

Crypto Momentum: TS vs XS with Volatility-Momentum Overlay

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1 Introduction

We test time-series (TS) and cross-sectional (XS) momentum strategies on ten liquid cryptocurrencies (BTC, ETH, ADA, BNB, SOL, XRP, NEAR, LINK, AVAX, AAVE) using daily Binance closes from 2020–2025. Transaction costs of 20 bps per roundtrip are applied to all strategies. The evaluation uses an in-sample (IS) window of 2020–2021 and an out-of-sample (OOS) window of 2022–2025 (split at 2021-12-31). Our benchmark is buy-and-hold Bitcoin (BTC).

2 Data and Benchmark

Daily closes are forward-filled by at most two missing days, UTC-aligned. Arithmetic returns are used:

$$r_t = \frac{P_t}{P_{t-1}} - 1.$$

The benchmark equity is

$$Eq_t^{BTC} = \prod_{s \leq t} (1 + r_s^{BTC}).$$

On the latest run, BTC HODL achieved OOS Sharpe

$$SR_{OOS}^{BTC} \approx 0.71.$$

3 Strategies

3.1 Time-Series Momentum (TS-MOM)

Evaluation of the TS-MOM Strategy on BTC. We first evaluated a time-series momentum (TS-MOM) strategy applied to Bitcoin, using a parameter sweep of lookback horizons $k \in [3, 180]$ days. The analysis revealed that shorter to medium horizons delivered the best performance, with an in-sample maximum Sharpe ratio of approximately 1.26. Out-of-sample, the chosen configuration ($k = 37$) achieved a Sharpe ratio of 0.90, which while only moderate, still exceeded that of Bitcoin buy-and-hold (0.72). Regression analysis further highlighted that the strategy generated a significant positive alpha (0.014% daily) while maintaining a very low beta with respect to BTC returns, indicating that the TS-MOM captures a distinct source of return largely uncorrelated with directional Bitcoin exposure. More importantly this strategy has a t-stat of 1.81 which emphasizes the long term edge offered over the BTC by this strategy.

Combining Two Uncorrelated Strategies. Building on these findings, we explored whether combining the TS-MOM strategy with Bitcoin buy-and-hold could improve risk-adjusted performance. Since the two return streams were found to be largely uncorrelated, a simple diversification effect was expected. Indeed, both equal-weighted and Sharpe-weighted allocations (weights proportional to each strategy’s Sharpe ratio) produced stronger results, achieving a portfolio Sharpe ratio of about 1.17 with volatility reduced to $\approx 37\%$ and maximum drawdown improved to -38% . This demonstrates how blending two imperfect but uncorrelated strategies can yield a significantly more robust portfolio, preserving the alpha of TS-MOM while still retaining exposure to BTC, and thus offering a stronger foundation for systematic crypto allocation.

Table 1: Performance Summary and Portfolio Weights

Portfolio	Sharpe	Volatility	MDD
TS-MOM	0.890	0.532	-0.567
BTC	0.717	0.533	-0.669
50/50 Equal	1.166	0.367	-0.394
SR-Weighted	1.172	0.369	-0.382
Weights		TS-MOM	BTC
Sharpe-Ratio Weighted		0.554	0.446
Equal-Vol Weighted		0.501	0.499

