Liquidity Provision Strategies on DEXs

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Data source: https://thegraph.com/hosted-service/subgraph/uniswap/uniswap-v3

Introduction

Financial Markets have evolved over the years, with the introduction of the Automated Market Maker (AMM) model by Uniswap V2. This revolutionary innovation involving a simple constant product formula, x * y = k has since burgeoned in popularity for its ability to emulate an actual trading environment, whilst enhancing capital efficiency. Following which, Uniswap introduced its v3 in 2021 where liquidity providers (LP) can concentrate their capital within price ranges, bounded by upper and lower ticks. This aimed to provide a greater amount of liquidity around desired prices.

While it attempts to simulate a 'thicker maker order' side, an empirical study on the ETH/USDC and ETH/USDT pools on Uniswap V3 appear to show small fragilities in its design to accurately reflect changes in price in a timely fashion. In the next few sections, I will be discussing my analysis to shed light on LP behavior.

Assumptions:

1. On chain and off chain exchanges share the same volatility curve for ETH USDC, with USDC and USDT maintaining parity at 1:1
2. Efficient market hypothesis where market prices and behavior will reflect all available information in the market immediately.

Data Collection:

The pairs chosen are ETH-USDC, and ETH-USDT on Uniswap given that ETH records the one of the highest daily trading volumes and TVL on the protocol. Data was queried from Uniswap V3's official subgraphs to obtain the daily fees, volume, TVL and price of ETH for the ETH/USDC and ETH/USDT pools since Jan 3, 2023. The price of ETH-USDT, the largest trading volume on Binance (which also represents majority of market share) was obtained from Binance API for the latest 1000 days based on API limits. I consider its price the most reliable for cryptocurrencies traded across all exchanges.

Findings

Total Value Locked (TVL) refers to the overall value of assets deposited in the protocol, more specifically within the pool of Uniswap. It can be used as proxy to highlight the interest of users to deposit liquidity.

The ETH-USDC (0.05%) pool has the highest TVL as the 0.3% pool follows a similar trend, and the 0.01% appears to attract little interest with the lowest TVL out of all 5 pools.

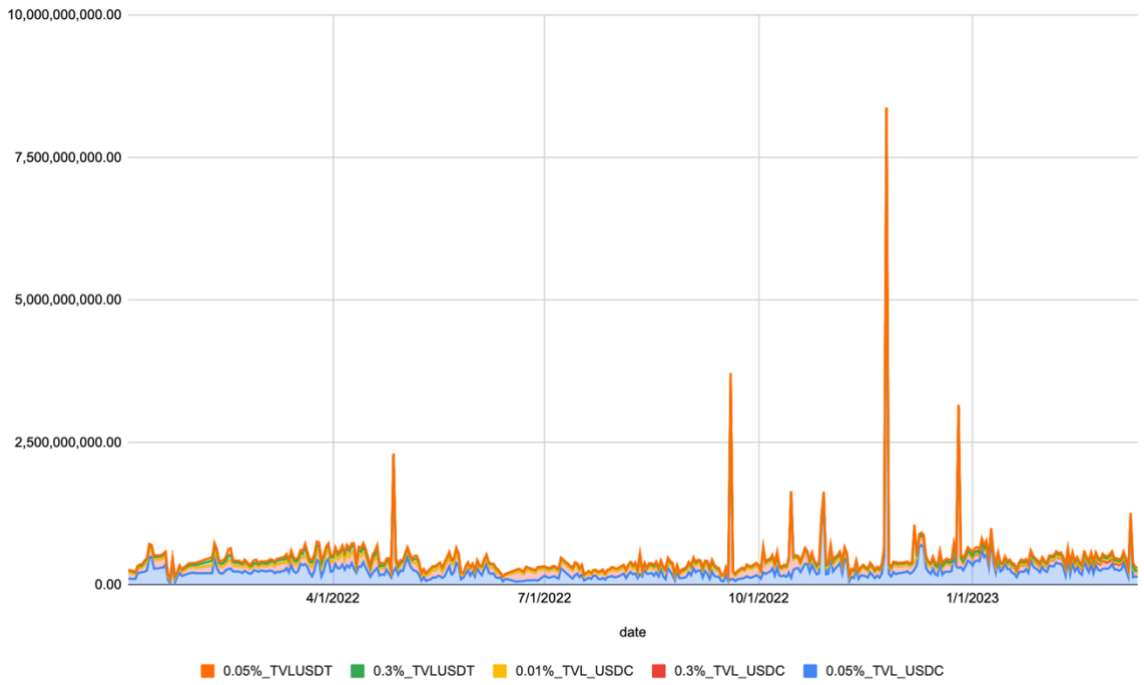


Fig 1: TVL of ETH-USDC and ETH-USDT Pools on Uniswap V3

Therefore, to understand the liquidity dynamics of this pool over time, I also look at other metrics: volume and fees generated at each fee tier for the pool.

