Working paper

Oracle-Relative Liquidity on Solana

An auditable SOL/USDC comparison with a concentrated-liquidity AMM

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Version 1.0

Abstract

This study evaluates whether liquidity indexed to an external reference can improve execution and liquidity-provider economics relative to a live concentrated-liquidity pool. We combine a finalized Solana account snapshot with 7,200 Helius transaction records and 1,836 vault-reconciled swaps from an Orca SOL/USDC Whirlpool. A counterfactual oracle-relative book deploys the same token inventory across a +/-2% range with a 4-basis-point half-spread. At an input notional of USD 100,000, modeled price impact falls from approximately 9.6 basis points to 0.7-4.1 basis points, and total execution savings are USD 54-89, depending on direction. Across the observed order-size sample, modeled savings are USD 44.36, or 0.296 basis points of sample notional. An analytically centered V3 control achieves similar instantaneous depth, showing that the snapshot advantage is principally attributable to capital placement. Relative repricing can preserve chosen offsets without an on-chain position reset, but net LP returns, oracle quality and continuous inventory sustainability remain unmeasured. Gross LP fee income increases by USD 6,154 per day only in a stated scenario with 25% more routed volume. All raw transaction payloads, account data, checksums and replication code accompany the paper.

Keywords: automated market makers; Solana; concentrated liquidity; oracle-relative pricing; price impact; liquidity-provider returns; reproducibility.

Observed evidence comprises on-chain accounts and swaps and indexed volume statistics. Modeled results are independent, zero-deviation counterfactual order quotes. Volume growth, daily extrapolations and LP income are conditional scenarios.

Status: research working paper; no peer review or production deployment validation is claimed. Observations were captured on 16 November 2026.

1. Introduction and research questions

Concentrated-liquidity AMMs allow liquidity providers (LPs) to place capital within chosen price intervals [1,2]. This increases local depth but makes the location of liquidity consequential: a position can become inactive when the market leaves its fixed bounds. An oracle-relative design expresses quoted liquidity in offsets from an updated reference rather than in fixed absolute prices.

The relevant comparison has three distinct dimensions: executable depth at one instant, maintenance of concentration as the reference changes, and the economic return earned by inventory exposed to trading. A design can improve the first dimension without demonstrating improvements in the other two. The present study measures a live baseline, specifies a mathematical counterfactual, and reports the boundary between observations and assumptions.

1.1 Questions and estimands

RQ1: Execution. At the same initial SOL and USDC inventory and a comparable four-basis-point charge, how does a relative book change exact-input output, price impact and total execution cost?

RQ2: Attribution. Does the observed execution difference persist against a V3 book that is analytically centered and equally concentrated?

RQ3: LP economics. Under which volume, spread and fee-sharing assumptions does gross LP fee income increase, and which additional inputs would be required to infer net profitability?

1.2 Definition of efficiency

Dimension	Operational definition	Status
Capital / depth	Output available near the reference for a fixed inventory.	Modeled and controlled
Maintenance	Repricing chosen offsets when the reference changes.	Analytical property
Trader outcome	Execution-cost reduction on a specified input order.	Modeled counterfactual
LP return	Fees plus inventory trading result less operating costs.	Net return not estimated

Table 1. Efficiency is evaluated by separate estimands; the measures are not interchangeable.

1.3 Scope

The baseline is one liquid Solana Whirlpool, not every V3 implementation or every LP strategy. The relative book is a fully specified counterfactual and has no program address in this study. The exercise does not identify a causal effect on aggregator routing, model the arrival of new order flow, or claim that reduced price impact automatically increases LP profit.

All numerical results use USDC as the numeraire and assume USD 1 per USDC. The research contribution is the transparent comparison and its replication record. The formulas and chosen parameters are stated explicitly so that the counterfactual can be evaluated without relying on a deployed implementation.

2. Data, account identity and baseline state

The baseline pool is identified by its account address and ownership under the Orca Whirlpool program [2,3]. Token mints, decimals and vault balances were decoded from the recorded account response. The pool, both vaults and nine tick arrays were retrieved in one finalized getMultipleAccounts response, at slot **470257547** [4]. The associated block time is **2026-11-16 19:59:06 UTC**.

Account / role	Public key
Whirlpool pool	`Czfq3xZZDmsdGdUyrNLtRhGc47cXcZtLG4crryfu44zE`
Whirlpool program	`whirLbMiicVdio4qvUfM5KAg6Ct8VwpYzGff3uctyCc`
Wrapped SOL mint	`So11111111111111111111111111111111111111112`
USDC mint	`EPjFWdd5AufqSSqeM2qN1xzybapC8G4wEGGkZwyTDt1v`
SOL vault	`EUuUbDcafPrmVTD5M6qoJAoyyNbihBhugADAxRMn5he9`
USDC vault	`2WLWEuKDgkDUccTpbwYp1GToYktiSB1cXvreHUwiSUVP`

Table 2. Contracts and token accounts used in the benchmark. Account ownership was checked; this is not an independent audit of deployed bytecode.

Recorded quantity	Value	Interpretation
Spot price	71.426195744 USDC per SOL	Decoded sqrt-price, decimals 9 / 6
SOL vault	202,043.517350395 SOL	Raw amount / 10^9
USDC vault	2,426,642.859505 USDC	Raw amount / 10^6
Gross vault value	USD 16,857,842.68	SOL at spot plus USDC
Pool fee	0.0004 = 4 bps	Fixed-fee pool
Protocol share	13% of the swap fee	LP share: 87%
Active liquidity L	391,481,171,017,920	Protocol internal units
Current tick	-26,393	Tick spacing: 4

Table 3. Baseline state. Gross vault value can include accrued, unclaimed fees; it is not audited net LP principal.

The Orca indexer response reports USD 79,922,709.92 of 24-hour volume, USD 640,931,546.20 over seven days and USD 2,778,393,817.26 over thirty days [6]. Its update timestamp is 19:52:18.291538 UTC, approximately seven minutes before the quote snapshot. These indexed totals were not reconstructed from a full-day Helius transaction scan.