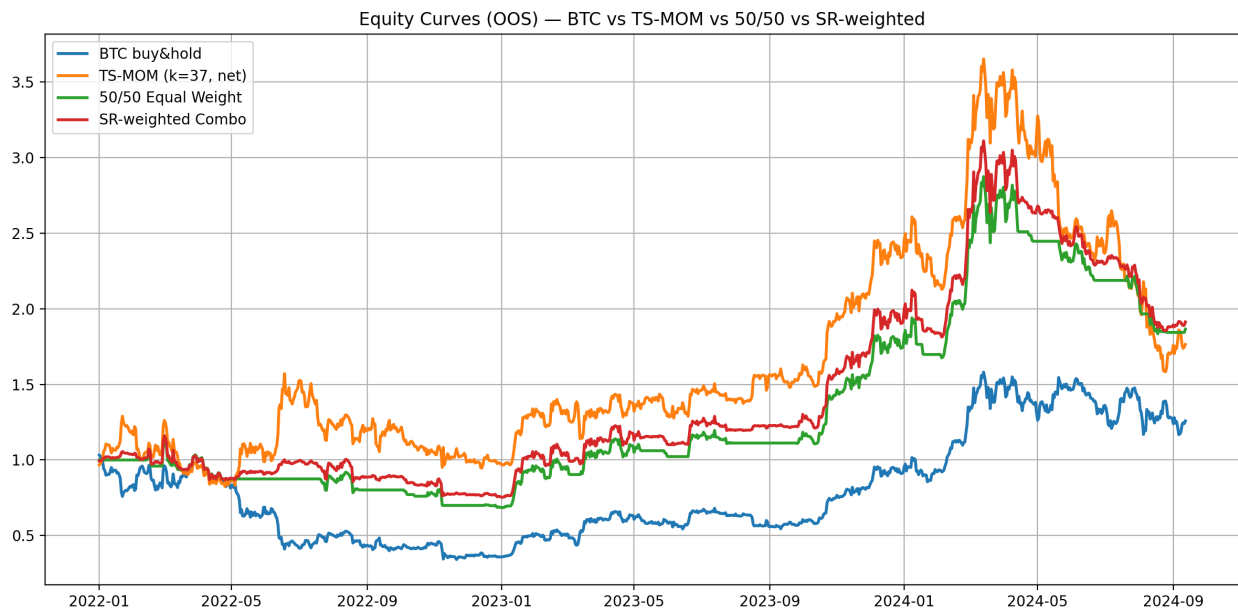


Figure 1: OOS equity curves comparing BTC buy-and-hold, TS-MOM ($k = 37$, net of 20 bps costs, daily freq = 365), a 50/50 mix, and an SR-weighted static allocation (weights \propto each sleeve’s Sharpe over the OOS window).

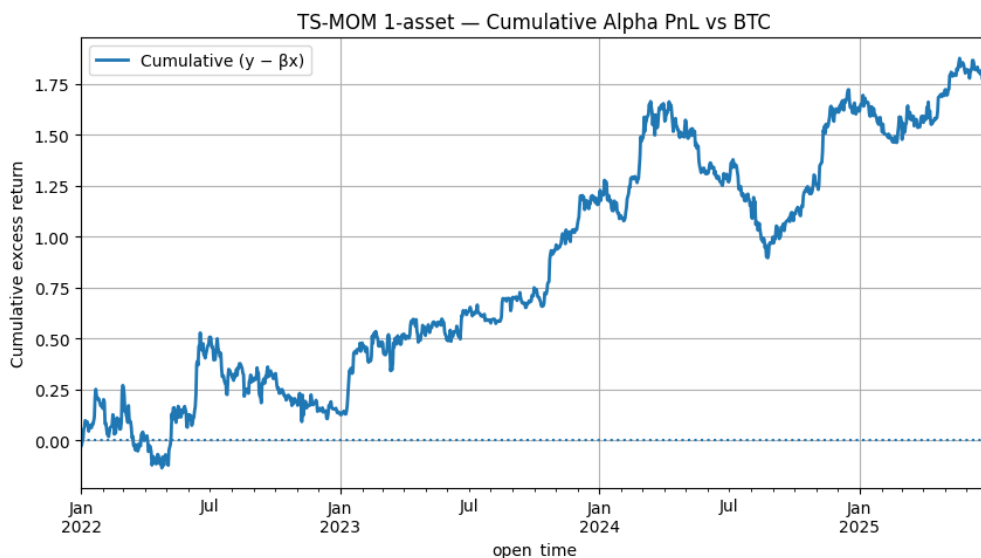


Figure 2: Cumulative Alpha of TS-Momentum Strategy

Mutualized TS-MOM across Ten Cryptocurrencies. We evaluated a mutualized time-series momentum portfolio by applying the same lookback window k to six large-cap cryptocurrencies, averaging their daily net returns (transaction costs included) to form an equal-weight sleeve. The optimal k was selected on the training set (maximizing train Sharpe) and fixed for the out-of-sample evaluation. Although the training curve peaked at a short-medium horizon (yielding $k \approx 33$), the out-of-sample Sharpe of the mutualized sleeve proved inferior to both the BTC buy-and-hold benchmark and to our earlier single-asset TS-MOM strategy on BTC. Given that this construction

uses a *raw* time-series signal applied uniformly across assets, the result suggests limited exploitation of cross-asset structure. These findings motivate transitioning to a cross-sectional (XS) momentum framework—ranking assets by relative strength and allocating to winners versus losers—which is better suited to extracting diversified premia while attenuating common beta and idiosyncratic noise.

