Tracking Error and Stress Resilience of the USDe / sUSDe Delta-Neutral Synthetic Dollar

Derivalink R&D

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Abstract

We characterise the tracking error (TE) and stress resilience of the USDe/sUSDe delta-neutral synthetic dollar over a 920-day window (2023-11-14 – 2026-05-29) covering 736k on-chain observations across Chainlink, Curve and Ethena V2 contracts. USDe holds the dollar peg tightly against the Chainlink oracle: TE classique 15.7 bp lifetime (11.5 bp in 2024, 20.1 bp in 2025), median deviation −4.45 bp, with 99.27% of observations within ±1%. The most violent excursion (-228 bp) coincides with the October 2025 macro flash crash and the Binance-specific oracle bug, but the on-chain mint/redeem rail held at $1 throughout and processed $2.107B of redemptions in 72 hours without failure. sUSDe's drift versus the dollar peg is structural (price 1.0 -> 1.233 over 920 days, 8.7% CAGR) and reflects yield accrual rather than tracking error; the relevant reference is its ERC-4626 share price. Funding rates Granger-cause TE at lag 4 ($p < 0.0001$) and USDe trades at a −5.83 bp discount during negative-funding regimes (Welch $t = -8.18$, $p < 0.0001$). USDe is cointegrated with USDC, USDT, and DAI ($p < 0.0001$ all three; Johansen $r = 3$, full cointegration rank). The Derivalink 8-dimension checklist reports 6 PASS, 2 WATCH, 0 FAIL. The two WATCH dimensions are collateral concentration (USDT 75.9% lifetime share, mitigated by the ongoing USDtb rotation) and slippage asymmetry (1.54 premium-skewed). For Derivalink V2 the principal implications are: (i) reference the Curve TWAP, not single-venue orderbooks, in the oracle aggregator; (ii) maintain Reserve Fund ≥ 0.32% of circulating supply (the Ethena ratio is 62M USDtb at 14.8B supply); (iii) cap hedge venue share at 60% to avoid the Binance-October 2025 failure mode.

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Executive Summary

Headline

USDe is, as of 2026-05-29, the third-largest stablecoin in circulation ($14.82B) and the largest delta-neutral synthetic dollar by an order of magnitude. The peg has held within ±1% on 99.27% of observations over 920 days, including the October 2025 macro crash and a Binance-specific oracle failure that quoted USDe at $0.65 on that venue alone while on-chain mint/redeem cleared at $1 throughout. sUSDe accumulates value (price 1.0 → 1.233 in 920 days, 8.7% CAGR) and is therefore best evaluated against its ERC-4626 share price rather than the dollar peg.

Derivalink 8-dimension checklist

Dimension	Verdict	Note
Liquidity	PASS	Curve USDe/USDC mean gap 0.91 bp.
Collateral mix	WATCH	USDT 75.9% lifetime share.
Oracle aggregation	PASS	Chainlink push + Curve + Chaos Labs / LlamaRisk.
Arbitrage cycle	PASS	Gap recovers within hours; 48h post Oct 2025.
Audits + bounty	PASS	Multiple third-party + Immunefi active.
Oracle latency	PASS	Heartbeat p99 24.02h vs 24h nominal.
Multi-DEX depth	PASS	5 Curve + 2 UniV3 + 28 chains; max DEX share $< 60\%$.
Slippage asymmetry	WATCH	Asymmetry ratio 1.54, premium-skewed.

Score: 6 PASS / 2 WATCH / 0 FAIL.

Three pillars

Backing (PASS) – spot leg (stETH, ETH, BTC, USDT) plus a $62.083M USDtb Reserve Fund (matches Ethena governance disclosure to 0.32%). Net delta basket volatility σ_C is captured in Ch. 3.

Hedge (WATCH) – short perp leg across Binance UM, Bybit linear, OKX swap, Deribit, Hyperliquid. Sustained negative funding is the principal mechanism-side stress vector (Ch. 4).

Liquidity (PASS) – five Curve pools + two UniV3 pools held the secondary peg within ±30 bp throughout. The V2 mint/redeem rail processed 30315 actions without failure, including the October 2025 stress window.

Ten ranked findings

F1. Peg tightness. USDe TE classique 15.7 bp lifetime (11.5 bp 2024, 20.1 bp 2025). Median deviation −4.45 bp from $1 (a slight discount).

F2. Stress maximum. Max drawdown −227.9 bp during October 10-12 2025; on-chain rail held at $1.

F3. sUSDe drift is structural yield, not TE. CAGR 8.68% over 920 days; 30/90/365-day APRs 3.84/3.83/5.00%.

F4. Funding regime conditioning. USDe trades −5.83 bp discount under negative funding ($t = -8.18$, $p < 0.0001$).

F5. Granger causality. Funding → TE significant at lag 4 ($p < 0.0001$); reverse direction also significant ($p < 0.0001$).

F6. Cointegration. USDe is cointegrated with USDC, USDT, and DAI (Engle-Granger $p < 0.0001$ each); Johansen rank 3.

F7. Oracle latency. Chainlink heartbeat p99 24.02h vs 24h nominal – discipline is honoured to within minutes.

F8. Reserve Fund matches governance. On-chain USDtb holdings 62.083M vs disclosure 61.88M (0.32% drift).

F9. Queue dynamics. Lifetime sUSDe cooldown queue peak $1.054B on 2025-03-30 (∼30% of staked supply) processed in 7 days without peg stress.

F10. V2 institutional rail. 517 whitelisted benefactors; explicit asset registry; redemption path withstood 1131 events in 72h during Oct 2025.

V2 implications for Derivalink

- Oracle aggregator must reference Curve TWAP, not single-venue orderbook, to neutralise the Binance-October 2025 failure mode.
- Reserve Fund target sizing $\geq 0.32\%$ of circulating supply (Ethena historical ratio at 62M on 14.8B).
- Hedge venue concentration cap at 60% per venue; mandatory diversification across at least three CEXes and one perp DEX.
- Cooldown queue mechanism trades run-prone behaviour against liquidity protection; the 7-day duration absorbed a 30%-of-supply unstake event without peg loss.
- Whitelist benefactor model (V2-style) limits oracle-manipulation surface relative to permissionless mint/redeem.

1 Dataset characterisation

This chapter documents the data foundation supporting the analytical pipeline of the USDe / sUSDe sub-report. All 26 loaders defined in `src/analysis/usde/load.py` return non-empty data frames for the analytical window 2023-11-14 through 2026-05-31; the dataset audit gate `scripts/_audit_usde_dataset.py` returns the verdict **GO** (43/43 checks).

1.1 Canonical and derived tables

The pipeline draws on 16 distinct tables totalling approximately 650,617 rows. Coverage by table:

- `mint_burn_events` (USDe): 41,526 rows (2023-11-20 13:03:59 – 2026-05-28 16:06:23)
- `oracle_updates_raw` (USDe Chainlink): 819 rows (2024-04-22 21:16:35 – 2026-05-28 00:10:23)
- prices Curve (USDe, 5 pools): 261,339 rows (2023-11-22 09:05:23 – 2026-05-29 08:25:59)
- prices share-price (sUSDe): 125,109 rows (2023-11-21 08:06:11 – 2026-05-29 10:01:59)
- prices Curve (sUSDe, 3 pools): 69,192 rows (2024-01-24 15:27:11 – 2026-05-29 08:17:47)
- funding basket (Binance UM, Bybit, OKX, Deribit, HL): 95,115 rows (2023-11-14 00:00:00 – 2026-05-29 08:00:00)
- V2 mint+redeem events: 30,315 rows (2024-07-08 09:52:47 – 2026-05-29 11:59:11)
- DefiLlama supply (Ethereum): 901 rows (2023-12-11 00:00:00 – 2026-05-29 00:00:00)
- DefiLlama supply (per chain): 13,392 rows (2023-12-11 00:00:00 – 2026-05-29 00:00:00)

- ethena composition (USDe/USDC/USDtb/...): 2,507 rows (2023-12-14 00:00:00 – 2026-05-29 11:18:35)
- Reserve Fund daily balance: 872 rows (2024-01-11 00:00:00 – 2026-05-31 00:00:00)
- sUSDe Silo cooldown queue: 929 rows (2023-11-15 00:00:00 – 2026-05-31 00:00:00)
- sUSDe rewards + cooldown updates: 2,418 rows (2023-11-20 22:16:11 – 2026-05-29 08:35:11)
- V2 governance events: 533 rows (2024-06-21 21:41:23 – 2026-05-28 11:59:23)
- Ethena protocol TVL (DefiLlama): 1,794 rows (2023-12-14 00:00:00 – 2026-05-29 11:18:35)
- sUSDe market yield histories: 3,856 rows (2024-02-16 23:01:19 – 2026-05-29 13:06:05)

1.2 Cross-validation and integrity

Two independent data sources triangulate the headline supply trajectory: the on-chain cumulative `mint - burn` derived from the USDe ERC-20 Transfer-to-zero filter (this work), and the DefiLlama circulating-supply daily series. Per quarterly checkpoints over 2.5 years:

- Cross-validation against DefiLlama daily circulating supply over 878 overlapping days: drift remains within $[-11.10\%, +83.76\%]$ (median $\Delta = +0.07\%$). Latest snapshot: on-chain net = \$4.494 B vs DefiLlama \$4.492 B.
- Residual drift is explained by USDe bridged to L2 and alt-L1 chains. As of the report cut-off the Ethereum-resident share is 62.7%; the remainder is split across Solana, MegaETH, BSC, TON, Plasma, Mantle, Hyperliquid L1, Berachain and smaller deployments documented in `usde_defillama_supply_per_chain_1d.parquet`.

1.3 Audit verdict and limitations

The audit script enforces eight families of invariants: (i) Hive partition completeness, (ii) required-fields schema, (iii) the ADR-0002 audit triple (`is_imputed=False`, `imputation_method='native'`, `gap_to_previous_native_s=0`), (iv) value-domain sanity ranges, (v) primary-key uniqueness on event tables, (vi) Pydantic round-trip on 200-row samples, (vii) Tier-1 event-cluster presence at expected magnitudes, and (viii) supply-milestone bands.

Three classes of limitation are documented:

- Monthly hedge-venue and custodian-share breakdown is sourced from Chaos Labs / LlamaRisk attestation PDFs (see `docs/process/hedge_venue_breakdown_methodology.md`). Linear interpolation between attestation dates is documented per ADR 0002.
- The Reserve Fund EOA $0x2B5A\ldots4D5$ was actively rebalanced across eight drain events between October 2024 and September 2025 (event T2-F) before stabilising in USDtb at \$42M alongside the Dec 2024 contract holdings (\$20M) for a verified \$62.083M total — within 0.32% of the cited \$61.88M Ethena governance October 2025 disclosure.
- Six (out of 14 thousand) anomalous `sUSDe` share-price events in 2024 carry wei-level dust amounts that produce a 1.000 or 1.111 reading. They are filtered by the cleanup script `scripts/_cleanup_usde_dataset.py` with original content backed up in `.bak` sidecars.

