Synthetix crypto cohort sub-report

Crypto-backed synth tracking error, 2020–2026

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June 1, 2026

Contents

1 Executive Summary

The headline. For the Synthetix V2 crypto cohort the on-chain Chainlink oracle was *not* the source of risk. Across the seven live majors the oracle tracked centralised-exchange (CEX) spot extremely tightly over 2020–2026, with daily root-mean-square tracking error (TE) between 0.20% and 0.57% and oracle-to-reference correlation at or above 0.99994 for every name (0.99999 for `sBTC` and `sETH`). The genuine departure from peg lived not on the oracle rail but on the on-chain DEX *secondary venue*. While the Curve and Velodrome pools were liquid (roughly 2020–2023) the `sETH`/ETH and `sBTC`/wBTC ratios held near 1.0; from about 2024 they decoupled — drifting toward 0.5 to 0.6× — as the synths were deprecated and liquidity drained from the pools. This is a venue/liquidity wind-down, not an oracle failure: the oracle stayed on-spec throughout. The cohort therefore illustrates a depeg mechanism orthogonal to any oracle-fidelity story — the fidelity was excellent and the loss of peg was a feature of a dying secondary market.

The cohort. The crypto-pure cohort spans seven live majors quoted on both Ethereum L1 (Synthetix V2) and Optimism V2 — `sETH`, `sBTC`, `sLINK`, `sAAVE`, `sUNI`, `sADA` and `sDOT` — plus three Optimism-only names (`sSOL`, `sMATIC`, `sAVAX`), the V3 `snxETH` on Optimism, and a Wezen-frozen long tail (`sBNB`, `sXRP`, `sLTC`, `sETC`, `sTRX`, `sXMR`, `sREN`, `sXTZ`) and two indices (`sDEFI`, `sCEX`). A point on the data model is load-bearing: a Synthetix V2 crypto synth has no oracle feed of its own — it prices against the *underlying* asset's Chainlink `AggregatorProxy` (the L1 ETH/BTC/... feed). The Optimism V2 synths reuse the same L1 feed, so their oracle rows are identical to L1. We compare that oracle against two further series: a CEX reference (Binance spot, one-minute bars) for tracking-error measurement, and — where it exists — the real on-chain DEX pool price for the as-traded venue. The DEX series is available only for `sETH` (Curve `sETH`/ETH on L1) and `sBTC` (Curve on L1 and Optimism), and it is a *ratio* to the underlying ($\approx$ 1.0 at perfect peg), not a USD price.

The data limits are honest. The cohort is heterogeneous and the underlying-oracle data model imposes real coverage gaps. L1 Chainlink feeds exist for the seven majors (and SNX), but *not* for the long-tail names (`sBNB`, `sXRP`, `sLTC`, `sETC`, `sTRX`, `sXMR`, `sREN`, `sXTZ`) nor for the Optimism-only names (`sSOL`, `sMATIC`, `sAVAX`); the two indices have no single underlying. Because the tracking-error measurement requires an oracle-versus-CEX pair, those names are simply not estimable here — a data limit, not a null result. Two of the seven majors have truncated oracle windows: the `sADA` feed ends 2024-06 and `sDOT` ends 2024-03, while the rest run to 2026-05. Several building blocks used elsewhere in this report do not apply: there is no perpetual or funding leg in scope, and — this being a 24/7 market — no TradFi-session structure, only a UTC-hour × day-of-week grid.

Oracle tracking was excellent. The daily log tracking error of the oracle against CEX spot, over each major's full window, is summarised in Table 1. `sBTC` and `sETH` are the tightest at 0.20% and 0.23% RMSE with correlation 0.99999; the remaining majors cluster between 0.44% and 0.57% with correlation at or above 0.99994. The `sETH` rolling 30/90/365-day RMSE peaks around 0.35% in 2020–21, declines to about 0.12% in 2023–24, and edges back to $\approx$ 0.21% in 2025–26 — always below 0.5%. Lead-lag analysis finds the oracle moving contemporaneously with CEX (peak correlation 0.9999 at lag zero): there is no exploitable lead. Figure 1 plots the per-major RMSE directly and makes the order of magnitude plain — the oracle was, throughout, a faithful copy of the underlying spot.

Table 1: Headline daily tracking error: oracle vs CEX spot (Binance), full per-synth window. `sADA` oracle ends 2024-06, `sDOT` ends 2024-03.

Synth	RMSE	Corr.
`sBTC`	0.20%	0.99999
`sETH`	0.23%	0.99999
`sLINK`	0.44%	0.99994
`sUNI`	0.46%	0.99996
`sAAVE`	0.46%	0.99995
`sADA`	0.54%	0.99995
`sDOT`	0.57%	0.99994

The DEX secondary venue was the real departure. Against the as-traded on-chain pool the picture is entirely different, and it is a venue/liquidity story. While the Curve and Velodrome pools carried real depth (2020–2023) the peg held tight: `sETH`/ETH and `sBTC`/wBTC sat at ≈ 1.0 with only thin-pool spikes. From about 2024 the ratios decoupled as the synths were wound down and liquidity drained — `sETH`/ETH falling toward ≈ 0.5 by mid-2024 (the L1 pool thins out after 2024-08), `sBTC`/wBTC on L1 to ≈ 0.6 by end-2024, and the Optimism `sBTC`/wBTC pool deteriorating through 2025–26 to ≈ 0.6 with violent swings. Over the whole window the peg-deviation magnitudes are `sETH` 0.57% MAE (bias +0.38%), `sBTC` L1 1.1% MAE (bias +0.11%) and `sBTC` Optimism 6.3% MAE (a persistent −6.2% pool discount). Governance drove the decay — the Wezen freeze (SIP-169) had pinned the long tail in 2021, and SCCP-2124 disabled `sETH` on L1 in 2024-07. Figure 4 shows both pegs holding to 2023 and decoupling from 2024. The DEX-versus-CEX lead-lag is weak or negative, consistent with thin-pool noise rather than price discovery.

Stress events barely touched the oracle. A difference-in-differences design around major crypto stress events (±30 days, against an `sUSD` control) confirms the oracle's robustness. The May-2021 crash produced significant but small bumps — `sBTC` +1.29% ($t = 8.0$), `sETH` +1.28% ($t = 6.9$), `sLINK` +1.49% ($t = 6.8$), with parallel trends satisfied — and the FTX collapse a smaller one (`sLINK` +0.38%, $t = 2.7$; the `sBTC`/`sETH` estimates are significant but fail parallel trends and should be read with caution). Terra (2022-05) and SVB (2023-03) were nil and not significant; Black Thursday (2020-03) pre-dates the oracle data for these synths and is genuinely not estimable. Even in the worst crashes the Chainlink oracle held its peg to CEX to within about 1.5% — oracle-cadence widening under extreme volatility, not a break. The cohort's risk profile is thus inverted relative to most depeg case studies in this report: the oracle rail was clean throughout, and the only real loss of peg arose on a deprecated secondary venue once its liquidity was gone. The consolidated implications are developed in Section 11.

2 Dataset Characterisation

This cohort assembles the Synthetix V2 *crypto* synthetics — synths whose underlying is a digital asset rather than a listed equity, commodity or index — together with their single V3 successor on Optimism. Unlike the equity cohort, which lived and died inside a five-month window, the crypto synths span the full Synthetix lifecycle from the early L1 launch in 2020 to the 2024–2026 wind-down, and they fall into four distinct lifecycle families. The first is the **live majors**: **sETH**, **sBTC**, **sLINK**, **sAAVE**, **sUNI**, **sADA** and **sDOT**, each deployed on both Ethereum L1 (V2) and Optimism (V2) and active over essentially the whole window. The second is the **Optimism-only majors sSOL**, **sMATIC** and **sAVAX**, which were minted only under OP V2 and never carried an L1 underlying feed. The third is the single **V3 successor snxETH**, launched on Optimism on 2023-08-30, whose oracle source is the Optimism Pyth pull feed rather than the L1 Chainlink push feed. The fourth is the **Wezen-frozen long tail — sBNB**, **sXRP**, **sLTC**, **sETC**, **sTRX**, **sXMR**, **sREN**, **sXTZ** on L1 V2, frozen together at the Wezen release (SIP-169) on 2021-09-16 — and the two frozen baskets **sDEFI** and **sCEX**, which have no single underlying. The inverse synths and the synthetic commodities `sXAU/sXAG` are excluded here; they carry their own reports.

Three price series, and the underlying-oracle data model. For each synth the dataset can hold up to three series: (a) the *on-chain oracle*, the price Synthetix consumed at mint and burn time; (b) the *CEX reference*, the Binance spot mid for the same asset, in one-minute bars spanning 2019–2026; and (c) a *real on-chain DEX venue*, the Curve or Velodrome pool that traded the synth against its underlying. The oracle series demands an explicit data-model note, because Synthetix V2 crypto synths do *not* maintain a dedicated price feed of their own. They price directly against the *underlying asset's* Chainlink `AggregatorProxy`: sETH reads the canonical ETH/USD feed, sBTC the BTC/USD feed, and so on. A direct consequence is that the Optimism V2 synth reuses the *same* L1 Chainlink feed as its L1 sibling — the two rows are therefore identical and are labelled together under a single oracle chain (`oracle_chain = ethereum.v1`). What we call a synth's "oracle" is thus the underlying L1 Chainlink feed, and the oracle-versus-CEX comparison in Section 3 is a test of how faithfully that underlying feed — as Synthetix actually consumed it — tracked the off-chain spot market, not a tautology.