3. Acquisition, event decoding and validation

Transaction history was acquired through getTransactionsForAddress with full details, descending order, successful-status filtering and maximum supported transaction version 1 [5]. For each of 24 hourly query windows, the latest 300 successful address transactions were retained, using three pages of 100 records. The extraction therefore used 72 full history requests, plus an initial probe.

```
method: getTransactionsForAddress
address: pool public key in Table 2
transactionDetails: full; limit: 100; sortOrder: desc
maxSupportedTransactionVersion: 1
filters: status=succeeded; blockTime in [end-3600, end]
pages per window: 3; windows: 24
```

Only logs with the SHA-256 discriminator for `event:Traded` and the target pool key were decoded as swaps. The event contains direction, pre- and post-sqrt-price, input, output, transfer fees and LP/protocol fees [3]. Successful address references without a corresponding swap event were excluded from trading volume.

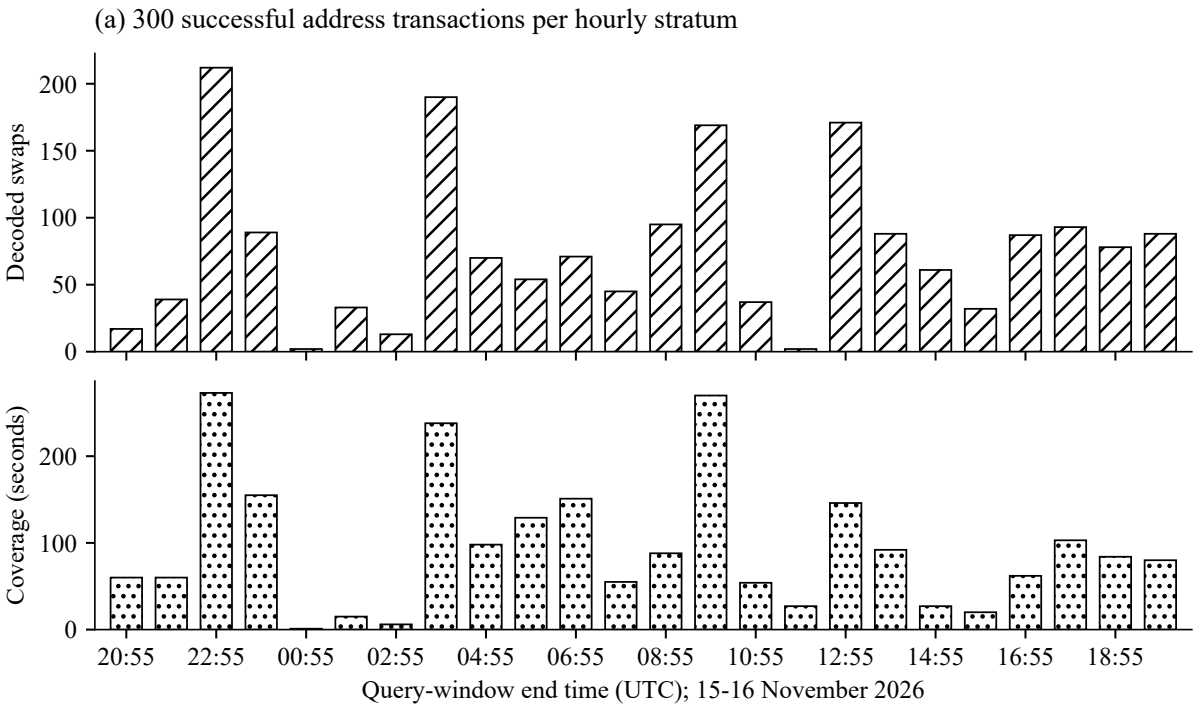

Figure 1. Observed sample coverage. Each stratum contains 300 address transactions, but elapsed time and swap counts vary. Coverage totals 2,294 seconds, or 2.66% of the nominal 24-hour query horizon. This is a non-probability sample.

There were 7,200 unique transactions and 1,836 decoded swaps. For each swap transaction, the sum of event-implied SOL and USDC deltas exactly matched the recorded vault balance changes in raw integer units. Thirty-two non-swap liquidity/fee-operation transactions were excluded from that reconciliation path. Swap fee totals also agreed with the four-basis-point rate within integer-rounding tolerance. No statistical population confidence interval is assigned to this sample.

4. Mathematical framework

4.1 Notation and execution-cost definitions

Symbol	Definition
P, R	USDC per SOL spot price and external reference, respectively.
x, y	SOL and USDC inventory in human token units.
q, o	Input and output token amounts for one swap.
w, h	Relative half-width and individual bin width; 0.02 and 0.0001.
f, rho	Directional charge and fraction of fee income retained by LPs.
C, V	Gross initial vault value and reference daily trading volume.

For an input q USDC buying SOL, frictionless output is q/P. For an input q SOL selling into USDC, it is qP. Define e as the ratio of actual to frictionless output. Total execution cost in basis points is:

$$c_{\text{bps}} = 10^4(1-e), \qquad c_{\text{USD}} = Q(1-e) \tag{1}$$

Here Q is input notional valued at the pre-swap reference. Fee-free price impact is recomputed with the same book state and the directional fee set to zero. This measures deterministic size-dependent execution impact; it does not measure quote-to-inclusion slippage, slippage tolerance, sandwich losses or network charges.

4.2 Concentrated-liquidity benchmark

Within one active-liquidity segment bounded by prices P_a and P_b, the V3 inventory relations are [1]:

$$x = L\left(\frac{1}{\sqrt{P}} - \frac{1}{\sqrt{P_b}}\right), \qquad y = L\left(\sqrt{P} - \sqrt{P_a}\right) \tag{2}$$

In these human-token equations, L equals native protocol liquidity divided by 10^((9+6)/2). Table 3 reports the unscaled native state value.