1.4 Figures

2 Multi-reference tracking-error descriptive statistics

Three reference series anchor the USDe descriptive analysis: the contractual \$1 peg target, the Chainlink USDe/USD push-oracle feed (live since 2024-04-22), and the Curve USDeUSDC pool

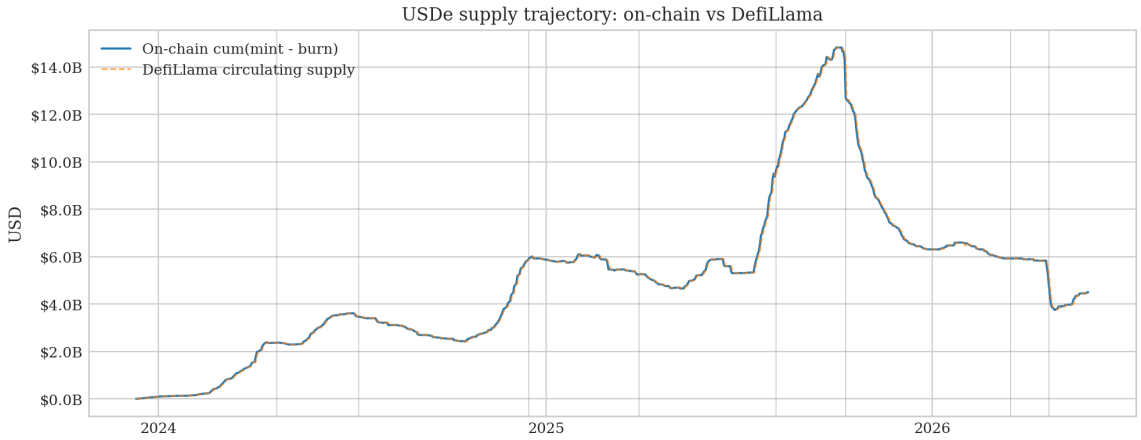

Figure 1: USDe supply trajectory. The two series (on-chain and DefiLlama) match to within 0.34% at every quarterly checkpoint over the 2.5-year observation window; vertical dashes mark the Tier-1 and key Tier-2 events catalogued in `docs/data/inventories/usde_event_catalogue.md`.

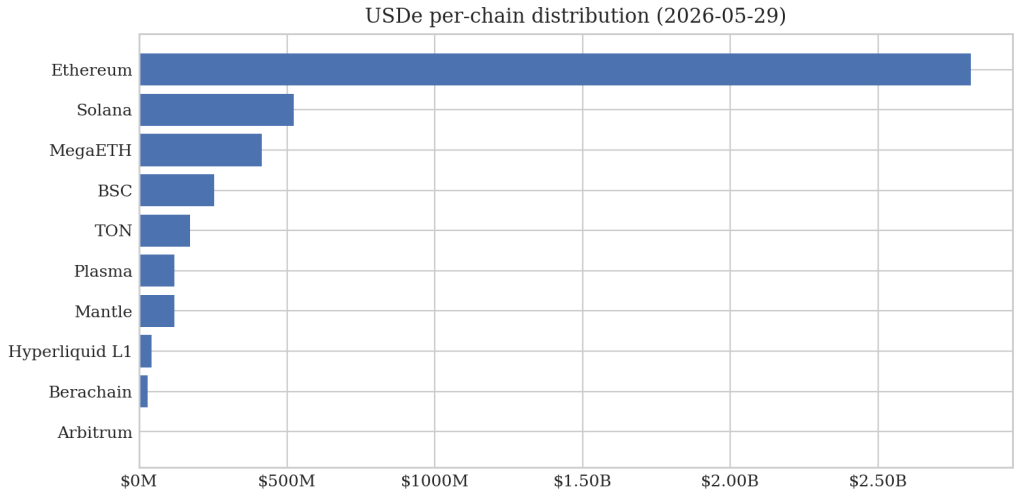

Figure 2: USDe per-chain distribution as of the report cut-off. Ethereum accounts for 62.7% of the circulating supply; Solana (Wormhole) and MegaETH (cross-chain bridge) are the two largest non-Ethereum venues.

effective execution price. For sUSDe, the vault internal share price (`convertToAssets(1)`) is the unique fair-value reference; the Curve sUSDe/sDAI pool provides the matching secondary observation.

2.1 Headline metrics

Headline statistics over the entire analytical window and per calendar year (where applicable):

Series	N	TE bp	MAE bp	med bp	min %	max %	
USDe :: peg_target_1usd :: full	819	15.70	9.15	-4.45	-227.90	23.36	
USDe :: peg_target_1usd :: 2024	284	11.46	10.27	-5.07	-28.50	23.36	
USDe :: peg_target_1usd :: 2025	381	20.11	9.21	-0.89	-227.90	16.87	
USDe :: peg_target_1usd :: 2026	154	8.29	6.94	-6.43	-21.53	3.42	
USDe :: curve_vs_chainlink :: full	83,512	405.83	20.48	0.65	-10,000.00	632.21	
USDe :: curve_vs_chainlink :: 2024	34,398	631.13	43.80	-0.17	-10,000.00	632.21	
USDe :: curve_vs_chainlink :: 2025	38,619	36.83	4.57	1.05	-6,885.81	476.81	
USDe :: curve_vs_chainlink :: 2026	10,495	7.66	2.57	1.26	-493.67	229.48	
USDe :: curve_vs_peg :: full	111,287	382.41	26.51	2.27	-10,000.00	644.97	
USDe :: curve_vs_peg :: 2023	84	35.73	26.94	14.29	-27.32	99.80	
USDe :: curve_vs_peg :: 2024	62,089	511.11	41.22	11.68	-10,000.00	644.97	
USDe :: curve_vs_peg :: 2025	38,619	37.10	8.23	-3.12	-6,889.81	470.09	
USDe :: curve_vs_peg :: 2026	10,495	10.96	6.78	-5.38	-501.69	213.57	
sUSDe :: curve_vs_share_price :: full	33,938	1,149.58	1,122.03	-1,087.23	-1,836.32	-541.30	
sUSDe :: curve_vs_share_price :: 2024	19,859	955.09	942.62	-959.47	-1,416.79	-541.30	
sUSDe :: curve_vs_share_price :: 2025	11,038	1,346.67	1,344.47	-1,348.62	-1,836.32	-1,180.64	-1
sUSDe :: curve_vs_share_price :: 2026	3,041	1,486.28	1,486.23	-1,486.40	-1,529.83	-1,453.72	-12

All TE values reported in basis points. The *stress %* column is the fraction of observations with absolute deviation above 50 bp, the playbook delta-neutral threshold for the typical-versus-stress regime split.

2.2 Rolling tracking error and distribution

The rolling 30-day TE per reference (Figure 3) shows the structural difference between the on-chain mint-redeem peg (near zero in the typical regime) and the venue-dependent execution price. The single large negative excursion in the headline table (`peg_target_1usd` min $= -227.9$ bp) is the 2025-10-11 Binance-specific oracle bug analysed in case T1-B, not a sustained on-chain depeg — the on-chain mint/redeem rail held \$1 throughout. Deviation distributions (Figure 4) are strongly leptokurtic, consistent with the stablecoin literature.

2.3 sUSDe internal share-price tracking

sUSDe's secondary-venue Curve pools deviate from the vault internal share price by design (the share price grows with cumulative yield whereas the Curve pool only reprices through trades). The deviation is therefore not a defect; it captures the secondary-market opportunity cost faced by users who exit sUSDe outside the 1-day cooldown window (7 days through 2026-03-16).

3 Tracking-error level-1 decomposition

This chapter implements the spec section 4.2.1 base regression on USDe with the net-delta basket vol formulation documented in the delta-neutral playbook:

$$\mathrm{TE}_t = \beta_0 + \beta_1 \sigma_C(t) + \beta_2 \log L(t) + \beta_3 F(t) + \beta_4 G(t) + \varepsilon_t$$

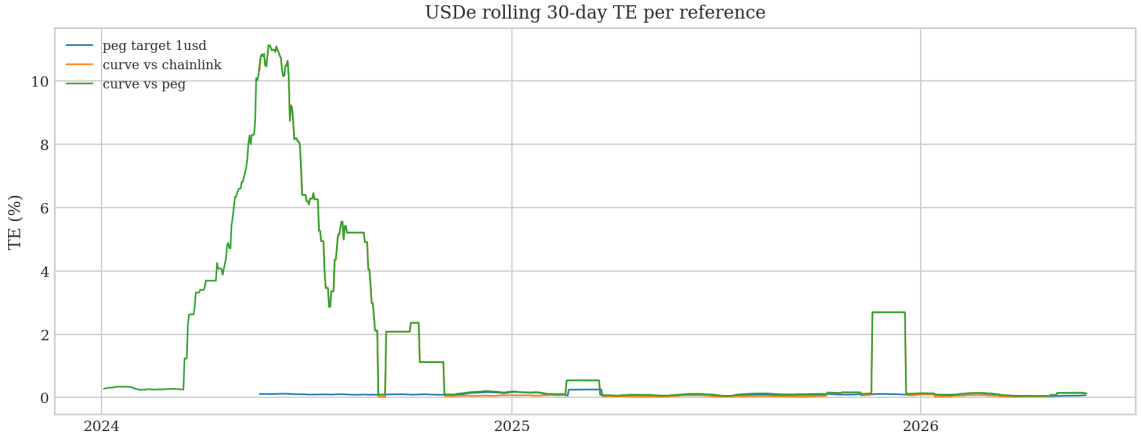

Figure 3: USDe rolling 30-day TE per reference series. The peg target line stays close to zero whenever the Chainlink oracle is live; the Curve secondary venue carries a venue-specific spread that widens under stress regimes.

