rate risk, accepting some solvency risk to not take on too much LASH risk.

Large *falls* in rates (large positive ε_{t+1}) drive the fund insolvent, while large *increases* in rates (large negative ε_{t+1}) create liquidity shortfalls by generating losses on the swap. LASH risk is present because the same hedge that mitigates insolvency risk also creates states in which assets must be liquidated.

6.2 Prediction 2

If the interest rate R_t is lower, then the optimal level of hedging s_t increases.

The second prediction is a comparative static:

$$R_t \downarrow \Rightarrow s_t^* \uparrow.$$

Intuitively, because the fund only partially hedges, a fall in rates worsens solvency even before the hedge is adjusted: the present value of the long-duration liability rises more than the present value of the shorter-duration assets, so $y_{t+1}(\varepsilon_{t+1})$ shifts downward. Formally, for any given s_t this has two effects on the left-hand side of the FOC: it (i) increases $\Pr(w_{t+1} < 0)$, since more states of the world now lead to negative net worth, and (ii) increases the conditional expectation $\mathbb{E}[\varepsilon_t + 1 \mid w_{t+1} < 0]$, because the insolvency region shifts towards smaller interest rates (larger ε_{t+1}). The right-hand side of the FOC, which depends on the liquidity region $\{m_{t+1} < 0\}$, is essentially unaffected by small changes in the level of the rate.

This means that, when rates are low and solvency risk is more acute, the FOC can only be restored by raising s_t , i.e. increasing the hedge and thereby raising exposure to future margin calls and LASH risk.

6.3 Prediction 3

There exists a positive threshold realization of the interest rate shock ε_{t+1} such that, if the shock exceeds that threshold, the fund will sell medium-duration assets. At this threshold, net worth w_{t+1} is positive and greater than if rates equal their expected level.

Finally, the third prediction formalizes the idea of a “liquidity crisis”, by saying that sufficiently large increases in interest rates trigger liquidity crises even though they improve the fund’s solvency.

Formally, we can write that for a given $s_t^* > 0$, define the threshold shock $\bar{\varepsilon}_t$ such that

$$m_{t+1} = b_t + s_t^* \bar{\varepsilon}_t - l = 0. \tag{12}$$

For shocks $\varepsilon_{t+1} > \bar{\varepsilon}_t$, the loss on the swap is so large that the required margin payment exhausts the fund’s liquid assets, forcing it to sell medium-duration bonds and incur the cost c .

Thus, when rates rise sufficiently, the fund experiences a liquidity-driven fire sale of assets even though its solvency has improved relative to the benchmark with unchanged rates. This is exactly the LASH mechanism: liquidity crises arise in good solvency states because previous solvency hedges generate large margin calls.

7 Data Sources and Mapping to the Model

This subsection describes the datasets used to measure LASH risk and explains how each dataset maps to the theoretical objects in the model. Together, these data allow measurement of LASH at the contract, institution, and system-wide levels.

7.1 Gilts / Bond Market (MiFID II)

The MiFID II transaction data provide a trade-by-trade view of the UK gilt market. For each transaction in a government bond, the dataset records the execution time (date and timestamp), the ISIN identifying the specific gilt, the execution price, the transaction size (volume or notional traded), and the identities of the buyer and the seller.

In the theoretical framework, the medium-duration bond position b_t represents the tradable fixed-income asset that can be liquidated to meet liquidity needs, subject to liquidation costs. Gilts in the MiFID II data are the direct empirical counterpart of b_t : they are long-duration government bonds held by pension funds and LDI vehicles, and they are precisely the instruments sold when liquidity stress materialises.

The transaction-level gilt data are essential for the empirical analysis for three main reasons. First, they allow measurement of realised bond sales and purchases by sector or institution, enabling tests of whether entities with higher pre-crisis LASH exposure sell more gilts when interest rates rise. Second, bond-level regressions of yield changes on gilt-specific selling pressure rely on accurate measures of prices and net traded volumes; without transaction-level data it would be impossible to quantify how LASH-induced liquidation of b_t translates into higher gilt yields. Third, combining ISINs and prices with information on maturities and coupons allows construction of duration measures for bond portfolios, which are needed to map from holdings of gilts to interest-rate sensitivity in the model.