- Daily Trading Volume Per Pool

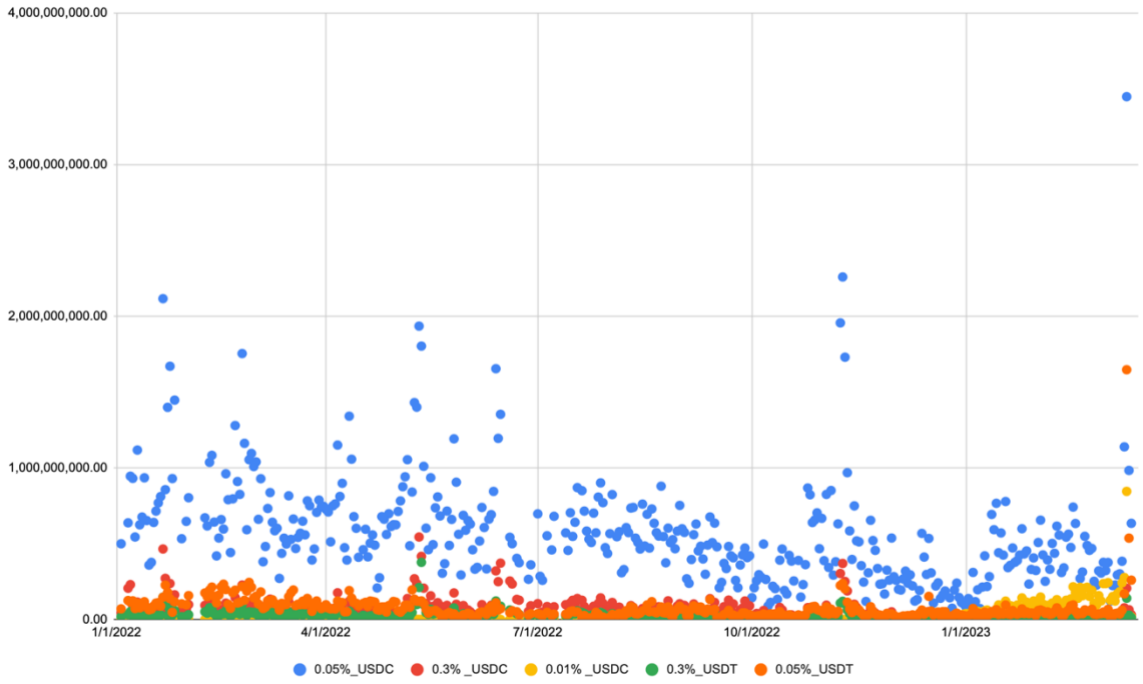


Fig 2: Daily Trading Volume of ETH-USDC and ETH-USDT Pools on Uniswap V3

The ETH-USDC (0.05%) pool receives the highest daily trading volume. Interestingly, the ETH-USDC (0.3%) fee tier seems to pale in comparison, following the 0.1% fee tier closely. The ETH-USDT pools are also performing with relatively low volumes.

- Daily Fees Generated Per Pool

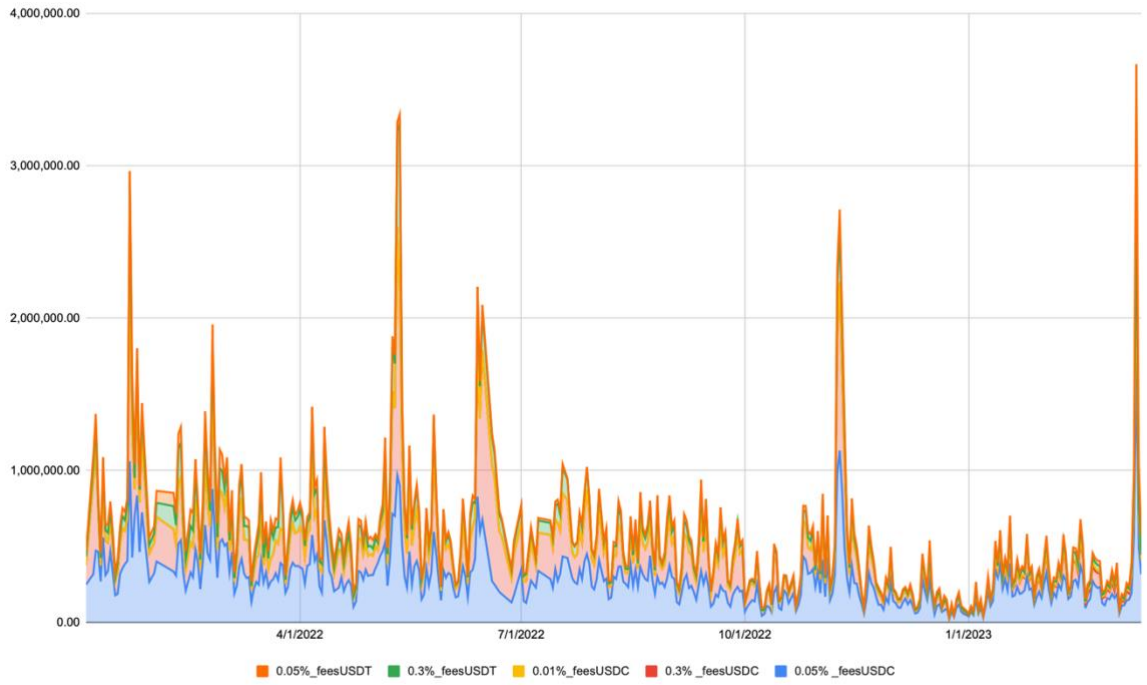


Fig 3: Daily Fees generated for ETH-USDC and ETH-USDT Pools on Uniswap V3

A similar trend is observed for fees generated per pool, with the ETH-USDC (0.3%) topping the sample instead.

