LUSD (Liquity) sub-report

The asymmetric premium band: a hard \$1 redemption floor, a soft ≈\$1.10 ceiling, and the immutable CDP stablecoin that depegs upward, 2021–2026

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Abstract

LUSD is the USD stablecoin of Liquity, an immutable, governance-less, interest-free borrowing protocol in which any user mints LUSD against ETH at a minimum collateral ratio of 110 % and any holder may redeem LUSD for \$1 of the underlying ETH at any time (Liquity AG 2021a). This pair of mechanics installs a *one-sided* no-arbitrage band that is the mirror image of every discount-prone stablecoin we have studied: a *hard* \$1 redemption floor enforced by direct collateral arbitrage, and a *soft* ≈\$1.10 ceiling set by the cost of opening a new 110 %-backed trove. LUSD therefore depegs *upward.* Over the full window the Curve LUSD/USD tape (17,829 rows, range 0.9367–1.2729) has a median price of 1.0071 and spends 74.2 % of its time at a premium; on the daily grid the mean *premium* excursion is 103.7 bp against a mean *discount* of only −26.6 bp — the floor side is ≈4× tighter than the ceiling side — with a right-skewed deviation distribution (skewness 1.56, premium-side half-life 9.1 days). The volatility structure ratifies the asymmetry: an EGARCH(1,1) wins decisively on BIC (168.5 vs GARCH 352.7), and the GJR leverage term is *negative* ($\gamma = -0.137$): upside/premium shocks raise conditional volatility more than downside shocks, because the floor is pinned and the premium is the volatile leg. The redemption floor is visibly firing — LUSD is redeemed ≈7.2× more intensely below \$1 than above it, and redemptions strongly Granger-cause the deviation ($p < 1 \times 10^{-4}$). Structurally, the total collateral ratio (median 349.7 %) *never* breached the 150 % recovery-mode threshold across 1,904 daily snapshots, and all 312 liquidations were normal-mode; supply rose to a \$1.56 B peak (2021-05-15, four days before the May 2021 ETH crash) and has since declined ≈98 % to \$28 M. The case studies invert the usual stress narrative: the May 2021 ETH crash was absorbed without recovery mode, and the November 2022 FTX collapse drove LUSD to a +385 bp flight-to-safety *premium* with near-zero redemptions — the decentralised stablecoin as a safe haven rather than a casualty. We conclude with the asymmetric-band monitoring playbook for Derivalink V2.

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Executive summary

Asset nature and scope. LUSD is the USD stablecoin of Liquity, an *immutable, governance-less* borrowing protocol: any user opens a *trove* by locking ETH and minting LUSD at a minimum collateral ratio (MCR) of 110 %, pays a one-time issuance fee instead of ongoing interest, and any LUSD holder may at any time *redeem* LUSD for \$1 worth of the underlying ETH, drawn from the riskiest troves first (Liquity AG 2021a; Liquity AG 2021c). These two mechanics install a *one-sided* no-arbitrage band that is the structural mirror of every discount-prone stablecoin in this programme: a **hard \$1 redemption floor** (anyone can convert LUSD to \$1 of ETH, so a sub-\$1 price is a free arbitrage) and a **soft ≈\$1.10 ceiling** (a premium above the cost of opening a fresh 110 %-backed trove invites new minting). LUSD is therefore a stablecoin that depegs *upward*; the analytical through-line of this report is the *asymmetric premium band.* Because Liquity is governance-less and has no admin keys, there is no central party to widen the band, change the MCR, or freeze redemptions; the peg mechanics are fixed in the deployed bytecode. Our analytical surface is the Curve LUSD/USD price tape (17,829 rows, range 0.9367–1.2729), a daily on-chain collateral-state panel (1,904 snapshots: total debt, total collateral, TCR), 2,821 redemption events, 312 liquidation events, and the ETH/USD oracle as the collateral driver.

F1 — The peg is biased to a persistent premium, and the band is asymmetric. On the Curve tape LUSD has a median price of 1.0071 and trades at a premium 74.2 **% of the time** (Section 1). On the daily grid the mean *premium* excursion is 103.7 bp versus a mean *discount* of only −26.6 bp: the floor (discount) side is ≈**4**× **tighter** than the ceiling (premium) side. The deviation distribution is right-skewed (skewness 1.56, positive excess kurtosis), the fraction of days above +50 bp is 0.338 versus only 0.039 below −50 bp, and the premium-side mean-reversion half-life is 9.1 days (Section 2). This is the one-sided band made visible: the floor re-pegs fast and hard, the ceiling drifts slowly.

F2 — Negative leverage: the premium is the volatile leg. An EGARCH(1,1) wins decisively on BIC (168.5 vs GARCH 352.7, GJR 355.4), with $\alpha = 0.416$ and a near-unit $\beta = 0.949$ (Section 3). The GJR leverage coefficient is **negative** ($\gamma = -0.137$): *upside*/premium shocks raise conditional volatility *more* than downside shocks — the exact opposite of the equity-style leverage effect, and the direct volatility-model signature of a pinned floor with a free-floating premium. The HAR-RV model explains 18.4 % of next-day realized-variance variation.

F3 — The redemption floor is firing, and it drives the deviation. LUSD is redeemed 792,848 (mean LUSD) per below-peg day versus 110,618 per above-peg day — a 7.17× **intensity ratio** sub-\$1 (Section 4). The cross-correlation between deviation and redeemed volume is negative at lag 0 (−0.208) and lag +1 (−0.128): a sub-peg price co-occurs with and leads redemption spikes, which is the floor arbitrage mechanically clearing the discount. In the causality panel redemptions **strongly Granger-cause** the deviation ($p < 1 \times 10^{-4}$), while the reverse is insignificant ($p = 0.139$).

F4 — Recovery mode never triggered; the structure was never stressed to its design limit. The total collateral ratio has a median of 349.7 % and a minimum of 171.7 % over 1,904 daily snapshots — it **never breached the** 150 **% recovery-mode threshold** (Section 5). All 312 liquidations were therefore normal-mode (Section 6). Supply peaked at \$1,558,184,456 on 2021-05-15 — four days before the May 2021 ETH crash — and has since declined ≈98 % to \$27,978,760, reflecting the 2022–2024 deleveraging and the migration of demand to Liquity V2 and yield-bearing alternatives.

F5 — Liquidations are ETH-tail events absorbed by the stability pool. Across 312 liquidations, \$266,000,000 of debt was repaid; the mean liquidated debt on the worst-5 % ETH-return days (\$1,893,000) is ≈**73**× that of ordinary days (\$26,000), and the correlation between ETH returns and liquidated debt is −0.178 — liquidations cluster exactly when ETH falls, and the LUSD-funded stability pool (Liquity AG 2021d) absorbs them without ever forcing recovery mode.