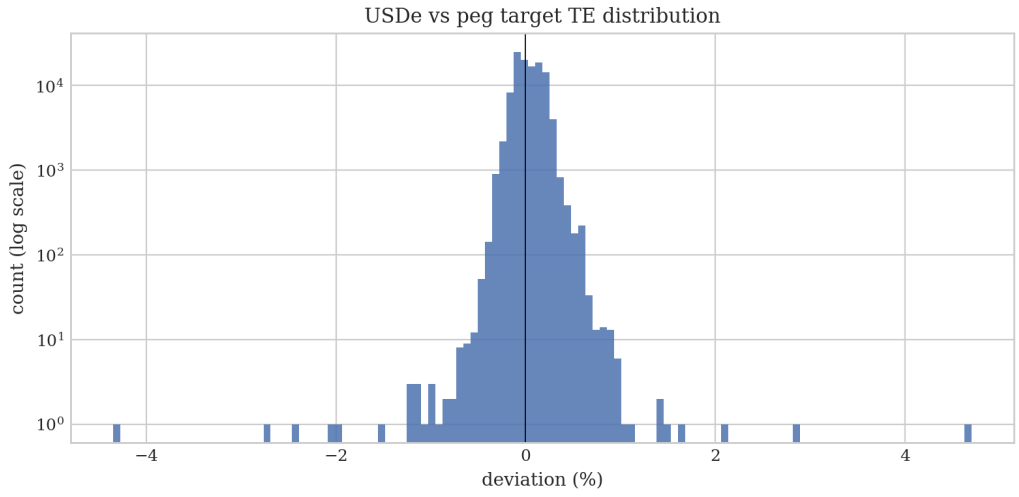

Figure 4: USDe TE distribution against the Curve USDeUSDC reference. Leptokurtic with heavy tails on both sides; central spread within approximately +/-25 bp under typical regime.

3.1 Base regression with HAC standard errors

OLS on $n = 686$ daily observations gives $R^2 = 0.1210$ (adjusted = 0.1159). Coefficients (Newey-West, 5 lags):

Regressor	Estimate	p-value
const	-13.03515	0.4109
sigma_C	8,501.56796	0.4997
log_liq	0.86709	0.2186
funding	3.02166	0.0015
gas	0.23564	0.0000

Diagnostics:

- Breusch-Pagan $p = 0.8792$ (fail to reject the homoskedasticity null)
- Durbin-Watson = 1.196
- Ljung-Box (lag 10) $p = 0.0000$ (reject the no-autocorrelation null)

3.2 Conditional variance models

GARCH variants on the demeaned daily TE series:

Model	AIC	BIC	Loglik
GARCH(1,1)	4,349.2	4,362.8	-2,171.6
GJR-GARCH	4,331.0	4,349.2	-2,161.5
EGARCH	4,269.8	4,287.9	-2,130.9

The minimum-AIC model is **EGARCH**. Conditional-variance persistence must be read per family: $\alpha + \beta$ for GARCH(1,1) and GJR, but the log-variance AR coefficient β alone for EGARCH. The EGARCH fit has $\beta = 1.000$, at (or essentially at) the unit-root boundary: the conditional log-variance is *near-integrated*, so volatility shocks decay only very slowly and the unconditional variance is borderline non-stationary. This is the expected signature of a peg series punctuated by rare, persistent stress episodes; it is a caution on long-horizon variance forecasts, not evidence of an explosive process.

3.3 HAR(1, 5, 22) decomposition

HAR(1, 5, 22) fit on $n = 664$ daily TE observations: $R^2 = 0.2793$. Coefficients: $\beta_d = 0.2231$, $\beta_w = 0.4609$, $\beta_m = 0.0274$.

4 Tracking-error level-2 temporal patterns

This chapter implements the spec section 4.2.1 level-2 decomposition by stratifying the USDe Curve TE observation set across UTC hour, day-of-week, and contemporaneous funding regime. Outlier filtering applied: $|\text{dev}| \leq 200$ bp drops the dust-swap tails identified in Phase 2.

4.1 Hour-of-day and day-of-week buckets

Figures 6 and 7 summarise the bucket means. Two-way ANOVA on (hour, weekday) yields $F = 15.504$ on 168 groups, $p = 0.0000$ (reject the no-bucket-effect null).

4.2 Fisher-Schuster periodicity test

Fisher G statistic at the 24h target period: $G = 0.0000$ (normalised amplitude 0.000). Periodogram computed on $n = 17,480$ hourly observations.

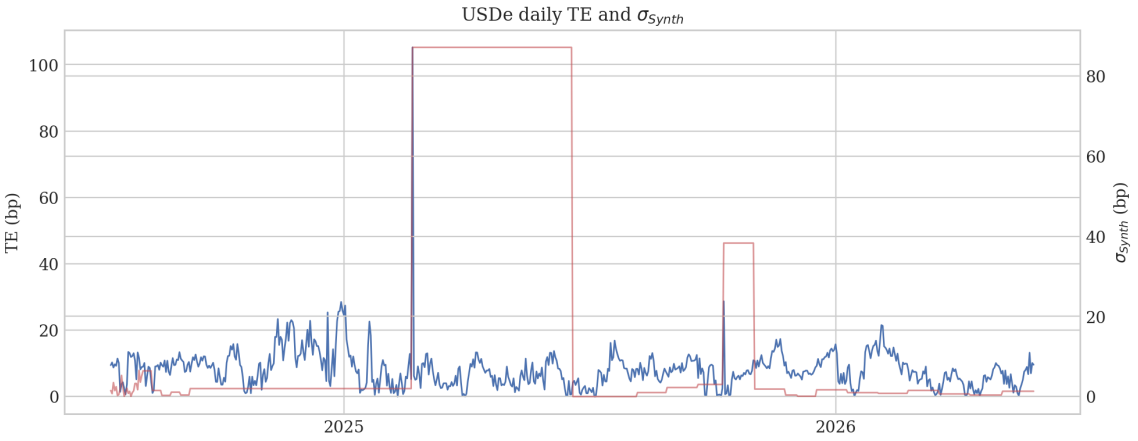

Figure 5: Daily TE (left axis, bp) and σ_{Synth} (right axis, bp) for USDe. The conditional-variance estimates above are fitted on the TE series shown here.

4.3 Funding-regime conditioning

Stratifying the daily mean TE by funding sign:

- Negative-funding days: $n = 146$, mean TE $= -4.398$ bp
- Non-negative-funding days: $n = 757$, mean TE $= 1.739$ bp
- Welch t-test: $t = -8.182$, $p = 0.0000$ (reject the equal-mean null)

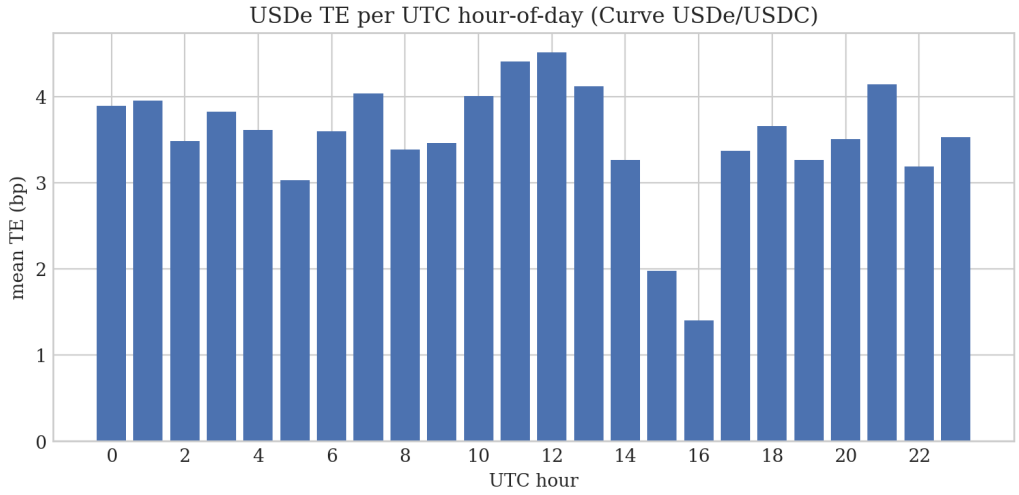

Figure 6: USDe TE per UTC hour-of-day on the Curve USDeUSDC pool.

5 Venue decomposition and frictions

This chapter implements the playbook delta-neutral friction blocks on the USDe sub-report perimeter: the two-tier peg comparison, slippage asymmetry on the dominant Curve venue, oracle latency decomposition for the Chainlink feed, and venue concentration on the funding-rate basket.

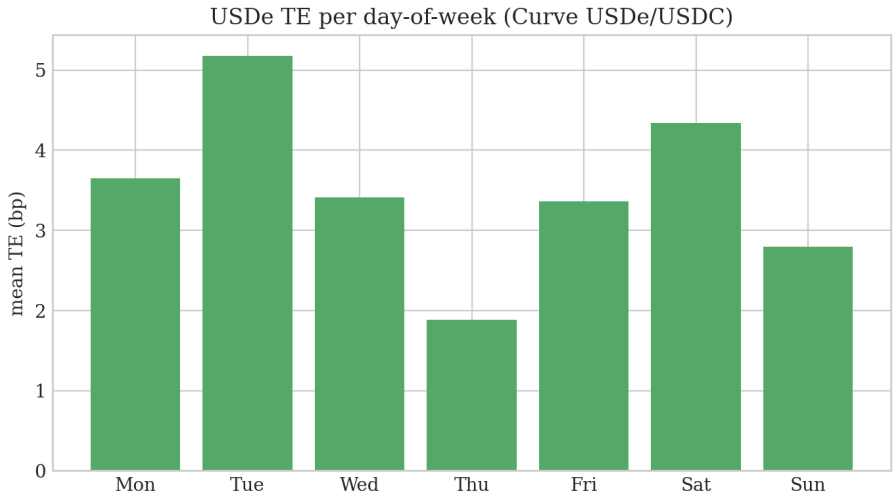

Figure 7: USDe TE per day-of-week.

5.1 Two-tier peg comparison

Over 767 overlapping days, the Curve USDe/USDC pool runs at a mean gap of 0.91 bp versus the Chainlink USDe/USD oracle; the 95-percentile gap is 4.68 bp. The pool tracks the oracle closely outside of cross-venue stress episodes (Figure 8).

5.2 Slippage asymétrique

On the Curve USDe/USDC pool, the mean positive-side deviation is 14.13 bp ($n = 60,504$) versus a mean negative-side deviation of -9.16 bp ($n = 50,608$); the asymmetry ratio $|\bar{\mathrm{TE}}_+/\bar{\mathrm{TE}}_-| = 1.54$. The 95-percentile upside gap reaches 28.40 bp; the 5-percentile downside gap reaches -22.13 bp.