In fact, amongst all 5 pools,

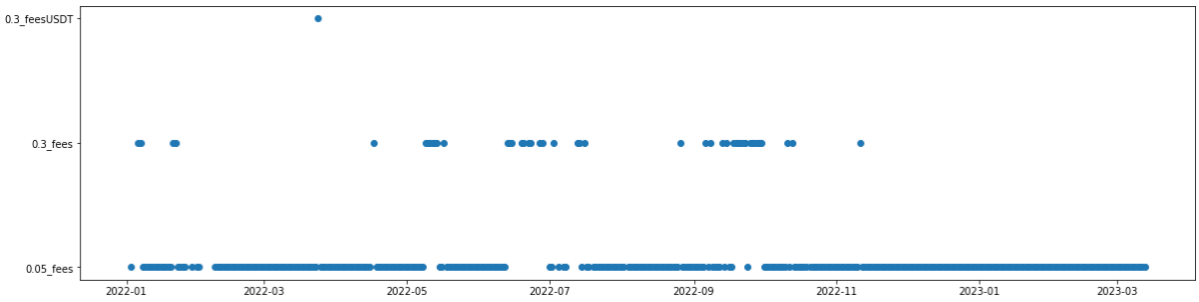


Fig 4: Daily maximum fees for ETH-USDC and ETH-USDT Pools on Uniswap V3

The ETH-USDC (0.05%) fee tier attracted the highest fees 88.6% of the time, while the ETH-USDC (0.3%), fee tier got it 11.1% of the remaining time, with ETH-USDT (0.3%) who yielded the highest fees only once throughout the period.

A new metric was also introduced: Fees per USD of liquidity to find the average revenue generated per USD deposited in the pool by traders.

$$Fees\ Per\ USD = \frac{Fees\ Generated\ Per\ Pool}{Total\ Liquidity\ (\$USD) in\ Pool}$$

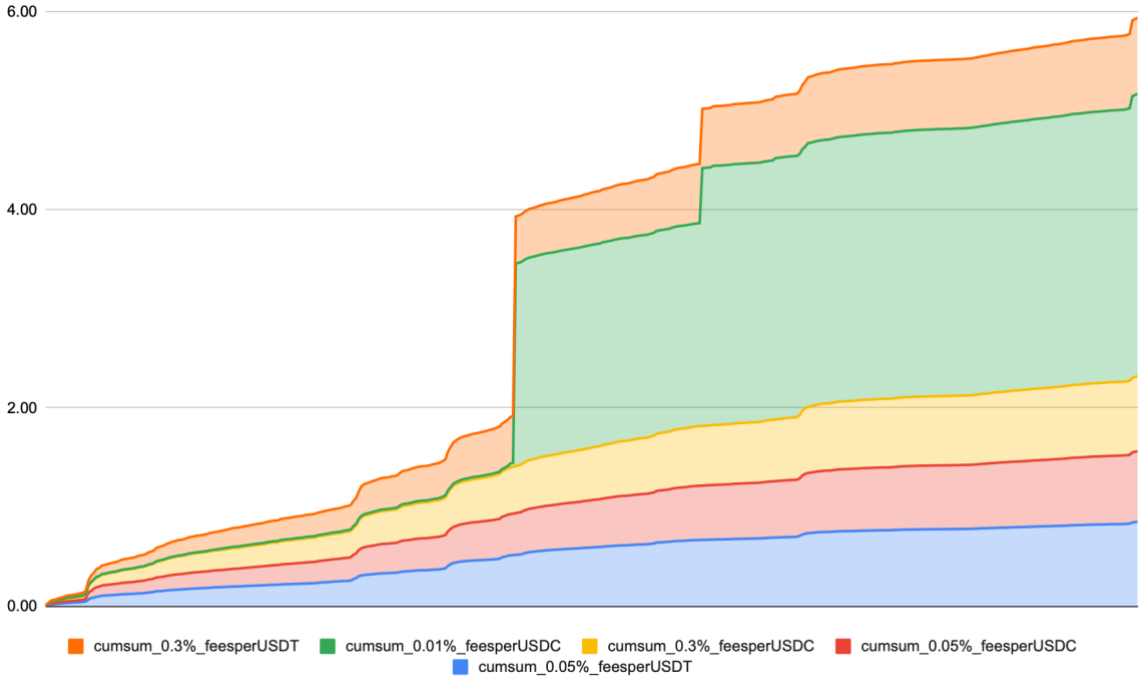


Fig 5: Fees Generated Per USD for ETH-USDC and ETH-USDT Pools on Uniswap V3

In this case, the ETH-USDC (0.01%) fee tier appears to outshine the other 4 tiers very significantly as it generated significant interest, with 2 spikes on 24 Jul and 2 Oct 2022. Treating these as anomalies and removing these 2 data points, we yield the following curve:

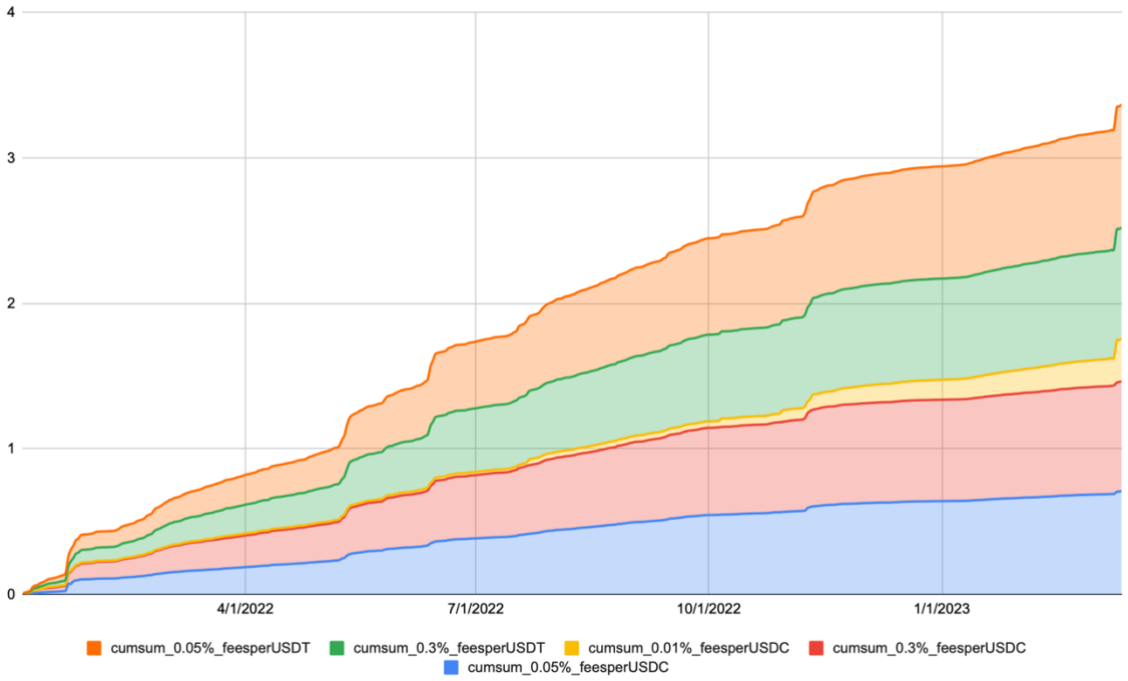


Fig 6: Fees Generated Per USD for ETH-USDC and ETH-USDT Pools on Uniswap V3, without 24 Jul and 2 Oct 2022

Evidently, the ETH-USDC (0.01%) pool substantially underperforms the other two throughout the period. It appears that this liquidity pool is receiving an excess supply of liquidity relative to the others. Through these examples, another interesting trend is also observed.

The ETH-USDT (0.05%) pool yields the highest return on liquidity while the ETH-USDC (0.3%) and ETH-USDT (0.3%) yields comparably the second highest return on liquidity.

While the TVL of the ETH-USDC (0.05%) pool is the highest, it yielded a lower return instead. This coincides with the earlier findings on volume and fees generated per pool as the ETH-USDC (0.05%) has a lower swap volume and hence, each unit of liquidity added captures a lower proportion of the fees generated by the pool.

From these graphs, we need to recognize that liquidity is unevenly fractured across all tiers given the way liquidity providers have set different ranges of limit orders.

- In the ideal case where there is perfect knowledge on the exact range of the price of ETH, liquidity providers will set them within a pre-determined range, akin to a stable-stable pair. This is because every taker will likely swap through this range based on the true price of ETH and will have a deference towards a very low fee tier. Therefore, an aggregation of liquidity by makers will be seen in the lowest fee tiers (0.01%).

- Instead LPs will inadvertently choose to set the ranges of their positions higher to capture more trading fees with increased volatility. They then demand a higher fee tier to cover for potential impermanent losses incurred, looking for 0.3% pools.

- In this case, we see the following, excluding USDT base:

    - Highest TVL: ETH-USDC (0.05%)
    - Highest Cumulative Fees Generated: ETH-USDC (0.3%)
    - Highest Fee per Dollar Liquidity: ETH-USDC (0.3%)

  There exists a tradeoff where traders exhibited a preference for ETH-USDC (0.05%) pools with the highest liquidity available yet shying away from the pool with the highest ROI cumulatively. Traders could be possibly choosing a safer bet and overcompensating for the volatility of ETH prices.