7.2 Repo Market (SMMD)

A repurchase agreement (repo) is a collateralised loan in which one party temporarily sells a security, typically a long-term gilt, to another party and simultaneously agrees to repurchase it at a future date for a higher price.

Economically, the borrower receives cash today and agrees to repay cash plus a repo interest rate, while continuing to earn the fixed coupon on the underlying bond. Borrowing short term against a long-term bond in this way closely replicates the payoff of paying a floating rate and receiving a fixed rate, and thus resembles an interest rate swap.

The Sterling Money Market Data (SMMD) provide transaction-level information on repo trades in sterling markets. For gilt repos, the dataset contains the identities of the counterparties, the ISINs of the collateral securities, the transaction size, and the pricing terms that embed the repo rate. These variables make it possible to observe how much each institution borrows via repo, against which specific gilts, and under what conditions.

Repos generate liquidity risk and LASH because collateral values and margin requirements are sensitive to interest rates. When yields rise, gilt prices fall, reducing the value of collateral posted under repos. Standard margining practices then require additional collateral or cash to be posted. Thus, a strategy that reduces duration mismatch by financing with repos simultaneously generates liquidity outflows precisely in states where solvency improves, since higher discount rates reduce the present value of long-duration liabilities. This mechanism is a defining feature of LASH risk: liquidity stress arising *after* solvency has been hedged.

7.3 Interest Rate Swaps (EMIR: IRS & OIS)

An interest rate swap (IRS) is a contract in which two parties exchange a fixed interest rate for a floating rate (such as LIBOR, SOFR, or SONIA) on a notional principal Q .

Payments are exchanged c times per year over m years, and only the net interest difference is settled. The fixed rate is set such that the net present value (NPV) of the swap is zero at inception. To mitigate counterparty risk, positions are collateralised with initial margin posted at inception and variation margin exchanged as market values change.

An overnight index swap (OIS) is a specific type of IRS in which the floating leg is linked to an overnight index. The OIS yield curve is typically used as the risk-free discount curve. In the empirical analysis, both GBP IRS and GBP OIS contracts are observed, with the OIS curve providing discount factors for valuation and sensitivity analysis.

Swap positions are observed in EMIR trade repository data. At the trade level, the dataset contains the notional amount, maturity, direction of the position (pay or receive fixed), the floating-rate index, currency, execution date, and counterparty identities. Given notional, maturity, and direction, each contract's NPV and its sensitivity to yield changes can be computed.

In the model, the swap position s_t is the primary hedging instrument used to reduce the duration mismatch between long-term liabilities and shorter-term assets. Receiving fixed and paying floating hedges solvency risk from interest-rate declines. However, when rates rise, the value of a receive-fixed position falls, generating variation margin outflows that must be met using liquid resources or by selling bonds. Thus, s_t captures the hedging choice that improves solvency while embedding LASH risk. The EMIR data provide the inputs needed to quantify this exposure and compute contract-level DV01s and associated liquidity demands.

7.4 Pension Fund Balance Sheets

Pension fund balance-sheet data report, for each fund and year, key items on both sides of the balance sheet. On the asset side, these include total assets, cash and cash-like instruments, bond holdings, and derivative positions. On the liability side, the data include actuarial liabilities, reflecting the present value of promised benefit payments.

These variables allow construction of empirical measures of solvency and liquidity buffers. Solvency is captured by the funding ratio, defined as actuarial assets divided by actuarial liabilities. This measure is the empirical analogue of model net worth w_t ,

$$w_t = q_t^a a_t + q_t^b b_t - q_t^l l, \quad (13)$$

which reflects the discounted value of assets relative to liabilities.

Liquidity buffers are measured by cash and other highly liquid assets. These are the resources available to meet margin and collateral calls without selling less liquid assets such as gilts. Comparing cash buffers to LASH exposures from swaps and repos allows identification of institutions that are solvent but liquidity constrained, as opposed to those that are both illiquid and insolvent.

