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Distributed Computing

Comparing Liquidity Pools of Decentralized Exchanges

Bachelor's Thesis

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Abstract

The rise of decentralized finance introduces new investment opportunities. This bachelor's thesis aims to compare liquidity pools on a variety of decentralized exchanges on different blockchains. We analyze the decentralized exchanges of Uniswap (v2 & v3), Sushiswap, Curve, Pancakeswap and Trader Joe. We include results from Etherum, Arbitrum, Optimism, Matic, Binance and Avalanche. We compare liquidity pools according to a number of metrics, including return on investment, volume and volatility. Our analysis gives a broad overview of the state of decentralized markets in 2022. Further, we inspect market efficiency of decentralized exchanges and show that so far liquidity providers and traders are not acting in the most efficient way.

Contents

Chapter 1
Introduction

1.1 Rise of Decentralized Finance

The rise of blockchain technology has brought growth to crypto currencies and is starting to shake up traditional finance. Decentralized finance (DeFi) includes all financial applications that are built on the blockchain. It is a fast moving field with new applications launched on a monthly bases. DeFi covers a range of financial services from lending or insurances to money transfers. In 2022 the average daily trade volume on Uniswap, the largest decentralized exchange (DEX) is at around 1.58 billion USD[1] [1]. The SIX swiss stock exchanges had a daily trade volume of around 4.35 billion USD[2] [2]. This shows that DeFi is becoming more important. It raises the questions of how DEXs have gained their market share and how they work. Who is benefiting of this boom and how should investors, traders and people of interest manoeuvre this new market?

In this bachelor's thesis we compare markets on different decentralized exchanges, on a variety of blockchains and for different token pairs. How can liquidity providers (LPs) find the best opportunity for their needs? Our comparison uses metrics like return on investment, volume or volatility. Additionally, the results are analyzed for the market efficiency of LPs. As we look at data from the years 2021 and 2022, our information reflects today's market state and explains why certain developments on DEXs are observed. Further, we study who is providing liquidity by separating LPs into different groups.

Our results should not be looked at as investment advice but rather as a first analysis of the differences between investment opportunities on DEXs.

1.2 Related Work

Several research papers have been written recently on DEXs. Heimbach and Wang [3] looked among other things at risks and returns of providing liquidity.

[1]Data from 01.01.22-24.01.22
[2]Data from 01.01.22-31.03.22

They showed that returns vary a lot depending on the choice of investment. Capponi and Jia [4] argue that investors should only finance liquidity pools with high volume or tokens with stable prices.

Some research focused on impermanent loss and the risk associated with it. This has been analyzed by Aigner and Dhaliwal [5]. Loesch et al. [6] focused on impermanent loss on Uniswap v3 and further concluded that investors who actively managed their liquidity positions neither performed better or worse than investors who stayed "inactive".

Uniswap v3 brought investment strategies, which were analyzed by Fritsch [7]. Huynh [8] extended the analysis of different strategies on Uniswap v3 and showed that impermanent loss impacted returns.

Market efficiency was studied using arbitrage. Arbitrage describes the possibility to make profits through price differences. Wang et al. [9] questioned the efficiency of DEX markets. Berg et al. [10] showed that 30% of analyzed trades on Uniswap and Sushiswap were made at an inconvenient exchange rate. Qin et al. [11] argued that the amount of money made through arbitrage on DEXs reduces blockchain security and has grown with the growth of DeFi.

So far only some attention was given to the difference in returns. We aim to expand upon this work with a bigger analysis of more DEXs as well as comparing the same DEX on different blockchains. An additional focus is given to market efficiency and analysing the behaviour of LPs.

1.3 The graph API

the graph [1] is an indexing protocol that allows to query blockchains. It is used for most data collection in this bachelor's thesis and allows us to directly access values of the blockchain without relying on information by DEXs. Several subgraphs were used in order to derive the metrics on different blockchains and DEXs.

In the course of the work, some errors or contradictory values were discovered in *the graph*. Therefore, some results may differ from reality. Nevertheless, *the graph* is used by DEXs to provide market information and is therefore considered a reliable source for DeFi.

Chapter 2

Decentralized Exchanges

2.1 Continuous Innovations

At the heart of DeFi are decentralized exchanges (DEX). They allow traders to exchange tokens in a decentralized process. Centralized exchanges (CEXs), which have existed for longer, apply order booking similar to stock exchanges to exchange financial products. CEXs play an important role in the world of crypto currencies, as they provide an exchange-platform between fiat currencies and crypto currencies. On the other hand, DEXs have only emerged in recent years, with leading platforms like Uniswap being founded in 2018 [12]. Since then, there has been a big expansion of DEXs. For example, we have seen clones of Uniswap like Sushiswap [13] or Pancakeswap [14]. And DEXs have expanded to other blockchains like Uniswap to Arbitrum.