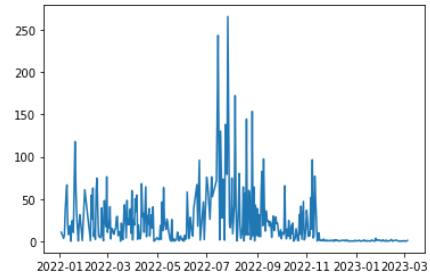
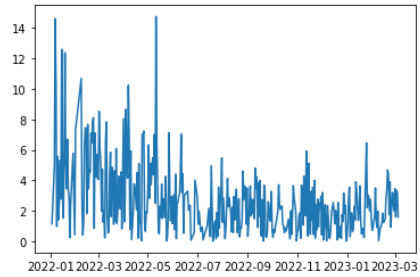
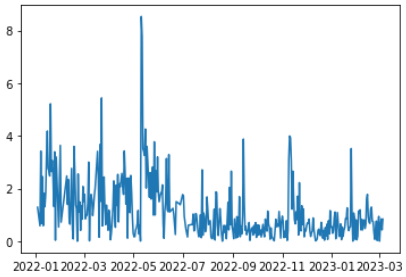
Next, when I observe the correlation amongst the various business metrices, I notice highly positive correlations between the ETH-USDC (0.05%), ETH-USDC (0.3%), ETH-USDT (0.05%), ETH-USDT (0.3%) pools in terms of both fees and transaction volume. This is akin to the aforementioned observation where similarities in trends between the 0.3% fee and 0.5% fee tiers can be seen as well.

Fig 7: Correlation Matrices among all factors – TVL, Fees, Price for ETH-USDC and ETH-USDT Pools on Uniswap V3

Price Dynamics

When I studied the price curves of the 5 Uniswap V3 pools and the ETH-USDT on Binance, I observe unexpectedly large price discrepancies across all 6 sectors.

Differences in ETH pricing across Uniswap pools vs Binance

0.01% ETH-USDC Pool vs Binance ETH-USDT Price	0.3% ETH-USDC Pool vs Binance ETH-USDT Price	0.05% ETH-USDC Pool vs Binance ETH-USDT Price
		

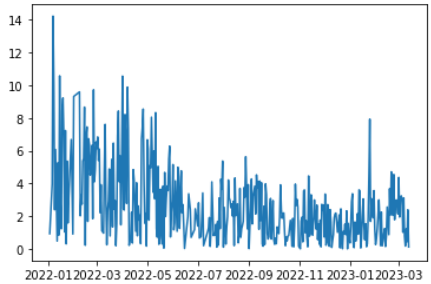
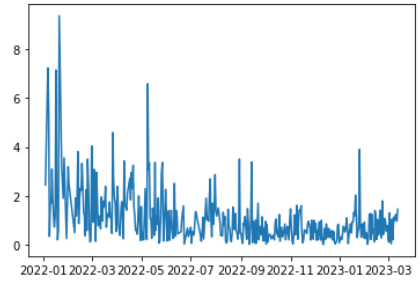
0.3% ETH-USDT Pool vs Binance ETH-USDT Price	0.05% ETH-USDT Pool vs Binance ETH-USDT Price
	

Fig 8: Price difference between ETH-USDC, ETH-USDT Pools on Uniswap V3 and ETH-USDT on Binance

Upon closer analysis, I then compared the price difference and flagged out occasions where it had an over 5% deviation from prices on Binance. These periods didn't observe prolonged changes in TVL but rather fluctuations in trading volumes as seen in Fig 9 and Fig 10. The periods include: `['2022-06-19', '2022-06-22', '2022-07-01', '2022-07-02', '2022-07-03', '2022-07-07', '2022-07-13', '2022-07-14', '2022-07-15', '2022-07-16', '2022-07-18', '2022-07-24', '2022-07-25', '2022-07-26', '2022-07-27', '2022-07-28', '2022-08-05', '2022-08-19', '2022-08-26', '2022-09-07', '2022-09-09', '2022-11-08', '2022-11-11']`.