For a buy with fee-adjusted USDC input q_net, the segment transition is:

$$\sqrt{P'} = \sqrt{P} + q_{\text{net}}/L, \qquad o = L\left(P^{-1/2} - (P')^{-1/2}\right) \tag{3}$$

Liquidity changes at initialized ticks. Rather than extending a constant-L approximation across the pool, the recorded baseline quotes use the official Orca SDK, including tick crossings, integer output rounding and the fixed swap fee. The fee-free counterfactual changes only the pool fee parameter.

The price grid is already logarithmic: P_tick is proportional to 1.0001 raised to the tick index, with token-decimal conversion. Relative binning therefore differs by its moving reference anchor, not merely by using percentage increments.

4.3 Oracle-relative book and exact-input solution

Let a bin j start at relative offset d_j, have width h and normalized position z in [0,1]. Its pre-spread price is defined as:

$$p_j(z,t) = R_t(1 + d_j + hz) \tag{4}$$

At a fixed reference, trading moves z. A change in R alone changes quoted prices while leaving z and token quantities unchanged. In the benchmark, h = 0.0001 and w = 0.02: 200 SOL-funded bins lie above zero and 200 USDC-funded bins below zero. Output inventory is uniform within each side. The starting deviation is zero.

Effective ask bounds multiply the pre-spread prices by (1+f). Effective bid bounds divide them by (1+f). This is a price markup convention, whereas V3 deducts its fee from input. The charges are equal to first order at four basis points; their approximately f-squared difference is retained in the exact output calculations.

Buying SOL within a bin

Let B be the SOL output available in the full unconsumed bin, p_s its opening effective ask and a the increase in effective ask across it. Removing o SOL moves the price linearly with o/B, giving:

$$I(o) = p_s o + \frac{ao^2}{2B}, \qquad 0 \le o \le B \tag{5}$$

$$o(I) = \frac{2I}{p_s + \sqrt{p_s^2 + 2aI/B}} \tag{6}$$

Selling SOL within a bin

For a USDC-funded bid bin with opening effective price p_h and a price decline a, output o USDC requires SOL input:

$$I(o) = \frac{o}{2}\left(\frac{1}{p_h} + \frac{1}{p_h - ao/B}\right) \tag{7}$$

This function is monotone over the positive price interval. The implementation solves partial fills by 70 bisection iterations and traverses full bins when remaining input exceeds I(B). Input left after all available bins is reported as unspent. No evaluated primary-scenario order exhausted a side.

The counterfactual uses continuous arithmetic and double-precision price conversion. It does not reproduce protocol-specific integer accounting, Solana compute limits, transaction account limits or an on-chain executable program. Raw amounts and the observed baseline outputs remain available as integers in the supplement.

5. Experimental design and attribution controls

5.1 Matched inventories and independent snapshots

For the primary snapshot comparison, the relative book receives exactly 202,043.517350395 SOL and 2,426,642.859505 USDC, matching the baseline vault balances. The SOL share of gross value is 85.61%; an uncharged rebalance to 50/50 is not assumed. Spread, range and inventory are held fixed while input notionals vary from USD 1,000 to USD 500,000.

For the historical-size exercise, each recorded swap is quoted independently using its own pre-swap Orca price as a hypothetical fresh reference. SOL quantity is rescaled inversely with that price to preserve the snapshot capital and inventory value fractions. The model consequently resets deviation and available depth for every order. It is an optimistic capacity comparison, not a sequential inventory strategy.

5.2 Repricing property

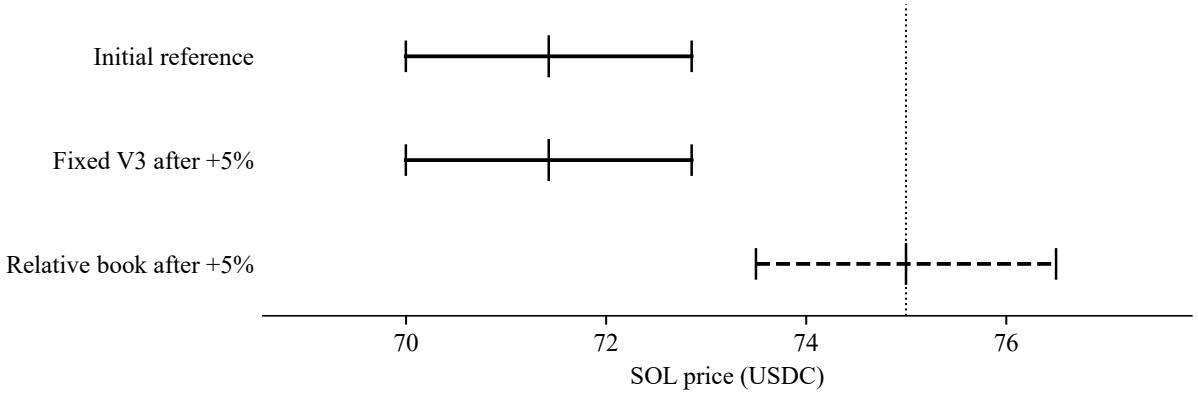

Figure 2. Schematic reference change of +5%; this is not an observed price path. Relative price bounds move with the reference while token balances are unchanged. Fixed V3 bounds remain where they were placed.

For a pure reference update R to kR with no intervening trade, Eq. (4) implies p to kp and leaves p/R - 1 unchanged. Thus the design can retain the chosen offset geometry without a position-removal and re-addition transaction. This property does not reset an inventory-induced deviation or replenish the output side.

5.3 Centered V3 control

To separate placement from curve shape, an analytical V3 control allocates all SOL to [P,1.02P] and all USDC to [0.98P,P]. The corresponding side-specific liquidities are:

$$L_a = \frac{x}{P^{-1/2} - (1.02P)^{-1/2}}, \qquad L_b = \frac{y}{\sqrt{P} - \sqrt{0.98P}} \tag{8}$$

The control uses the same inventories and a four-basis-point fee. It omits tick-boundary rounding and the costs of maintaining such placement. It is a local-depth attribution test, not an observed managed LP portfolio.