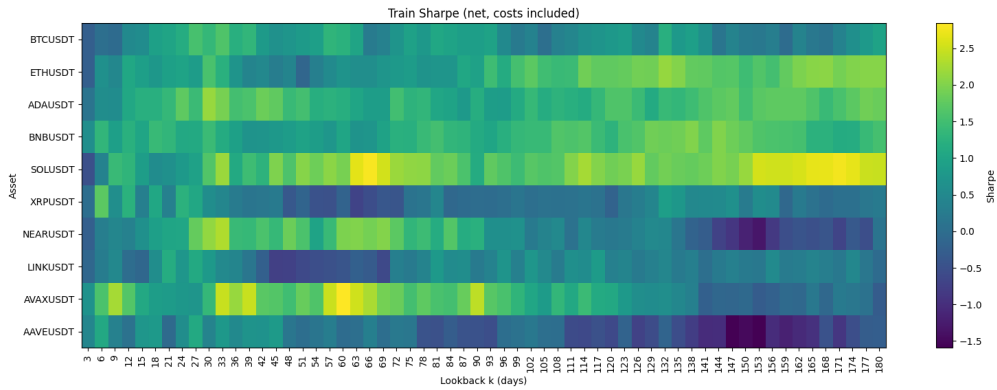


Figure 3: Mutualized TS-Momentum: Training Sharpe Ratio Grid

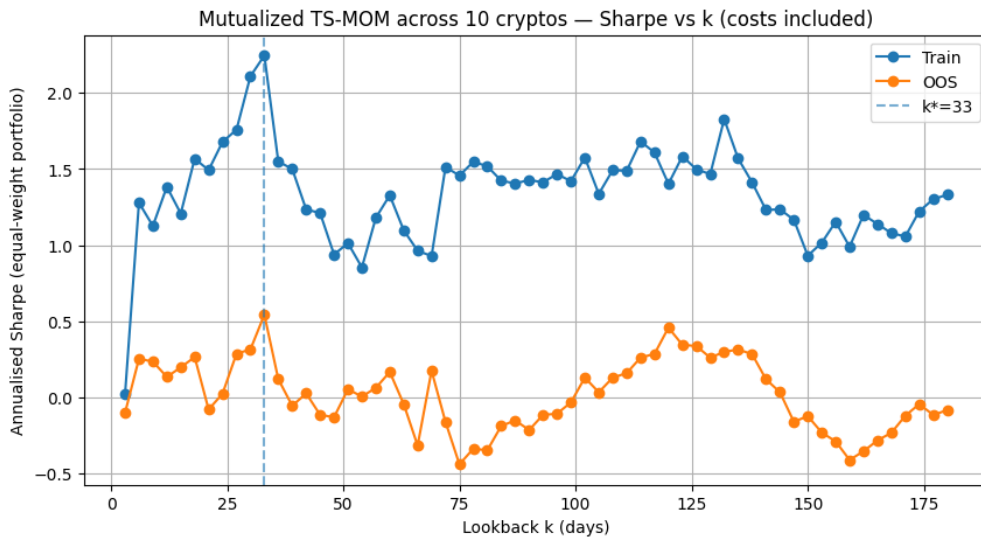


Figure 4: Picking the Best k for the Mutualized TS-Momentum Strategy

3.2 Cross-Sectional Momentum (XS-MOM)

XS Momentum (Weekly, $k = 13$).