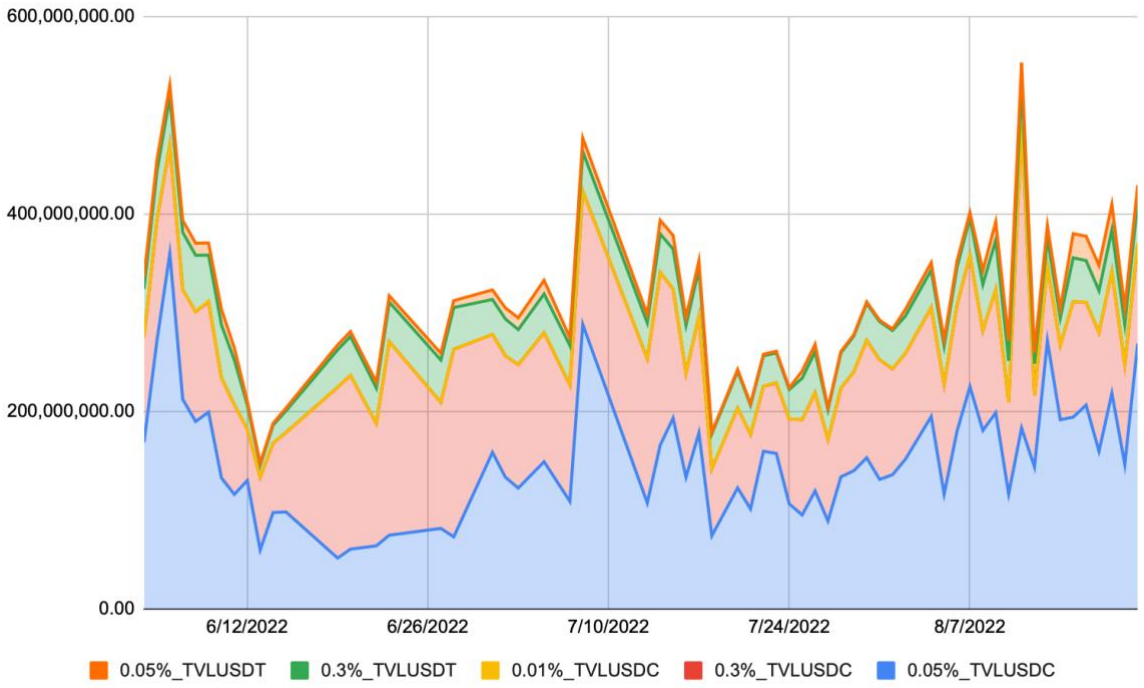


Fig 9: TVL for ETH-USDC and ETH-USDT Pools on Uniswap V3 between June and August

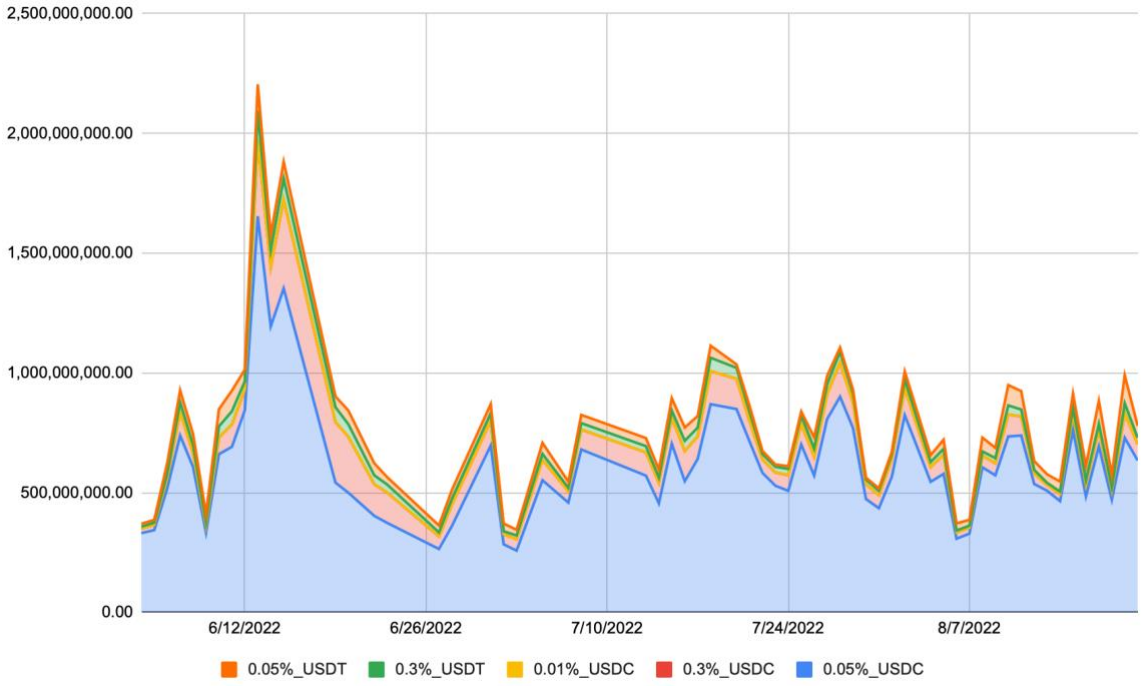


Fig 10: Daily Volume for ETH-USDC and ETH-USDT Pools on Uniswap V3 between June and August

Uniswap V3 LPs appear to exhibit inertia in adhering to market prices across all 3 fee tiers during these dates - changes in TVL did not coincide with fluctuations in volume. LPs were not fast enough to adapt to changes in pool volume as well to take advantage of the increased fees distributed.