6. Results: snapshot execution

Direction / USD input value	V3 (bps)	Relative (bps)	Saving (USD)
Buy / 1,000	4.096	4.005	0.009
Sell / 1,000	4.096	4.040	0.006
Buy / 10,000	4.955	4.068	0.89
Sell / 10,000	4.955	4.410	0.54
Buy / 100,000	13.565	4.691	88.75
Sell / 100,000	13.554	8.115	54.39
Buy / 500,000	54.197	7.458	2,336.94
Sell / 500,000	55.977	24.558	1,570.93

Table 4. Exact-input snapshot comparisons at four basis points. Sell notionals are valued at the initial spot. Costs include fee/spread and price impact, but exclude network and maintenance costs.

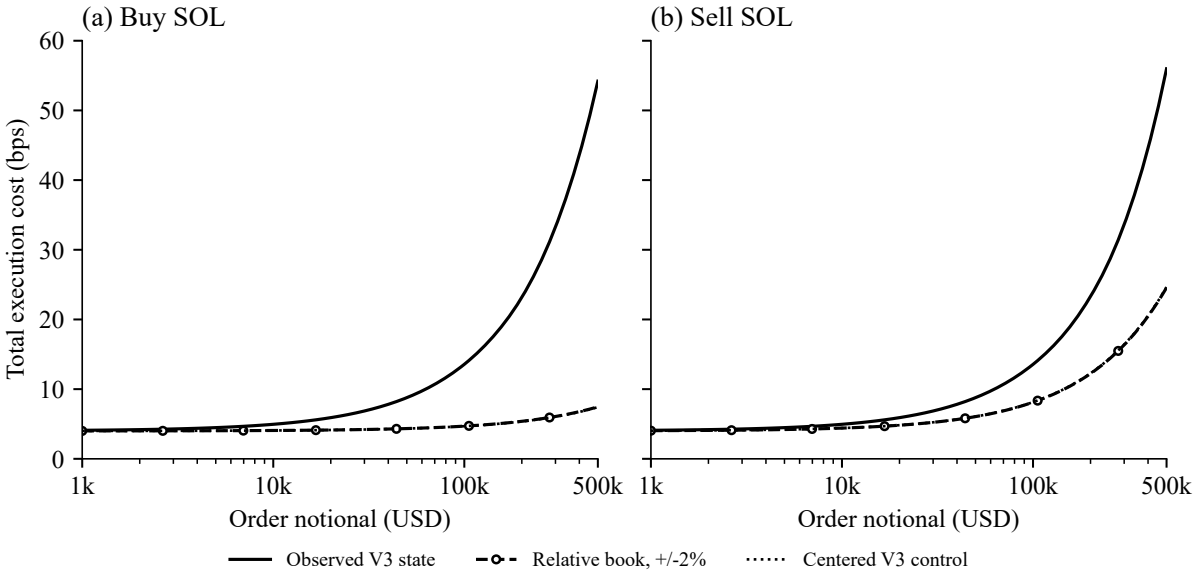

Figure 3. Total execution cost over 136 additional offline SDK quotes and corresponding relative-book solutions. The centered V3 control nearly overlaps the relative book; all curves use the same initial token quantities.

At USD 100,000, buying SOL costs 13.565 bps in the observed V3 state and 4.691 bps in the relative book, a saving of USD 88.75. Selling SOL costs 13.554 versus 8.115 bps, saving USD 54.39. Fee-free impact falls by 92.76% for buys and 56.91% for sells. Total-cost reductions, which include the common charge, are smaller: 65.42% and 40.13%, respectively.

At the same notional, the centered V3 control costs 4.682 bps for buys and 8.137 bps for sells. These values are within 0.022 bps of the relative book. The large improvement over the observed pool therefore reflects concentrated capital placement rather than a demonstrated intrinsic superiority of one local curve.

6.2 Observed order sizes and counterfactual costs

The 1,836 recorded swaps represent USD 1,497,794.96 of input notional. Median order size is USD 268.65 and the 90th percentile is USD 2,366.95. Median total execution cost is 4.041 bps and the volume-weighted cost is 4.372 bps. The sample is dominated by much smaller trades than the USD 100,000 illustration.

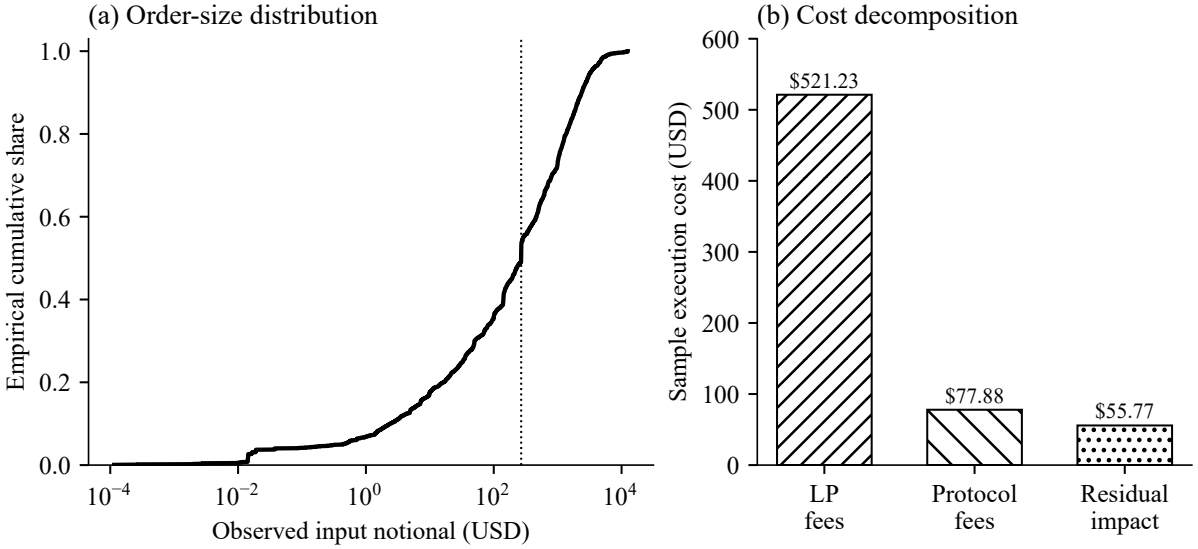

Figure 4. Observed order-size distribution and fee decomposition. Residual impact is the cost relative to pre-swap spot after recorded LP and protocol fees; it is not an independently measured adverse-selection cost.