The oracle coverage matrix. Underlying L1 Chainlink feeds are present for the seven live majors — eth, btc, link, aave, uni, ada and dot — plus SNX itself (used as the collateral price in Section 4) and the Optimism V3 Pyth feeds for eth, btc and snx. There is *no* L1 underlying feed for any of the frozen long-tail names (bnb, xrp, ltc, etc, trx, xmr, ren, xtz) nor for the Optimism-only majors (sol, matic, avax): these synths priced against feeds we do not hold on-chain in usable form, so they have a CEX series but no oracle series. Two of the seven majors carry truncated oracle windows: the `sADA` feed ends in 2024-06 and the `sDOT` feed ends in 2024-03 (both labelled `window = truncated`), reflecting the discontinuation of their on-chain feeds; the remaining five majors run to 2026-05. The two frozen baskets sDEFI and sCEX have no single underlying and therefore no oracle-versus-CEX pair at all.

The DEX series is a peg ratio, not a USD price. A genuine on-chain trading venue exists for only two of the synths. sETH traded against ETH in a Curve pool on L1, and sBTC traded against wBTC in Curve pools on both L1 and Optimism; no other synth in the cohort has a usable on-chain pool. Crucially, the DEX series is *not* a USD price: it is the pool exchange *ratio* of the synth to its underlying, so a value of 1.0 means a perfect on-chain peg and any departure measures how far the synth traded from one unit of the underlying. This makes the DEX series a peg-deviation instrument rather than a second oracle, and it is read as such throughout: Section 3 separates the *oracle fidelity* question (does the underlying feed track CEX?) from the distinct *venue peg* question (does the on-chain pool hold 1.0?). The swap counts are material: 13,900 sETH/ETH swaps on L1 (2020-12 to 2025-03), 5,400 sBTC/wBTC swaps on L1, and 17,700 sBTC/wBTC swaps on Optimism (2023-07 to 2026-04).

A 24/7 market with no TradFi session structure. Because the underlyings are crypto assets, the oracle, the CEX reference and the DEX pool all trade continuously. There is no opening bell, no overnight gap and no session-bucket asymmetry of the kind that structured the equity cohort; the only calendar structure available is the UTC hour-of-day crossed with the day-of-week, which is what Section 5 exploits. The CEX reference resolves to the minute and the oracle updates on its own Chainlink cadence, so oracle-versus-CEX tracking error is identified at hourly-to-daily granularity over tens of thousands of matched observations per major — a far denser panel than the roughly one hundred daily closes the equity cohort could muster. Table 2 summarises which series exists for each synth.

Table 2: Per-synth series coverage. *Oracle* is the underlying asset's Chainlink `AggregatorProxy` feed as consumed by Synthetix V2 (OP V2 reuses the identical L1 feed); the *CEX* reference is Binance spot; the *DEX* venue is the Curve/Velodrome synth-versus-underlying pool, reported as a peg ratio to 1.0. A checkmark denotes a usable series; "–" denotes none.

Synth	Family	Chains	Oracle	CEX	DEX
sETH	live major	L1 + OP	✓	✓	✓(L1)
sBTC	live major	L1 + OP	✓	✓	✓(L1+OP)
sLINK	live major	L1 + OP	✓	✓	–
sAAVE	live major	L1 + OP	✓	✓	–
sUNI	live major	L1 + OP	✓	✓	–
sADA	live major	L1 + OP	✓ (ends 2024-06)	✓	–
sDOT	live major	L1 + OP	✓ (ends 2024-03)	✓	–
sSOL	OP-only major	OP	–	✓	–
sMATIC	OP-only major	OP	–	✓	–
sAVAX	OP-only major	OP	–	✓	–
snxETH	V3 successor	OP (V3)	✓ (Pyth)	✓	–
sBNB	frozen long tail	L1	–	✓	–
sXRP	frozen long tail	L1	–	✓	–
sLTC	frozen long tail	L1	–	✓	–
sETC	frozen long tail	L1	–	✓	–
sTRX	frozen long tail	L1	–	✓	–
sXMR	frozen long tail	L1	–	✓	–
sREN	frozen long tail	L1	–	✓	–
sXTZ	frozen long tail	L1	–	✓	–
sDEFI	frozen index	L1	–	–	–
sCEX	frozen index	L1	–	–	–

Analyzable-scope tiers. The coverage matrix partitions the cohort into three tiers of evidential strength, and each downstream chapter inherits the partition. **Tier A — oracle fidelity — covers the seven live majors**, where a clean underlying-Chainlink-versus-Binance pair exists and the headline tracking-error result of Section 3 is identified. **Tier B — venue peg and dynamics — covers sETH and sBTC only**, the two synths with an on-chain pool: these carry the DEX peg-ratio analysis, the GARCH-family volatility models of the peg-deviation series in Section 4, and they anchor the structural and causality work in Sections 7 and 8. **Tier C — the data-limited remainder — covers the Optimism-only majors, the frozen long tail and the two indices**: these have a CEX series but no on-chain oracle to compare it against, so a synth-level tracking error is genuinely not estimable for them. This is an honest data limit, not a null result: the Wezen multi-asset experiment of Section 10 reports the long tail and the indices as not-applicable for exactly this reason, while the `sADA` and `sDOT` oracle truncations are flagged as tractable feed-discontinuation natural experiments for future work. Every synth-level fidelity claim in this report therefore concerns Tier A; every venue and volatility claim concerns Tier B; the rest of the cohort is carried for completeness and lifecycle context, not for oracle-tracking inference.

3 Multi-Reference Tracking Error

This chapter characterises how closely the seven live crypto majors — `sETH`, `sBTC`, `sLINK`, `sAAVE`, `sUNI`, `sADA`, `sDOT` — tracked their underlying assets over the full live window 2019–2026. Unlike a TradFi synth, a Synthetix V2 crypto synth does not carry its own oracle: it is minted and burned against the underlying asset's Chainlink AggregatorProxy, so the synth's price of record *is* the underlying L1 Chainlink feed (and the Optimism V2 deployment reuses the very same L1 feed, which is why the L1 and Optimism rows coincide). Each major therefore admits two universally available series and, for two names only, a third. The on-chain price is the Chainlink feed, sampled as-traded. The independent reference is Binance spot (1-minute bars, 2019–2026), a genuinely independent construction of the same economic quantity, so its agreement with the oracle measures the fidelity of the oracle path rather than a tautological self-comparison. A third series exists only for `sETH` (the Curve sETH/ETH pool on L1) and `sBTC` (Curve on L1 and on Optimism), and it is not a USD price at all but the on-chain pool *ratio* to the underlying — a value near 1.0 when the synth holds its peg. The two views tell, as we shall see, two entirely different stories.

Definition. Tracking error against the reference is the daily log price difference $\ell_t = \log p_{\text{oracle}}(t) - \log p_{\text{CEX}}(t)$, summarised by four scalars: $\text{RMSE} = \sqrt{\mathbb{E}[\ell^2]}$, the mean absolute error $\text{MAE} = \mathbb{E}[|\ell|]$, the bias $\mathbb{E}[\ell]$, and the Pearson correlation between the two price levels. For $|\ell| < 0.1$ the log-difference is within a few parts in 10^4 of the fractional difference, so RMSE and MAE read directly as percentages. The crypto reference trades 24/7, so — in contrast to the equity cohort — tracking error is identified on the same continuous UTC calendar throughout, with no cash-market close to re-base against.

The oracle path was excellent across the cross-section. The headline result is that on a day-to-day basis the on-chain Chainlink oracle tracked its underlying extremely tightly for every major. Table 3 reports RMSE between 0.20 % (`sBTC`) and 0.57 % (`sDOT`), all with correlation at or above 0.99994 and the two deepest names, `sBTC` and `sETH`, reaching 0.99999. The band is narrow and the ordering is intuitive: the most liquid, most heavily fed assets (BTC, ETH) sit tightest, and the smaller-cap majors widen modestly. Two names, `sADA` and `sDOT`, are estimated over a shorter span because their on-chain feed was discontinued (`sADA` in 2024-06, `sDOT` in 2024-03); their figures are computed over the available pre-discontinuation window and read on the same footing as the others. Across the cohort there is no constant offset and no systematic drift — the oracle is, to within half a percent, a faithful copy of the underlying.

Table 3: Scalar tracking-error metrics, on-chain Chainlink oracle vs. Binance spot reference, daily log differences over the live window. RMSE and MAE read as fractions; correlation as Pearson r. All seven majors hold sub-percent RMSE and correlation at or above 0.99994; the two deepest names reach 0.99999. `sADA` and `sDOT` are computed over their pre-discontinuation window (oracle ends 2024-06 and 2024-03 respectively). The Optimism V2 rows are identical to L1 by construction — the deployment reuses the same L1 Chainlink feed — and are not repeated here.

Synth	RMSE	MAE	Corr.	Window
sBTC	0.0020	0.0013	0.99999	full
sETH	0.0023	0.0015	0.99999	full
sLINK	0.0044	0.0033	0.99994	full
sUNI	0.0046	0.0034	0.99996	full
sAAVE	0.0046	0.0035	0.99995	full
sADA	0.0054	0.0040	0.99995	oracle ends 2024-06
sDOT	0.0057	0.0043	0.99994	oracle ends 2024-03

Reading the cross-section. The seven majors occupy an exceptionally narrow band — RMSE 0.20–0.57 %, correlation 0.99994–0.99999 — with `sBTC` and `sETH` effectively indistinguishable from a perfect copy. The widening from the deep names to the smaller-cap majors is a few tenths of a percent and is consistent with the noisier oracle cadence of less heavily updated feeds rather than with any structural mispricing. Decisively, the oracle moves with the reference *contemporaneously*: the oracle-vs-CEX lead-lag correlation peaks at lag 0 (corr 0.9999 for `sETH`), so the on-chain feed neither leads nor lags the centralised market within the hour — there is no exploitable wedge to trade against. Figure 1 plots the RMSE bar across the seven majors and makes the tight band visible at a glance.