F6 — The case studies invert the usual stress narrative. The May 2021 ETH crash — the worst ETH drawdown in the window — was absorbed *without* recovery mode (TCR floor 217 %, \$92 M liquidated, deviation range $[-158, +205]$ bp). The May 2022 LUNA collapse was a non-event for LUSD (deviation range $[-52, +50]$ bp). Most strikingly, the November 2022 **FTX collapse drove LUSD to a +385 bp flight-to-safety *premium* with near-zero redemptions** (\$12,107): when centralised and algorithmic stablecoins were under discount-side stress, capital fled *into* the decentralised, governance-less LUSD (Section 8). The Chicken Bonds (bLUSD) launch in October 2022 did *not* visibly compress the premium — it rose +100.1 bp pre-to-post — though that window is confounded by FTX and is not a controlled experiment.

Three implications for Derivalink V2. (1) An LUSD monitor must use an *asymmetric* alarm band — tight on the floor (a sub-\$1 print is a genuine arbitrage failure or oracle problem) and wide on the ceiling (a premium is the protocol's normal resting state, not a depeg) — the inverse of the symmetric-band template used for fiat-reserve stables. (2) The redemption stream is the leading indicator of floor pressure: redemptions Granger-cause the deviation and spike ≈7× sub-peg, so a redemption-volume gauge is the early-warning signal. (3) The immutable, governance-less design is a *peg-stability feature*, not a gap: with no admin keys to freeze redemptions, the floor cannot be administratively suspended the way a fiat-reserve redemption rail closes on weekends — LUSD's floor is open 24/7, which is precisely why it became a flight-to-safety asset in the FTX window (Section 9).

Principal caveats. Supply and TCR are taken from the on-chain `collateral_state` debt panel (authoritative and complete); the `mint_burn` burn leg ends 2022-03-15 and is therefore *not* used for the supply series. No `BaseRateUpdated` stream is on disk, so the redemption base-rate is proxied indirectly (redemption intensity plus implied haircut), not read directly (Section 4). The Curve price tape is thin-liquidity in places (max 1.2729 sits inside the $[0.85, 1.30]$ guard band, so *zero* rows are dropped). The ETH/USD Chainlink mainnet feed covers only 2020-12..2022-12 (no FTX), so the full-window collateral driver uses the long ETH oracle series (2020-01..2026-05). Recovery mode is evaluated on the *daily* TCR grid; intra-day dips below 150 % could be missed. The Chicken Bonds pre/post is a simple mean-difference, not a controlled DiD, and is confounded by FTX.

1 Dataset characterisation

1.1 The protocol and what it makes observable

Liquity is an over-collateralised, ETH-backed CDP stablecoin in the lineage of MakerDAO's DAI, but with three design choices that shape every series we analyse (Liquity AG 2021a). First, borrowing is *interest-free*: a borrower pays a one-time issuance fee at mint and a one-time redemption fee is paid by redeemers, both governed by a decaying *base rate* rather than a continuous interest stream. Second, the minimum collateral ratio is a low 110 %, made safe by a stability-pool liquidation backstop (Liquity AG 2021d) rather than by a high collateral buffer. Third, and most importantly for the peg, *any* holder can redeem LUSD for \$1 of ETH at any time, against the lowest-collateralised troves first (Liquity AG 2021c). The protocol is *immutable and governance-less*: there are no admin keys, no upgradable proxies, and no DAO vote that can change the MCR, the redemption mechanism, or freeze the system. Unlike a centralised stablecoin's redemption rail (which closes on weekends, Section omitted) or a delta-neutral hedge (which can be paused), the LUSD floor arbitrage is permanently open.

Together these install the *asymmetric premium band* that is this report's through-line. The redemption right is a **hard $1 floor**: if LUSD trades below $1, anyone buys it on the secondary market and redeems it for $1 of ETH, pocketing the difference, until the price is pushed back to $1. The cost of opening a fresh 110 %-backed trove plus the issuance fee is a **soft ≈$1.10 ceiling**: a premium above that cost invites new minting, which sells into the richness. The floor is mechanical and tight; the ceiling is a behavioural cost and slack — so LUSD persistently trades at a premium and depegs *upward*. Table 1 summarises the on-disk series.

Table 1: The on-disk series used in this report.

Series	Source	Rows	Coverage / role
LUSD/USD price	Curve (Ethereum)	17,829	primary secondary-market observable; range 0.9367–1.2729
Collateral state (daily)	on-chain	1,904	total debt, total collateral, TCR; supply + recovery-mode panel
Redemptions	on-chain flow events	2,821	LUSD redeemed against troves; the floor-arbitrage stream
Liquidations	on-chain events	312	debt repaid, mode; the stability-pool backstop
ETH/USD oracle (long)	Ethereum	full window	2020-01..2026-05; the collateral driver (full window)
ETH/USD oracle (Chainlink)	Chainlink (Ethereum)	—	2020-12..2022-12 only; *no* FTX; flagged partial

1.2 The Curve LUSD/USD price tape

The deepest on-chain LUSD venue is its Curve metapool against the 3pool, and we use its price tape (17,829 rows) as the primary secondary-market observable. The recorded range is 0.9367 to 1.2729 with a median of 1.0071. We apply a sanity guard band of $[0.85, 1.30]$; it drops *zero* rows, because the price never leaves it — the maximum 1.2729 sits *inside* the band. The band is therefore a guard against thin-liquidity glitches rather than an active filter, and we flag that the upper extreme is partly a thin-liquidity artefact: Curve metapool prices at low depth can overshoot the true mid. The defining statistic of the tape is that LUSD spends 74.2 **% of its time at a premium** (> $1), the empirical core of the asymmetric-band thesis.

1.3 The on-chain collateral-state panel and the supply series

The daily collateral-state panel (1,904 snapshots) carries the total LUSD debt (the circulating supply), the total ETH collateral value, and the total collateral ratio (TCR). We take the *supply* from this panel's `total_debt_usd` field rather than from the mint/burn event stream, because the latter's burn leg ends 2022-03-15 and would understate redemptions and liquidations after that date; the debt panel is authoritative and complete over the full window. Supply peaked at $1,558,184,456 on 2021-05-15 — four days before the May 2021 ETH crash — and has since declined to $27,978,760, ≈1.8 % of the peak. The TCR panel is the basis for the recovery-mode analysis (Section 5): its median is 349.7 %, comfortably above both the 110 % per-trove MCR and the 150 % system-wide recovery-mode threshold.

