Uniswap v3 LP Rebalancing - Analysis & Performance Evaluation

Harsh Khandelwal

1. Introduction

This document presents an analysis of Uniswap v3 liquidity provision (LP) strategies by simulating rebalancing events and comparing their performance to a simple buy-and-hold (HODL) strategy. The study involves historical data processing, liquidity range calculations, rebalancing logic, and risk-adjusted return evaluations.

2. Approach

Data Processing & Retrieval:

Historical ETH/USD hourly prices were fetched from CoinGecko for the past year. Due to API constraints, data had to be retrieved in 90-day segments and subsequently compiled into a continuous dataset. After collection, the data was filtered to ensure that it covered the most recent year up to the current date, aligning with the simulation requirements.

Liquidity Provision Setup:

In accordance with the assignment guidelines, the simulation sets up an initial LP position using a 50/50 allocation of ETH and USDC. For a given spot price P and a configurable range parameter x, the active liquidity range is defined as $[P/(1+x), P \cdot (1+x)]$.

The code computes liquidity L based on Uniswap v3 formulas using the square roots of price values.

As market prices evolve, the simulation continuously monitors the current price. If the price exits the active liquidity range, the framework:

- Calculates the impermanent loss (or gain) by comparing the LP position value against a simple HODL (buy-and-hold) position.
- Rebalances the portfolio to restore a 50/50 allocation.
- Opens a new LP position centered at the current price.

HODL Strategy Simulation

Maintains an initial 50/50 ETH and USDC balance without any rebalancing. It serves as a benchmark to compare LP strategy effectiveness.

Optimal x Value Search

Grid search conducted over x values ranging from **0.01 to 0.20**.

```
x_grid = np.linspace(0.01, 0.20, 50)
```

Optimal value of x is calculated based on a composite metric that averages the Sharpe ratio (a measure of risk-adjusted return) and a Calmar-like ratio (total return divided by the absolute value of maximum drawdown).

```
if abs(max_drawdown_pct) > 0:
    calmar_ratio = total_return / abs(max_drawdown_pct)
else:
    calmar_ratio = np.nan
composite = (sharpe + calmar_ratio) / 2
```

3. Outcomes

A) Performance Metrics

Summary Metrics for Different x Values:

	x	Final Portfolio Value (USDC)	Total Return (%)	Average Impermanent Loss	Sharpe Ratio	Max Drawdown (%)
0	0.05	285833.762723	4.101590	4920.547497	0.053708	-25.863979
1	0.10	288583.525592	5.103063	8951.243148	0.057164	-25.980745
2	0.15	285456.522772	3.964198	11989.443786	0.051952	-25.647080
3	0.20	287564.378239	4.731886	16160.225342	0.055161	-28.311943

B) Optimal x Value Search

Optimal performance metrics:

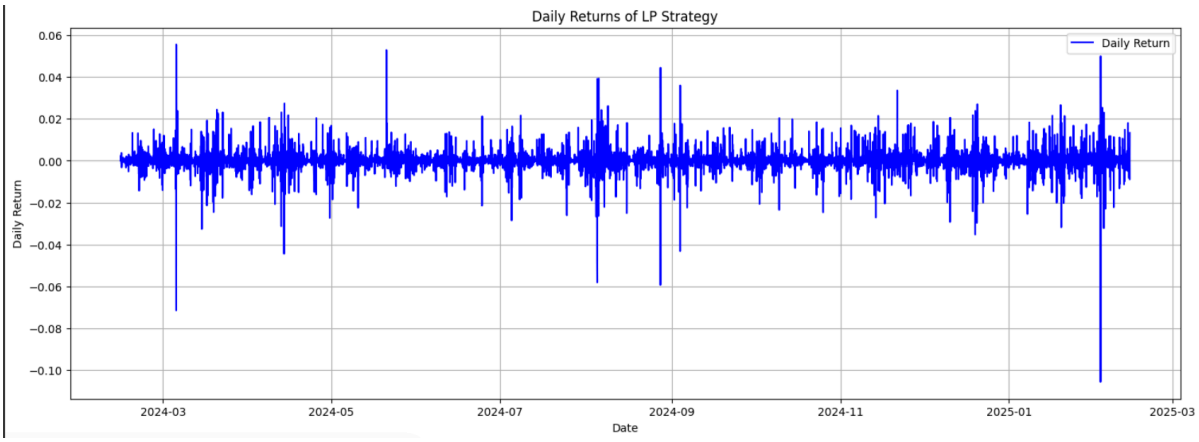
	8
x	0.041020
Sharpe Ratio	0.056016
Total Returns (%)	4.757144
Max Drawdown (%)	-26.098248