Markets in DeFi have only been around for a decade. This makes it difficult to interpret data. Some exchanges have changed details in their smart contracts in recent years. Uniswap introduced a new version in May 2021 called v3 which significantly changed the underlying process. On other DEXs, communities can vote on a weekly basis which pools should be incentivized for investors. Therefore, we will first provide a brief overview into DEXs and tokens. Then we explain how DEXs work, before exploring liquidity pools in detail.

2.2 Overview

In the following sections we will provide a brief overview over the DEXs included in this bachelor's thesis. The selection is based on historical and technological importance. There are many other DEXs that can be analyzed. However, the smaller the trading volume, the higher the market volatility. Therefore we focus on a small but relevant sample of DEXs.

Uniswap is the oldest DEX and introduced automated market makers to decentralized finance. Uniswap is operating three versions, Uniswap version 1 (v1), version 2 (v2) and version 3 (v3). Version 3 launched in May of 2021. The latest protocol has brought significant changes to DEXs. The impact of v3 is still ongoing and we will cover it in depth. Although, Uniswap v1 is still usable, we exclude results from v1 because the newer versions dominate the market. Uniswap is operating in May 2022 on Etherum, Arbitrum, Optimism and Matic (Polygon).

Sushiswap is a clone of Uniswap, which means that their original smart contract was the same. However, Sushiswap has introduced new features which separates it from Uniswap. Sushiswap is currently available on Etherum, Arbitrum, Avalanche and Matic (Polygon). Some features are only available on certain blockchains.

Curve is unique as it combines similar tokens like stable coins or wrapped versions of tokens into one liquidity pool. That's why you can find pools with three or more tokens on Curve. We focus on the *3pool* which contains three stable coins. Further, it has some of the lowest fees of all DEXs which makes it very interesting for traders to exchange tokens. Curve is available on several blockchains, however we only look at Etherum.

Pancakeswap is another Uniswap clone and has its own features. It is operating on the Binance blockchain.

Finally, there is Trader Joe which is another clone of Uniswap. It is only available on the Avalanche blockchain.

2.3 Tokens and Currencies

The diversity in crypto currencies is expanding with the recent development of blockchains. On Uniswap v3 there are currently more than four thousand tokens available for trade[1]. Although, not every token has to represent a currency, the difference between tokens and currencies on blockchains is not always distinguishable. Our goal has never been to analyze the currencies. However, price fluctuations have an impact on profits from investing in DEXs. Further, Matkovskyy [15] showed a higher volatility for Bitcoin [16] on DEXs than on CEXs. Therefore, investors must consider underlying tokens for their investment, because they are a risk factor. While analyzing DEXs, high volatility in token prices might lead to contradicting results.

In this bachelor's thesis, we will consider the tokens in table 2.1.

[1] At the time of writing (18.04.2022), *"the Graph"* [1] lists 4454 tokens on Uniswap v3

Table 2.1: Token table.

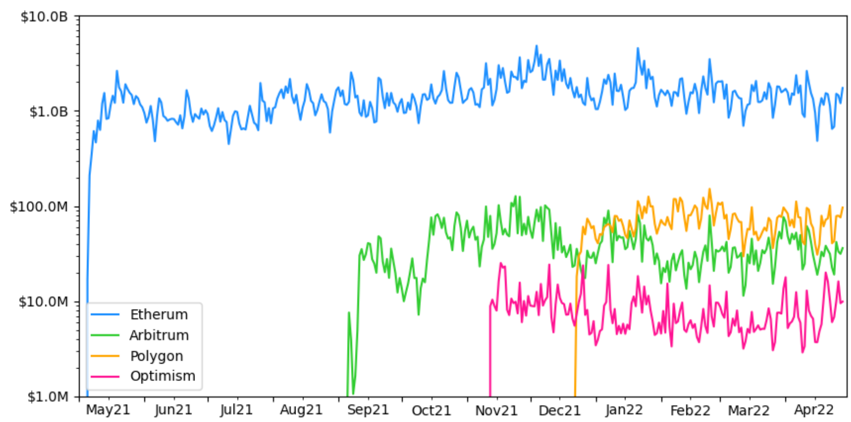
name	symbol	type	native blockchain
Ether	ETH	alternative coin	Etherum
USD Coin	USDC	stable coin	Etherum
Tether	USDT	stable coin	Bitcoin, Etherum
Dai	DAI	stable coin	Etherum

We will analyze exchanges of ETH-USDC which are rather volatile because of the price fluctuations of Ether. Additionally, we consider stable pools involving USDC, USDT and DAI. Stable pools only contain stable coins. In our analysis all stable coins are pegged to USD. Therefore, all three tokens should have a value of around 1 USD. Stable pools will allow us to ignore price fluctuations and focus on market efficiency.