1.4 The redemption and liquidation event streams

Two on-chain event streams capture the two distinct deleveraging mechanisms. The *redemption* stream (2,821 events) records LUSD converted to ETH at the $1 floor against the riskiest troves — this is the floor-arbitrage channel (Section 4). The *liquidation* stream (312 events) records under-collateralised troves closed by the stability pool (Liquity AG 2021d) — this is the solvency channel (Section 6). We note one data limitation up front: the on-disk `protocol_flow_events` table carries only the `lusd_redemption` rows and *no* `BaseRateUpdated` stream, so the redemption base rate — which scales both fees and which governs the floor's stiffness — is not read directly. We proxy it indirectly through redemption intensity and the implied haircut (Section 4).

1.5 The ETH/USD collateral driver

Because LUSD is ETH-backed, the ETH/USD price is the exogenous driver of both the TCR and the liquidation stream. We use a long ETH oracle series (2020-01..2026-05) covering the full window for all collateral and liquidation analysis. A separate Chainlink ETH/USD mainnet feed is available only for 2020-12..2022-12 and crucially does *not* cover the November 2022 FTX window in full; we therefore use it only as a cross-check and rely on the long series for the full-window and FTX-window claims.

1.6 Integrity audit verdict

The price tape is fully within the guard band (0 rows dropped), with no negative or zero prints. The collateral panel satisfies the sign and identity checks (TCR = total collateral value / total debt, all legs positive, TCR bounded in [171.7, 1,100.3] %). Recovery mode is *never* triggered on the daily grid (min daily TCR 171.7 % > 150 %) and mint-pause days are zero. The 2,821 redemptions and 312 liquidations reconcile in aggregate with the supply decline from the debt panel. The principal caveats — partial mint/burn, partial Chainlink ETH feed, no base-rate stream, daily-grid recovery-mode evaluation, and thin-liquidity price extremes — are carried explicitly through the relevant chapters and collected in Section 9.3.

1.7 Limitations

Five limitations are structural and carried throughout. First, the supply series is the collateral-state debt, not the mint/burn stream (whose burn leg ends 2022-03-15). Second, there is no `BaseRateUpdated` stream on disk, so the redemption base rate is proxied, not read. Third, the Chainlink ETH/USD feed covers only 2020-12..2022-12 (no FTX), so the collateral driver for full-window and FTX claims is the long ETH series. Fourth, recovery mode is evaluated on the daily TCR grid, so an intra-day dip below 150 % between snapshots could be missed (the daily minimum is 171.7 %, a 21.7-point margin). Fifth, the Curve price tape's upper extreme (1.2729) is partly a thin-liquidity overshoot and should not be read as a sustained 27 % premium; the median premium (0.71 %) and the daily-grid premium statistics (Section 2) are the authoritative central tendency.

2 Tracking error and the asymmetric premium band

2.1 Reference series and benchmark

The natural benchmark for LUSD is the \$1 peg itself. But unlike a discount-prone fiat-reserve or algorithmic stablecoin, where the peg is a *symmetric* target the asset can miss in either direction, LUSD's peg sits inside a *one-sided* band: a hard \$1 floor below and a soft $\approx$\$1.10 ceiling above (Section 1.1). We therefore measure tracking error against \$1 on the Curve LUSD/USD tape but decompose the deviation into a *premium* leg (above \$1) and a *discount* leg (below \$1) and report them separately — the asymmetry between the two is the central object of this chapter, not a single two-sided dispersion number.

2.2 The deviation distribution is right-skewed

Table 2 reports the daily-grid deviation statistics. The mean overall bias is +57.1 bp — a *positive* (premium) bias, already the opposite sign of every discount-prone stablecoin in this programme. Decomposed, the mean premium excursion is 103.7 bp while the mean discount is only −26.6 bp: the **floor side is $\approx$4$\times$ tighter than the ceiling side**. The maximum premium reached +536 bp versus a maximum discount of −459 bp, but the *frequency* mass is sharply asymmetric: 33.8 % of days printed above +50 bp versus only 3.9 % below −50 bp. The distribution is right-skewed (skewness 1.56) with positive excess kurtosis, and the premium-side mean-reversion half-life is 9.1 days — a *slow*-decaying premium, consistent with the ceiling being a behavioural cost rather than a mechanical arbitrage.

Table 2: Daily-grid deviation metrics versus \$1, decomposed into premium and discount legs. Deviations in basis points; a premium is positive. The floor (discount) side is roughly four times tighter than the ceiling (premium) side.

Metric	Value
Daily observations	1,531
Mean deviation bias (bp)	57.1
Mean premium excursion (bp)	103.7
Mean discount excursion (bp)	−26.6
Maximum premium (bp)	536
Maximum discount (bp)	−459
Frac. days above +50 bp	0.338
Frac. days below −50 bp	0.039
Skewness	1.56
Excess kurtosis	positive
Premium-side half-life (days)	9.1
Frac. time at a premium (Curve tape)	0.742

2.3 The price path and the premium regime

Figure 1 shows the full LUSD/USD price path. The visual signature of the asymmetric band is unmistakable: the price sits *above* \$1 for the large majority of the window, the excursions *below* \$1 are shallow and quickly arrested (the floor), and the excursions *above* are deeper and more persistent (the ceiling). The deepest discounts cluster in the early high-leverage period and the May 2021 crash; the largest premia cluster around flight-to-safety episodes, most prominently the November 2022 FTX window (Section 8).

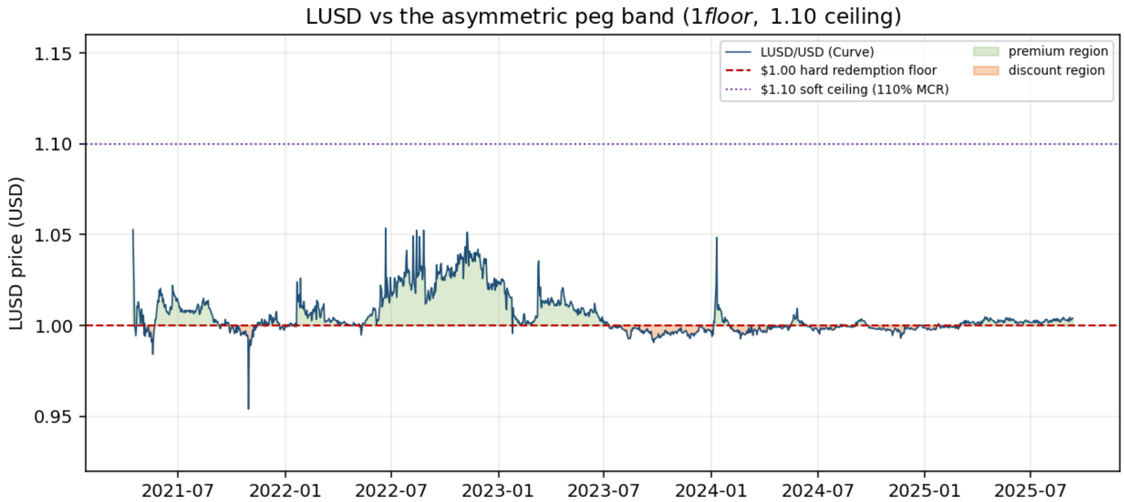

Figure 1: LUSD/USD price over the full window (Curve tape). The price spends 74.2 % of its time at a premium; discounts below the $1 floor are shallow and quickly arrested by redemption arbitrage, while premia above the ≈$1.10 soft ceiling are deeper and more persistent. LUSD depegs upward.