C) From HODL Strategy :

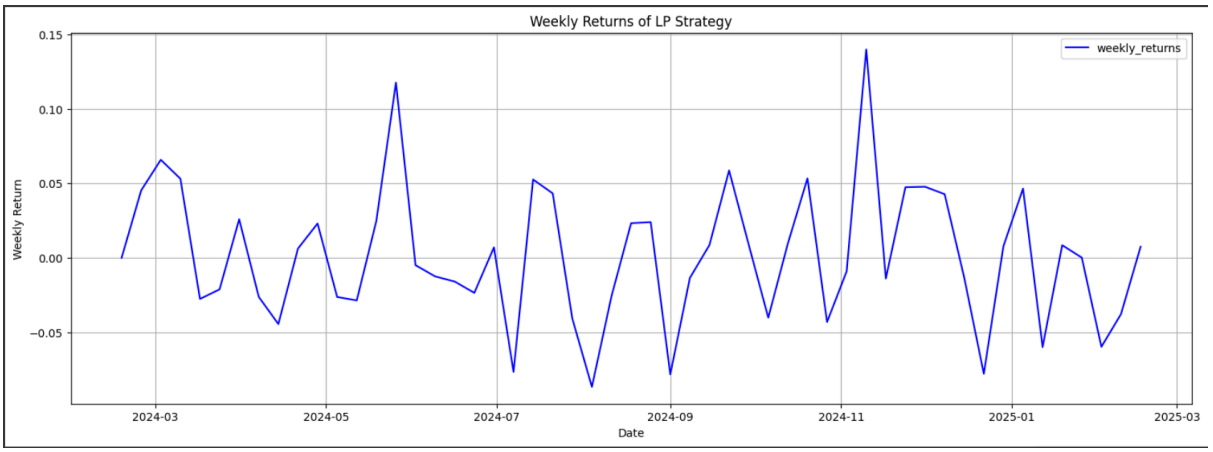
Final portfolio value: 269715.35 USDC, Total Return: -1.77%, Sharpe Ratio: 0.02, Max Drawdown: -27.55%

D) Time Based Returns

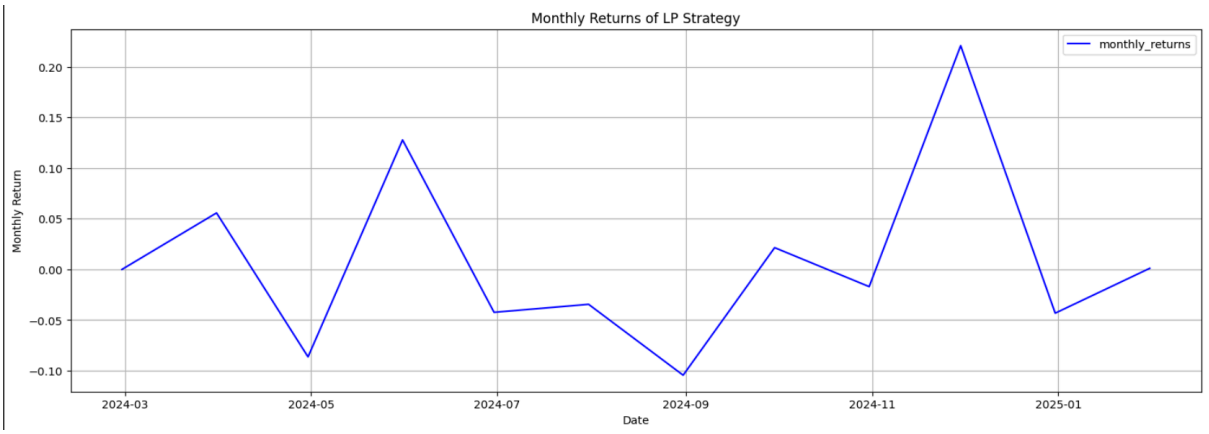
A. Daily Returns:



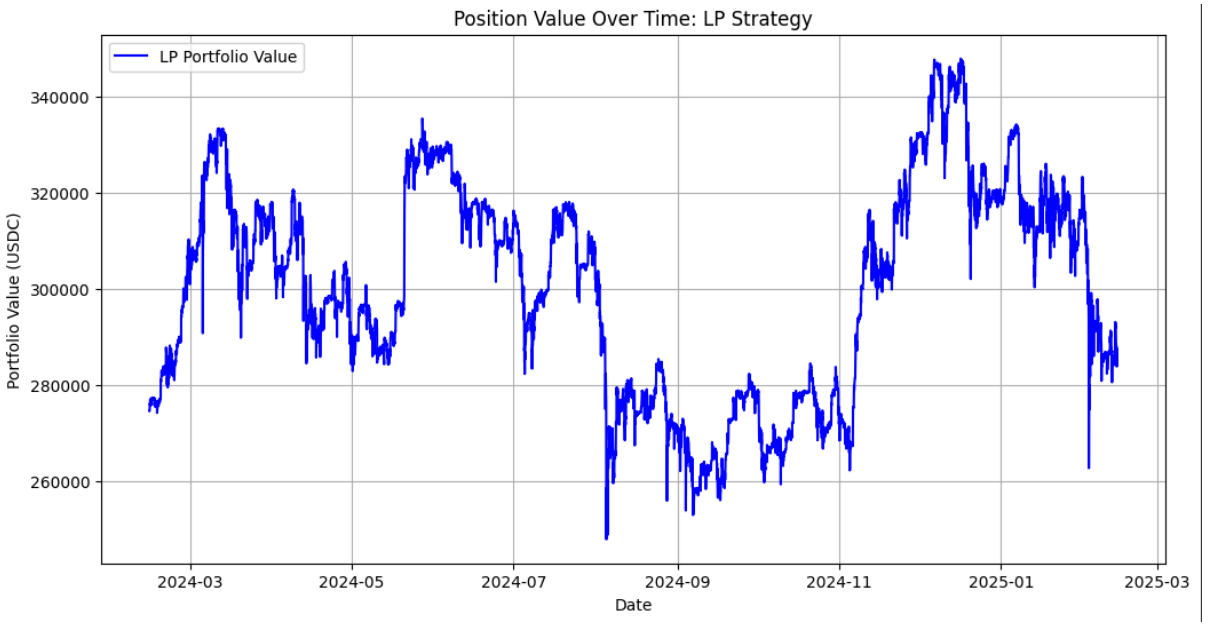
B. Weekly Returns:



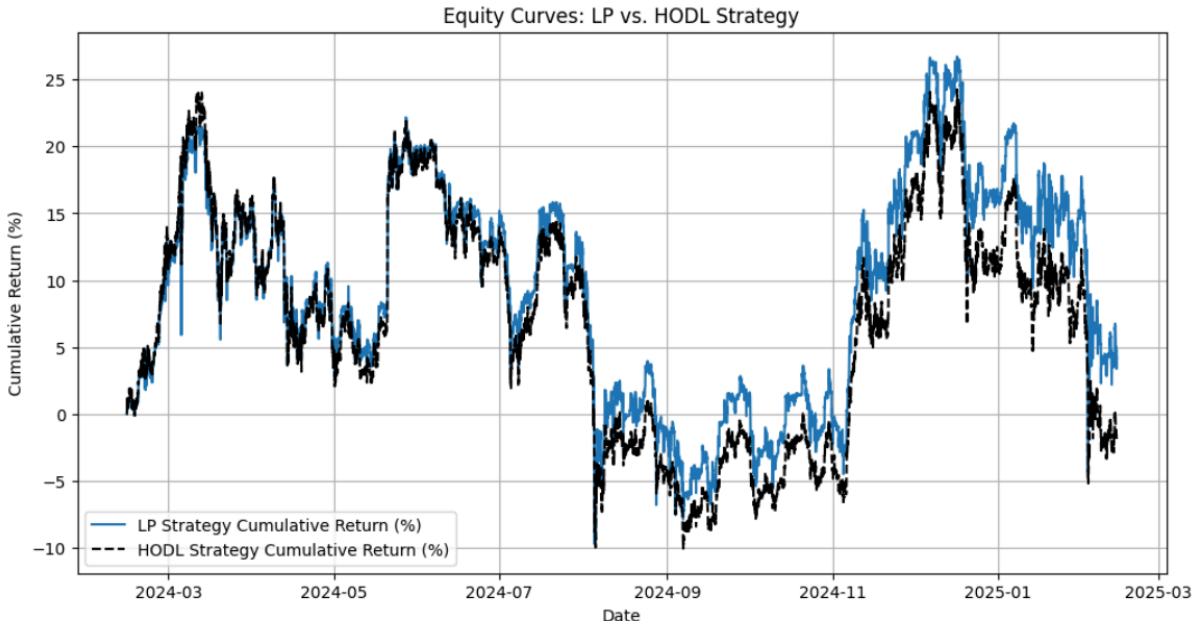
C. Monthly Returns:

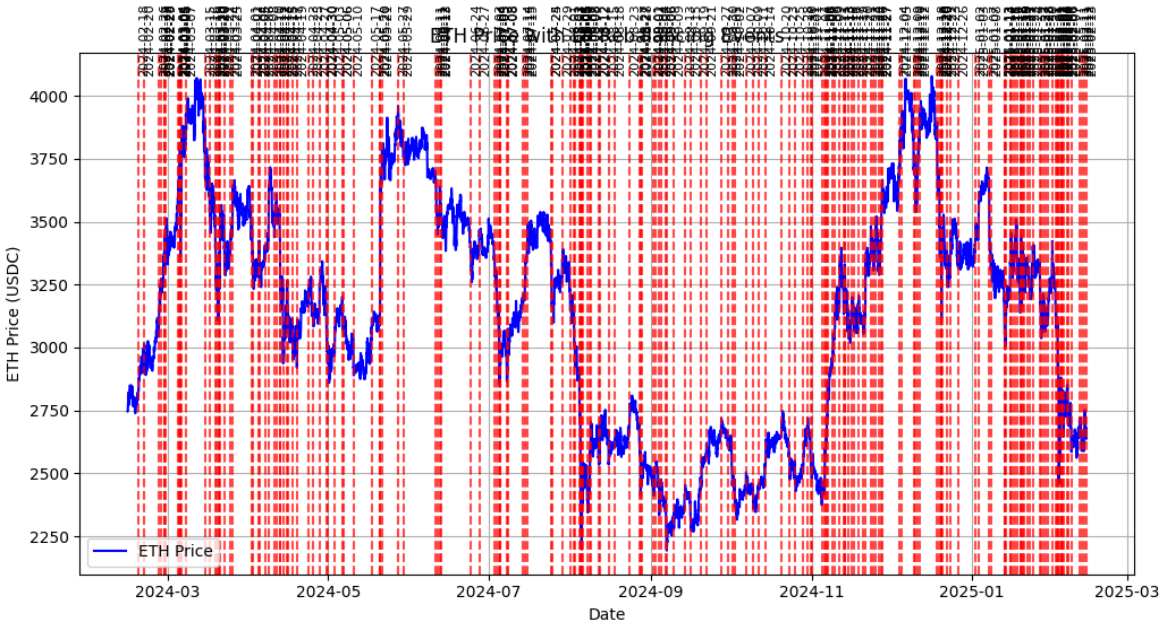


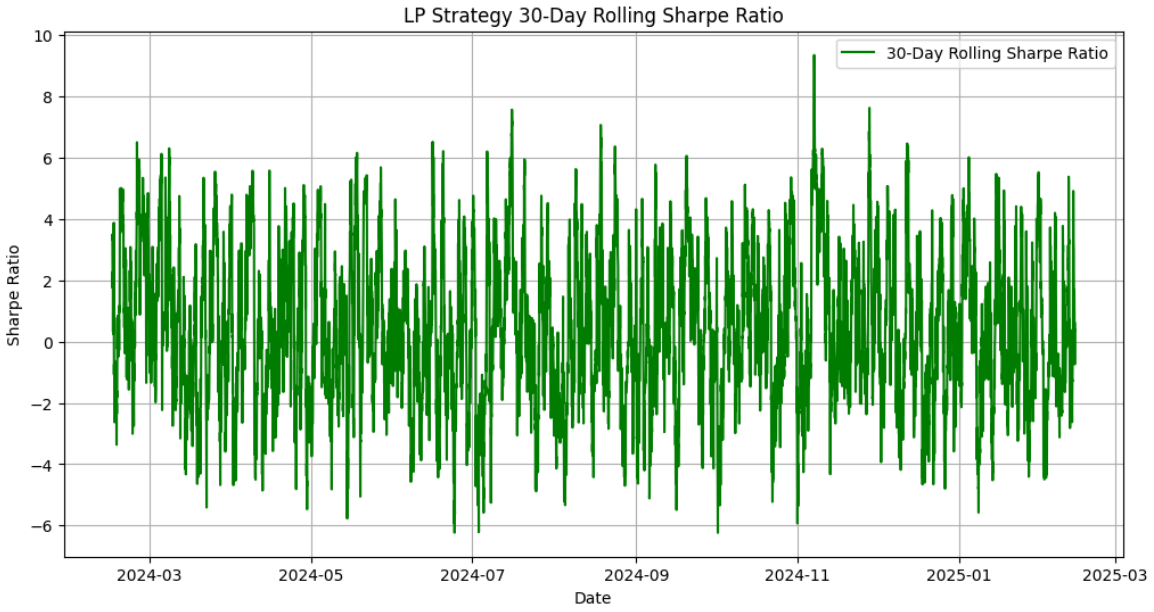
E) LP Strategy Position Value over Time:

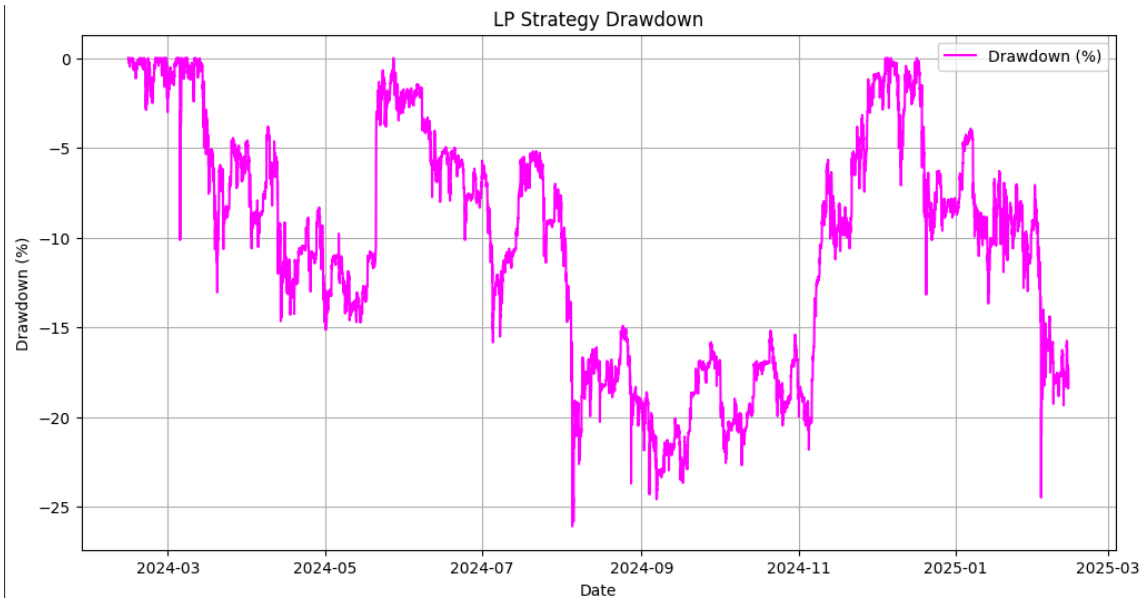


F) Visualization Curves for optimal_x:




ETH Price (USDC)
Date
ETH Price


LP Strategy 30-Day Rolling Sharpe Ratio
Sharpe Ratio
Date
30-Day Rolling Sharpe Ratio


LP Strategy Drawdown
Drawdown (%)
Date
Drawdown (%)

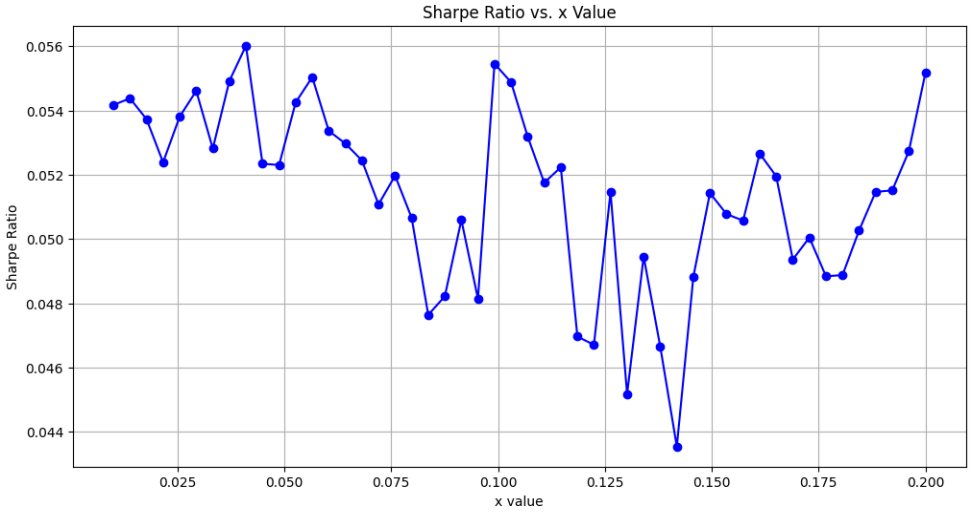
4) Insights:

- As value of x increases IL points decreases as larger range leads to lesser chances of price going out of range.

	x	Total Impermanent Loss points
0	0.05	144
1	0.10	48
2	0.15	22
3	0.20	14

- The current simulation assumes idealized conditions (e.g., no fee accrual, no gas fees, and perfect rebalancing) which may differ from live market conditions.
- <u>Sharpe ratio v/s different x value:</u>

  The trend can be seen from the graph that the sharpe ratio is approximately in range of 0.45 - 0.55 for all values of x.



- <u>Max Drawdown v/s x value</u> : Approx all values lie in the range of -25% to -28.5%