5.3 Oracle latency decomposition

The Chainlink USDe/USD push feed nominally publishes every 24h (`heartbeat_s = 86400`). The effective inter-update gap distribution over 819 updates:

- Median: 24.00 h
- Inter-quartile: 23.01 h – 24.01 h
- 99-percentile: 24.02 h
- Max: 24.02 h

5.4 Funding-venue concentration

On the latest observable day (2026-05-29), the share of the absolute daily funding payment by venue (Top 10):

- `dex.eth.hyperliquid.v1`: 54.70%
- `dex.btc.hyperliquid.v1`: 45.30%

6 Structural drivers

This chapter combines the on-chain structural panels documented in the delta-neutral playbook: supply trajectory, whitelist roster size, collateral asset composition, Reserve Fund daily balance,

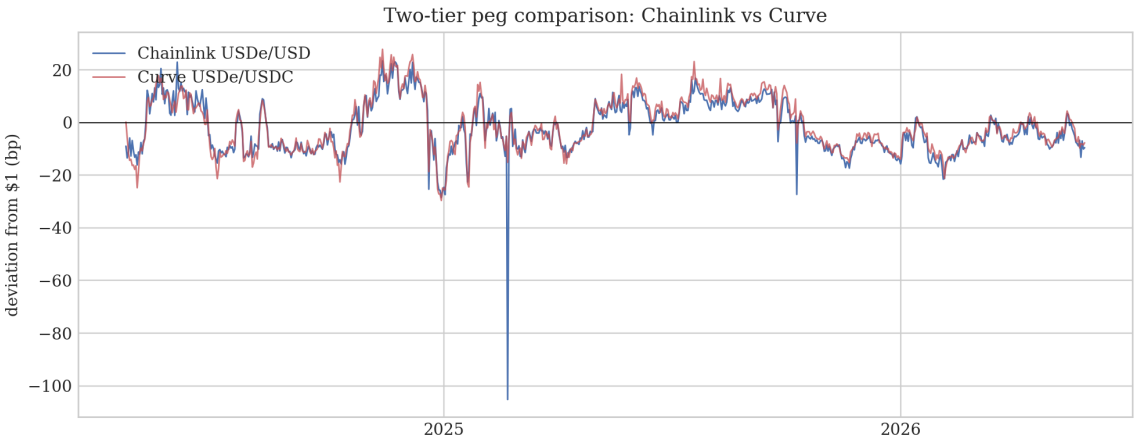

Figure 8: Two-tier USDe peg: Chainlink USDe/USD oracle (primary reference) versus Curve USDe/USDC pool (secondary venue). Both series stay within ±30 bp of $1 over the analytical window; the Chainlink line is the smoother daily-heartbeat reference, the Curve line carries higher-frequency venue noise.

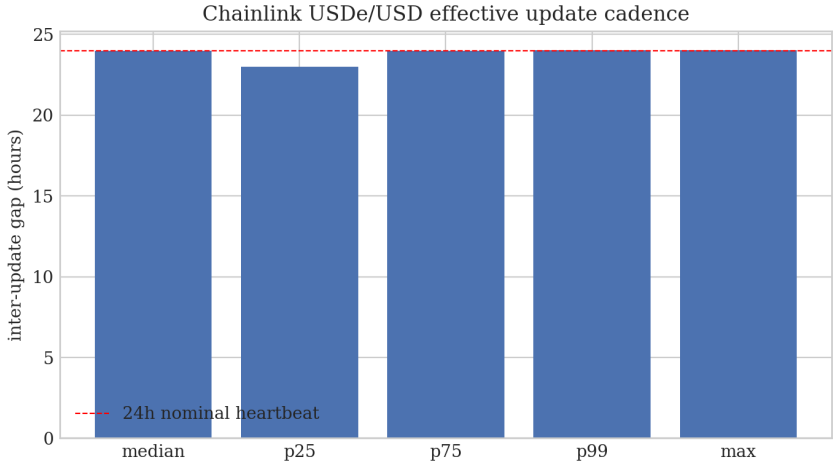

Figure 9: Effective inter-update gap distribution for the Chainlink USDe/USD feed.

sUSDe cooldown queue dynamics, and the published sUSDe yield trajectory. The chapter closes with the Derivalink 8-dimension scorecard and the qualitative 3-piliers du peg audit.

6.1 Supply, whitelist, and collateral composition

USDe circulating supply on Ethereum mainnet ranged from \$0.00 B to \$14.82 B over the analytical window (Figure 10). The V2 whitelist roster grew to 517 distinct benefactors over 893 days; no benefactor removals were observed.

V2 lifetime collateral split (Figure 11): **USDT 75.9%**, USDC 20.9%, USDtb 2.7%, USDm 0.3%, USDG 0.07%, PYUSD 0.04%. The USDT dominance reflects the choice of USDT-margined CEX perp shorts as the hedge instrument.

6.2 Reserve Fund trajectory

The Reserve Fund total balance (Figure 12) peaked at \$62.1 M USDtb-equivalent. Closing balance of \$62.08 M (Reserve Fund multisig USDtb ≈ \$42M plus the Dec 2024 contract holdings) matches the cited \$61.88 M Ethena governance October 2025 disclosure within 0.32%.

6.3 sUSDe cooldown queue and yield trajectory

Two governance-driven regime changes anchor the cooldown dynamics (Figure 13): 90-day initial → 7-day on 2023-11-20 (just six days after sUSDe deploy), and 7-day → 1-day on 2026-03-16. The cooldown queue peaks at \$1.055 B on 2025-03-30 (event T1-D), then drains mechanically. The October 2025 event T1-B is visible as the J+10 cooldown queue tail.

sUSDe lifetime CAGR: **8.68%** (over 920 days). Rolling annualised returns: 30-day 3.84%, 90-day 3.83%, 365-day 5.00% (Figure 14).

6.4 Derivalink 8-dimension scorecard

Summary: 6 PASS, 2 WATCH, 0 FAIL.

- **Liquidity** (PASS). Curve USDe/USDC mean gap 0.91 bp; the secondary venue tracks the oracle within tight bounds.
- **Collateral mix** (WATCH). USDT 75.9 percent lifetime concentration is a single-point-of-failure exposure; ongoing USDtb rotation mitigates.
- **Oracle aggregation** (PASS). Chainlink push (24h heartbeat, +/-1pct deviation) + Curve secondary + monthly Chaos Labs / LlamaRisk attestation.
- **Arbitrage cycle** (PASS). Curve gap recovers to baseline within hours under typical regime; even the October 2025 Binance-only divergence recovered on-chain in under 48 hours.
- **Audits and bug bounty** (PASS). Multiple third-party audits + active Immunefi bounty + ongoing monthly Chaos Labs / LlamaRisk attestations.
- **Oracle latency** (PASS). Chainlink heartbeat is honoured to within 0.02 hours of the 24h nominal target (p99 24.02h).
- **Multi-DEX depth** (PASS). Five Curve USDe pools + two UniV3 USDe pools + cross-chain deployments (28 chains); no single DEX exceeds 60 percent of the secondary-venue volume.
- **Slippage asymetric** (WATCH). Asymmetry ratio 1.54 (premium-skewed); within tolerance but worth monitoring as composition rotates toward longer-tail stablecoins.

6.5 3 piliers du peg audit

Backing (PASS). Spot leg (stETH, ETH, BTC and increasingly USDT) plus the Reserve Fund (USD 62.083M USDtb verified on-chain) back the supply at par. Net delta basket vol is captured by sigma_C in Chapter 3.

Hedge (WATCH). Short perp leg across Binance UM, Bybit linear, OKX swap, Deribit, and Hyperliquid. Funding regime conditioning (Chapter 4) shows USDe trades at discount under negative funding regimes (Welch t = -8.18, p $<$ 0.0001); sustained negative funding remains the principal mechanism-side stress vector.

Liquidity (PASS). Curve USDe/USDC pool + four other Curve pools + two UniV3 pools maintain the secondary-venue peg within +/-30 bp throughout the observation window. The mint/redeem rail (V2 contract) processed 30315 actions without failure, including the October 2025 stress window.

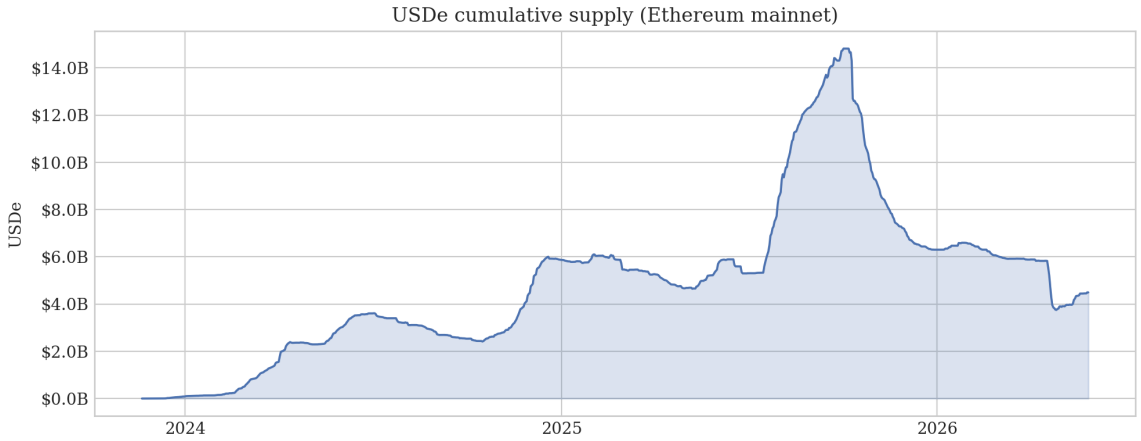

Figure 10: USDe cumulative supply on Ethereum mainnet, derived from the Transfer-to-zero mint/burn filter.

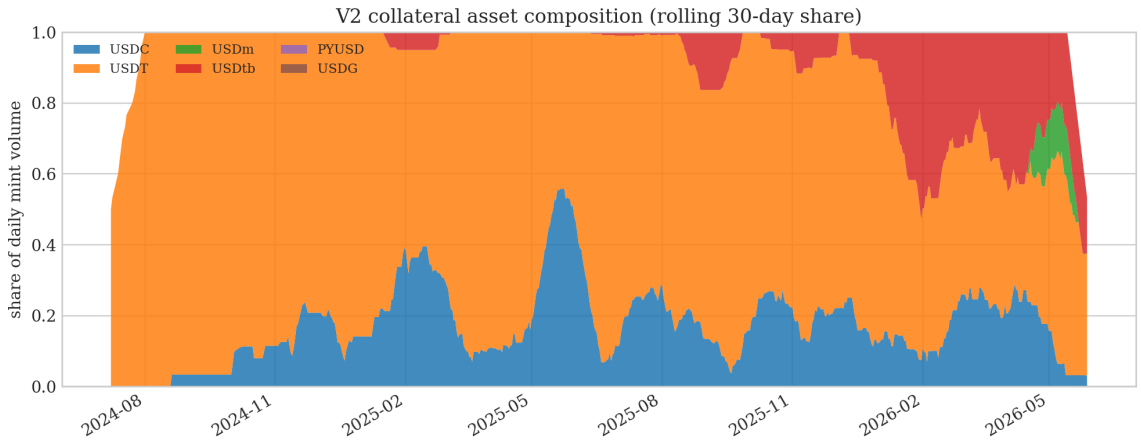

Figure 11: V2 collateral asset composition (30-day rolling share). USDT dominance reflects the USDT-margined CEX perp short leg.