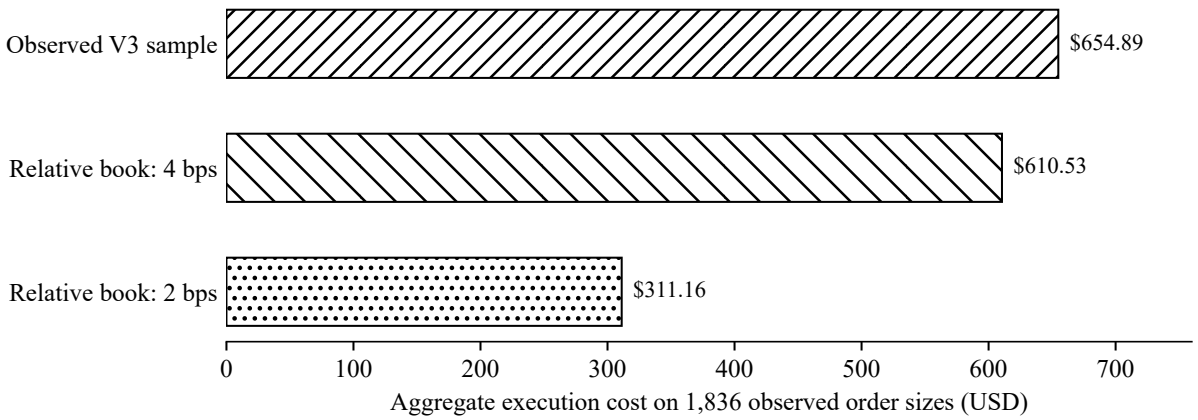

Figure 5. Independent counterfactual quotes on the same observed inputs. Lowering the spread to two basis points reduces trader charges, but also reduces LP fee generation.

Observed aggregate execution cost is USD 654.89. Recorded LP fees are USD 521.23 and protocol fees are USD 77.88, leaving approximately USD 55.77 in residual price impact. The four-basis-point relative scenario costs USD 610.53, saving USD 44.36 or 6.77% of observed execution cost. The saving equals 0.296 bps of sample notional.

Multiplying that sample-weighted saving by the indexed 24-hour volume gives USD 2,366.95 per day. This is a mechanical scenario requiring the same order mix, independent reset depth and unchanged routed volume. Because inclusion probabilities are unknown and inventories are reset between orders, it is not an estimate of realized daily savings.

7. Sensitivity to concentration and inventory

We evaluate half-widths of +/-0.1%, +/-0.5% and +/-2%, two spread settings (2 and 4 bps), and two inventory allocations (observed quantities and a 50/50 value counterfactual). These twelve configurations use the same total gross value. The balanced allocation is a sensitivity case and assumes a different initial asset mix; its rebalance cost is not included.

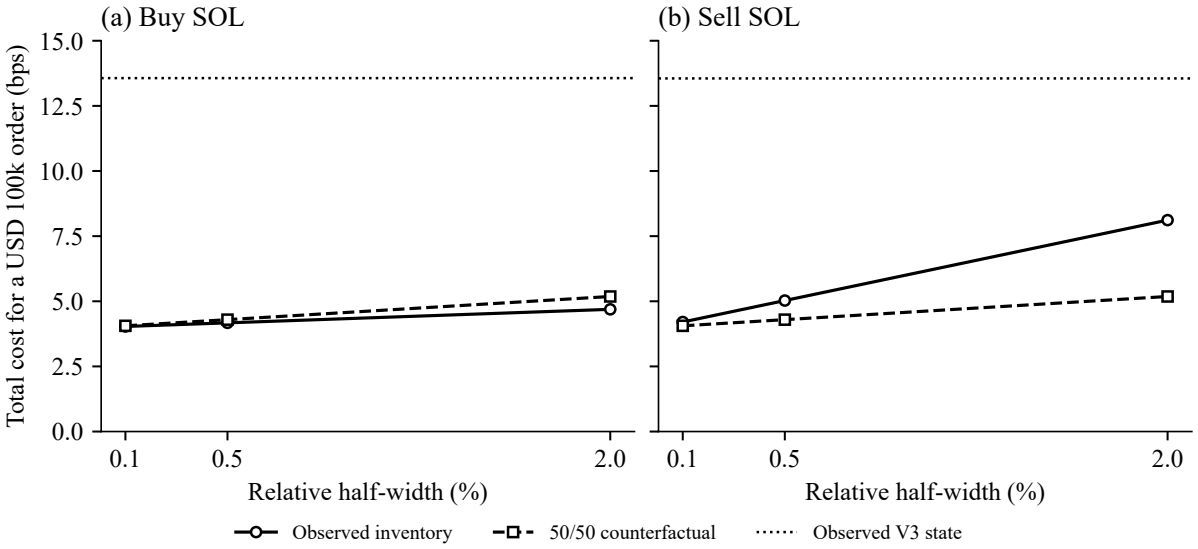

Figure 6. Cost of a USD 100,000 trade at four basis points. A narrower book increases local depth; a balanced book improves bid-side capacity while reducing the SOL-heavy baseline ask inventory. This is a parameter sensitivity, not a volatility-robust trading strategy.

Half-width	Buy: observed inventory	Sell: observed inventory	Buy / sell: 50/50
+/-0.1%	4.033 bps	4.204 bps	4.058 / 4.058 bps
+/-0.5%	4.171 bps	5.028 bps	4.295 / 4.295 bps
+/-2%	4.691 bps	8.115 bps	5.184 / 5.184 bps

Table 5. Concentration sensitivity at USD 100,000 input value.