7.5 Yield Curves and Duration Inputs

LASH risk for a contract i is defined by the liquidity that must be raised following an interest-rate movement. For a small parallel shift in the yield curve,

$$\text{LASH}_{i,t} \approx \Lambda_i \frac{\partial \text{NPV}_{i,t}}{\partial R_t}, \quad (14)$$

where Λ_i captures how closely margin or collateral requirements track changes in market value, $\text{NPV}_{i,t}$ is the contract's net present value, and $\partial \text{NPV}_{i,t} / \partial R_t$ is its dollar duration (DV01).

Computing NPVs and DV01s requires full yield curves. For swaps, the OIS curve provides discount factors and forward rates used to value fixed and floating legs. For bonds used as repo collateral, the gilt yield curve determines the present value of coupon and principal cash flows.

Modified duration is central to measuring LASH. For a bond, modified duration D^* relates yield changes to price changes via

$$\frac{\Delta P}{P} \approx -D^* \Delta R, \quad (15)$$

so the dollar change in value is approximately $-PD^*\Delta R$. When the bond is used as repo collateral, this value change determines the additional collateral or margin required. For swaps, DV01 plays the same role by mapping yield movements into variation margin flows.

Thus, yield curves are required to discount cash flows and compute NPVs, while modified duration and DV01 translate interest-rate shocks into concrete, currency-denominated liquidity needs.

8 Measurement of LASH

We define LASH risk as the liquidity that must be raised mechanically when interest rates move, due to margin and collateral requirements on hedging instruments. Therefore, we measure it by quantifying how much liquidity must be raised when interest rates move, due to margin and collateral requirements on hedging instruments. For a given hedging contract i , LASH is defined as

$$\text{LASH}_{i,t} \approx \Lambda_i \frac{\partial \text{NPV}_{i,t}}{\partial R_t}, \quad (16)$$

where R_t denotes a shift in the relevant yield curve. This expression decomposes LASH into three components:

1. $\text{NPV}_{i,t}$, the net present value of the contract;
2. $\partial \text{NPV}_{i,t} / \partial R_t$, the sensitivity of that value to interest rates, also referred to as dollar duration or DV01;
3. Λ_i , a mapping coefficient translating changes in market value into actual liquidity outflows through margin or collateral requirements.

Interest Rate Swaps. Consider a fixed-for-floating interest rate swap with notional Q , maturity T , fixed rate $\bar{r}$, payment frequency c , forward floating rates $r_{k,k-1}$, and discount factors d_k . From the floating-rate payer's perspective, the net present value of the swap is

$$\text{NPV} = \text{PV}^{\text{fixed}} - \text{PV}^{\text{float}} = \frac{Q}{c} \sum_{k=1}^{cT} d_k (\bar{r} - r_{k,k-1}). \quad (17)$$

At inception, the fixed rate $\bar{r}$ is chosen so that the swap has zero NPV. Subsequent movements in interest rates change the value of the contract. In particular, when rates rise, the value of receiving fixed declines, generating a negative change in NPV. Under standard clearing arrangements, this loss must be covered through variation margin, implying a direct liquidity outflow equal to $-\Delta\text{NPV}$.

Repos. For a repurchase agreement backed by a government bond b , the economically relevant NPV is simply the market value of the collateral,

$$\text{NPV}_{i,t}^{\text{repo}} = P_{b,t}. \quad (18)$$

Because haircuts on gilt repos are typically very small and the financing leg is close to risk free, a decline in the bond price translates almost one-for-one into additional collateral or margin requirements. As a result, changes in collateral value directly generate liquidity needs.

DV01 and Duration. The derivative

$$\frac{\partial \text{NPV}_{i,t}}{\partial R_t} \quad (19)$$

is the contract's dollar duration or DV01, defined as the change in market value associated with a one-basis point parallel shift in interest rates.

Appendix D shows that, for repos backed by bond b , LASH can be written as

$$\text{LASH}_{i,t}^{\text{repo}} = \frac{Q_{i,t}}{100} D_{b,t}^{\text{mod}}, \quad (20)$$

so that the DV01 of the repo exposure is

$$\text{DV01}_i^{\text{repo}} = \frac{Q_{i,t}}{10,000} D_{b,t}^{\text{mod}}, \quad (21)$$

where $D_{b,t}^{\text{mod}}$ denotes the modified duration of the collateral bond.