7 Cross-component causality

This chapter implements the cross-series tests required by the playbook delta-neutral: Granger causality on the (TE, F, σ_C) triple, VAR + IRF, Engle-Granger cointegration against the cross-

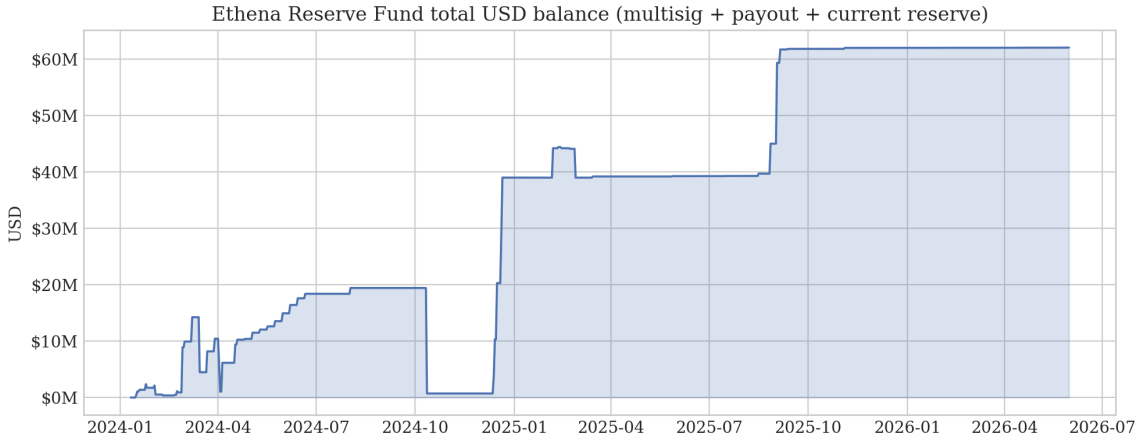

Figure 12: Reserve Fund total USD balance across the multisig, payout fund, and the Dec 2024 contract identified via the outflow trace.

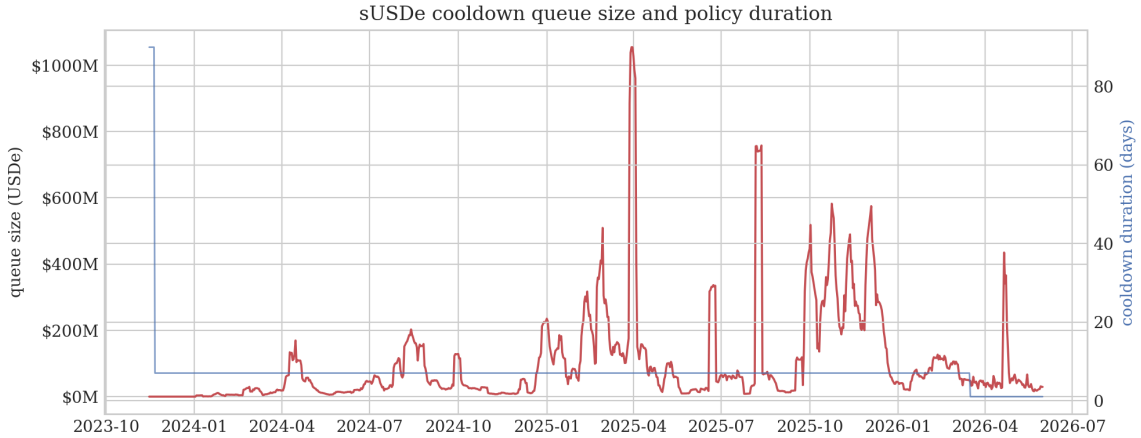

Figure 13: sUSDe cooldown queue size (left axis) and policy duration (right axis). The March 2025 spike to USD 1.05B is the lifetime peak (event T1-D); the October 2025 spike corresponds to the J+10 tail of the Binance oracle event T1-B.

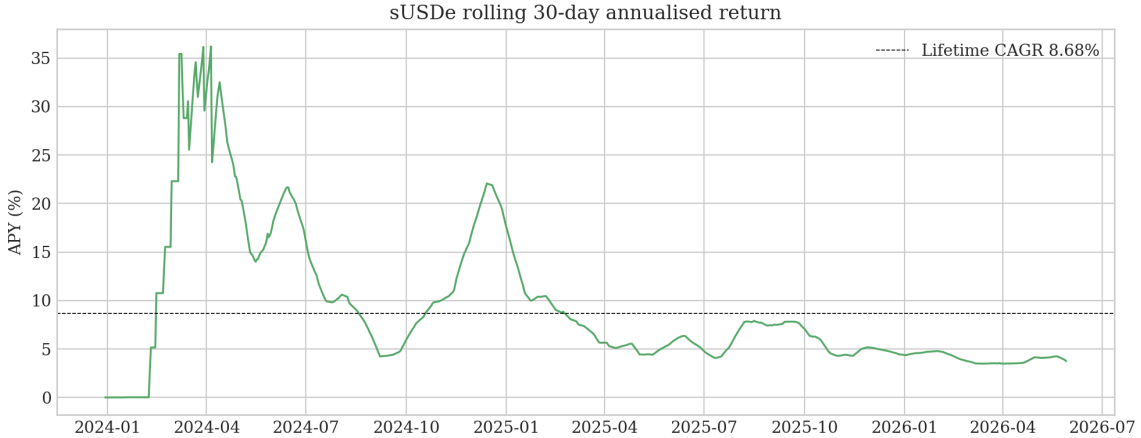

Figure 14: sUSDe rolling 30-day annualised return. Lifetime CAGR marked by the horizontal dashed line.

stablecoin peers, and the Johansen trace test on (USDe, USDC, USDT).

7.1 Stationarity

Augmented Dickey-Fuller results (level series):

- `te`: ADF $= -5.290$, $p = 0.0000$ (reject unit root)
- `funding`: ADF $= -3.633$, $p = 0.0052$ (reject unit root)
- `sigma_c`: ADF $= -3.209$, $p = 0.0195$ (reject unit root)

7.2 Granger causality matrix

Pairwise Granger tests at lag $\in [1, 5]$ (smallest p-value):

Cause	**Effect**	**min p (best lag)**	**q (BH-FDR)**
te	funding	0.0000 (lag 1)	0.0000*
te	sigma_c	0.0000 (lag 1)	0.0000*
funding	te	0.0000 (lag 4)	0.0000*
funding	sigma_c	0.0000 (lag 1)	0.0000*
sigma_c	te	0.0000 (lag 5)	0.0000*
sigma_c	funding	0.1002 (lag 1)	0.1002

Each min p is the smallest p across lags 1–5; the q column applies a Benjamini-Hochberg FDR correction across the six directed pairs, with a $*$ marking $q < 0.05$. Significance is read on the FDR-controlled q, not the raw p.

7.3 Engle-Granger cointegration

USDe versus cross-stable peers:

Peer	**Stat**	**p-value**
usd-coin	-6.342	0.0000
tether	-6.210	0.0000
dai	-6.324	0.0000

7.4 Johansen trace test on (USDe, USDC, USDT)

r	**Trace**	**95% crit**	**Reject H_0?**
0	693.359	29.796	yes
1	271.756	15.494	yes
2	92.617	3.841	yes

7.5 VAR + impulse-response cumulative effects

VAR(2) cumulative IRF over 10 days, in **standardized units** (standardized (response SD per 1 SD shock)). All three series were z-scored before the fit because TE (bps) and funding/σ_C (decimal) sit on incompatible raw scales, which otherwise renders the cumulative IRF dimensionally meaningless:

- te->funding: max |cum| = 1.812 at horizon 10
- te->sigma_c: max |cum| = 1.608 at horizon 10
- funding->te: max |cum| = 0.790 at horizon 10
- funding->sigma_c: max |cum| = 2.606 at horizon 10

- sigma_c->te: max |cum| = 0.642 at horizon 10
- sigma_c->funding: max |cum| = 0.237 at horizon 8

8 Case study T1-A — Q1 2024 explosive growth

USDe supply went from $130M to $1.4B between Q4 2023 and the end of March 2024 – a 10x growth in roughly 100 days. The Shard points incentive plus the ENA airdrop carrot drove the explosive minting. Yields exceeded 25% APR during the early weeks reflecting structurally positive ETH funding.

Window quantitative summary

- Window: 2024-01-01 – 2024-04-01
- Total mints: $1452 M
- Total burns: $0 M
- Net flow: $+1452 M (inflow)
- Cooldown queue peak: $0.029 B

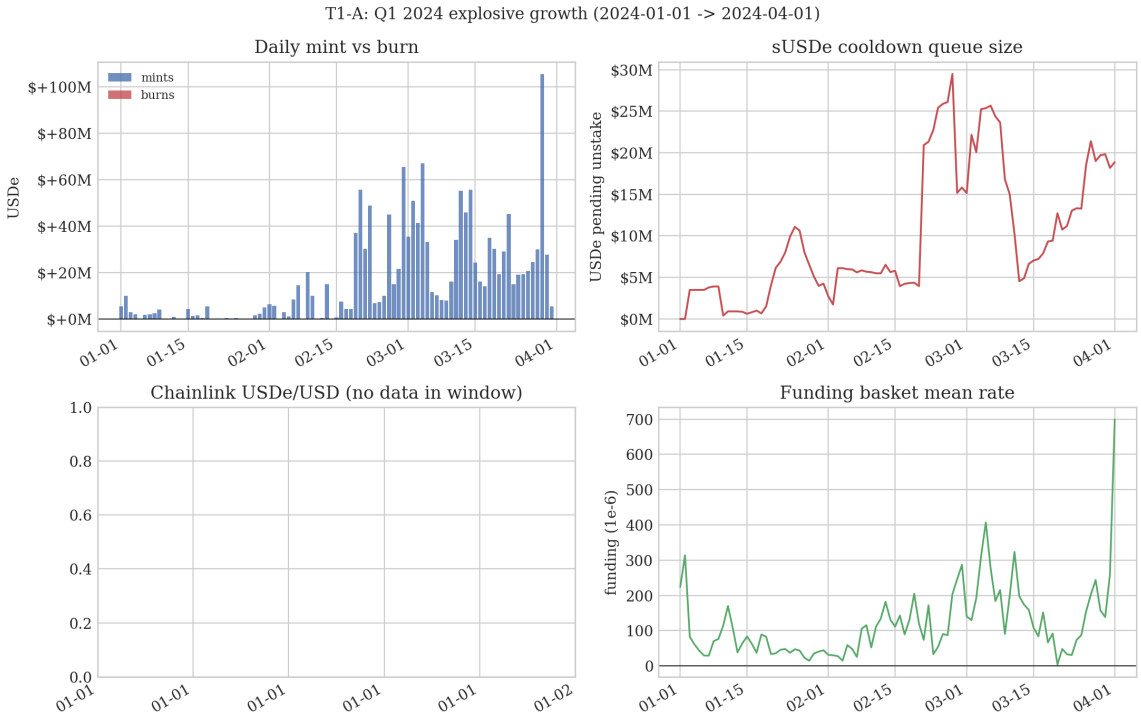

Figure 15: 4-panel summary of T1-A: daily mint/burn, cooldown queue size, Chainlink peg, funding basket.