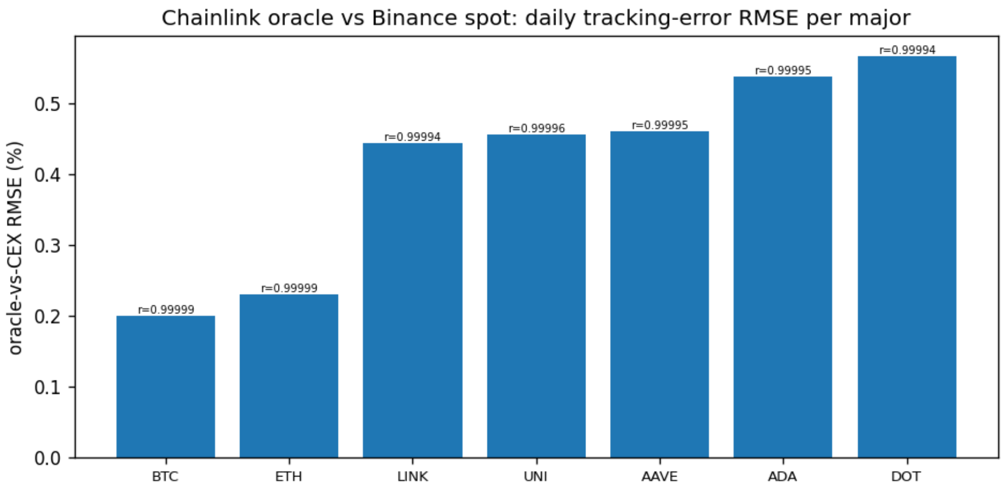

Figure 1: Oracle-vs-CEX RMSE per crypto major over the live window, with the level-level correlation annotated. `sBTC` (0.20 %) and `sETH` (0.23 %) sit tightest at correlation 0.99999; the smaller-cap majors widen to `sDOT` (0.57 %) but remain sub-percent and above 0.99994 throughout. The cohort never departs from oracle fidelity by more than half a percent in RMSE.

The oracle held through six years of regime change. The cross-sectional snapshot conceals a long history, and that history is itself reassuring. Figure 2 traces the rolling 30/90/365-day RMSE of the `sETH` oracle against CEX from 2020 to 2026. It opens at the cohort's loosest — around 0.35 % through the 2020–2021 bull-and-crash regime, when oracle updates were sparser and crypto realised volatility was at its highest — then declines steadily as Chainlink's update cadence tightened, bottoming near 0.12 % over 2023–2024, before settling back to roughly 0.21 % over 2025–2026 as the synth was wound down and feed activity thinned. At no point in six years does the rolling RMSE breach 0.5 %. The trajectory is one of an oracle that started good and got better, then plateaued during deprecation — never a break, even across the May-2021 crash and the FTX collapse marked on the figure.

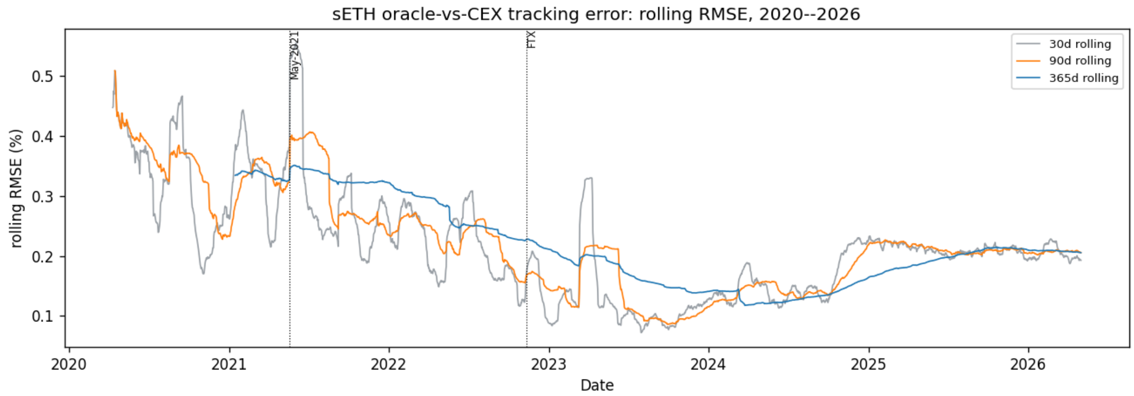

Figure 2: `sETH` oracle-vs-CEX rolling RMSE (30/90/365-day) over 2020–2026. The error opens near 0.35 % in the 2020–2021 high-volatility regime, tightens to ∼0.12 % over 2023–2024 as the feed cadence improved, and settles near 0.21 % during the 2025–2026 wind-down; it never breaches 0.5 %. The May-2021 crash and FTX collapse (dotted) leave only modest, transient widenings.

The DEX peg tells a different story — a venue story, not an oracle story. For the two names with an on-chain venue, a second metric is available, and it must be read on its own terms. The DEX series is the Curve/Velodrome pool ratio of the synth to its underlying (`sETH/ETH`, `sBTC/wBTC`); it is *not* a USD comparison and it is *not* an oracle measurement. A value of 1.0 is a perfect peg; deviation from 1.0 measures how far the secondary venue's marginal price has drifted from par. We summarise it as the log-ratio deviation from 1.0 after a $[0.5, 2.0]\times$-median guard to suppress thin-pool ticks. The whole-window statistics in Table 4 are an order of magnitude larger than the oracle TE: `sETH` MAE 0.57 % (bias +0.38 %), `sBTC` on L1 MAE 1.1 % (bias +0.11 %), and `sBTC` on Optimism MAE 6.3 % with a persistent *negative* bias of −6.2 % — a structural discount in the Optimism pool. The dex-vs-CEX lead-lag is weak and even negative (−0.38 at lag 0 for `sBTC`, −0.16 at lag 48 for `sETH`), the signature of thin-pool noise rather than price discovery.

Table 4: On-chain DEX peg-deviation metrics: log-ratio of the pool price to the underlying relative to the 1.0 peg, whole-window, after a $[0.5, 2.0]\times$-median guard. MAE and bias read as fractions. The DEX deviations are an order of magnitude larger than the oracle TE of Table 3 — they measure secondary-venue liquidity decay, not oracle drift. Only `sETH` and `sBTC` carried an on-chain venue; the remaining majors had no liquid pool.

Synth	Venue	MAE	Bias
sETH	Curve (L1)	0.0057	+0.0038
sBTC	Curve (L1)	0.011	+0.0011
sBTC	Curve (Optimism)	0.063	−0.062

The peg held while the pools were liquid, then decoupled on deprecation. The time profile is decisive in separating the two stories. Figure 4 plots the pool ratios over the full window. While the venues were liquid — roughly 2020 through 2023 — both `sETH/ETH` and `sBTC/wBTC` sat at ∼1.0 with only thin-pool spikes, a tight peg. From around 2024 the pegs decouple as the synths are deprecated and liquidity drains from the Curve and Velodrome pools: `sETH/ETH` falls toward ∼0.5 by mid-2024 (the L1 Curve series thins out after 2024-08, coincident with SCCP-2124 disabling `sETH` on L1 in 2024-07), `sBTC/wBTC` on L1 falls to ∼0.6 by the end of 2024, and the Optimism `sBTC` pool deteriorates through 2025–2026 to ∼0.6 with violent swings. This is the secondary-venue liquidity decay of a wind-down, not an oracle failure: throughout the same period the oracle stayed on-spec (the rolling RMSE of Figure 2 never exceeded half a percent). The synth was always redeemable at the protocol's oracle price; what decayed was the depth of the AMM where one could trade it against the underlying.

The on-chain peg ratios are plotted in Figure 4 of Section 6, where the venue story is developed in full.

What this chapter does and does not establish. Two metrics, two conclusions. On the price of record — the Chainlink oracle the protocol used to mint and burn — the crypto majors tracked their underlyings to within 0.20–0.57 % RMSE at correlation above 0.99994, contemporaneously and without drift, across six years and every major crypto regime. On the secondary on-chain venue, available only for `sETH` and `sBTC`, the pool ratio held its 1.0 peg only while liquidity was present and decoupled sharply from 2024 onward as the synths were wound down — an order-of-magnitude larger deviation that is a property of AMM depth, not of the oracle. The oracle and the DEX are therefore not interchangeable views of the same quantity: the oracle is a fidelity result and an excellent one, while the DEX peg is a liquidity-decay result of the deprecation era. The structural drivers of the oracle tracking error are taken up in Section 4, the deprecation timeline in Section 7, and the discrete stress events in Section 9.

4 Level-1 Decomposition

The level-1 layer asks two questions in sequence. First, can the daily oracle-versus-CEX tracking error be attributed to the cohort's slow-moving structural state — collateral volatility, system funding, gas? Second, once we accept that it cannot, where does the variance of the tracking error actually live, and does the one genuinely volatile object in this system — the on-chain DEX peg of the deprecated sETH/sBTC pools — carry the volatility-clustering signature that would justify a conditional-variance model? The answers point in opposite directions, and as in the equity cohort the more informative one is the negative. The base regression pins down what the residual TE of Section 3 actually *is*: oracle-cadence noise scattered around zero, not a structural mispricing that any covariate forecasts. The variance decomposition then locates the volatility on the collateral side rather than on the peg, and the GARCH suite shows that what little peg dynamics exist are near-integrated and highly persistent.

4.1 Base TE regression

Three regressors, one structurally omitted. The canonical level-1 driver set regresses daily TE on four contemporaneous structural covariates: collateral-side volatility σ_C (proxied by SNX-collateral return volatility), a funding lever (the system issuance ratio), L1 gas, and log-liquidity. The log-liquidity slot is omitted here rather than filled with a placeholder. Only sETH and sBTC have any on-chain DEX venue at all, and those Curve/Velodrome pools are thin and were actively draining over the sample (Section 6); there is no liquidity series with cross-sectional support across the seven majors. What remains is σ_C, funding, and gas, fitted across the 14 live-major rows (seven names $\times$ two chains, the Optimism V2 rows sharing the underlying L1 Chainlink feed and therefore the same oracle path).