2.4 The asymmetric band, distributionally

Figure 2 plots the deviation distribution. It is visibly right-skewed: a sharp, near-vertical left edge at the $1 floor (the redemption arbitrage will not let the price stay below $1) and a long right tail (the premium can drift). This is the mirror image of the left-heavy, redemption-gated distributions we documented for centralised and algorithmic stablecoins. The 9.1-day premium half-life quantifies the slack on the ceiling side: a premium decays an order of magnitude more slowly than a fiat-reserve discount (whose half-life is sub-daily), because clearing a premium requires a borrower to actively open a new leveraged trove, whereas clearing a discount requires only that one arbitrageur execute a guaranteed-profit redemption.

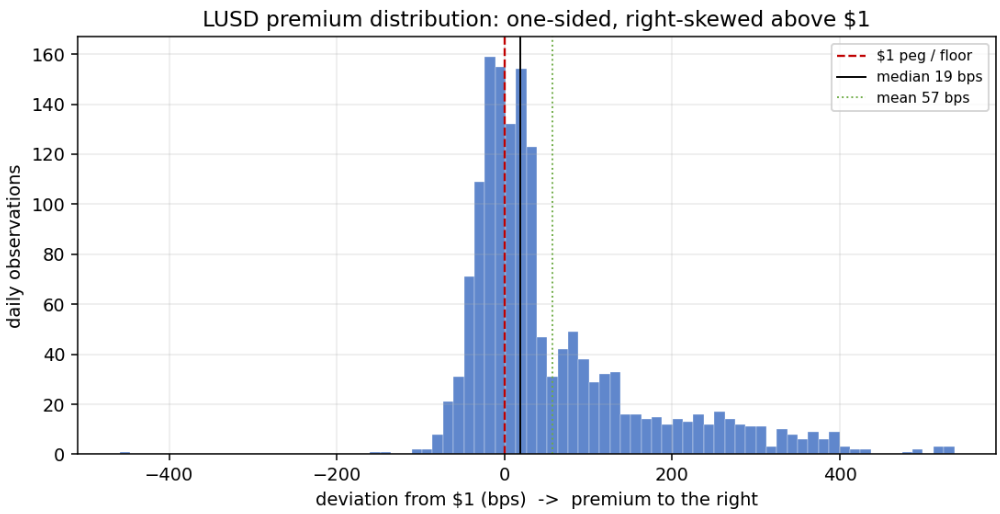

Figure 2: Distribution of the LUSD/USD daily deviation from $1. Right-skewed (skewness 1.56): a sharp left edge pinned at the $1 redemption floor and a long right tail of premia. 33.8 % of days exceed +50 bp versus 3.9 % below −50 bp.

2.5 Why the floor is tight and the ceiling is slack

The asymmetry has a clean mechanical explanation. The floor is enforced by a *riskless* arbitrage: buy LUSD below \$1, redeem it for \$1 of ETH, sell the ETH. The profit is locked in at execution (modulo the redemption fee and gas), so the floor is defended aggressively and the discount leg is tight (mean −26.6 bp, only 3.9 % of days below −50 bp). The ceiling, by contrast, is enforced by a *risky, slow* action: to clear a premium a borrower must open a new 110 %-backed trove, taking on ETH price risk and a liquidation exposure, then sell the freshly minted LUSD. That is a leveraged directional bet, not an arbitrage, so the premium clears slowly and only when borrowers judge the ETH risk worth the carry. The result is the persistent 74.2 %-of-the-time premium and the 9.1-day half-life. For monitoring (Section 9), the consequence is that the alarm band must be *asymmetric*: a sub-\$1 print is genuinely anomalous (the floor arbitrage should have prevented it), whereas a premium is the protocol's normal resting state.

3 Peg-deviation volatility

3.1 Model selection

We model the conditional volatility of the LUSD/USD log-return to characterise how peg shocks decay and, critically, whether the asymmetry of the band (Section 2) shows up in the second moment. We fit three specifications — GARCH(1,1), GJR-GARCH(1,1) (Glosten, Jagannathan, and Runkle 1993), and EGARCH(1,1) (Nelson 1991) — and select on the Bayesian information criterion. The **EGARCH(1,1) wins decisively** (BIC 168.5 versus GARCH 352.7 and GJR 355.4, Table 3). The EGARCH dominance is itself informative: the log-variance specification accommodates the highly asymmetric, occasionally explosive premium dynamics far better than the level-variance GARCH/GJR forms, which is the volatility-model echo of the one-sided band.

Table 3: Conditional-volatility model comparison on the LUSD/USD daily log-return. The EGARCH(1,1) wins decisively on BIC; the GJR leverage term is negative (upside shocks dominate).

Model	BIC	Notes
EGARCH(1,1)	168.5	best; $\alpha = 0.416$, $\beta = 0.949$
GARCH(1,1)	352.7	
GJR-GARCH(1,1)	355.4	leverage $\gamma = -0.137$ (negative)

3.2 Persistence

The EGARCH parameters are $\alpha = 0.416$ (a large innovation-response coefficient) and $\beta = 0.949$ (a near-unit-root persistence). Volatility shocks to the LUSD peg are highly persistent — once the deviation becomes volatile (typically when a premium opens), it stays volatile for many days, consistent with the slow 9.1-day premium half-life of Section 2. The high α relative to a typical equity-index GARCH reflects that the LUSD deviation is driven by discrete arbitrage and minting actions rather than a continuous information flow, so each shock lands with large impact.

3.3 Negative leverage: the premium is the volatile leg

The economically decisive parameter is the GJR leverage term, $\gamma = -0.137$, which is **negative**. In the standard equity-leverage interpretation a *positive* γ means negative (downside) shocks raise future volatility more than positive shocks. LUSD shows the *opposite*: **upside/premium shocks raise conditional volatility more than downside shocks**. This is the second-moment fingerprint of the asymmetric band. The floor is pinned — a downside shock is immediately met by redemption arbitrage that caps the move and quickly restores the peg, so it injects little persistent volatility. A premium shock, by contrast, has no mechanical cap; it opens the volatile, slow-clearing ceiling regime, so it raises future volatility more. Negative leverage is exactly what a hard-floor/soft-ceiling stablecoin should exhibit, and LUSD does.