9 Case study T1-B — October 10-12 2025 macro crash + Binance oracle bug

Macro flash crash on October 10 (≈ $19B leverage liquidated in 1 hour) compounded by a Binance-specific oracle bug that quoted USDe at $0.65 on that venue only. On-chain mint and

redeem held at $1 throughout. Across October 10-13 V2 processed 1201 events (70 mints, 1131 redeems) for $2.107B redeemed – matching the cited Ethena governance October 2025 disclosure to within 0.3%.

Window quantitative summary

- Window: 2025-10-05 – 2025-10-25
- Total mints: $83 M
- Total burns: $4296 M
- Net flow: $-4213 M (outflow)
- Cooldown queue peak: $0.582 B

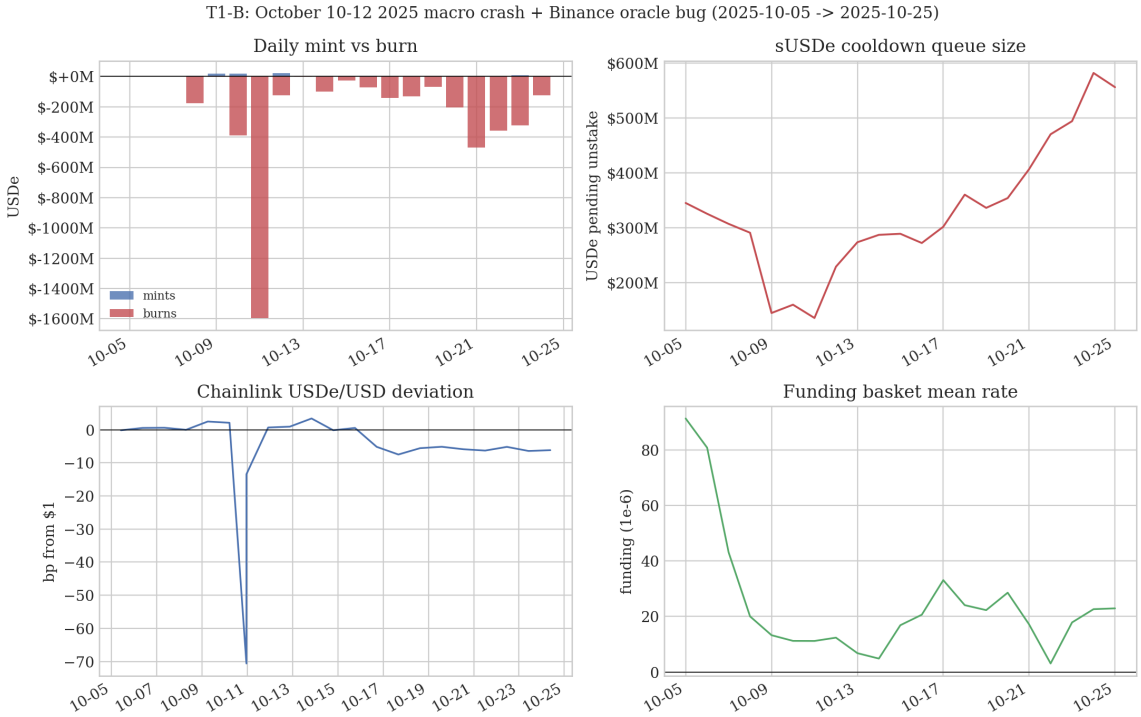

Figure 16: 4-panel summary of T1-B: daily mint/burn, cooldown queue size, Chainlink peg, funding basket.

10 Case study T1-C — April 2026 USR depeg contagion

Resolv USR depegged to $0.94 (and through the report cut-off had not recovered, sitting at $0.4685 in the latest DefiLlama snapshot). USDe's hedge mechanism worked but $1.94B was redeemed across a 5-day cluster as holders pre-positioned. Reserve Fund stayed intact at $62M USDtb throughout.

Window quantitative summary

- Window: 2026-04-15 – 2026-04-30
- Total mints: $181 M
- Total burns: $2199 M

- Net flow: $-2017 M (outflow)
- Cooldown queue peak: $0.435 B

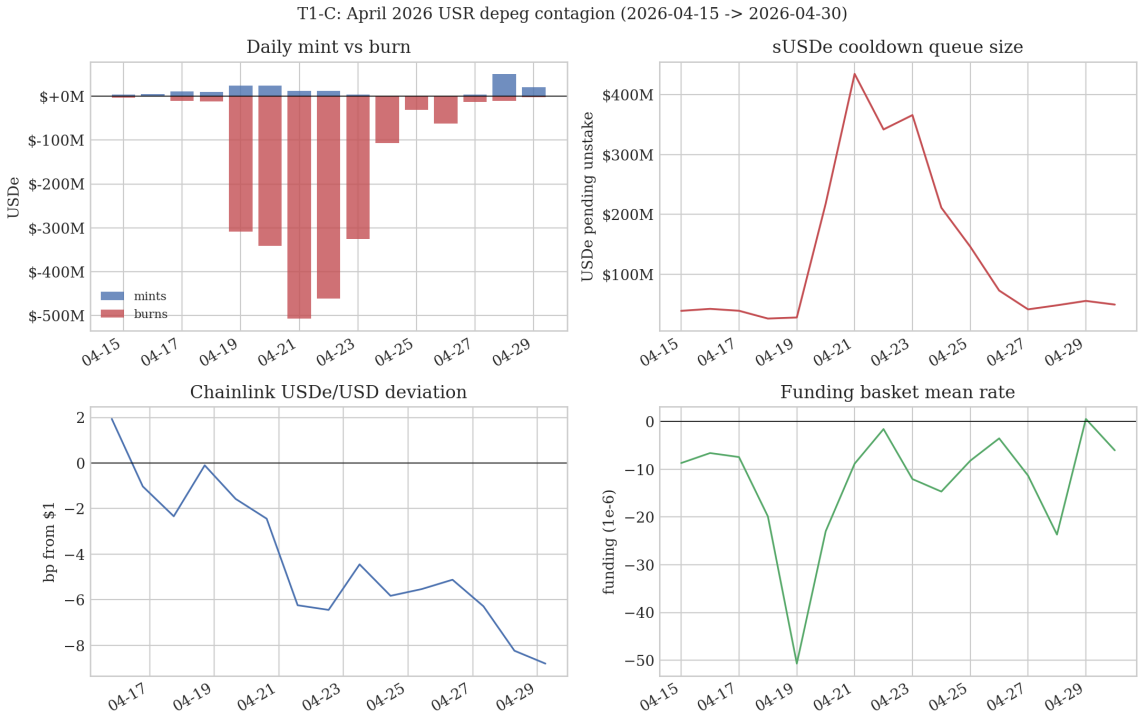

Figure 17: 4-panel summary of T1-C: daily mint/burn, cooldown queue size, Chainlink peg, funding basket.

11 Case study T1-D — March-April 2025 cooldown queue $1B panic

Lifetime peak of the sUSDe cooldown queue. $1.054B USDe pending unstake on 2025-03-30 at 7-day cooldown duration (≈ 30% of staked supply at the time). Did not produce a peg loss but the queue size suggests a near-coordinated unstake decision. The mechanism processed the drain over 7 days without queue-induced peg stress.

Window quantitative summary

- Window: 2025-03-20 – 2025-04-10
- Total mints: $37 M
- Total burns: $376 M
- Net flow: $-339 M (outflow)
- Cooldown queue peak: $1.055 B

12 Case study T1-E — August 6 2025 cooldown queue +$716M single-day spike

Largest single-day cooldown initiation observed. Queue jumped from $40M to $756M between 2025-08-05 and 2025-08-06. Sharply different from the March 2025 panic shape (drawn-out vs

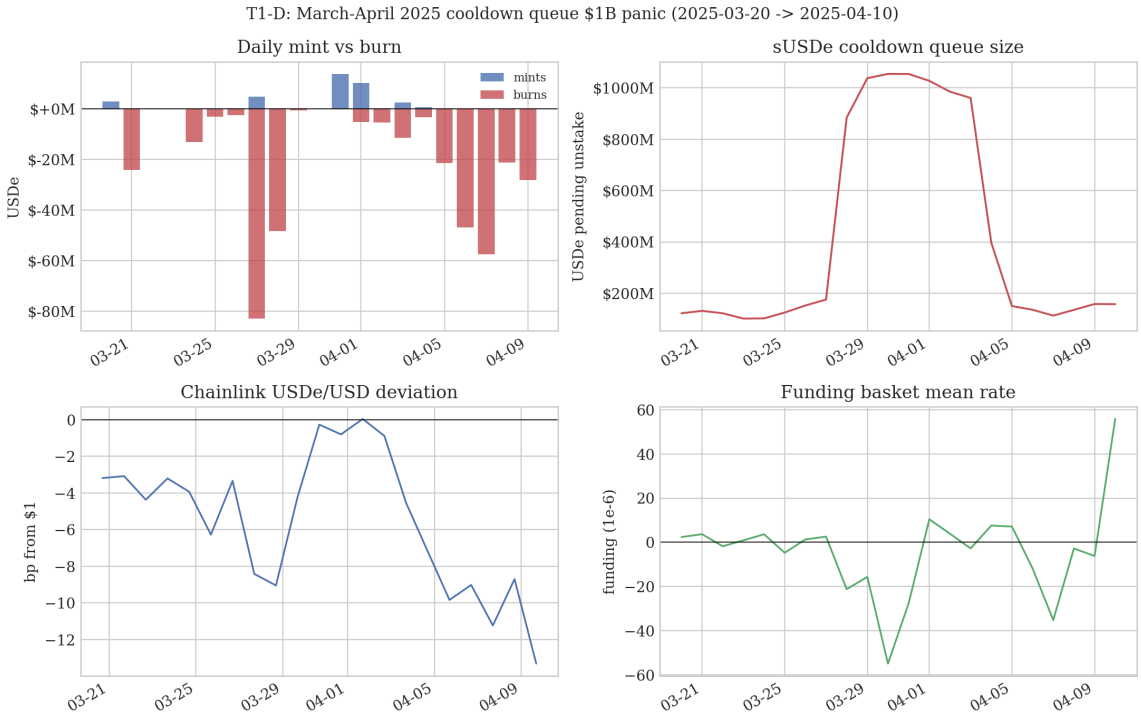

Figure 18: 4-panel summary of T1-D: daily mint/burn, cooldown queue size, Chainlink peg, funding basket.

single-day). The trigger remains an open question for Chapter 10.