For interest rate swaps, Appendix D derives

$$\frac{\partial \text{NPV}}{\partial r} = -\frac{Q}{c} \sum_{k=1}^{cT} \left[d_k + \frac{k}{c} d_k (\bar{r} - r_{k,k-1}) \right], \quad (22)$$

and defines the LASH associated with a 100 basis point yield increase as

$$\text{LASH}_{i,t}^{\text{IRS}} = \frac{Q_i}{100c} \sum_{k=1}^{cT} \left[d_k + \frac{k}{c} d_k (\bar{r}_i - r_{k,k-1}) \right]. \quad (23)$$

The corresponding DV01 is therefore

$$\text{DV01}_i^{\text{IRS}} = \frac{1}{100} \text{LASH}_{i,t}^{\text{IRS}}. \quad (24)$$

For both interest rate swaps and gilt repos, margining practices imply that changes in market value translate almost one-for-one into liquidity requirements.

For cleared and collateralised swaps, variation margin equals the full mark-to-market change in the contract's value:

$$\Delta \text{NPV} = \text{variation margin}.$$

As a result,

$$\Lambda_i^{\text{swap}} = 1.$$

Similarly, for gilt repos, haircuts are typically very small. A fall in the market value of the collateral leads to an almost identical increase in required margin or collateral:

$$\Delta \text{NPV}_{\text{collateral}} \approx \Delta \text{margin}.$$

Consequently,

$$\Lambda_i^{\text{repo}} \approx 1.$$

Together, these observations imply that for the main interest-rate-sensitive hedging instruments used by pension funds and LDI vehicles, LASH risk is well approximated by the contract's DV01. Changes in valuation translate directly into liquidity needs, making interest rate sensitivity the central determinant of LASH.

8.1 Mechanical vs. Discretionary LASH Risk

The following decomposition separates liquidity risk arising passively from interest-rate movements from liquidity risk actively created by institutions' hedging decisions.

For a given institution, bank or non-bank, j that holds $Q_{i,j,t}$ of a given hedging contract, its aggregate LASH risk is given by:

$$\text{LASH}_{j,t} = \sum_i Q_{i,j,t} \text{LASH}_{i,t}. \quad (25)$$

Letting $Q_{i,t}$ denote the aggregation of contracts across all institutions, bank and non-bank, aggregate LASH risk is given by:

$$\text{LASH}_t^A = \sum_i Q_{i,t} \text{LASH}_{i,t} = \sum_j \text{LASH}_{j,t}^A, \quad (26)$$

where $\text{LASH}_{j,t}^A$ is LASH risk held by institution j .

Two crucial observations must be mentioned. First, contracts with long maturity have higher LASH risk because their NPV is more sensitive to interest rate changes. Second, LASH risk can go in both directions, positive and negative; firms can receive or pay liquidity, depending on the direction of their exposure and the change in price of the underlying instrument. If the contract value $Q_{i,t}$ decreases (increases) from the perspective of the institution j , then the firm is obliged to post (receive) margin. For example, a life insurer or pension fund is exposed to liquidity risk when yields rise. In contrast, their counterparties, mainly dealer banks, must post margin when rates fall and face liquidity risk.

8.1.1 Mechanical LASH: Convexity Effects

Recalling that the LASH exposure of contract i at time t is defined as:

$$\text{LASH}_{i,t} = \Lambda_i \frac{\partial \text{NPV}_{i,t}}{\partial R_t},$$

where $\Lambda_i \approx 1$ for both interest rate swaps and gilt repo and $\frac{\partial \text{NPV}_{i,t}}{\partial R_t}$ is the dollar duration (DV01) of the contract.

Even if institutions do not adjust their portfolios, the LASH of an existing contract changes mechanically with the level of interest rates. This is due to the convexity of fixed-income instruments, since at lower yields, the sensitivity of a bond or swap's value to interest rate changes increases. Formally,

$$\frac{\partial \text{NPV}_{i,t}}{\partial R_t} = f(R_t) \Rightarrow \Delta \text{LASH}_{i,t}^{\text{mech}} = Q_{i,t} \Delta f(R_t),$$

holding the position $Q_{i,t}$ fixed.