7.1 Interpretation of narrower ranges

Greater concentration lowers an independent quote's slope, but provides less distance for one-sided order flow before deviation changes materially. Even when the external reference is accurate, inventory can accumulate on one side. A narrow book therefore requires a specification of replenishment, skew, spreads, pauses and hedging to become a sustainable market-making strategy.

7.2 The role of the external price

The main saving of 0.296 bps is small relative to plausible combined pricing and operating errors. A similarly sized adverse reference error or additional charge can remove the sample-average benefit. Historical oracle validation could not be completed: the attempted Pyth timestamp endpoint returned HTTP 401. Accordingly, no claim is made about attainable oracle latency or a validated historical external fair value [7].

8. Liquidity-provider economics

Gross LP fee income is modeled separately from trading profit. Let V be the reference daily volume, g the hypothetical volume multiplier, f the directional charge and rho the LP-retained fraction. The first-order fee-income relation is:

$$F_{\mathrm{LP}} = Vgf\rho, \qquad \Delta F_{\mathrm{LP}} = V(gf\rho - f_0\rho_0) \tag{9}$$

For the baseline, f_0 = 0.0004 and rho_0 = 0.87. For the relative scenarios we choose rho = 0.85, no curator share and no additional notional charge. The 85% retention is a modeling parameter, not a deployed Orriss configuration. The first-order relation differs negligibly from exact price-markup accounting at these spreads.

Scenario	Gross LP fees/day	Change vs. baseline
Observed-volume V3 baseline	$27,813.10	-
Same volume; relative 4 bps	$27,173.72	$-639.38
Volume +25%; relative 4 bps	$33,967.15	+$6,154.05
Same volume; relative 2 bps	$13,586.86	$-14,226.24
Volume x2; relative 2 bps	$27,173.72	$-639.38

Table 6. Conditional gross fee income, before inventory gains/losses and all maintenance costs. The baseline is V x fee x LP share, not audited LP net revenue.

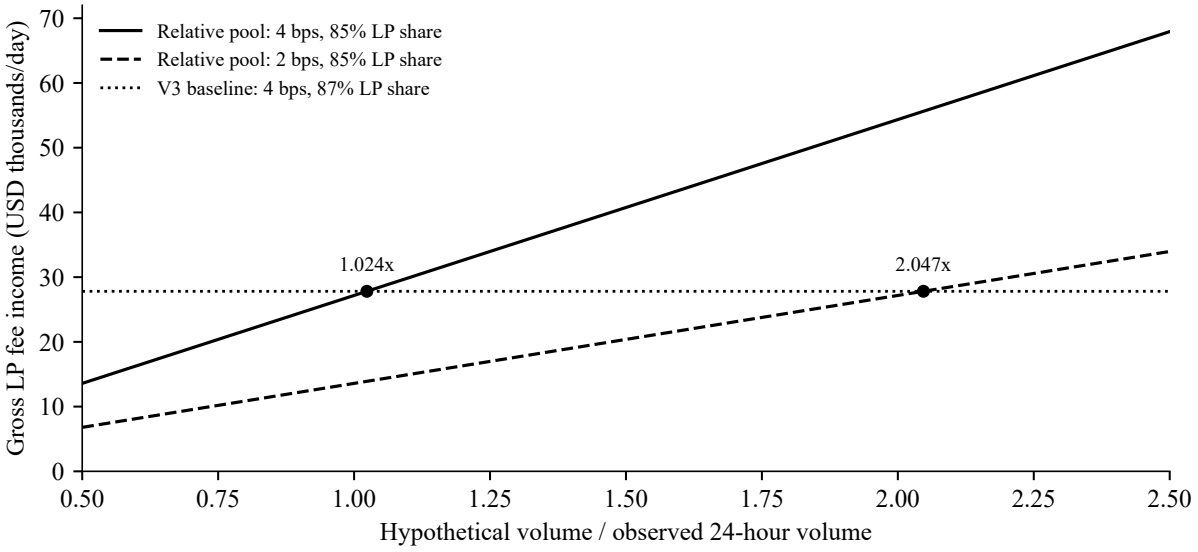

Figure 7. Fee-income sensitivity to hypothetical routed volume. Break-even volume is approximately 1.024x at 4 bps and 2.047x at 2 bps, given 85% relative-pool LP retention.

At unchanged volume and spread, reducing LP retention from 87% to 85% lowers gross LP income by USD 639.38 per day. If retention were held equal, the fee-income figures would match. The USD 6,154 increase requires the assumed 25% volume growth; routing growth was not measured.

9. Net returns and threats to validity

9.1 Execution quality and LP profit are different outcomes

LP performance combines fees, the prices at which inventory is exchanged, subsequent asset-price movements and operating costs. Loss-versus-rebalancing formalizes a component of adverse-selection loss from stale pricing; it is distinct from fees and from loss-versus-holding [8]. No LVR reduction is directly estimated here.

$$\Pi_{\text{trade},\,h} = \sum_i (\Delta x_i R_{t_i+h} + \Delta y_i) - K_h \tag{10}$$

Equation (10) is a reference-horizon markout expression in the numeraire. The inventory deltas already contain retained trading charges; adding those fees a second time would double-count revenue. K_h represents the chosen operating and hedging costs. A finite-horizon markout is also not terminal wealth or an annualized investment return.

9.2 Economic sensitivity, not measured alpha

If net execution performance, excluding the separately modeled fee-share change, improved by b basis points of daily volume, its value would be Vb/10,000. An improvement of 0.5 bps equals USD 3,996.14 per day, or USD 3,356.75 after the modeled USD 639.38 retention difference and before operating costs. This sensitivity must already account for any reduction in the price-impact premium paid to LPs; trader savings cannot be added to LP profit as if they were independent benefits.

9.3 Sampling and external validity

The 24 address-history strata are deterministic latest-record slices, not probability draws. Their durations vary from seconds to minutes. Transaction intensity, bot traffic and trade size can affect inclusion. The sample does not support population confidence intervals, a representative daily savings estimate or a claim about other assets and market regimes.