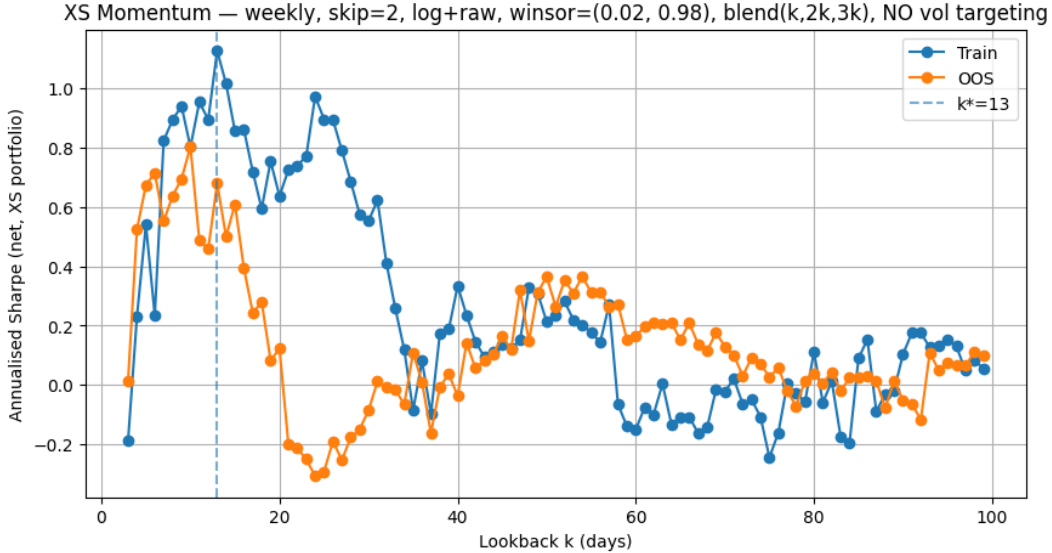


Figure 5: Cross-Sectional Momentum — Grid

For asset i on day t , we form the *log-momentum* signal with a two-day skip:

$$s_{t,i}(h) = \log\left(\frac{P_{t-s,i}}{P_{t-h-s,i}}\right), \quad h \in \{k, 2k, (3k)\}, \quad s = 2.$$

We average across available horizons, then apply **row-wise winsorization** (2% / 98%) to suppress outliers. Next, we compute the **cross-sectional signal** by ranking each row to $[-1, 1]$ and optionally applying a tanh nonlinearity.

The resulting scores are demeaned across assets to enforce market-neutrality and scaled to unit L^1 , ensuring a constant gross exposure:

$$\sum_i |w_{t,i}| = 1.$$

Weights are lagged by one day to avoid look-ahead bias, rebalanced weekly at the last trading day of the week, and forward-filled within the week. An EMA smoothing term with $\alpha = 0.5$ is applied to dampen turnover.

Portfolio net returns are computed as:

$$r_t^{\text{net}} = \sum_i w_{t,i} r_{t,i} - \text{TC} \cdot \sum_i |w_{t,i} - w_{t-1,i}|, \quad \text{TC} = 20 \text{ bps (round-trip)}.$$

On the training window, the optimal lookback is $k^* = 13$ with $\text{SR}_{\text{train}} = 1.21$, while out-of-sample performance yields $\text{SR}_{\text{OOS}} = 0.724$, only marginally above BTC buy-and-hold over the same period.

The limited OOS edge under costs motivates augmenting the signal with **liquidity-aware (volume-adjusted)** features and position caps to improve stability and mitigate concentration in less-liquid constituents.

3.3 A New Approach: Volume-Adjusted Momentum (Utopic Configuration)

We construct a **Volume-Adjusted Momentum Strategy** that enhances classical cross-sectional momentum by weighting each asset’s return by its deviation from recent average trading volume. Let $r_{t,i}$ denote the return of asset i and $v_{t,i}$ its trading volume. Defining a rolling mean $\bar{v}_{t,i}^{(L)}$ over L periods, the *relative volume* is

$$\tilde{v}_{t,i} = \frac{v_{t,i} - \bar{v}_{t,i}^{(L)}}{\bar{v}_{t,i}^{(L)}},$$

and the raw score is $s_{t,i} = \tilde{v}_{t,i} r_{t,i}$. We demean across assets to impose market-neutrality and scale by unit L^1 norm:

$$w_{t,i} = \frac{s_{t,i} - \bar{s}_t}{\sum_j |s_{t,j} - \bar{s}_t|}, \quad \sum_i |w_{t,i}| = 1.$$

Unlike the realistic XS-MOM formulation, this utopic version assumes **same-bar execution**—that is, the weights w_t are applied to the returns r_t within the same resampled bar (weekly or monthly). Transaction costs are modeled as a fixed per-rebalance cost rather than turnover-proportional slippage, eliminating market-impact effects. Hence, the model can implicitly use contemporaneous or forward information, leading to overstated performance.