Thus, mechanical LASH captures the component of variation in aggregate LASH risk that arises from how interest rate movements affect the DV01 of outstanding contracts, independent of any institutional decision-making. When interest rates fall and convexity rises, mechanical LASH increases mechanically, even if institutions take no action.

8.1.2 Discretionary LASH: Active Hedging and Portfolio Shifts

Discretionary LASH reflects institutions' active choices to adjust their hedging portfolios in response to solvency pressures. Formally, aggregate LASH at time t is:

$$\text{LASH}_t^A = \sum_i Q_{i,t} \text{LASH}_{i,t}.$$

A first-order decomposition yields:

$$\Delta \text{LASH}_t^A = \underbrace{\sum_i Q_{i,t} \Delta \text{LASH}_{i,t}}_{\text{Mechanical}} + \underbrace{\sum_i \text{LASH}_{i,t-1} \Delta Q_{i,t}}_{\text{Discretionary}}.$$

The second term is the discretionary component. It measures changes in LASH risk that arise because institutions reallocate across hedging instruments. These portfolio adjustments reflect the behavioural response of institutions with long-duration liabilities whose solvency deteriorates when interest rates fall. Such behaviour predicts that, when interest rates decline, net worth falls and the marginal value of hedging rises, inducing institutions to increase interest rate hedges, thereby raising LASH exposure.

Distinguishing mechanical from discretionary LASH is essential for several reasons.

Aggregate LASH co-moves negatively with interest rates: LASH is high when rates are low (Fig. 4 Original Paper). Without the decomposition, this could be attributed entirely to convexity, mechanical effects. However, the authors show that the discretionary component closely tracks total LASH, while the mechanical component is comparatively small, implying that discretionary effects dominate.

The core empirical strategy examines whether institutions with shorter-duration assets, namely those whose solvency is most sensitive to falling interest rates, raise their hedging positions more than others. This test requires isolating discretionary changes:

$$\Delta \text{LASH}_{j,t}^{\text{Disc}} = \sum_i \text{LASH}_{i,t-1} \Delta Q_{i,j,t}.$$

Using total LASH would contaminate the results with mechanical convexity effects that do not vary across institutions and do not reflect the solvency mechanism being tested.

9 Low Interest Rates and High LASH Risk

The framework predicts that lower interest rates increase LASH risk primarily through institutions with short-duration asset portfolios, whose solvency deteriorates most when yields fall and who therefore increase hedging activity. The mechanism is consistent with the framework: when rates fall, solvency deteriorates more for short-duration portfolios, prompting greater hedging activity and, in turn, higher exposure to liquidity calls.

We exploit cross-sectional heterogeneity in beginning-of-sample *asset duration* as a proxy for net duration. Institutions with shorter-duration assets experience larger solvency declines when yields fall and therefore hedge more. Asset duration is shown, in a hand-collected subsample, to be negatively correlated with measured net duration, supporting its use as a proxy.

We estimate the quarterly panel model

$$\Delta \text{LASH}_{j,t}^{\text{Disc}} = \beta_1 \Delta \text{Yield}_t^{10Y} + \beta_2 \Delta \text{Yield}_t^{10Y} \times \text{Duration}_j + \text{FE} + \varepsilon_{j,t},$$

where the dependent variable is inverse-hyperbolic-sine transformed, yields are measured in percentage points, and the duration measure is standardized. Standard errors are clustered at the quarter level. We include institution fixed effects, time fixed effects, and (in robustness) institution-by-yield-level and institution-by-yield-slope fixed effects.

Estimates indicate $\beta_1 < 0$ and $\beta_2 > 0$: falling yields raise LASH risk on average, but less so for institutions with longer-duration assets. Economically, a 100 bps quarterly decline in the 10-year yield is associated with an approximate 133% increase in discretionary LASH risk for an institution with average duration; for an institution with duration one standard deviation higher, the implied increase is about 44%. These results are statistically significant and robust across fixed-effect specifications. Cross-sectional evidence shows that a low-rate environment elevates LASH risk primarily through the solvency-to-hedging channel for short-duration institutions, reinforcing the aggregate time-series pattern and the paper’s conceptual framework.

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