Realized Volatility of ETH Pricing, across Uniswap Pools

Based on a rolling window of 5 days, the realized volatility of ETH on each of the Uniswap pools were also calculated. This involved the following formulae:

$$Realized\ Volatility = (Rolling\ Variance(\log(returns) * annualized\ factor)^{0.5},$$

Where Annualized Factor = 365 days / 10 days (rolling window)

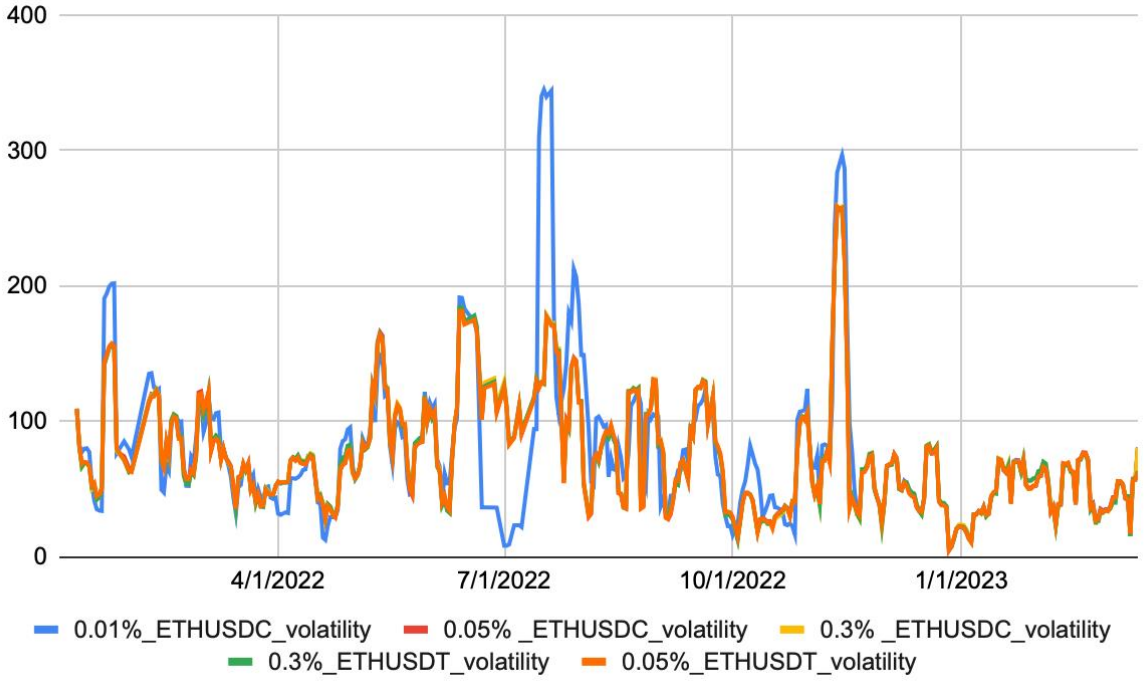
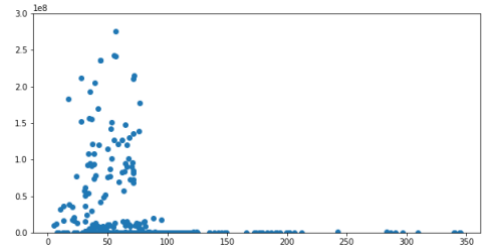
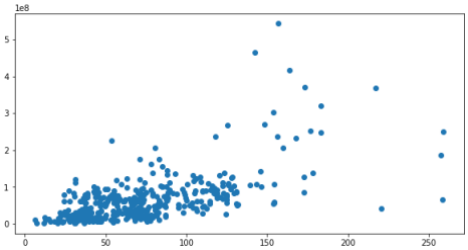
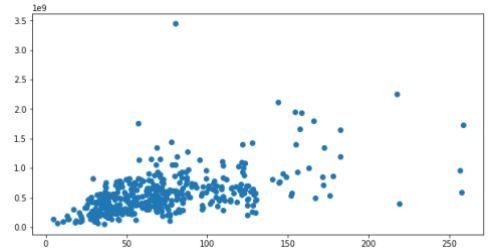


Fig 10: Realized Volatility for ETH in ETH-USDC and ETH-USDT Pools on Uniswap V3

The analysis is consistent with Fig 10 as the price of ETH in the ETH-USDC (0.01%) exhibits the widest and most deviant realized volatility with a high of over 300% compared to the other pools. This is plausibly attributed to the low volumes and liquidity available to sustain market shocks. As for the other ETH-USDC and ETH-USDT pools in the 0.05% and 0.3% fee tiers, they appear to model closely together as it stems from the prices and transaction volume being highly correlated.