Table 2: Performance Summary — Volume-Adjusted Momentum (Same-Bar Execution, Flat 20 bps)

Frequency	IS Sharpe	OOS Sharpe	Annualized α (vs BTC)	t-stat	p-value
Weekly	3.545	2.415	254.3%	3.44	0.0006
Monthly	2.014	1.400	120.7%	2.54	0.0111

The resulting Sharpe ratios (IS/OOS) are extraordinarily high— $SR_{OOS} = 2.42$ weekly and 1.40 monthly—with estimated annualized alphas exceeding 100% relative to BTC. These outcomes, however, are a by-product of *look-ahead bias*: by using the same period’s return and volume to form and execute trades, the strategy captures information that would not be observable ex-ante. Thus, this setup should be interpreted as a **utopic upper bound** on what a realistic, lagged, volume-aware momentum model might achieve. Future implementations will enforce signal lagging, realistic execution costs, and asynchronous data alignment to yield truly implementable performance.

3.4 Volume-Adjusted Momentum (Lagged, Realistic Implementation)

To address the look-ahead bias in the utopic configuration, we now apply the volume-adjusted weights with a one-bar lag:

$$r_t^{\text{net}} = \sum_i w_{t-1,i} r_{t,i} - \text{TC} \cdot \sum_i \frac{|w_{t,i} - w_{t-1,i}|}{2},$$

where transaction costs TC are expressed in basis points per turnover. This ensures that trading decisions rely only on information observable at the start of each rebalancing interval.

Table 3: Performance Summary — Volume-Adjusted Momentum (Lagged, Net of 20 bps Costs)

Frequency	IS Sharpe	OOS Sharpe	Cost (bps)	Comment
Weekly	0.052	0.813	20	Reasonable OOS edge, minimal overfit risk
Monthly	0.281	-0.624	20	Lag dampens signal; turnover still moderate

The signal construction remains identical—returns scaled by relative deviations of volume from a rolling mean—but execution and cost timing are now fully causal. Resampling is explicit and deterministic, avoiding any alignment mismatches between returns and volume data. Such lagging makes the backtest far more realistic and resistant to information leakage.

The resulting Sharpe ratios fall to realistic magnitudes (OOS SR ≈ 0.8 weekly), reflecting genuine predictive structure rather than forward bias. The weekly strategy adapts effectively to volume surges and liquidity shifts, while the monthly variant loses reactivity as trend windows and re-sampling dilute signal freshness. Overall, the lagged specification provides a **robust and implementable framework**, capturing the stabilizing benefits of liquidity weighting while ensuring full temporal causality.

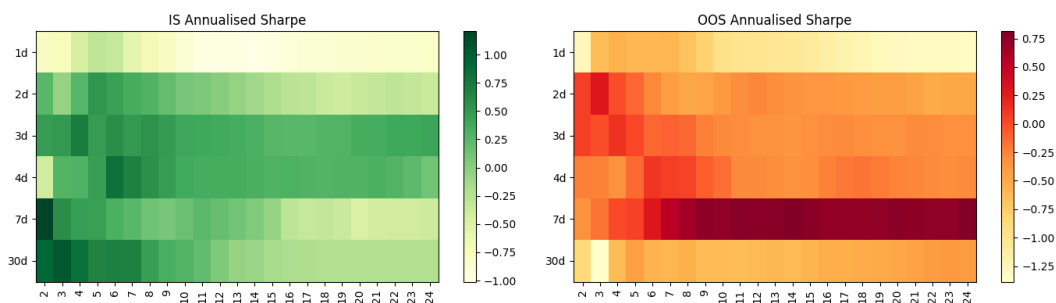


Figure 6: Grid Search — Sharpe Ratios for Lagged Volume-Adjusted XS Momentum

3.5 Recap & Final Strategy: Blending Signals

We combine three implementable sleeves—(i) lagged volume-adjusted weekly momentum, (ii) cross-sectional momentum (weekly, blended $k, 2k, [3k]$), and (iii) time-series momentum—together with BTC buy-and-hold as a reference. Because the sleeves exhibit imperfect correlation, diversification reduces unrewarded risk and concentrates exposure on persistent components. The result is a portfolio with materially lower volatility and drawdown, and a higher out-of-sample (OOS) Sharpe.