9.4 Counterfactual and deployment limits

Every modeled order starts with zero deviation and replenished snapshot depth. No full sequence of inventory changes, endogenous arbitrage, routing feedback, inventory skew or depletion process is replayed. Oracle updates, keeper transactions, compute units, priority fees, account locks, rounding, outages and hedging are not costed. A 400-bin mathematical layout is not evidence of acceptable Solana transaction performance.

9.5 Capital and timing comparability

Gross vault balances include claims that may not be freely redeployable LP principal. The indexed 24-hour turnover and finalized quote snapshot differ by approximately seven minutes. Spot-valued USDC and SOL ignore any dollar depeg and external valuation error. These choices are explicit proxies, not matched audited portfolio capital over a full day.

9.6 Researcher affiliation

The Orriss Team is developing the modeled design and therefore has an interest in its evaluation. The provided controls, raw records and unfavorable fee-income cases are retained to facilitate external scrutiny. Independent audit, peer review and third-party replication have not been performed.

10. Conclusions

Under the specified matched-inventory, fresh-reference and zero-deviation assumptions, the oracle-relative book is substantially more depth-efficient than the observed Orca SOL/USDC state. On a USD 100,000 order, fee-free impact is approximately 0.7-4.1 bps rather than 9.6 bps, producing USD 54-89 in lower total execution cost at a comparable four-basis-point charge. This is the principal quantitative finding.

Why the specified relative book can be more efficient

First, it concentrates the inventory used in this experiment close to the reference. All SOL and USDC output capacity is assigned within +/-2%. This places more usable inventory near the modeled trading price than exists in the observed pool state and explains the lower quote slope.

Second, its price coordinates can follow an external market without an inventory-changing swap. A pure reference update reprices the same offsets and does not require the LP position itself to be withdrawn and recreated. The design can therefore maintain the intended concentration geometry as the reference changes, conditional on valid pricing and sufficient inventory.

Third, favorable execution can support higher turnover per unit of capital. If it attracts 25% more routed volume at the same spread, the stated LP-retention scenario produces approximately USD 6,154 more gross LP fees per day. This is an economically meaningful conditional channel, but the volume response is not established by the data.

What the evidence does and does not establish

The centered V3 control produces nearly the same instantaneous quotes. Consequently, this study does not establish universal superiority over actively maintained V3 liquidity. It establishes lower modeled cost relative to one recorded pool state and a theoretical repricing property. On the observed small-order sample, savings are 0.296 bps of volume, not the large percentage reductions seen in isolated large-order price impact. Net LP profitability and sustainable two-sided liquidity remain open empirical questions.

Data and code availability

The full replication supplement is embedded as a PDF attachment and is also supplied separately as **Orriss_SOL_USDC_Replication.zip**. It contains the 7,200 original transaction records, all decoded swaps, account snapshots, 136 figure quotes, checksum manifest and offline Python/Node.js scripts. Appendix C explains replication. The study has not been assigned a DOI or published to a public repository.

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The next validation stage is a continuous full-window replay with an independent timestamped oracle, inventory controls, measured update/hedging costs and 1-, 5- and 30-minute markouts. Those tests are needed before the present execution scenarios can be presented as realized trader savings or incremental LP net return.

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Research paper and version record
https://arxiv.org/abs/2208.06046v6

[D1] Orriss Team (2026). *SOL/USDC Replication Supplement.* Version 1.0. Original Helius response payloads, Orca account snapshot, indexed statistics and reproducible calculations. Supplied as a companion archive and embedded PDF attachment.
Public explorer for the benchmark pool
https://solscan.io/account/Czfq3xZZDmsdGdUyrNLtRhGc47cXcZtLG4crryfu44zE

Protocol documentation and literature links were checked on 17 November 2026. On-chain observations and indexer statistics retain their original 16 November capture timestamps. Repository links refer to upstream paths; the retrieved event schema and package lock are preserved for local verification.

Appendix A. Raw observations and traceability

The supplement contains all 1,836 decoded swaps and the full 7,200 raw transaction records. The six observations below are deterministic examples: minimum, middle-ranked and maximum input notional within each direction. They are provided for auditability and are not a statistically representative subsample. Each signature links to a public transaction explorer.

ID / direction	Slot	Input token amount	Output token amount	Input value (USD)
E1 / buy	469904572	0.000200	0.000002751	0.0002
E2 / buy	469954782	267.618095	3.751896563	267.6181
E3 / buy	470105575	12205.405480	170.561057961	12,205.4055
E4 / sell	470055158	0.000001616	0.000115	0.0001
E5 / sell	470087706	4.138579932	292.326144	292.4443
E6 / sell	470222853	175.111595372	12486.400223	12,492.9917

Table A1. Human-unit decoded values. Buy input is USDC and output is SOL; sell input is SOL and output is USDC. Exact integer values for the largest examples are shown in Appendix B.

Transaction signatures and raw source files

E1. 2026-11-15 22:55:20 UTC; raw file: history-hour-21.json.gz; log index: 23.

`52r55MkZhUuzA3XrDHjHdvBgoBAvEmngGHaoZ5BPAYNCipLmDcnSz9XetiP1J3WGmtS4wbFLmxPKuFSZgvzjbALY`

E2. 2026-11-16 01:55:45 UTC; raw file: history-hour-18.json.gz; log index: 29.

`3LShSutYgBAsHfxCwBuoryLuRjXFE76AZUAuFXdASoe6SJeM6XFvGA1zcQ9AyBqJtHqA5w37YYjFemXBCN8Y3rWs`

E3. 2026-11-16 10:55:21 UTC; raw file: history-hour-09.json.gz; log index: 14.

`5DyQSvQTGhkGjw8cryd3Laq3efQhWZQupJVFxnDFj1JUPZm6nyK9Bp4ni94p34yrdKLYwbyY6V738Yero2j4CQQf`

E4. 2026-11-16 07:54:53 UTC; raw file: history-hour-12.json.gz; log index: 34.