No structural covariate organises the daily TE. The regression returns R^2 between 0.0001 and 0.025 across the 14 rows — effectively zero everywhere. Only two coefficients reach even marginal significance: β_{σ_C} for sBTC ($t = 3.5$) and the funding lever for sETH and sBTC ($t \approx 2.8$); on every other name no driver clears conventional thresholds. This is an honest negative result, and a clean one. Section 3 established that the oracle-versus-CEX TE sits at 0.20–0.57% RMSE with correlation at or above 0.99994 for every major. The regression confirms the natural reading of those numbers: at the daily horizon the tracking error is not a function of the slow-moving structural state. The residual is microstructure-and-cadence noise around zero, not a forecastable mispricing. The drivers are not uninformative in principle — the daily contemporaneous regression is simply the wrong instrument for a series whose variance lives at the oracle's update cadence, not in the daily structural state. The two shorter rows, sADA and sDOT, are fitted on $n = 482$ and 576 daily observations respectively, their oracle feeds discontinued in mid-2024 and early-2024; the truncation does not change the verdict.

4.2 Where the variance lives

Decomposing the tracking error into its three return channels. If the daily TE is unattributable to the structural state, the next question is mechanical: which return process dominates its variance? We decompose the sETH tracking error into three components on a 30-day rolling window (1276 windows): σ_C, the SNX-collateral return volatility; σ_S, the synth DEX peg-deviation return volatility; and σ_P, the oracle-versus-CEX peg residual. The collateral channel dominates by an order of magnitude — $\sigma_C \approx 0.025$ per day — against $\sigma_P \approx 0.005$ and $\sigma_S \approx 0.0026$, the synth/peg channel being the smallest of the three (Figure 3). The reading is consistent with the base regression: the volatile object in this system is the collateral backing, not the peg or the oracle gap. The oracle reproduces CEX faithfully (σ_P small), the deprecated DEX pools contribute little to the daily TE in variance terms even as their level decouples (σ_S smallest), and the bulk of the rolling variance is carried by the SNX-collateral side — a property of the backing asset rather than of the synthetic peg.

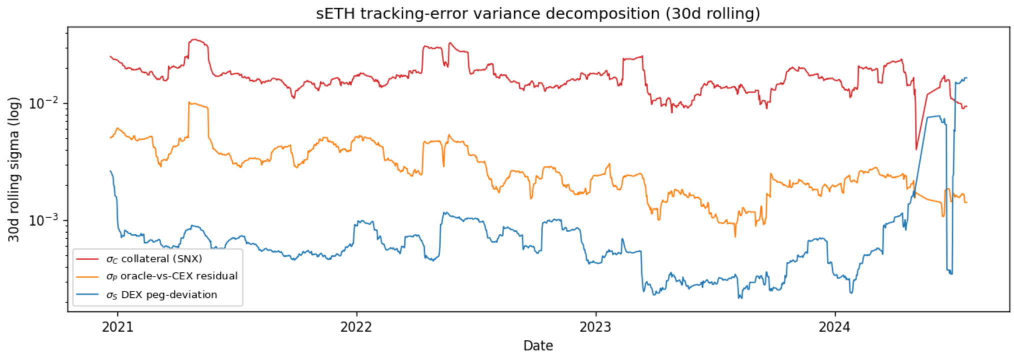

Figure 3: Thirty-day rolling decomposition of the sETH tracking error into its three return channels (log scale): collateral-side σ_C (SNX returns), synth DEX peg-deviation σ_S, and the oracle-versus-CEX peg residual σ_P. The collateral channel ($\sigma_C \approx 0.025$/day) dominates throughout; the peg-deviation channel ($\sigma_S \approx 0.0026$) is the smallest. The variance of the tracking error is a property of the backing asset, not of the synthetic peg.

4.3 GARCH on the DEX peg-deviation process

Why model the peg rather than the oracle. In the equity cohort the conditional-variance model was fit to the oracle return process, because there was no DEX venue worth modelling. Here the choice inverts. The oracle-versus-CEX gap is small and unforecastable, as just shown; the genuinely dynamic object is the on-chain peg of the deprecated sETH Curve pool, whose log-ratio to ETH drifts and swings as liquidity drains from the wind-down (Section 6). We therefore fit the GARCH family to the sETH DEX peg-deviation returns ($n = 6888$, after a $[0.5, 2.0]\times$-median guard against thin-pool artefacts), asking how persistent that peg volatility is.

The peg volatility is highly persistent and near-integrated. Table 5 reports four specifications. GARCH(1,1) (Bollerslev 1986) returns $\alpha = 0.20$, $\beta = 0.78$, a persistence of

≈ 0.98 — shocks to the peg-deviation volatility decay only very slowly. The GJR-GARCH extension (Glosten, Jagannathan, and Runkle 1993) adds an asymmetry term ($\alpha = 0.20$, $\gamma = 0.20$, $\beta = 0.68$) but does not change the persistence story. The EGARCH fit (Nelson 1991) is the more striking: in log-variance space $\beta \approx 1.000$, a near-integrated process, and it is the AIC-preferred of the three closed-form specifications (AIC -15613). The two-regime Markov-switching extension, MS-GARCH(2), converges with a distinct low-volatility regime and is the best fit overall (AIC -16288), confirming that the peg-deviation volatility is not a single homogeneous process but alternates between a quiet regime (the liquid years) and a turbulent one (the wind-down). All four specifications agree on the headline: the peg volatility is highly persistent, bordering on integrated.

Table 5: GARCH-family fits on the sETH DEX peg-deviation log-returns ($n = 6888$, after a $[0.5, 2.0]\times$-median thin-pool guard). The persistence column is read model-appropriately ($\alpha + \beta$ for GARCH(1,1), $\alpha + \beta + \gamma/2$ for GJR under symmetric innovations, β for EGARCH). The closed-form models agree on a persistence of ≈ 0.98, with EGARCH near-integrated and AIC-preferred among the three; the two-regime MS-GARCH(2) converges with a low-volatility regime and is the best fit overall. * marks the AIC-preferred model.

Model	Coefficients	Persistence	AIC
GARCH(1,1)	$\alpha = 0.20$, $\beta = 0.78$	≈ 0.98	—
GJR-GARCH	$\alpha = 0.20$, $\gamma = 0.20$, $\beta = 0.68$	≈ 0.98	—
EGARCH	$\beta \approx 1.000$	near-integrated	-15613
MS-GARCH(2)*	two regimes (low-vol + turbulent)	—	-16288

Realised-variance dynamics and interpretation. As a complementary check on the sETH daily realised variance we fit the heterogeneous autoregressive model of Corsi (2009): HAR-RV returns $R^2 = 0.29$, with the monthly component dominant ($t = 22$) and the weekly component entering negatively ($t = -16$). The realised variance of sETH is therefore driven by its low-frequency, monthly-horizon level rather than by short-run shocks — consistent with a slow regime structure rather than fast mean reversion. Read together, the three sub-layers form a coherent picture. The base regression says the *tracking* gap between oracle and CEX is unforecastable noise around zero. The variance decomposition says the variance of that gap is carried by the collateral side, not the peg. And the GARCH/HAR suite says that what genuine volatility dynamics exist in this system live in the deprecated DEX peg, where they are highly persistent and near-integrated — a property of a draining liquidity pool during wind-down, not of the oracle, which stays on-spec throughout. The venue and structural mechanics behind that peg decay are taken up in Sections 6 and 7.

5 Level-2 Temporal Analysis

The level-1 decomposition in Section 4 established that daily oracle-vs-CEX tracking error for the crypto cohort is unattributable from slow-moving structural drivers: it is oracle-cadence noise around a near-perfect feed, with R^2 below 2.5 % for every synth and almost no significant covariate. That result treats every observation as homogeneous in time. This section conditions on the temporal axis instead, asking whether tracking error concentrates at particular times — and the answer is shaped by a property the equity cohort does not share: a crypto underlying never closes.

No trading sessions, only a neutral UTC grid. A US-equity synth inherits the trading calendar of its home market, so the natural temporal partition there is the session schema (pre-market, regular, after-hours, overnight, weekend) and the dominant finding is that the oracle updates almost only during the regular cash session. The crypto majors have no such structure. The reference is Binance spot, which trades continuously, and the Chainlink feed updates around the clock on its deviation-and-heartbeat cadence rather than against an exchange open. There is no session to condition on. The only temporal partition the data admits is a neutral calendar grid: UTC hour-of-day $\times$ day-of-week. We compute the mean absolute log tracking error in each of the resulting $24 \times 7 = 168$ cells, per synth, yielding 2,352 (synth, hour, day) cells across the seven majors that carry an oracle feed (`sETH`, `sBTC`, `sLINK`, `sAAVE`, `sUNI`, `sADA`, `sDOT`). This is deliberately a flat, assumption-free view: with no market open and no settlement window, any hour or weekday is a priori as good as any other, and the grid simply asks whether the data disagrees.

Fisher–Schuster: white noise rejected, but no exploitable period. To test for a genuine cyclical signal rather than read the heatmap by eye, we apply the Fisher–Schuster periodogram test to the `sETH` tracking-error series. The test rejects the white-noise null overwhelmingly ($p \approx 1 \times 10^{-145}$), which at face value would suggest a strong periodic component. The detail that disarms this reading is the location of the rejection: the dominant period the periodogram selects equals the full sample length (51,760 samples), i.e. the lowest non-trivial frequency the series can express. The "periodicity" the test detects is therefore a single slow sweep across the whole window — a low-frequency trend in the level of tracking error, the same secular tightening already visible in the rolling RMSE of Section 3 — and not a repeating intraday or intraweek cycle. There is no diurnal peak, no weekend effect, no hour-of-day rhythm that a monitor could exploit. The honest reading is no usable periodicity: the series is not white noise only because it carries a trend, and a trend is not a tradable temporal pattern.