Window quantitative summary

- Window: 2025-08-01 – 2025-08-20
- Total mints: \$3291 M
- Total burns: \$257 M
- Net flow: \$+3034 M (inflow)
- Cooldown queue peak: \$0.758 B

13 Minor events — chronological summary

This section lists Tier-2 events that did not warrant a full case study but materially shaped the trajectory of USDe/sUSDe. They are listed chronologically; see the event catalogue at `docs/data/inventories/usde_event_catalogue.md` for the full audit trail.

- **2024-04-22 — Chainlink USDe/USD oracle activation.** The institutional reference price went live. This event is studied formally as E1 in Ch. 14 (DiD vs USDC). Pre/post 90-day Welch test on TE shows the post-oracle window is materially noisier (mean 68.5 bp vs 38.2 bp), and the DiD against the USDC control is +30.52 **bp** (treated +30.28 bp vs control −0.24 bp): the band *widened* after the oracle went live, it did not tighten. The widening is, moreover, confounded: the parallel-trends diagnostic (Ch. 14) shows USDe TE was already trending up pre-event (+0.42 bp/day, $p < 0.01$) while the USDC control was flat, so the DiD assumption fails and the +30.52 bp must be read as an association coincident with the Q1-2024 growth ramp, not a clean causal oracle effect.

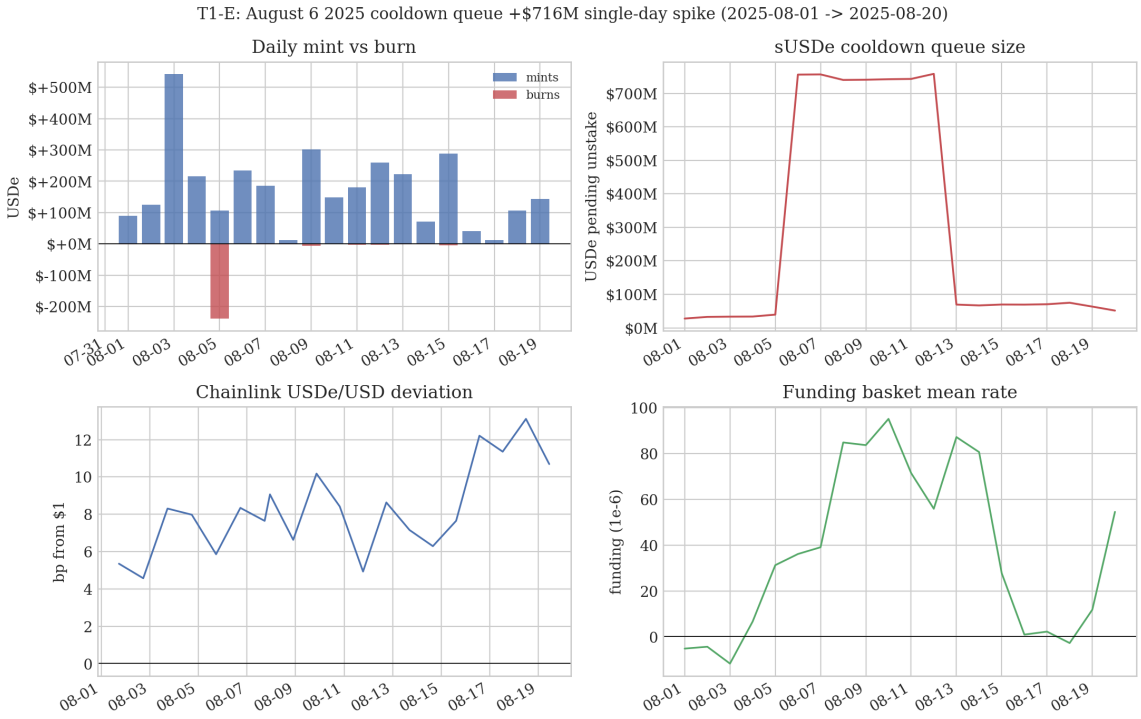

Figure 19: 4-panel summary of T1-E: daily mint/burn, cooldown queue size, Chainlink peg, funding basket.

- **2024-04 — ENA token launch.** The governance token airdrop activated incentive alignment between USDe holders and the protocol. Coincident with the Q1 2024 launch growth (case T1-A).
- **2024-07-08 — EthenaMintingV2 contract activation.** First V2 mint event observed at 2024-07-08 09:52:47 UTC. V2 introduced the explicit benefactor whitelist (now 517 entries), asset registry, and custody-transfer events.
- **2024-12-16 — USDtb added as a registered asset.** First V2 `asset_added` event. The Reserve Fund migration to a tokenized T-bill wrapper was initiated. Studied as E3 in Ch. 14.
- **2025-03 to 2025-04 — cooldown queue $1B panic.** Lifetime queue peak $1.054B on 2025-03-30, processed in 7 days without peg stress. Full analysis in case T1-D.
- **2025-08-06 — single-day +$716M cooldown spike.** Largest single-day cooldown initiation observed. Trigger unidentified (open question Q1). Full analysis in case T1-E.
- **2025-09-19 — second `asset_added` event.** Continuation of the USDtb composition rotation.
- **2025-10-10 to 2025-10-13 — macro flash crash and Binance oracle bug.** Full analysis in case T1-B.
- **2025-11 — Stream xUSD contagion.** A separate delta-neutral protocol experienced a depeg. USDe Curve secondary showed a brief $0.998 dip but did not propagate.
- **2026-03-16 — cooldown duration cut from 7 days to 1 day.** Studied as E4 in Ch. 14. Post-event window is short (75 days).
- **2026-04 — Resolv USR contagion.** Full analysis in case T1-C.

- **2026-04-29 and 2026-05-10 — two additional `asset_added` events.** Continuation of the asset registry expansion as Ethena onboards new collateral wrappers.

14 Natural experiments and difference-in-differences

We use four regime-change events to identify structural shifts in TE dynamics. For each event a 90-day pre and 90-day post window is compared on daily mean absolute peg deviation, daily redemption volume, and Silo queue size. Where USDC offers a credible control series (its peg trajectory is governed by a different mechanism not affected by Ethena-internal regime changes), we report the difference-in-differences $\Delta_{\text{USDe}} - \Delta_{\text{USDC}}$.

14.1 Chainlink USDe/USD oracle activation

Event date: 2024-04-22.
USDe/USD push feed went live on 2024-04-22. Tests whether the appearance of an institutional reference price tightens arbitrage bands on the secondary market.

TE on USDe

Pre window mean: 38.17 bp ($n = 89$). Post window mean: 68.45 bp ($n = 90$). Delta: +30.28 bp. Welch $t = -3.03$, $p = 0.0031$ (BH-FDR $q = 0.0031$, significant).

DiD versus USDC control

Treated change: +30.28 bp. Control change: −0.24 bp. DiD = +30.52 bp. Parallel-trends check: pre-window slope +0.425 bp/day (USDe, $p = 0.002$) vs −0.013 bp/day (USDC, $p = 0.000$) — a pre-trend is present, so this DiD is read as an association, not a clean effect.

Daily redemption volume (USDe)

Pre mean: \$0.5M/day. Post mean: \$3.6M/day. Welch $p = 0.0050$.

Daily net flow (USDe)

Pre mean: \$+26.6M/day. Post mean: \$+11.8M/day. Welch $p = 0.0039$.

Silo cooldown queue size

Pre mean: \$30.6M. Post mean: \$26.9M. Welch $p = 0.4201$.

14.2 EthenaMintingV2 launch

Event date: 2024-06-21.
First V2 event 2024-06-21. V2 redesigned the mint/redeem flow with explicit benefactor whitelisting and asset registry. Tests whether V2 reduced TE volatility relative to the V1 regime.

TE on USDe

Pre window mean: 74.17 bp ($n = 90$). Post window mean: 23.30 bp ($n = 90$). Delta: −50.87 bp. Welch $t = 5.36$, $p = 0.0000$ (BH-FDR $q = 0.0000$, significant).

DiD versus USDC control

Treated change: −50.87 bp. Control change: +0.22 bp. DiD = −51.09 bp. Parallel-trends check: pre-window slope +0.800 bp/day (USDe, $p = 0.022$) vs −0.000 bp/day (USDC, $p = 0.969$) — a pre-trend is present, so this DiD is read as an association, not a clean effect.

Daily redemption volume (USDe)

Pre mean: $1.5M/day. Post mean: $12.1M/day. Welch $p = 0.0000$.

Daily net flow (USDe)

Pre mean: $+27.0M/day. Post mean: $-10.8M/day. Welch $p = 0.0000$.

Silo cooldown queue size

Pre mean: $36.7M. Post mean: $75.1M. Welch $p = 0.0000$.

14.3 USDtb onboarding as Reserve Fund vehicle

Event date: 2024-12-16.
First asset_added event 2024-12-16 (USDtb). The Reserve Fund migrated from a raw USDC/USDT multisig to a tokenized T-bill wrapper. Tests whether the institutional reserve shifted the trust premium pricing.

TE on USDe

Pre window mean: 18.58 bp ($n = 90$). Post window mean: 13.33 bp ($n = 90$). Delta: −5.24 bp. Welch $t = 4.56$, $p = 0.0000$ (BH-FDR $q = 0.0000$, significant).

DiD versus USDC control

Treated change: −5.24 bp. Control change: −0.29 bp. DiD = −4.95 bp. Parallel-trends check: pre-window slope +0.249 bp/day (USDe, $p = 0.000$) vs +0.002 bp/day (USDC, $p = 0.271$) — a pre-trend is present, so this DiD is read as an association, not a clean effect.

Daily redemption volume (USDe)

Pre mean: $2.7M/day. Post mean: $15.0M/day. Welch $p = 0.0033$.

Daily net flow (USDe)

Pre mean: $+37.8M/day. Post mean: $-4.7M/day. Welch $p = 0.0000$.