2.4 Blockchains

Several DEXs are running on different blockchains at the same time. For example Uniswap v3 is operating on four different blockchains in May 2022. In figure 2.1 we see that Etherum is still the dominating blockchain in terms of volume for Uniswap, despite the launch on other blockchains in 2021. Nevertheless, investors must consider the competition between different blockchains even if they are using the same DEX. Further, with blockchains switching to new technologies, like Etherum towards proof of stake [17], the choice of blockchain could have an impact on markets.

Figure 2.1: Uniswap v3 daily volumes in USD on different blockchains since launch.



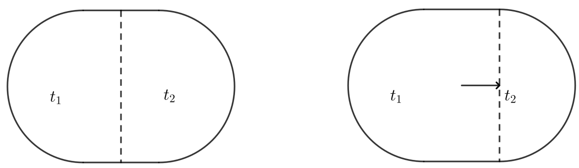
2.5 Liquidity Pools

To exchange tokens on DEXs liquidity pools are used. Most pools contain two tokens t_1 and t_2. Traders then put token t_1 into the pool in exchange for token t_2 or reverse. All of this is implemented through a smart contract on the blockchain. DEXs use automated market makers (AMM) which determined a price p by looking at the reserves of t_1 and t_2 and applying the formula:

$$p = \frac{reserve(t_1)}{reserve(t_2)} \tag{2.1}$$

This method is still in use for Uniswap v2 [18] and its clones like Sushiswap [13] and Pancakeswap [19]. Despite the simplicity, Angeris et al. [20] showed that this formula will accurately follow market prices. Let us take a look at what happens during a swap. This is illustrated in figure 2.2.

Figure 2.2: Liquidity pool illustration.



At the beginning we have the same amount of t_1 and t_2. Then a swap is made, in which t_1 is traded for t_2. This reduces the amount of t_2 in the pool and increases the amount of t_1. The price of the two tokens changes and t_2 will become more expensive. Liquidity pools offer an investment opportunity to liquidity providers (LPs). LPs deposit tokens into the pool in exchange for a fraction of each transaction. This fraction is called distributed fee and is paid by the trader. On original DEXs like Uniswap v2 a LP always has to deposit liquidity in both tokens, in a way that:

$$value(\#t_1) = value(\#t_2) \tag{2.2}$$

With $\#t_1$ and $\#t_2$ being the amount of token t_1 and token t_2 respectively. The big advantage of AMMs is decentralization, which replaces the middle man on CEXs with a smart contract. However, becoming a LP is not risk free. One issue is impermanent loss. Impermanent loss occurs when asset prices change significantly while providing these assets to a liquidity pool. The consequence is that an LP will withdraw less dollar value than they initially deposited, despite the returns in fees from the liquidity pool. It is called impermanent loss because asset prices might return to their original value in the future. In a worst case scenario this leaves LPs with all their asset in one token, which could have no value.

2.5.1 Uniswap v3

Uniswap v3 adds pools with different distributed fees to DEXs. Only 0.3% pools existed in v2. In v3 there are now 1.0%, 0.3%, 0.05% and 0.01% pools. These new pools create a competitive environment, because for example for the USDC-ETH pair, there are now four distinct pools with a fee of 1.0%, 0.3%, 0.05% and 0.01%. The biggest change for investors in v3 is concentrated liquidity. It allows LPs to restrict the range in which they are providing liquidity. For example, a LP can now only invest in a price-range of 3000 USDC to 3800 USDC per ETH. In this case if the price of ETH drops below 3000 USDC all his investments in the pool are turned into ETH. This can also be used to place stop orders. On the downside for investors, swap fees are only distributed to LPs which provide liquidity at the current price range. The range in which an LP provides liquidity is called active range.

Concentrated Liquidity

In v3 LPs can limit the range in which their liquidity is active. Therefore, the liquidity might now only cover the price range $[p_a, p_b]$ instead of the full range as in v2 $[0, \infty[$. This allows investors to provide liquidity in different strategies. Such strategies have been analyzed by Huynh [8] and Fritsch [7]. For our analysis we try to imitate investing in Uniswap v3 in the same way as we would have in v2. Therefore we assume that our investors provide liquidity in the range $[0, \infty[$. This is done to neglect strategies and focus on differences between pools.