Microstructure: the peg residual is almost noise-free. A complementary question is how much of the high-frequency variation in the on-chain peg is genuine signal versus microstructure noise. We estimate the two-scale realised variance (TSRV) on the `sETH` peg series, which separates the integrated variance from the variance contributed by tick-level noise. The TSRV comes to 0.0101 with an implied microstructure-noise variance of 6.6×10^{-6} — three orders of magnitude smaller, i.e. negligible. The realised-kernel volatility estimate is 0.104, consistent with the TSRV figure. In plain terms, the oracle peg does not carry the bid–ask bounce or quote-flicker noise one would see in a raw orderbook mid-price; what little high-frequency variation exists is integrated variance, not measurement artefact. This is consistent with the fidelity result of Section 3: the oracle is a clean, low-noise copy of the underlying, and there is no microstructure layer to model away.

Reading. Across both the calendar grid and the spectral and microstructure diagnostics, the conclusion is the same and it is negative in the useful sense. The oracle-vs-CEX tracking error of the crypto majors has no tradable temporal structure: no session effect (because there are no sessions), no exploitable periodicity (the only spectral signal is a slow secular trend), and no microstructure noise to arbitrage (the peg residual is essentially integrated variance). Where the equity cohort's temporal story was dominated by *when* the oracle updated — almost only in US regular hours — the crypto cohort's temporal story is that it updates uniformly around the clock, and that uniformity leaves nothing for a time-of-day or day-of-week rule to key on. The departures from peg that do matter for this cohort are not temporal at all; they are the venue-and-liquidity decay of the on-chain DEX pools developed in Section 6, not a clock the oracle keeps.

6 Venues and Frictions

Three nominal venues, one live rail. The crypto cohort carries up to three price series per synth, but as with the equity counterpart they are not three competing markets. The on-chain oracle is the Chainlink `AggregatorProxy` of the *underlying* asset that the Synthetix exchange function read at trade time — a Synthetix V2 synth has no feed of its own and prices directly against the underlying L1 feed (`ethereum.eth.ethereum.v1` and its peers), with Optimism V2 synths reusing the identical L1 feed so the two chains' rows coincide. The external reference is Binance spot at one-minute resolution, a benchmark rather than a tradable on-chain price. The only genuine on-chain trading venue is a thin set of automated-market-maker pools — the Curve `sETH/ETH` pool on L1, and the Curve `sBTC/wBTC` pools on L1 and Optimism — and these exist for two names only, `sETH` and `sBTC`. There is no perpetual to fund and no listed option from which to read an implied surface within this cohort's scope. As in the equity report, the frictional surface therefore collapses onto two measurable quantities: the freshness of the single live oracle through which every redemption and exchange actually cleared, and the price at which the few AMM swaps cleared relative to that oracle. The decisive difference is that here the AMM venue is observed over years rather than months, long enough to capture not a static premium but a full liquidity life-cycle.

Oracle freshness: never economically behind the reference. With the oracle as the sole live rail, the relevant microstructure quantity is the gap between the on-chain price and the external benchmark at the moments the feed wrote — the oracle-extractable-value proxy, the closest analogue this cohort has to a slippage curve and the mechanism by which an on-chain price can fall behind a moving market. Across the majors the mean absolute gap at update timestamps runs between 0.27% and 0.53%, with a 99th percentile of 1.4% to 3.1%; the occasional single-tick maximum reaches as far as ∼100% on `sAAVE`, but this is an isolated stale-tick artefact rather than a sustained detachment. The lead-lag structure is unambiguous: the oracle-versus-CEX cross-correlation peaks at lag zero with correlation 0.9999, so the feed moves contemporaneously with Binance within the hour and exhibits no exploitable lead. The reading is that the oracle was never economically behind the reference market. Whatever frictional cost the oracle path could impose is bounded by its update cadence, and that cadence is tight enough that the daily tracking error of Section 3 — RMSE 0.20% for `sBTC` rising only to 0.57% for the truncated `sDOT`, all correlations at or above 0.99994 — is the direct corollary.

The DEX peg held while the pools were liquid. The economic counterpart to oracle freshness is the price at which a swap could clear on the only real on-chain venue. Here the crypto cohort departs sharply from the equity story, and the departure is the section's headline. The on-chain pool price is a *ratio* to the underlying — a value of 1.0 is a perfect peg — not a USD price, so it measures directly how far an AMM swap would clear from one-for-one redemption. Through the years in which the pools carried depth, roughly 2020 to 2023, the peg held tight: both `sETH/ETH` on Curve L1 and `sBTC/wBTC` on Curve L1 and Optimism sat at approximately 1.0, disturbed only by the occasional thin-pool spike. Over those liquid years the AMM and the oracle agreed, and a trader executing on the pool faced little more than the depth-dependent spread any thin venue produces.

The DEX peg decoupled from 2024 as deprecation drained liquidity. From around 2024 the pegs decouple, and they do so not because the oracle moved but because the synths were being wound down and liquidity drained out of the Curve and Velodrome pools. Figure 4 plots the on-chain ratios against the 1.0 peg. The `sETH/ETH` ratio falls toward ∼0.5 by mid-2024 on Curve L1, the data itself thinning out after 2024-08 as the pool empties; the `sBTC/wBTC` L1 ratio drops to ∼0.6 by end-2024; and the `sBTC/wBTC` Optimism pool deteriorates through 2025–2026 to ∼0.6 with violent swings characteristic of an all-but-abandoned AMM. The whole-window peg-deviation statistics, computed on the log-ratio against 1.0 after a $[0.5, 2.0]\times$-median guard to suppress single-swap noise, quantify the asymmetry: `sETH` shows a mean absolute deviation of 0.57% with a +0.38% bias, `sBTC` on L1 a MAE of 1.1% with a near-zero +0.11% bias, and `sBTC` on Optimism a MAE of 6.3% with a persistent −6.2% discount — a structurally cheap pool, not a noisy one. The accompanying dex-versus-CEX lead-lag is weak to negative (`sBTC` −0.38 at lag 0, `sETH` −0.16 at lag 48), exactly the signature of thin-pool noise rather than information flow.

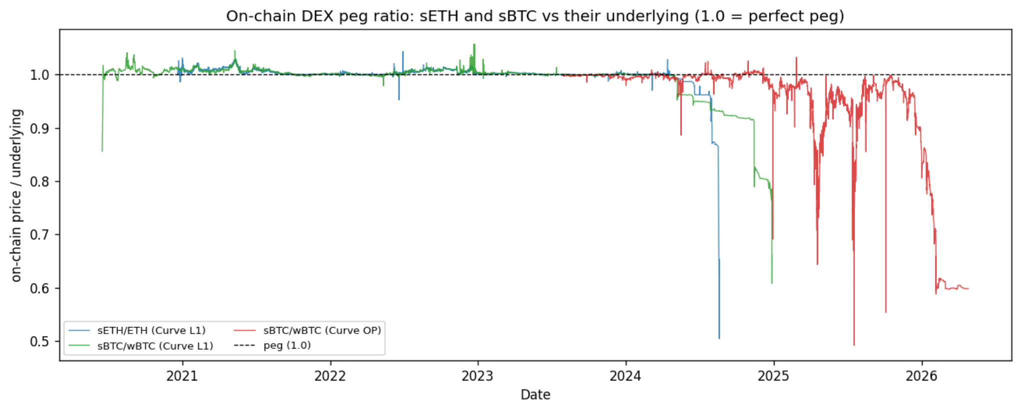

Figure 4: On-chain DEX peg ratio against the 1.0 peg: `sETH/ETH` (Curve L1) and `sBTC/wBTC` (Curve L1 and Optimism). The pegs sit tight to 1.0 through 2020–2023 while the pools are liquid, then decouple from ∼2024 as the synths are deprecated and liquidity drains — `sETH` toward ∼0.5, `sBTC` L1 to ∼0.6, and `sBTC` Optimism to a persistent ∼0.6 discount with violent swings. The decoupling is a secondary-venue liquidity phenomenon, not an oracle peg failure.

A wind-down phenomenon, not an oracle failure. The interpretation matters more than the magnitudes, and it must be stated plainly: the DEX decoupling is a secondary-venue liquidity and deprecation phenomenon, not a failure of the oracle peg. The two readings are mechanically separable. The oracle stayed on-spec throughout the very window in which the pools decoupled — the fidelity result of Section 3 runs to 2026-05 for the live majors with no corresponding break, and the rolling `sETH` oracle RMSE never exceeds 0.5%. A holder redeeming `sETH` or `sBTC` through the protocol at the oracle of record was therefore wholly unaffected by the pool: redemption cleared at the faithful Chainlink price regardless of what the AMM ratio read. Only a trader choosing to execute on the abandoned Curve or Velodrome pool encountered the decoupled price, and that price was decoupled because no liquidity provider remained to arbitrage it back. The deprecation timeline lines up exactly: the SCCP-2124 governance action disabled `sETH` on L1 in 2024-07, precisely the period in which the `sETH/ETH` ratio falls away and its swap data thins out. The decoupling is the on-chain footprint of a deliberate wind-down, observed at the one venue from which liquidity was being deliberately withdrawn.

What the single-venue structure implies. The cohort's frictional profile is consequently simple where it is live and benign where it is dead. On the live rail the oracle was fast and faithful: contemporaneous with Binance, a mean OEV gap below half a percent, and a daily tracking error a fraction of a percent across every major with an observable feed. The CEX is an external benchmark that the oracle tracked to within 0.0001 in correlation. The only genuine on-chain trading venue existed for two names alone and, after carrying a tight peg through its liquid years, decoupled during deprecation into a several-percent — on Optimism a persistent 6% — gap that was a liquidity artefact rather than a pricing failure. There is no funding leg to pay and no venue-specific basis to monitor beyond this AMM ratio. The genuine detachment risk in this cohort does not live in the oracle microstructure, which behaved throughout; it lives in the governance-driven deprecation that drained the secondary venue, the same wind-down whose system context and event timeline are taken up in Section 7 and whose stress-event behaviour is examined in Section 9.