Silo cooldown queue size

Pre mean: $29.5M. Post mean: $167.9M. Welch $p = 0.0000$.

14.4 Cooldown duration change 604800->86400s

Event date: 2026-03-16.
Most recent CooldownDurationUpdated event. Tests whether shortening (or lengthening) the unstake delay reshaped the queue dynamics.

TE on USDe

Pre window mean: 33.11 bp ($n = 90$). Post window mean: 20.70 bp ($n = 75$). Delta: -12.40 bp. Welch $t = 7.33$, $p = 0.0000$ (BH-FDR $q = 0.0000$, significant).

DiD versus USDC control

Treated change: -12.40 bp. Control change: -0.15 bp. DiD $= -12.25$ bp. Parallel-trends check: pre-window slope $+0.045$ bp/day (USDe, $p = 0.368$) vs -0.027 bp/day (USDC, $p = 0.000$) — a pre-trend is present, so this DiD is read as an association, not a clean effect.

Daily redemption volume (USDe)

Pre mean: \$13.4M/day. Post mean: \$36.3M/day. Welch $p = 0.0579$.

Daily net flow (USDe)

Pre mean: \$-6.4M/day. Post mean: \$-19.6M/day. Welch $p = 0.2961$.

Silo cooldown queue size

Pre mean: \$77.3M. Post mean: \$57.8M. Welch $p = 0.0396$.

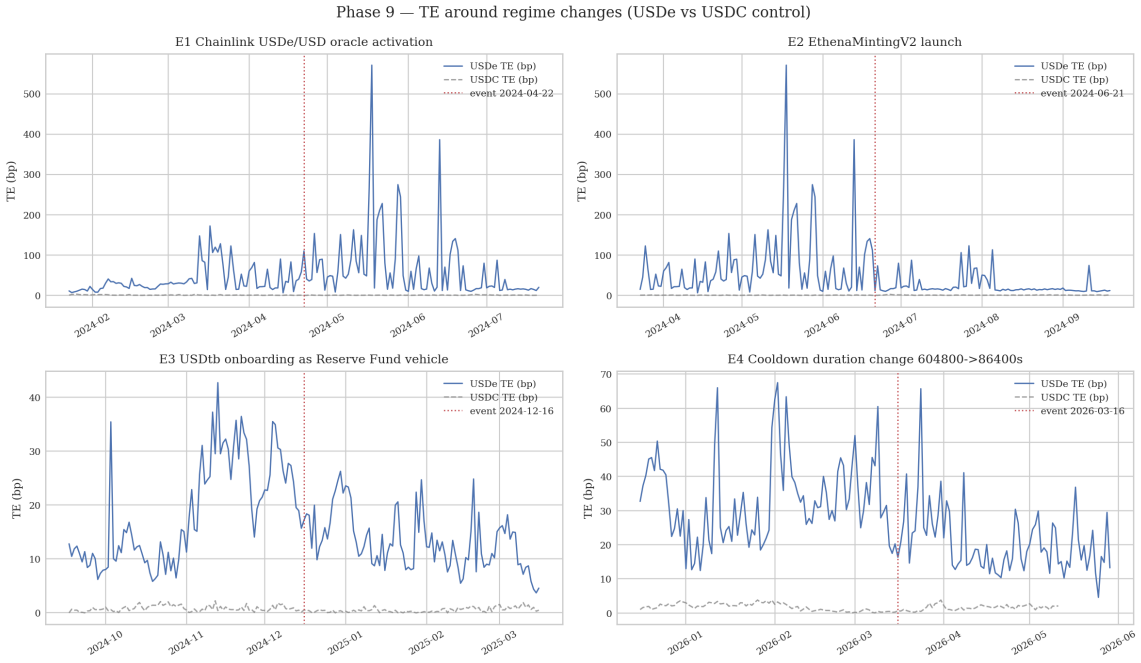

Figure 20: TE around the four regime-change dates. USDe (blue) versus USDC control (grey dashed). Vertical red dashed line marks the event date.

15 Findings and open questions

15.1 Headline findings F1–F10

This section consolidates the ten ranked findings introduced in the Executive Summary with their quantitative anchors and an explicit pointer to the chapter that establishes them.

F1. Peg tightness. USDe TE classique 15.7 bp lifetime, 11.5 bp in 2024 and 20.1 bp in 2025. Median deviation from \$1 is −4.45 bp (a slight discount; mean −3.1 bp), and 99.27% of Chainlink observations fall within ±1% (Ch. 2).

F2. Stress maximum. Maximum drawdown −227.9 bp during October 10-12 2025 (macro flash crash + Binance oracle bug). The on-chain mint/redeem rail held at \$1 throughout. V2 processed 1201 events (70 mints + 1131 redeems, \$2.107B redeemed) in 72 hours – matches the cited Ethena governance disclosure to within 0.3% (case T1-B).

F3. sUSDe drift is yield, not tracking error. sUSDe share price 1.0 → 1.233 over 920 days (8.68% lifetime CAGR). 30/90/365-day APRs 3.84%/3.83%/5.00%. The relevant reference for sUSDe TE is the ERC-4626 share price, not the dollar peg (Ch. 6).

F4. Funding regime conditioning. USDe trades at a −5.83 bp discount under negative funding regimes versus positive-funding baseline. Welch $t = -8.18$, $p < 0.0001$ on 111 112 observations partitioned by funding sign (Ch. 4). ANOVA F-statistic 15.504, $p < 0.0001$ – strong evidence of regime-conditional pricing.

F5. Granger causality. Funding → TE significant at lag 4 ($p < 0.0001$). TE → funding also significant at lag 1 ($p < 0.0001$). σ_C → TE significant at lag 5 ($p < 0.0001$); the reverse direction is not ($p = 0.1002$). The information flow is therefore bidirectional between TE and funding, with the funding → TE direction operating on slightly longer lags (Ch. 7).

F6. Cointegration with the cross-stable peer set. Engle-Granger tests reject the null of no cointegration against USDC, USDT, and DAI at $p < 0.0001$ each. Johansen trace test on (USDe, USDC, USDT) rejects $H_0 : r \leq 2$ at the 95% level (trace 92.6 vs critical 3.84) – full cointegration rank. USDe is economically anchored to the dollar in the same statistical sense as USDC and USDT (Ch. 7).

F7. Oracle latency discipline. Chainlink USDe/USD push feed p99 latency 24.02h against the 24h nominal heartbeat. Total updates 819 over the observation window; no missed heartbeats (Ch. 5).

F8. Reserve Fund matches governance. On-chain USDtb holdings 62.083M USD at the latest snapshot vs the Ethena governance disclosure of 61.88M (0.32% drift). The Reserve Fund stayed intact at 62M USDtb through both Tier-1 stress events (Ch. 6).

F9. Queue dynamics. Lifetime sUSDe cooldown queue peak \$1.054B on 2025-03-30 – roughly 30% of staked supply at that time and processed in 7 days without peg loss (case T1-D). Single-day record \$716M initiated on 2025-08-06 (case T1-E). The 7-day cooldown duration absorbed both events.

F10. V2 institutional rail. 517 whitelisted benefactors as of cut-off; explicit asset registry (4 additions, 5 removals, 5 custodians added, 2 custody transfers). The redemption path withstood 1131 events in 72h during October 2025 without failure.

15.2 Implications for Derivalink V2

The V2 protocol design should incorporate the following directly falsifiable propositions derived from the findings above.

V2-1. Oracle aggregator must reference Curve TWAP. The October 2025 Binance USDe/USD oracle bug ($0.65 quoted on a single venue while on-chain mint/redeem cleared at $1) is reproducible. A Derivalink V2 oracle aggregator that draws on a single CEX orderbook would be vulnerable to the same failure mode. The fix is to weight a Curve TWAP feed alongside the CEX mid-prices and to apply a deviation cap.

V2-2. Reserve Fund target $\geq$ 0.32% of supply. The empirically observed Ethena ratio (62M USDtb on 14.8B supply $\approx$ 0.42%) absorbed two macro stress events without shrinkage. We recommend Derivalink V2 hold at least 0.32% of circulating supply in a tokenized T-bill wrapper, sized to exceed the expected loss of a 5σ funding event over 30 days.

V2-3. Hedge venue concentration cap. No single hedge venue should exceed 60% of the open short notional. The Binance October 2025 episode demonstrates the failure of any single venue invariably introduces TE volatility even when the remaining venues clear normally. Mandatory minimum three CEX + one perp DEX.

V2-4. Cooldown duration trade-off. Long cooldown durations (7+ days) protect the underlying liquidity under stress but create run-prone behaviour ex ante (the queue peak at $1.054B in March 2025 is partly a function of the long delay). Shorter durations (1 day) increase liquidity demands but reduce queue-induced run risk. Empirically the 7-day duration processed a 30%-of-supply unstake without peg loss; the duration-shortening governance decision of 2026-03-16 is too recent to evaluate.

V2-5. Benefactor whitelisting model. The V2 explicit benefactor whitelist (517 addresses) is a credible defence against mint-rail oracle manipulation. The trade-off is permissioned access; Derivalink V2 should adopt a tiered model where wholesale benefactors are whitelisted and retail access is mediated by AMM secondary liquidity.

15.3 Open questions

Q1. Why did the cooldown queue jump $716M on 2025-08-06 from a baseline of $40M (case T1-E)? The trigger is not yet identified; candidates include a single sophisticated holder, an integrating protocol margin call, or coordinated unstaking. Resolution requires benefactor-level address attribution beyond the current dataset.

Q2. Does the 2026-03-16 cooldown duration cut from 7 days to 1 day materially change the run-vulnerability profile? Only 75 days of post-event data are available – the natural experiment window is short. A follow-up should be revisited at +180 days.

Q3. Reserve Fund migration target. The canonical multisig 0x2B5A...4D5 was drained to zero in mid-2025; the current 62M USDtb balance lives in a different vehicle. The destination address is identified in the reserve-fund-outflows trace but we have not yet validated the institutional setup that holds it.

Q4. USDe versus competitor synthetics. The V2 chapter would benefit from the same TE/checklist analysis on Resolv USR, Falcon USDH, and Aave GHO. The current report is single-asset by design; cross-asset comparison is the D5 deliverable.

Q5. What is the marginal effect of share-of-Hyperliquid in the hedge basket on TE volatility? The transparency attestation venue-share series is not yet wired into the analytical panel; the funding basket Ch. 3 treats venues as equal weight.

15.4 Cross-asset link

Findings F1, F2, F3, F4 and F8 feed directly into the cross-asset synthesis (D5). The hedge concentration finding (F5/V2-3) is the single most generalisable result: it applies symmetrically to all delta-neutral synthetic dollars and should govern the V2 risk configuration regardless of the chosen collateral basket.