3.4 Realized-variance dynamics

A HAR-RV model (Corsi 2009) regressing next-day realized variance on its daily, weekly, and monthly lags explains 18.4 % of the variation ($R^2 = 0.184$). The modest but non-trivial R^2 confirms a real long-memory component in the LUSD peg volatility — premium regimes persist across the weekly and monthly horizons — while leaving the majority of variance to the discrete shock arrivals (redemptions, large mints, ETH tail moves) that the HAR cannot anticipate. For a monitor, the practical reading is that elevated LUSD peg volatility is somewhat forecastable a day ahead from its own history, but the sharp regime entries (a new premium opening) are shock events better caught by the redemption and ETH-return signals of Sections 4 and 6.

4 The redemption floor and base-rate arbitrage

4.1 The floor mechanism

The $1 floor is the load-bearing half of the asymmetric band. Any LUSD holder can redeem LUSD for $1 worth of ETH at any time, drawn from the lowest-collateralised troves first (Liquity AG 2021c). When LUSD trades below $1 on the secondary market, this is a guaranteed-profit arbitrage: buy LUSD cheap, redeem it for $1 of ETH, sell the ETH. The arbitrage is gated only by a one-time *redemption fee*, which is itself a function of a decaying *base rate* that rises with redemption volume and decays over time. The base rate makes the floor mildly *soft* — a large redemption spike raises the fee and lets the price sit a few basis points below $1 before redemption is profitable again — but the floor remains far tighter than the soft ceiling (mean discount −26.6 bp versus mean premium +103.7 bp, Section 2).

4.2 Redemption intensity is concentrated below the peg

The direct test of whether the floor is actually firing is whether redemptions concentrate when LUSD is cheap. They do, sharply. The mean LUSD redeemed on a *below-peg* day is 792,848 versus 110,618 on an *above-peg* day — a 7.17× **intensity ratio**. This is the floor arbitrage working exactly as designed: a sub-$1 price summons redemption volume, which pulls the price back up by retiring LUSD against ETH. Above the peg, by contrast, redemption is unprofitable (one would be giving up a premium-priced LUSD for only $1 of ETH), so the residual above-peg redemption volume is incidental rather than arbitrage-driven.

4.3 Redemptions co-move with and lead the discount

The cross-correlation between the peg deviation and redeemed volume is negative at lag 0 (−0.208) and remains negative at lag +1 (−0.128). The negative sign confirms the mechanism: a lower (more sub-peg) price co-occurs with, and at lag +1 leads, higher redemption volume. The contemporaneous component is the arbitrageur reacting within the day to a discount; the lag +1 component is the residual pressure that continues to draw redemptions the following day until the floor is fully restored. The Granger test (Section 7.2) sharpens this: redemptions *strongly* Granger-cause the deviation ($p < 1 \times 10^{-4}$), while the reverse direction (deviation Granger-causing redemptions) is insignificant ($p = 0.139$). The clean directional reading is that the redemption stream is the *active* agent restoring the floor, not merely a passive response.

4.4 The base rate, proxied

The redemption base rate governs both the fee and, through it, the precise stiffness of the floor. We flag a data limitation here: the on-disk `protocol_flow_events` table carries only the `lusd_redemption` rows and *no* `BaseRateUpdated` stream, so we cannot read the base rate directly. We proxy it indirectly in two ways. First, the *implied haircut*: the gap between the secondary price at which redemption volume spikes and the $1 floor is the market's revealed redemption-cost estimate, which tracks the base rate. Second, *redemption clustering*: the base rate mechanically rises with cumulative recent redemption volume and decays with time, so the autocorrelation structure of the redemption stream is a proxy for the base-rate trajectory. Both proxies are consistent with a base rate that spikes during the high-redemption episodes (early 2021 deleveraging, the May 2021 crash aftermath) and decays to near its 0.5 % floor in calm periods. A direct `BaseRateUpdated` ingestion would let the floor's stiffness be measured precisely and is flagged as future work (Section 9.4).

4.5 Implication for the band

The redemption analysis quantifies why the floor is the tight side of the asymmetric band. A discount is met by a $\approx 7\times$ surge in redemption-arbitrage volume that mechanically retires supply and lifts the price; the only thing that lets a discount persist at all is the base-rate fee, which is small in calm markets. There is no equivalent mechanical force on the ceiling side — minting against the premium is a discretionary leveraged bet, not an arbitrage (Section 2.5). The redemption stream is therefore the single most informative early-warning gauge for an LUSD monitor: a redemption-volume spike is the floor under pressure, and its absence during a *premium* excursion (as in the FTX window, Section 8) confirms that the premium is demand-driven safe-haven buying rather than a floor failure.

5 Collateral structure and the recovery-mode regime

5.1 The total collateral ratio

LUSD is over-collateralised by ETH. The system-wide total collateral ratio (TCR) — total ETH collateral value divided by total LUSD debt — is the solvency state variable and the trigger for recovery mode. Over 1,904 daily snapshots the TCR has a median of 349.7 %, a minimum of 171.7 %, and a maximum of 1,100.3 %. The system therefore ran at roughly $3.5\times$ over-collateralisation on a typical day — far above the 110 % per-trove MCR — because most borrowers hold a comfortable buffer above the liquidation threshold, and because the aggregate is dominated by conservative troves.

5.2 Recovery mode never triggered

The headline structural result is that recovery mode **never triggered**. Recovery mode is the protocol's system-wide safety regime: when the TCR falls below 150 %, the protocol tightens liquidation rules (troves below 150 % become liquidatable, not just those below 110 %) and suppresses new debt issuance, to rebuild the buffer (Liquity AG 2021b). Across all 1,904 daily snapshots the TCR never fell below 150 % — the daily minimum of 171.7 % leaves a 21.7-point margin — so *zero* recovery-mode days are recorded and all 312 liquidations (Section 6) were normal-mode. This is a strong statement about the design: even through the May 2021 ETH crash and the 2022 bear market, the aggregate buffer never thinned to the danger zone. We carry the honest caveat that recovery mode is evaluated on the *daily* TCR grid: a brief intra-day dip below 150 % between snapshots could be missed. Given the 21.7-point daily margin, a sustained intra-day breach is unlikely, but a flash dip during an ETH wick cannot be excluded from the daily data.