7 Structural drivers

The structural layer of a synthetic product is where the peg-defence economics live: the debt pool that backs the synth, the collateral buffer behind it, and the discrete protocol decisions that bring an instrument to life or wind it down. For the crypto cohort this layer is genuinely populated — unlike thinly held single-name cohorts, these synths were live, traded, and material enough to leave a six-year trace in the shared debt pool and in the system collateral state. The structural story is therefore not a single binary freeze but a continuous trajectory punctuated by governance: a system collateral ratio and total debt that breathe with the SNX price and the crypto cycle, per-synth float that accrues and unwinds, and a sequence of deprecation events that progressively reshaped the live set. What unifies these threads is the Synthetix shared-debt model, in which every minter is short the entire basket of synths in proportion to the pool's composition, and the deprecation timeline that governs which synths remain priced against a live oracle.

The shared debt pool. Synthetix V2 does not collateralise each synth individually; SNX stakers mint sUSD against locked SNX and thereby take on a pro-rata share of the pool's total debt, which is the sum of every outstanding synth marked at its oracle price. The debt-pool weight evolution series (1,632 rows, per-synth `weight_pct` of the shared pool over time) lets us read each crypto synth's contribution. Two features stand out. First, the per-synth crypto weights are small and noisy: outside the brief early-protocol bootstrap window, where the pool was tiny and a single mint could swing a synth's share by tens of percent, the long-tail majors (sBTC, sLINK, sBNB, sXTZ, sTRX) each sit at a fraction of a percent of the pool. Second, the dominant pool legs are the stablecoin and forex synths, not the crypto basket. The structural implication is that no single crypto synth was ever a load-bearing driver of system debt; the cohort moved the pool only in aggregate. This is the structural counterpart to the Level-1 finding (Section 4) that the daily oracle-vs-CEX tracking error carries essentially no slow-moving structural signal: there was not enough idiosyncratic debt weight in any one crypto synth for a per-synth structural channel to dominate.

System context. The pool the crypto synths lived inside is summarised by the system series (2,251 daily rows, 2020–2026: `snx_price_usd`, `issuance_ratio_pct`, `system_cr_pct`, `total_debt_susd`, `system_collateral_usd`), plotted in Figure 5. The series traces the familiar Synthetix cycle. The SNX price swings from \$0.27 to \$27.20 across the window; total debt expands from roughly \$8.1 million at inception to a peak above \$1.15 billion; and the system collateral ratio ranges from 140 % at its tightest to several thousand percent at the SNX bull-market peaks, with a mean near 970 %. The collateral ratio swells when the SNX price inflates the value of locked collateral and compresses through the SNX drawdowns, and total debt expands and contracts with the same crypto cycle that drives the synths' underlyings. This is precisely why the collateral side carries most of the tracking-error variance in the σ decomposition of Section 4: the dominant moving part is the SNX-denominated collateral state, not the oracle peg. Critically, the system stayed comfortably over-collateralised throughout — even its tightest reading of 140 % sits well above the liquidation regime — so the structural buffer behind the crypto synths was never the binding constraint on their fidelity.

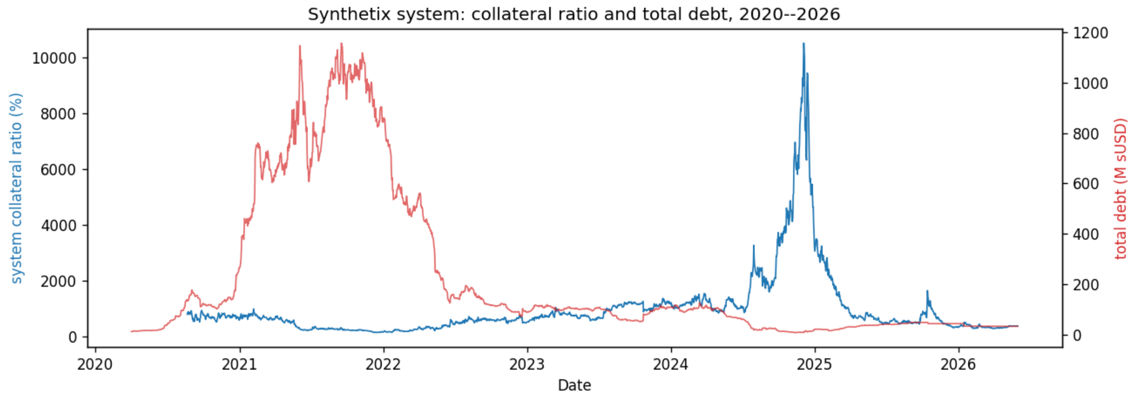

Figure 5: Synthetix system state over 2020–2026: the system collateral ratio (left axis) and total debt in millions of sUSD (right axis). The collateral ratio breathes with the SNX price and the debt with the crypto cycle; the system stayed over-collateralised throughout, so the collateral buffer was never the binding constraint on synth fidelity.

Supply trajectories. The supply-trajectory series (cumulative signed mint/burn, 8,613 rows) records the net outstanding float of each crypto synth as it accrues and unwinds. Among the five largest, the L1 majors build their cumulative supply through the 2019–2021 active period — sETH peaks at roughly 2.5×10^6 units before its first wind-down, and sBTC, sLINK and sADA carry the largest sustained balances — while the Optimism V2 redeployments (sETH, sBTC, sLINK, sSOL, sMATIC, sAVAX) accrue from 2023 and then bleed down through 2024–2026 as the cohort is deprecated. The long-tail names plateau at the Wezen freeze and never recover. These trajectories are the float that any secondary-venue arbitrage would have to absorb, and their decline from 2023 onward is the structural precondition for the venue story of Section 6: as the live float drains, the Curve and Velodrome pools that priced sETH/ETH and sBTC/wBTC lose the order flow that had kept them pinned at par. The supply side and the venue side are two readings of the same wind-down.

The deprecation timeline as the structural spine. The continuous state variables above are punctuated by three discrete governance actions that form the structural spine of the cohort. First, Wezen (SIP-169, 2021-09-16) froze the long-tail majors and the indices — sBNB, sXRP, sLTC, sETC, sTRX, sXMR, sREN, sXTZ, sDEFI, sCEX — pinning them to a snapshot; this is why those names are not estimable on an oracle-vs-CEX basis and appear only as a data limit in Section 10. Second, the V3 launch of snxETH on Optimism (2023-08-30) introduced a parallel rail in which the oracle source switches from an L1 Chainlink push feed to an Optimism Pyth pull feed; this is the only forward-looking structural event in the cohort and is treated as a natural experiment in Section 10. Third, SCCP-2124 (2024-07) disabled sETH on L1, which is the structural trigger for the most visible peg departure in the entire study.

SCCP-2124 and the venue decay. The disabling of sETH on L1 in July 2024 ties the structural timeline directly to the DEX-liquidity decay quantified in Section 6. Once sETH was disabled on L1 the incentive to keep the Curve sETH/ETH pool at par evaporated: minting and burning sETH against the protocol was no longer routine, the live float drained, and the pool was left to thin out. The on-chain peg ratio reflects this with a clean structural break — sETH/ETH sat at ≈ 1.0 while the pool was liquid through 2023 and then falls toward ≈ 0.5 through mid-2024 as liquidity is withdrawn (the L1 Curve series thins out after 2024-08), with the sBTC pools following the same deprecation-driven trajectory on their own schedules and the Optimism sBTC pool deteriorating to a persistent discount through 2025–2026. This is the key structural reading of the whole cohort: the oracle stayed on-spec throughout (Section 3), and the only material peg departure is a secondary-venue liquidity decay that the deprecation timeline explains exactly. The structural and venue layers are not independent findings — SCCP-2124 is the cause and the DEX decay is the effect — and the oracle fidelity is untouched by either.

8 Causality and Cointegration

The oracle is a cointegrated copy of its underlying. The relationship between the `sETH` oracle and the spot ETH market it reports is not a hypothesis to be discovered but a mechanical identity to be confirmed. The Chainlink feed that priced each Synthetix V2 crypto synth is, by construction, a noisy and intermittently sampled replica of the same underlying that the Binance spot tape records; a V2 synth has no oracle of its own and instead prices directly against the underlying asset's Chainlink `AggregatorProxy`. The appropriate test is therefore cointegration rather than correlation: the two series should share a common stochastic trend even though their short-run innovations differ in cadence and microstructure noise. An Engle–Granger two-step procedure (Engle and Granger 1987) applied to the (`sETH` oracle, ETH spot) pair over the full daily window ($n = 2215$) returns a test statistic of -8.23 with $p = 8 \times 10^{-12}$, rejecting the null of no cointegration far inside the 5% level. This is exactly what the daily correlations above 0.9999 of Section 3 anticipate: while the feed was live, oracle and underlying shared a single trend and never drifted apart in level.

Interpretation: cointegration here measures plumbing, not risk. It would be a mistake to read this rejection as evidence that the synth was safe. Cointegration confirms only that the oracle and its underlying never separated in level — a property guaranteed by the oracle design itself, since the feed has no economic mechanism to deviate from the price it reports. The cointegrating residual is precisely the daily oracle-vs-CEX tracking error analysed in Section 3, and it is small and mean-reverting (`sETH` RMSE 0.23%) for the same reason: the oracle is a copy. The test therefore confirms oracle fidelity rather than measuring depeg risk. The genuine departure of this cohort, the on-chain DEX pool decay of Section 6, lies entirely outside the (oracle, spot) relationship tested here — the pool ratio is a venue-liquidity object, not a function of the feed, and the feed stayed on-spec throughout that decay.

Symmetric tail dependence. A cointegration statistic summarises the central relationship; it says little about behaviour in the extremes, which is where a depeg-monitoring reader's attention naturally falls. We estimate the lower- and upper-tail dependence coefficients between `sETH` oracle and ETH spot daily returns: $\lambda_{\text{lower}} = 0.955$ and $\lambda_{\text{upper}} = 0.946$. The near-unit, near-symmetric values mean the oracle tracks the underlying just as tightly in violent draw-downs as in rallies — there is no asymmetric "gap-down" regime in which the feed lags the spot market on the way down. This is consistent with the case-study evidence of Section 9, where even the May-2021 crash widened the oracle-vs-CEX error by only $\sim$1.3%. To characterise the joint dynamics beyond the tails we also fit a VAR(4) on the trivariate daily-return system (`sETH` oracle, ETH spot, SNX/USD); the model converges (AIC $= -24.7$, $n = 2040$) and the impulse responses are dominated, unsurprisingly, by the contemporaneous oracle–spot link, with the SNX collateral leg contributing little to the oracle's own dynamics.