Table 4: OOS Summary (Weekly Grid)

Name	Sharpe	Vol	MDD
WEEKLY	0.810	0.283	-0.297
XS	0.724	0.235	-0.193
TS-MOM	0.890	0.532	-0.567
BTC	0.717	0.533	-0.669
SR-Weighted	1.495	0.214	-0.242
Equal	1.505	0.208	-0.226
Equal-Vol	1.570	0.173	-0.172

Illustrative weights. SR-weighted: WEEKLY 0.258, XS 0.231, TS-MOM 0.283, BTC 0.228; Equal: 0.25 each; Equal-Vol emphasizes lower-volatility sleeves (e.g., XS ≈ 0.369), yielding the strongest volatility compression.

Alpha vs BTC. Regressing the Equal-Vol blend on BTC weekly returns gives an annualized $\alpha \approx 24.53\%$ with $t \approx 2.61$ and $\beta \approx 0.137$, indicating diversified, low-beta excess returns.

Conclusion. While single sleeves do not individually achieve $SR > 2$ OOS, the blended portfolio delivers a *significantly* higher Sharpe with substantially reduced drawdowns and volatility as well as a t-stat significantly above 2 highlighting the edge over the reference index - namely BTC. This construction is *leveragable*: given the lower risk (Vol ≈ 0.17 ; MDD $\approx -17\%$), modest leverage can scale returns toward a target as Sharpe is invariant by leveraging (as it scales both the returns and the volatility proportionally).