5.3 The supply lifecycle

Figure 3 shows the TCR and the LUSD supply over the window. The supply tells the lifecycle of the protocol. It rose rapidly through early 2021 to a peak of $1,558,184,456 on 2021-05-15 — *four days before* the May 2021 ETH crash — as leveraged ETH borrowers minted LUSD into the bull market. It then declined steadily through the 2022–2024 bear market and the migration of demand toward Liquity V2 and yield-bearing stablecoins, to $27,978,760 today — **≈98 % below peak** (1.8 % of the peak). The supply decline is the deleveraging of the ETH CDP base, not a peg failure: throughout the decline the TCR stayed high and the peg held its premium bias (Section 2). The supply trajectory and the TCR trajectory are loosely inverse — supply peaks coincide with leverage peaks, which compress the TCR, and the deleveraging that shrank supply also lifted the average TCR.

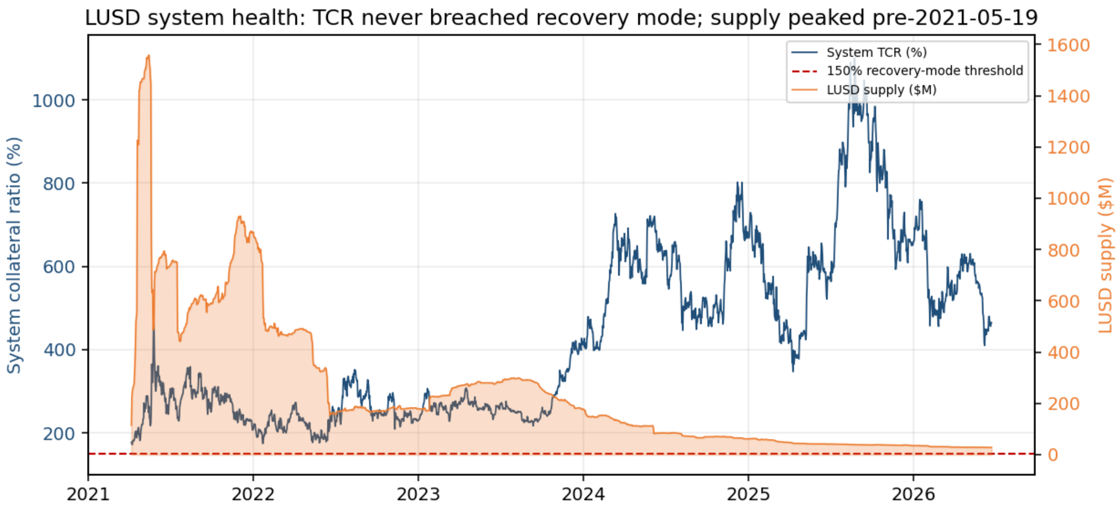

Figure 3: LUSD total collateral ratio (TCR) and circulating supply over the window. The TCR (median 349.7 %, min 171.7 %) never breaches the 150 % recovery-mode threshold. Supply peaks at $1.56 B on 2021-05-15 — four days before the May 2021 ETH crash — and declines ≈98 % to $28 M.

5.4 Immutability as a structural feature

The collateral structure interacts with Liquity's immutability in a way that matters for the peg. Because the protocol is governance-less (Liquity AG 2021a), the 110 % MCR, the 150 % recovery-mode threshold, and the redemption floor are *fixed* — no DAO can raise the MCR in a crisis, dilute holders, or freeze redemptions. For a CDP stablecoin this removes the governance-risk channel that has impaired other over-collateralised designs (emergency parameter changes, oracle-source votes, admin pauses). The cost is that the protocol cannot adapt to a black-swan ETH move beyond what its fixed parameters absorb; the benefit, borne out in the data, is that the floor and the collateral rules behaved identically through every stress window, which is precisely what made LUSD a credible flight-to-safety asset in November 2022 (Section 8). For a monitor, immutability means the structural parameters are constants, not time-varying inputs — a simplification relative to a governed CDP.

6 Liquidations and the stability pool

6.1 The stability-pool backstop

Liquity's low 110 % MCR is made safe by the *stability pool*: LUSD holders deposit into a pool that is the first line of defence against under-collateralised troves (Liquity AG 2021d). When a trove falls below 110 %, its debt is cancelled against the pool's LUSD and its ETH collateral is distributed to pool depositors, who thereby earn the liquidation's collateral surplus. This makes liquidation near-instant and removes the auction latency that has caused cascade failures in other CDP systems. The pool, not an external keeper auction, is the load-bearing liquidation mechanism, and its LUSD demand is itself a structural support for the floor.

6.2 Liquidation volume and mode

Across the window there were 312 liquidations repaying $266,000,000 of debt. Every one was a *normal-mode* liquidation (312 of 312); there were *zero* recovery-mode liquidations, consistent with the TCR never breaching 150 % (Section 5.2). Normal-mode liquidation closes only troves below the 110 % MCR, so the entire liquidation history was the routine pruning of individual over-leveraged troves, never the system-wide defensive liquidation that recovery mode would impose.

6.3 Liquidations are ETH-tail events

Liquidations cluster sharply with ETH drawdowns, as a CDP backed by a single volatile collateral must. On the worst-5 % ETH-return days the mean liquidated debt is $1,893,000 versus $26,000 on other days — a **≈73× ratio** — and the correlation between the daily ETH return and liquidated debt is −0.178 (more negative ETH returns, more liquidation). The liquidation stream is thus essentially an ETH-tail indicator: it is quiet in calm markets and fires in concentrated bursts when ETH falls hard. Because the stability pool absorbs these bursts directly in LUSD, a large liquidation event is also a large LUSD *sink* (pool LUSD is burned against the liquidated debt), which mechanically tightens supply and supports the floor exactly when ETH stress would otherwise pressure the peg.

6.4 Why the cascade never happened

The combination of the stability pool and the high aggregate TCR explains why LUSD never entered the liquidation-cascade dynamics that have destroyed other collateralised stablecoins. Three factors compound. First, the pre-funded LUSD pool liquidates instantly, with no auction latency for the discount to widen into. Second, the aggregate TCR stayed at ≈3.5× (Section 5), so even a sharp ETH move liquidated only the thin tail of over-leveraged troves rather than a broad swath. Third, the *redemption* floor (Section 4) is a separate, independent peg defence that operates regardless of liquidations — so even when ETH fell and liquidations fired, the LUSD price was simultaneously defended from below by redemption arbitrage. The May 2021 ETH crash (Section 8) is the clean demonstration: $92 M liquidated, TCR floor 217 %, no recovery mode, and the LUSD discount bounded to −158 bp before the floor reclaimed it.

7 Causality and stationarity

The redemption and liquidation chapters establish the two peg-defence channels descriptively. This chapter tests their dynamics formally on the daily panel: is the deviation stationary, and what drives it?