`563M3HZKmQi5N1gWrdMF5N6KBHcBpWQw5WdCPoVEBw2bwKeMZUVxUR6QYyieaAGJAnxAw3USaspMG639GQ1j8VvZ`

E5. 2026-11-16 09:51:26 UTC; raw file: history-hour-10.json.gz; log index: 27.

`js5qshoaSQycHq3BYf5rdZfPgggzyHwAwKCip58NuXWMU13Vqp436vhKkse2V88ML2cpu3cwbC2wgCNesw9Tr8w`

E6. 2026-11-16 17:54:45 UTC; raw file: history-hour-02.json.gz; log index: 19.

`5P6ncd3kBq1MNKqhFg7oJpQboNoYXSkxEuVFDpcUTn7xejxmft2iXwVGADecBjcCgUrhN2smQ4eTv811QhdoHVfc`

Quote-state raw values

The recorded Q64.64 sqrt-price is `4930017743169288036`. SOL raw vault amount is `202043517350395`; USDC raw amount is `2426642859505`. Vault token amounts are decoded from byte offset 64 as little-endian unsigned 64-bit integers. The complete base64 account response is retained in data/quote-accounts.json.

The event decoding evidence uses public transaction records and token-account changes. It demonstrates the consistency of observed amounts and pool identity; it does not classify informed flow, identify trader intent or establish an external fair price.

Appendix B. Binary event decoding

The retrieved Traded event payload has a minimum length of 121 bytes. Its first eight bytes are the event discriminator, followed by the pool public key and fields below. All integers are little-endian [3]. The discriminator is `e1ca49af932ba096`.

Offset	Length	Field
0	8	SHA-256("event:Traded")[0:8]
8	32	Pool public key
40	1	Direction: a_to_b; true means sell SOL
41 / 57	16 each	Pre / post Q64.64 sqrt-price
73 / 81	8 each	Input / output amounts
89 / 97	8 each	Input / output transfer fees
105 / 113	8 each	LP fee / protocol fee

Table B1. Event byte layout used by the replication decoder.

Exact integers for the largest buy and sell observations

Field	E3: largest buy	E6: largest sell
Input, raw	12205405480	175111595372
Output, raw	170561057961	12486400223
LP fee, raw	4247483	60938837
Protocol fee, raw	634680	9105802
Pre sqrt-price	4933276121107818496	4927146729279943680
Post sqrt-price	4934039175646610215	4926517709013261312

E3: original base64 event payload


```
4cpJr5MroJayNpDX0HWNHV2LiVDOx6m018ea6P+1xroNvWKhmDeTWwAAaIyZfoR2RAAAAAAAAAAAJwNHFH06eUQA
AAAAAAAACi1f9cCAAAAqTQ7ticAAAAAAAAAAAAAAAAAAAAAAAAAu89AAAAAAAA4rwkAAAAAAA==
```


E6: original base64 event payload


```
4cpJr5MroJayNpDX0HWNHV2LiVDOx6m018ea6P+1xroNvWKhmDeTWwEAdPVa2L1gRAAAAAAAAAAAABxoKcGBXkQA
AAAAAAAAGzldsUoAAAA31g/6AIAAAAAAAAAAAAAAAAAAAAAAAAVdqhAwAAAACK8YoAAAAAAA==
```


Decoding and reconciliation checks

```
price = (uint128(pre_sqrt_price) / 2**64)**2 * 10**(9-6)
if sell_SOL:
    vault_SOL_delta  += input_raw
    vault_USDC_delta -= output_raw
else:
    vault_SOL_delta  -= output_raw
    vault_USDC_delta += input_raw
assert event_deltas == post_token_balances - pre_token_balances
```

The independent Python replication uses arbitrary-precision integers to read raw fields and reconcile vault amounts. Conversion to human-unit prices and continuous counterfactual quotes uses floating point. Maximum reported snapshot discrepancies are below 10^-7 bps and the main sample-saving comparison agrees within USD 0.00001.

Appendix C. Sampling ledger and replication

Raw-file suffix	Query end (UTC)	Observed seconds	Swaps
23	15 Nov 20:55:48	60	17
22	15 Nov 21:55:48	60	39
21	15 Nov 22:55:48	273	212
20	15 Nov 23:55:48	155	89
19	16 Nov 00:55:48	1	2
18	16 Nov 01:55:48	15	33
17	16 Nov 02:55:48	6	13
16	16 Nov 03:55:48	238	190
15	16 Nov 04:55:48	98	70
14	16 Nov 05:55:48	129	54
13	16 Nov 06:55:48	151	71
12	16 Nov 07:55:48	55	45
11	16 Nov 08:55:48	88	95
10	16 Nov 09:55:48	270	169
09	16 Nov 10:55:48	54	37
08	16 Nov 11:55:48	27	2
07	16 Nov 12:55:48	146	171
06	16 Nov 13:55:48	92	88
05	16 Nov 14:55:48	27	61
04	16 Nov 15:55:48	20	32
03	16 Nov 16:55:48	62	87
02	16 Nov 17:55:48	103	93
01	16 Nov 18:55:48	84	78
00	16 Nov 19:55:48	80	88

Table C1. Each raw-file suffix identifies history-hour-XX.json.gz and contains 300 successful address transactions. Recorded elapsed durations sum to 2,294 seconds.

Offline replication

```
unzip Orriss_SOL_USDC_Replication.zip -d replication
cd replication
python reproduce.py
# Optional exact baseline quote reconstruction:
pnpm install --ignore-scripts
node quote_snapshot.mjs --offline
```

The standard-library Python path decodes every history payload, verifies raw vault deltas and reproduces the twelve counterfactual configurations. The optional Node.js path uses @orca-so/whirlpools-sdk 0.22.0, @solana/web3.js 1.98.4, bn.js 5.2.5 and decimal.js 10.6.0, with a package lock supplied. No network requests are issued in offline mode.

Every supplied data and code file has a SHA-256 digest and byte count in manifest.json. The archive digest printed in Section 10 authenticates the complete delivered package. API credentials are not included. Readers should preserve the recorded accounts rather than overwrite them with a later live capture.