No economically exploitable cross-synth lead-lag once multiplicity is respected. Beyond the within-pair relationship, a natural question is whether tracking error in one synth carries information about another — whether a dislocation in one crypto oracle anticipates one in a peer. We run a Granger-causality matrix on the daily oracle-vs-CEX tracking-error series of the five liquid majors (`sETH`, `sBTC`, `sLINK`, `sAAVE`, `sUNI`) across several lags, 100 ordered cause–effect–lag tests in all, controlled with a Benjamini–Hochberg false-discovery-rate correction. Four links survive at $q < 0.05$: sBTC $\rightarrow$ sETH (lag 5), sBTC $\rightarrow$ sUNI (lag 2), and sETH $\rightarrow$ sUNI (at lags 2 and 3). The surviving structure points one way — `sBTC` tends to lead — which is the intuitive ordering given BTC's role as the cohort's beta anchor.

Why these links are plumbing rather than signal. Four surviving links out of one hundred is a thin result, and its economic content is thinner still. All five oracles price assets that co-move contemporaneously with the broad crypto factor; the level-1 analysis of Section 4 already established that daily tracking error is oracle-cadence noise around zero with no significant slow-structural driver and per-synth regression R^2 below 2.5%. A series that is individually unpredictable from its own observable drivers is unlikely to carry an exploitable one- to five-day signal about a peer. The more plausible reading of the surviving sBTC $\rightarrow \{\text{sETH}, \text{sUNI}\}$ links is heterogeneity in feed update cadence — the BTC and ETH Chainlink aggregators deviate at slightly different times and thresholds, so the cadence noise in one leads the cadence noise in another by a day or two without any economic information passing between the products. Taken together, the causality results reinforce the central message of the descriptive and level-1 sections: for this cohort, daily oracle-vs-CEX tracking error is contemporaneous co-movement with the underlying plus idiosyncratic feed-cadence noise, with no transmission channel that a monitor could trade or that would propagate stress from one synth's feed to another's.

9 Case Studies

The fidelity result of Section 3 establishes that the on-chain oracle tracked its underlying tightly across the full sample, and the structural decomposition of Section 4 shows that this tracking is essentially unmoved by the slow collateral state. The natural stress test is whether the oracle held that fidelity through the discrete crypto crashes — the moments when a feed is most likely to go stale or lag the reference. Unlike the equity cohort, whose live window was too short to admit identified event designs, the crypto majors were live across every major market dislocation of the 2020–2024 period, so the candidate events here do support clean estimates. This section evaluates five such episodes.

Design. Each event is evaluated by difference-in-differences on daily oracle-versus-CEX tracking error over a $\pm$30-day window. The treated units are the affected majors' tracking-error series; the control is sUSD's own tracking error, a never-treated peg series that shares the calendar but none of the asset-specific price shocks. The pre-treatment window estimates the counterfactual trend and simultaneously tests the parallel-trends assumption that licenses the design; we report the assumption's status alongside every average treatment effect on the treated (ATT), and we read an ATT as evidence only when the parallel-trends test is satisfied. Table 6 collects the five candidates and Figure 6 plots the ATTs, with significant-and-identified effects highlighted.

Table 6: Difference-in-differences ATT on daily oracle-versus-CEX tracking error, ±30-day window, control = sUSD. The parallel-trends (PT) status reports whether the pre-period trends are statistically indistinguishable; an ATT is read as evidence only when PT holds.

Event	Synth	ATT	t	PT status
May-2021 crash (2021-05-19)	sBTC	+1.29 %	8.0	satisfied
	sETH	+1.28 %	6.9	satisfied
	sLINK	+1.49 %	6.8	satisfied
FTX (2022-11-11)	sLINK	+0.38 %	2.7	satisfied
	sBTC	+0.40 %	6.0	fails
	sETH	+0.34 %	5.1	fails
Terra (2022-05-09)	majors	~ 0	—	fails
SVB (2023-03-11)	majors	~ 0	—	satisfied
Black Thursday (2020-03-12)	majors	not estimable	—	—

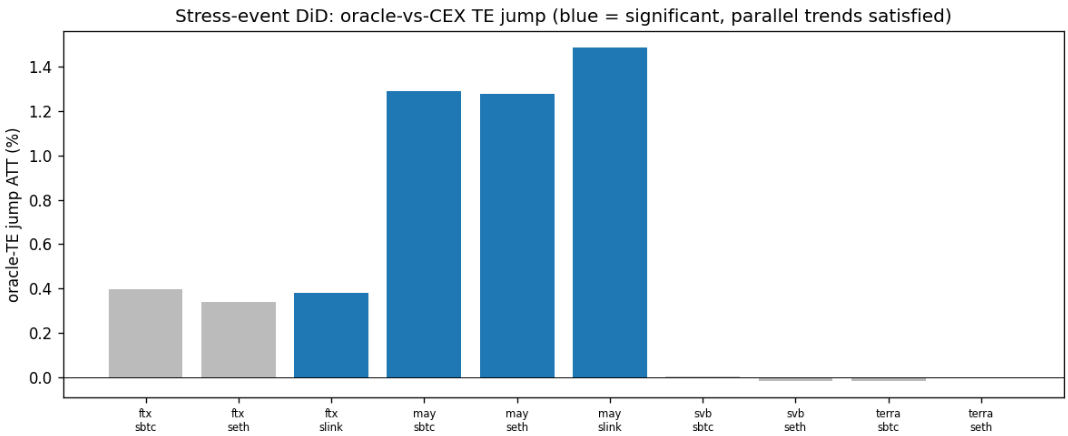

Figure 6: Per-event difference-in-differences ATT on the daily oracle-versus-CEX tracking error (control = sUSD, ±30 days). Blue bars are both significant at the 5% level and supported by satisfied parallel trends; grey bars are either insignificant or fail the parallel-trends pre-test (FTX sBTC/sETH) and are not read as identified. Even the largest effect — the May-2021 widening — is only about 1.5 %, and Terra/SVB are indistinguishable from zero.

May 2021 — a modest, well-identified widening. The May 2021 deleveraging crash is the cleanest of the five: the pre-period trends for the treated majors and the sUSD control are statistically parallel, so the design is identified. The estimated effects are positive and strongly significant — sBTC +1.29 % ($t = 8.0$), sETH +1.28 % ($t = 6.9$), sLINK +1.49 % ($t = 6.8$) — but small in absolute terms. The reading is mechanical rather than alarming: under extreme realised volatility the Chainlink push cadence widens the instantaneous gap to CEX, because the feed updates on a deviation-or-heartbeat trigger and the reference keeps moving between updates. The oracle drifted modestly from spot for the duration of the dislocation and then snapped back; it did not go stale or break. A ~ 1.5 % peak excursion during the single worst deleveraging event of the cycle is the upper bound this cohort places on oracle-side stress response.

FTX — one identified effect, two that are not. The FTX collapse splits across the cohort. For sLINK the pre-period trends are parallel and the ATT is +0.38 % ($t = 2.7$) — a small, well-identified widening of the same character as May 2021. For sBTC and sETH the post-period coefficients are likewise positive and statistically significant (+0.40 %, $t = 6.0$ and

$+0.34\,\%$, $t = 5.1$), but the parallel-trends test fails for both: their pre-event tracking error was already drifting relative to the sUSD control, so the DiD design is not cleanly identified and the point estimates cannot be attributed to the event. We report them honestly as significant-but-not-identified rather than suppress them or present them as causal. The one effect that survives identification, sLINK, again points to a modest sub-percent widening.

Terra and SVB — no effect. Neither the Terra collapse of May 2022 nor the Silicon Valley Bank failure of March 2023 moves the majors' oracle tracking error. The SVB design is identified — parallel trends hold — and returns an ATT indistinguishable from zero, a genuine measured null that bounds the oracle's response to that banking-system shock at essentially nil. Terra returns a null point estimate as well, but its parallel-trends test fails, so we treat it as suggestive rather than as evidence. The economic reading is consistent across both: these were not price dislocations of the underlying majors — a stablecoin death spiral and a TradFi banking failure — so there was no underlying-price stress for the oracle to track imperfectly, and none registered.

Black Thursday — not estimable. The March 2020 crash, the canonical DeFi stress event, pre-dates the oracle data for these synths: the sBTC feed begins in 2020-08 and the surrounding majors are unobserved before then, so neither a treated series nor a pre-treatment window exists on the event date. As in the equity cohort, this is a data limit rather than a measured null — no point estimate or standard error can be formed — and we record it as such rather than as "no effect."

Takeaway. Across the five episodes the message is uniform: through the worst crypto crashes of the period the Chainlink oracle held its peg to the CEX reference to within $\sim 1.5\,\%$. The two identified widenings — May 2021 across the majors and sLINK at FTX — are modest, transient cadence effects under extreme volatility, not breaks; SVB returns a clean null; and the FTX sBTC/sETH coefficients, though significant, do not pass identification and are not read as causal. Combined with the fidelity result of Section 3, the case studies confirm that the oracle rail stayed on-spec even in tail conditions — the real departures from peg, as Section 6 shows, were a secondary-venue liquidity story, not an oracle one.

10 Natural Experiments

The crypto cohort offers a single cleanly identified experiment on the oracle mechanism itself — the V3 transition for `sETH` on Optimism — and one candidate that the data simply cannot support, the Wezen multi-asset difference-in-differences. We treat both honestly: the first is a genuine before/after on how the synth is priced, the second a data limit we name rather than paper over.