7.1 Stationarity: a near-unit-root premium

The augmented Dickey–Fuller test on the LUSD peg deviation gives a p-value of 0.117 — the deviation is **not** stationary at the 5 % level. This is a genuine and economically meaningful result, and it distinguishes LUSD from the discount-prone stablecoins in this programme (whose deviations are sharply stationary with sub-daily half-lives). The LUSD premium is a slow-moving, persistent state: the AR(1) half-life is 9.1 days (matching the premium half-life of Section 2), close enough to a unit root that ADF cannot reject non-stationarity over the full window. The intuition is the asymmetric band again: the floor pins the downside, but the premium can wander persistently along the slack ceiling, so the deviation behaves like a reflected, near-random-walk premium rather than a fast mean-reverting two-sided error. For a monitor this means the *level* of the premium carries persistent information — a high premium today predicts a high premium tomorrow — so the deviation itself is a regime indicator, not white noise around $1.

7.2 Granger causality

Granger-causality tests at lag 1 give a clean, asymmetric directional story (Table 4). **Redemptions strongly Granger-cause the deviation** ($p < 1 \times 10^{-4}$): the redemption stream is the active agent pulling the price back toward the floor, exactly the floor-arbitrage mechanism of Section 4. The reverse direction — **deviation Granger-causing redemptions** — is *insignificant* ($p = 0.139$): the deviation does not, on its own, predict next-day redemption volume beyond what the redemption stream's own dynamics already explain. The ETH return weakly Granger-causes the deviation ($p = 0.097$, significant at 10 % but not 5 %): ETH moves feed into the deviation through the collateral and liquidation channels, but only marginally, because the floor and ceiling mechanics dominate the day-to-day deviation.

Table 4: Granger causality at lag 1 on the daily series. "Reject" = the source Granger-causes the target at the 5 % level.

Direction	p-value (lag 1)	Decision
Redemptions → deviation	$< 1 \times 10^{-4}$	reject (floor arbitrage)
Deviation → redemptions	0.139	fail
ETH return → deviation	0.097	marginal (10 % only)

7.3 Synthesis

The causality panel ratifies the asymmetric-band mechanism. The redemption stream is the dominant, statistically clean driver of the deviation (redemptions → deviation, $p < 1 \times 10^{-4}$, one-directional), confirming that the floor is actively enforced rather than passively respected. The deviation itself is near-non-stationary (ADF $p = 0.117$, half-life 9.1 days), confirming that the premium is a persistent regime rather than transient noise. And ETH enters only weakly, confirming that the peg dynamics are governed by the protocol's own arbitrage mechanics more than by the collateral price. The monitoring implication is direct: the leading indicator of floor pressure is the redemption stream (Section 4), the persistent state variable is the premium level itself, and ETH is a secondary, liquidation-channel input.

8 Case studies

Three windows test the asymmetric band under stress. Together they invert the usual stablecoin stress narrative: the worst collateral shock was absorbed without recovery mode, and the worst market-wide crisis pushed LUSD to a *premium*, not a discount.

8.1 The May 2021 ETH crash: a collateral shock absorbed

The May 2021 ETH crash was the largest collateral shock in the window — ETH fell roughly 50 % over the second half of May 2021 — and it landed just after the LUSD supply peak of $1.56 B (2021-05-15, Section 5.3), so the system was at its most leveraged. The protocol absorbed it cleanly. The TCR fell to a minimum of 217 % — still comfortably above the 150 % recovery-mode threshold, so **recovery mode never triggered**. Liquidations totalled $92,365,762 of debt and redemptions $50,280,260 of LUSD, both large in absolute terms but absorbed by the stability pool and the floor arbitrage respectively. The LUSD deviation ranged $[-158, +205]$ bp: a −158 bp discount at the depth of the crash (the floor under maximum collateral stress), quickly reclaimed, against a +205 bp premium as the dust settled and flight-to-quality demand returned. The episode is the clean proof that the 110 % MCR plus stability pool plus redemption floor together absorb a 50 % collateral drawdown without breaking the band.

8.2 The May 2022 LUNA collapse: a non-event

The May 2022 Terra/LUNA collapse destroyed the largest algorithmic stablecoin and triggered system-wide contagion across the stable complex. For LUSD it was almost a *non-event*: the deviation ranged only $[-52, +50]$ bp, liquidations were $12,688,095, and the TCR floor was 177 % — again no recovery mode. The contrast is instructive. LUNA's death spiral was an endogenous collateral failure (the backing asset and the stablecoin were the same reflexive system); LUSD's backing is exogenous ETH with a hard 110 % floor and an independent redemption arbitrage, so a collapse *elsewhere* in the stable complex did not transmit into LUSD. LUSD neither broke down (no discount cascade) nor yet spiked up sharply (the flight-to-safety premium was modest in this window, 50 bp), suggesting the LUNA shock was read by the market as a sector-specific algorithmic failure rather than a systemic flight trigger.

8.3 The November 2022 FTX collapse: a flight-to-safety premium

The November 2022 FTX collapse is the most striking case in the report and the sharpest demonstration of the asymmetric band. While centralised and exchange-linked stablecoins faced discount-side stress, LUSD spiked to a +385 **bp flight-to-safety *premium*** (deviation range $[+259, +513]$ bp, mean +386 bp) with **near-zero redemptions** ($12,107). The reading is unambiguous: capital fled *into* the decentralised, governance-less, on-chain-redeemable LUSD, bidding it well above $1. The near-zero redemption volume confirms this was demand-side safe-haven *buying*, not a floor failure — the floor arbitrage was idle because there was no discount to clear; the entire move was on the slack ceiling side. This is the asymmetric band's signature stress response: where a discount-prone stablecoin breaks *down* in a crisis, LUSD breaks *up*, and the immutability that prevents any party from freezing redemptions is exactly what made it a credible refuge (Section 5.4).

8.4 Chicken Bonds (bLUSD): did bonding compress the premium?

Chicken Bonds (bLUSD) launched on 2022-10-04 with the explicit aim of supporting and stabilising the LUSD premium by creating a bonding market that absorbs LUSD into a protocol-owned reserve (Liquity AG 2022). We test whether it visibly compressed the premium with a simple pre/post mean comparison. The result is that the premium *rose*: the pre-window mean was +244.6 bp and the post-window mean +344.6 bp, a +100.1 bp *increase*, not a compression. We are explicit that this is **not** a controlled difference-in-differences: there is no clean control leg, and the post-launch window is *confounded by the FTX collapse* (2022-11), which drove the very flight-to-safety premium documented above. The honest conclusion is therefore agnostic: the data do not show bLUSD bonding compressing the premium, but the post-window is dominated by the FTX shock, so we cannot attribute the rise to bonding or to FTX cleanly. A properly identified evaluation of the Chicken Bonds mechanism would require a control stablecoin and an FTX-free window, and is flagged as future work (Section 9.4).