- Daily Trading Volume vs Realized Price Volatility of ETH for each Pool

0.01% ETH-USDC Pool	0.3% ETH-USDC Pool	0.05% ETH-USDC Pool
		
Corr = -0.155	Corr = 0.600	Corr = 0.510

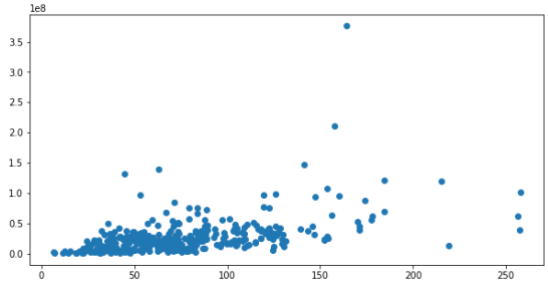
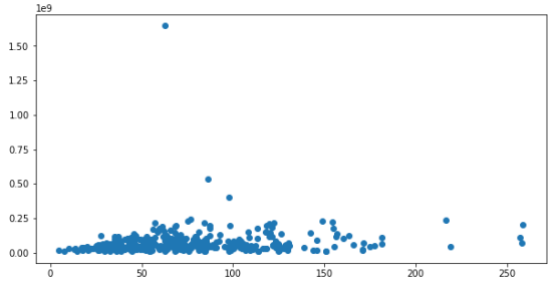
0.3% ETH-USDT Pool	0.05% ETH-USDT Pool
	
Corr = 0.500	Corr = 0.132

Fig 11: Realized Volatilities of ETH on Uniswap V3 Pools

The relationship between the daily trading volume and the realized volatility can also be seen in Fig 11, with the correlations calculated within. The ETH-USDC (0.01%) pool records a negative correlation, citing that higher trading volumes coincide with lower realized volatilities in the pool, exhibiting signs of a stable-stable pair. On the other hand, LPs yearn for higher trading volumes in periods of heightened volatility, but this is not entirely depicted across the pools which they may have incurred losses due to the price fluctuations beyond their liquidity positions

Discussion

The relative concentration of liquidity on the 0.05% pool suggests that LPs are exhibiting rational behavior in allocating capital between the 0.3% and 0.05% fee tiers. Nonetheless, while the ROI for the 0.3% is highest, the dichotomy between TVL and fees generated per dollar suggests signs of market failure:

- ETH-USDC (0.01% fee) pool continues to attract liquidity despite receiving the lowest fees, volume, and ROI. Furthermore, as seen in the section of Price Dynamics, this pool incurs the highest price volatility and would require the highest amount of fees per USD to compensate for the impermanent loss incurred by LPs. Evidently, this theory has not been seen.
- Despite the pools with 0.3% fee tiers yielding the highest returns, market participants still prefer the pool with 0.05% and provide more liquidity. This causes them to incur lesser fee revenue than expected.
- In the future, the study can directly query historical positions PnL as cases such as impermanent losses were discounted from this analysis.

Furthermore, the disparity in prices for the 5 pools vs Binance are appalling. Assuming 1:1 parity for USDC and USDT, the ETH-USDT, USDC (0.05%, 0.3%) pools exhibited stronger resilience with a maximum difference of $14.23 between Uniswap and Binance. The sudden spike experienced for USDC pools were due to the depeg crisis of the stablecoin from March 11 – 12 and are excluded from this discussion. Instead, those in the ETH-USDC (0.01%) pools experience the greatest fluctuations, reaching over $265 in Q3’2022. In this situation:

- LPs can be seen to respond relatively slow to the changes in liquidity. In fact, this was the period where prices were more volatile. Using the ETH-USDT price on Binance, this large difference in prices coincide with the following dates which showed over

10% difference in daily prices on Binance: July 16, 2022 ; July 18, 2022; July 27, 2022.

- Understandably, LPs may be reluctant to open new liquidity positions on the pool given the high volatility and unfavourable risk-reward ratios during times of extreme market dislocation. As such, Uniswap should consider compensating LPs for assuming risk during these heightened periods of uncertainty. Since research has shown that Uniswap V3 liquidity positions exhibit similarities with calls and put options, it could adopt a fee structure that would increase with volatility. This will be similar to traditional finance markets where market makers are compensated to assume leg risk when the bid-ask spread widens due to price fluctuations.

Conclusion

In conclusion, this data exploration on the liquidity and price dynamics seek to understand trading behavior of users on Uniswap v3 for the most popular pools with ETH and its stablecoin pairs, USDC and USDT. Forms of market failure exist where traders appear to not be fully optimising their returns in the setting of an efficient market to search for the highest returns per dollar provided. In particular, the trade-off between capital efficiency and price accuracy remains clear. The ETH-USDC (0.01%) pool clearly shows an example where price fluctuations are most apparent in periods of volatility and low liquidity in the pool. This opens the protocol to price oracle attacks by manipulating the TWAP on Uniswap as witnessed on other platforms.

Nonetheless, studies can be conducted in the future to include the historical liquidity depths for the various pools and compare the performance of Uniswap v3 on Ethereum mainnet relative to other chains such as Polygon, to gain deeper insights into the specific trading behavior across the protocol. Furthermore, the data obtained can be more granular at an hourly interval to more clearly define and unravel distinct changes over time. This could help to identify arbitrage opportunities across pools, as seen from the historically deviant prices and realized volatility of ETH in the earlier sections.

Through this research, I hope that it sheds light on the current liquidity and price dynamics for Uniswap V3 pools and consider new features to compensate traders for assuming higher risk in times of volatility, while actively managing liquidity assets for LPs in a more optimized manner.