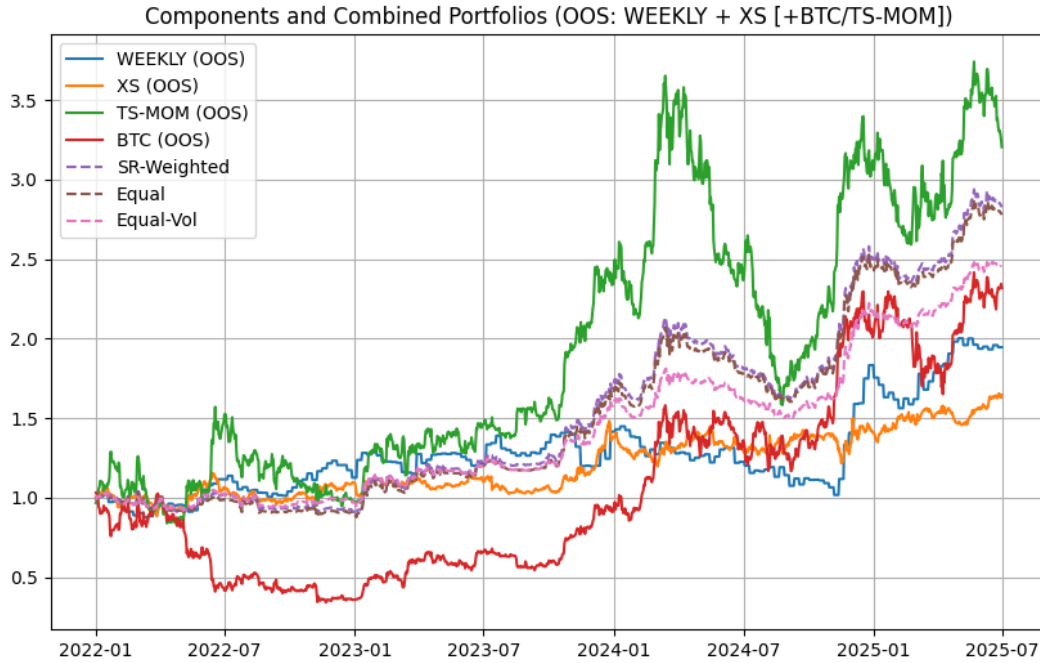


Figure 7: Blended Strategy — Portfolio Returns Comparison

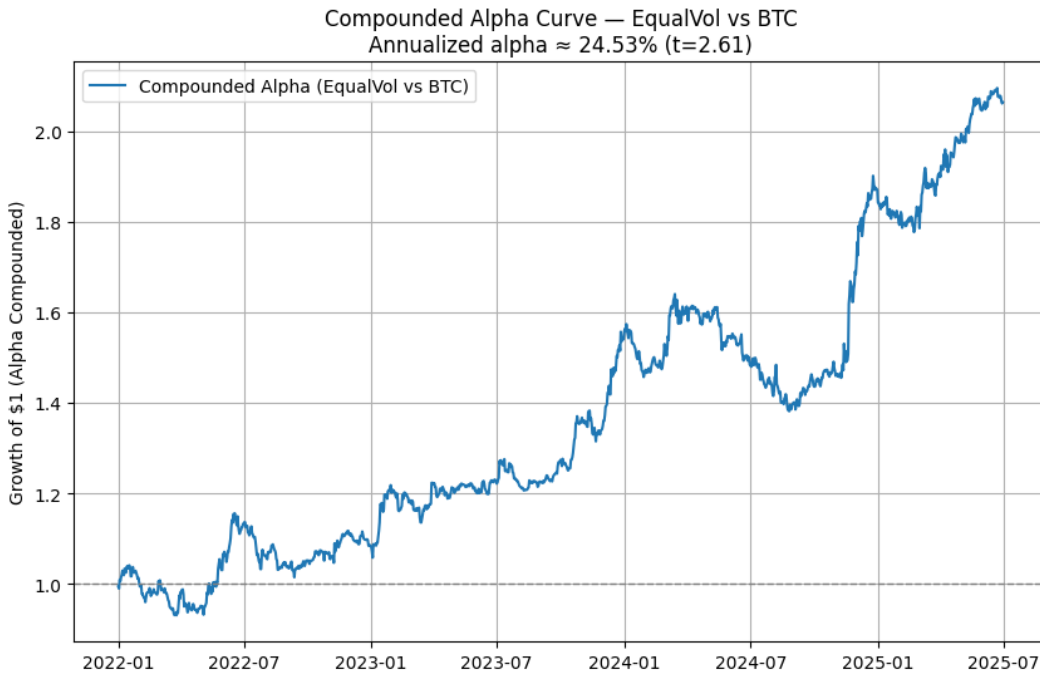


Figure 8: Compounded Alpha — Optimized Blended Strategy

4 Conclusion

Strengths. We built a fully causal pipeline (lagged signals, turnover-timed costs, explicit resampling) and showed that three implementable sleeves—lagged volume-adjusted weekly momentum, XS momentum, and TS momentum—*blend* into a materially better portfolio than any sleeve alone. The blended allocations deliver meaningfully lower volatility and drawdowns with a higher OOS Sharpe (≈ 1.5), and exhibit low beta to BTC with a statistically significant positive alpha for the Equal-Vol mix.

Weaknesses. Results remain sensitive to universe definition, cost assumptions (20 bps round-trip), and rebalancing cadence. XS-MOM’s standalone edge is modest, and TS-MOM carries higher standalone volatility. Our construction is long-only in gross (unit- L^1), so tail risk is still tied to market dislocations; moreover, Sharpe improvements from leverage assume stable costs and liquidity.

Next steps. (i) Introduce liquidity-aware *position caps* and ADV-based sizing across all sleeves; (ii) add simple *volatility targeting* at the portfolio level to stabilize risk and turnover; (iii) incorporate *HAC/Newey–West* alpha tests and *block bootstrap* to better gauge robustness; (iv) explore *regime conditioning* (e.g., simple risk-on/off filters via realized vol or funding rates); and (v) extend the blend with orthogonal signals (carry, funding-premia, intraday reversal) to further diversify residual risk.

Overall, while no single sleeve achieved a 2+ OOS Sharpe, the diversified blend provides a *credible, leverable core* with lower risk and persistent excess returns—an attractive foundation for systematic crypto allocation and for future enhancements along the lines above.