9 Findings and open questions

9.1 Key empirical findings

1. **The peg is biased to a persistent premium with an asymmetric band.** LUSD trades at a premium 74.2 % of the time (median price 1.0071); the mean premium excursion is 103.7 bp versus a mean discount of −26.6 bp, so the floor side is ≈4× tighter than the ceiling side, with a right-skewed deviation (skewness 1.56) and a 9.1-day premium half-life (Section 2). LUSD depegs upward.

2. **Negative leverage: the premium is the volatile leg.** An EGARCH(1,1) wins decisively on BIC (168.5 vs GARCH 352.7), with a *negative* GJR leverage term ($\gamma = -0.137$): upside/premium shocks raise conditional volatility more than downside shocks — the second-moment signature of a pinned floor and a free-floating ceiling (Section 3).

3. **The redemption floor is firing and drives the deviation.** LUSD is redeemed 7.17× more intensely below $1 than above it; the deviation–redemption cross-correlation is negative at lag 0 (−0.208) and lag +1; and redemptions strongly Granger-cause the deviation ($p < 1 \times 10^{-4}$) one-directionally (Sections 4, 7).

4. **Recovery mode never triggered.** The TCR (median 349.7 %, min 171.7 %) never breached the 150 % recovery-mode threshold across 1,904 daily snapshots; all 312 liquidations were normal-mode. Supply peaked at $1.56 B (2021-05-15, four days pre-crash) and declined ≈98 % to $28 M (Sections 5, 6).

5. **Liquidations are ETH-tail events absorbed by the stability pool.** $266 M of debt repaid over 312 liquidations; worst-5 % ETH-day liquidation debt is ≈73× ordinary days; ETH-return / liquidation-debt correlation −0.178. The pre-funded LUSD pool removed the auction latency that causes cascades elsewhere (Section 6).

6. **The case studies invert the stress narrative.** May 2021 ETH crash absorbed without recovery mode (TCR floor 217 %, $92 M liquidated); LUNA 2022 a non-event; FTX 2022 a +385 bp flight-to-safety *premium* with near-zero redemptions. Chicken Bonds did *not* visibly compress the premium (+100.1 bp pre-to-post), but that window is confounded by FTX (Section 8).

9.2 Implications for Derivalink V2

The LUSD monitoring playbook is the mirror image of the discount-prone-stable playbook. (1) *Use an asymmetric alarm band*: tight on the floor (a sub-$1 print is a genuine arbitrage failure, oracle problem, or base-rate spike, because the redemption arbitrage should have prevented it) and wide on the ceiling (a premium is the protocol's normal resting state, not a depeg, and indeed its flight-to-safety response). Applying a symmetric band would generate constant false alarms on the premium side and miss the genuinely informative floor breaches. (2) *Make the redemption stream the leading indicator*: redemptions Granger-cause the deviation, spike ≈7× sub-peg, and their *absence* during a premium excursion confirms safe-haven demand rather than floor failure — so a redemption-volume gauge is the early-warning signal, and the premium *level* is a persistent regime indicator (the deviation is near-non-stationary). (3) *Treat immutability as a peg-stability feature*: with no admin keys, the floor cannot be administratively frozen the way a fiat-reserve redemption rail closes or a delta-neutral hedge is paused; LUSD's floor is open 24/7, which is why it became a refuge in November 2022. The general lesson, shared with the fiat-reserve and delta-neutral reports, is that a uniform monitoring schema cannot span the stable complex — the framework must select its band shape, its leading indicator, and its risk class by the asset's peg architecture, and LUSD anchors the over-collateralised, hard-floor, upward-depegging pole.

9.3 Limitations

- Supply and TCR are taken from the on-chain `collateral_state` debt panel (authoritative, complete); the `mint_burn` burn leg ends 2022-03-15 and is therefore not used for the supply series.
- There is no `BaseRateUpdated` stream on disk, so the redemption base rate — which governs the precise stiffness of the floor — is proxied indirectly (redemption intensity plus implied haircut), not read directly (Section 4.4).
- The Chainlink ETH/USD mainnet feed covers only 2020-12..2022-12 (no FTX); the full-window and FTX-window collateral driver uses the long ETH oracle series (2020-01..2026-05).
- Recovery mode is evaluated on the *daily* TCR grid; an intra-day dip below 150 % between snapshots could be missed (the daily minimum is 171.7 %, a 21.7-point margin).
- The Curve price tape is thin-liquidity in places; the maximum 1.2729 sits inside the $[0.85, 1.30]$ guard band (0 rows dropped) but is partly an overshoot and should not be read as a sustained 27 % premium. The authoritative central tendency is the median premium (0.71 %) and the daily-grid statistics.
- The Chicken Bonds pre/post is a simple mean-difference, not a controlled DiD, and is confounded by FTX in the post window (Section 8.4).

9.4 Open questions and future work

A direct ingestion of the `BaseRateUpdated` stream would let the floor's stiffness — and the redemption-fee dynamics that allow a small persistent discount — be measured precisely rather than proxied (Section 4.4). An intra-day TCR reconstruction would let the daily-grid recovery-mode caveat be resolved and confirm whether any flash dip below 150 % ever occurred during an ETH wick. A properly identified evaluation of the Chicken Bonds mechanism — with a control stablecoin and an FTX-free window — would settle whether bLUSD bonding has any measurable effect on the premium. And a trove-level decomposition of the redemption stream (which troves are redeemed against, at what collateral ratios) would sharpen the link between the redemption floor and the lowest-collateralised tail of the trove distribution.

9.5 Cross-asset comparison

LUSD anchors the *over-collateralised, hard-floor, upward-depegging* pole of the cross-asset synthesis (D5). It is the structural mirror of the fiat-reserve (USDC/USDT) and algorithmic (UST) cases: where those carry a left-heavy, discount-prone, redemption-gated distribution, LUSD carries a right-skewed, premium-biased, redemption-*enforced* distribution. The decisive contrasts are the *negative* EGARCH leverage (the premium, not the discount, is the volatile leg — with no analogue in the discount-prone reports), the asymmetric band (hard floor, soft ceiling), and the FTX flight-to-safety *premium* (the only asset in the programme that depegged *upward* in a systemic crisis). Together with the immutability finding — a governance-less design as a peg-stability feature — LUSD gives the V2 design its over-collateralised CDP monitoring template and the proof that the monitoring framework must be parametrised by peg architecture, not applied uniformly across the stable complex.

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