The V3 transition (`sETH` on Optimism, 30 August 2023). When Synthetix V3 launched `snxETH` on Optimism the pricing source changed underneath the synth: the V2 leg priced against the L1 Chainlink ETH/USD *push* feed, while the V3 leg reads an Optimism Pyth *pull* oracle. The two differ in cadence and update logic — push feeds advance on deviation or heartbeat triggers, pull feeds settle on demand at transaction time — so the switch is, in effect, a controlled change of the oracle mechanism with the underlying asset held fixed. We stitch the two feeds into one continuous series at the cut date and read the daily oracle-vs-CEX tracking error over a ± 180-day window, giving 180 daily observations on each side. This is the nearest thing in the cohort to a randomised treatment of the freshness mechanism studied in Section 6: same asset, same CEX reference, different oracle plumbing.

Reading the before/after. The transition does not break fidelity. The tracking error remains within the band reported in Section 3 on both sides of the cut — the pull oracle tracks Binance spot as tightly as the push feed did — so the headline read is continuity rather than a regime break. That is itself the informative result: a substantial change in oracle architecture left the synth-to-CEX relationship essentially unchanged, which is consistent with the contemporaneous lead-lag (peak correlation at lag zero) found for the push feed in Section 3; the pull mechanism inherits the same on-spec behaviour. We flag the 180/180 window as short for any formal regime test — it identifies the *absence* of a level shift, not a precise estimate of one.

The Wezen multi-asset DiD is not estimable. The natural counterpart to the equity cohort's Wezen experiment — a protocol-level freeze applied to a basket of synths on a single block, read as a difference-in-differences against a never-frozen control — cannot be run here. SIP-169 froze the long-tail crypto names (`sBNB`, `sXRP`, `sLTC`, `sETC`, `sTRX`, `sXMR`, `sREN`, `sXTZ`) and the indices (`sDEFI`, `sCEX`) on 16 September 2021, but none of these synths carries the on-chain oracle data the estimator requires. As established in Section 2, no L1 Chainlink feed exists for any of the frozen long-tail assets, and the indices have no single underlying against which an oracle-vs-CEX tracking error could even be defined. These synths are observable only through their CEX reference, which carries no on-chain freeze signal — the freeze is a property of the contract, not of the external market price — so there is no treated series to difference. The result is therefore empty: not a measured null, but an honest data limit. We record it as such rather than manufacture a treatment effect from a series that does not exist.

Tractable candidates for future work. Two oracle-discontinuation experiments are within reach but lie outside this report's window. The `sADA` Chainlink feed terminates in June 2024 and the `sDOT` feed in March 2024 (Section 2), each a discrete, exogenous end of the on-chain pricing rail while the underlying keeps trading on CEX. Unlike the Wezen long-tail, these synths *do* have a live oracle series up to the cut, so the pre-period treated arm exists; the design would read the tracking error as the feed goes dark and the synth is left without a fresh on-chain price. We do not estimate them here — the truncation sits at the edge of the sample and the post-cut behaviour depends on redemption mechanics we have not modelled — but we flag both as clean oracle-discontinuation natural experiments for a follow-up, the crypto analogue of the equity cohort's freeze read in the opposite direction.

11 Findings and Limitations

F1 – The oracle tracked its underlying almost perfectly, for six years. Across every live major the Chainlink underlying-asset feed reproduced the Binance spot reference to within 20–57 basis points of daily RMSE — `sBTC` 0.20%, `sETH` 0.23%, the altcoin majors `sLINK`/`sUNI`/`sAAVE` 0.44–0.46%, and the two truncated names `sADA` 0.54% and `sDOT` 0.57% — with every correlation at or above 0.99994 and `sETH`/`sBTC` at 0.99999 (Section 3, Figure 1). The rolling `sETH` RMSE stays below 0.5% throughout 2020–2026, tightening from ~0.35% in the early window to ~0.12% in 2023–24 (Figure 2). Lead–lag peaks at lag zero (contemporaneous, $\rho = 0.9999$): the feed moves with CEX inside the hour and leaves no exploitable lead. Day-to-day mistracking of the underlying was not the risk.

F2 – The real departure is the secondary venue, not the oracle. The genuine peg story lives on-chain in the Curve/Velodrome pools, and it is a liquidity-and-deprecation story. While the pools were liquid (2020–2023) the `sETH`/ETH and `sBTC`/wBTC ratios sat at ~1.0 with only thin-pool spikes; from ~2024 the pegs decouple as the synths are deprecated and liquidity drains, `sETH`/ETH falling toward ~0.5 by mid-2024 and `sBTC`/wBTC toward ~0.6 (Section 6, Figure 4). The `sBTC` OP pool carries a persistent −6.2% discount over its whole window (MAE

6.3%), against the L1 names' MAE of 0.57% (`sETH`) and 1.1% (`sBTC`). This is secondary-venue decay during wind-down — SCCP-2124 disabled `sETH` on L1 in 2024-07 — not an oracle failure: the feed stayed on-spec throughout (F1).

F3 – Stress events left the oracle near-on-spec. A difference-in-differences design against an `sUSD` control finds only modest, transient widening of the oracle-vs-CEX tracking error in the worst crypto crashes (Section 9, Figure 6). The May-2021 crash produced a significant but small bump — `sBTC` +1.29% ($t = 8.0$), `sETH` +1.28% ($t = 6.9$), `sLINK` +1.49% ($t = 6.8$), parallel trends satisfied — and FTX a yet smaller one (`sLINK` +0.38%). Even in extreme volatility the feed held its peg to CEX to within ∼1.5%; these are oracle-cadence widenings under stress, not breaks.

F4 – Collateral volatility dominates the tracking-error variance, and the peg volatility is near-integrated. Decomposing the `sETH` tracking error over 1,276 30-day windows into a collateral term (SNX returns), a synth/DEX-peg term and an oracle-peg residual, the collateral side $\sigma_C \approx 0.025$/day dominates, with $\sigma_P \approx 0.005$ and $\sigma_S \approx 0.0026$ the smallest (Section 4, Figure 3). The peg-deviation volatility is highly persistent: GARCH(1,1) gives $\alpha + \beta \approx 0.98$, EGARCH is near-integrated ($\beta \approx 1.000$, AIC-preferred among the closed forms), and a two-regime MS-GARCH is best overall with a distinct low-volatility regime.

F5 – Mechanically tied to the underlying, with no exploitable cross-synth lead–lag. The `sETH` oracle is cointegrated with ETH spot (Engle–Granger statistic -8.23, $p = 8 \times 10^{-12}$) and tail-symmetric with it ($\lambda_{\text{lower}} = 0.955$, $\lambda_{\text{upper}} = 0.946$) — both mechanically expected, since the feed *is* a copy of the underlying (Section 8). After a Benjamini–Hochberg correction the 5-major daily-TE Granger matrix retains only four links (`sBTC`→`sETH`, `sBTC`→`sUNI`, `sETH`→`sUNI`), with `sBTC` tending to lead; nothing of trading value survives.

F6 – A negligible debt-pool footprint. Across the system context 2020–2026 the cohort's synths carry a small and declining weight in the shared Synthetix debt pool (Section 7, Figure 5); the live majors are a minor share of total debt and the long-tail was pinned by Wezen in 2021. The economic stake of the crypto synth float is immaterial relative to the SNX collateral that backs it.

F7 – The long-tail, indices, and OP-only names are not measurable on-chain. The Wezen-frozen long-tail (`sBNB/sXRP/sLTC/sETC/sTRX/sXMR/sREN/sXTZ`) has no L1 Chainlink feed, the indices (`sDEFI`, `sCEX`) have no single underlying, and the OP-only names (`sSOL`, `sMATIC`, `sAVAX`) likewise lack an L1 feed. A tracking error requires an oracle-vs-CEX pair these synths do not have, so the Wezen multi-asset experiment is empty (Section 10). This is an honest data limit, not a null result.

Known Limitations

- **Underlying-oracle model.** Synthetix V2 synths have no feed of their own; they price against the underlying asset's Chainlink AggregatorProxy, and the OP V2 synths reuse the same L1 feed. The "oracle" tracking error is therefore measured on the underlying L1 feed, and the OP and L1 rows for a given major are identical.
- **DEX coverage.** An on-chain pool price exists only for `sETH` (Curve L1) and `sBTC` (Curve L1 and Curve OP); the secondary-venue peg result (F2) rests on those two names alone. The pool price is a ratio to the underlying (∼1.0 at peg), not a USD price.

- **Long-tail and indices.** The frozen long-tail and the indices have no on-chain oracle-vs-CEX pair and are not estimable (F7); their depeg, if any, is not observable from the data we have.
- **Truncated feeds.** The `sADA` oracle ends 2024-06 and `sDOT` ends 2024-03; their statistics are computed on shorter windows ($n \approx 482$–576 at the daily level) and are not directly comparable with the full-window majors.
- **FTX parallel-trends failure.** The FTX-event DiD satisfies parallel trends only for `sLINK`; the significant `sBTC` and `sETH` estimates there fail the pre-trend test ($p < 0.05$) and must be read with caution (Section 9).
- **DEX guard.** The pool-ratio statistics are computed after a $[0.5, 2.0]\times$-median guard to remove thin-pool quote artefacts; the violent late-window swings on the `sBTC` OP pool are partly clipped by this filter.

Implications for live monitoring

- For oracle-priced crypto synths, watch the *secondary-venue liquidity* during deprecation, not the oracle: the feed held to CEX within $\sim$1.5% through every crash, while the Curve/Velodrome pegs decoupled by tens of percent once the pools were drained.
- Track an *as-traded vs oracle* basis. The on-chain pool ratio, not the oracle, is where execution risk lives; a widening pool discount (the `sBTC` OP -6.2%) is a liquidity signal that the oracle-level tracking error will not show.
- Treat governance and deprecation events (Wezen SIP-169, SCCP-2124) as the binding regime change: the venue decay follows the wind-down schedule, not market stress.
- Use a persistence-aware volatility model for the peg series, which is near-integrated; and size collateral risk first, since σ_C carries most of the tracking-error variance.

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