Liquidity Math

In the whitepaper of Uniswap v2 [18] liquidity is in the range $[0, \infty[$ and distributed such that the amount of token x and y is constant:

$$x * y = k \tag{2.3}$$

with k being constant. The relationship between liquidity l and price p with $p = \frac{y}{x}$ is as follows

$$l = \sqrt{xy} = \sqrt{x * (p * x)} = x * \sqrt{p} \tag{2.4}$$

or

$$l = \sqrt{xy} = \sqrt{\frac{y}{p} * y} = \frac{y}{\sqrt{p}} \tag{2.5}$$

In the whitepaper of Uniswap v3 [21] we have a liquidity range of $[p_a, p_b]$. The state of the liquidity pool is represented by a tick. If the current tick of the pool is within this range the liquidity is given by:

$$l = \frac{y}{\sqrt{p} - \sqrt{p_a}} \tag{2.6}$$

or

$$l = \frac{x}{\frac{1}{\sqrt{p}} - \frac{1}{\sqrt{p_b}}} \tag{2.7}$$

If we now let $p_a \to 0$ and $p_b \to \infty$, we get the same equations as in 2.4 and 2.5.

Ticks

To track the whole development of a liquidity pool in v3, the smart contract uses ticks. Ticks relate to the price in the pool as follows:

$$p(i) = 1.0001^i \tag{2.8}$$

or with regards to the square root price which is the value stored in the smart contract:

$$\sqrt{p(i)} = 1.0001^{\frac{i}{2}} \tag{2.9}$$

Every pool tracks the current tick and LPs invest in price ranges that are limited by ticks.

2.6 Liquidity Provider Rewards

Today we have a range of DEXs which copied Uniswap, like Pancakeswap or Sushsiwap. These new competitors had to find additional features to differentiate themselves from other DEXs.

Staking allows DEXs to promote or to subsidize pools that do not have enough liquidity. A LP contributes liquidity in a pool and receives liquidity provider tokens (LPTs) for their investment. LPTs resemble his share of the liquidity in the liquidity pool. The LP can now deposit his LPTs in another pool (sometimes called farm) and receives further rewards for storing his LPTs there. His LPTs are now staked in the farm. The additional liquidity provider rewards are mostly paid out in the proprietary token of the DEX. For example on Sushiswap the token is Sushi.

On some DEXs one can even further stake the returns of the farm to get voting rights on the DEX. However, this second staking process was not considered in our analysis. In general, we assume that all LPs stake their LPTs, because they guarantee an additional profit.

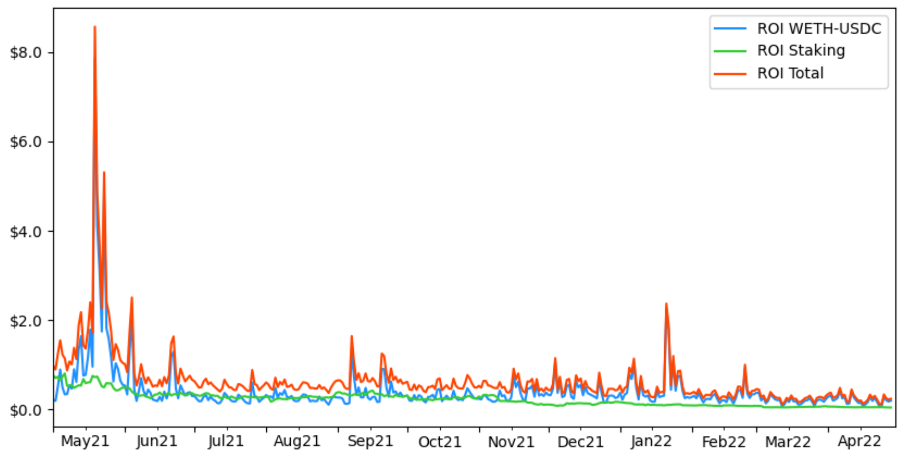
2.6.1 Sushiswap

Sushiswap's *Onsen Menu* allows investors to stake their LPTs in return for Sushi Tokens. Sushi is expected to reach its hard cap in November of 2023 [22]. We focus on the WETH-USDC pool to get some perspective whether staking has an impact on profits of such a volatile pair. According to Etherscan [23] the average blocktime on Etherum since 2021 is $13,23s$. This allows us to estimate 6530 blocks per day. We will use this value to determine returns from staking. Per Etherum block, Sushiswap distributes 100 Sushi towards all farms. The amount of Sushi distributed is constant. To adjust for inflation, with time more Sushi is allocated to a burner pool, which immediately burns the received Sushi. Sushiswap tracks this through *total allocation point (TAP)* which represents all allocation points for all farms. An *allocation point (AP)* stands for the individual pool. The daily allocation point is accessed through the *Master Chef* subgraph of Sushiswap. The fraction of the two determines how many of the 100 Sushi per block is distributed to the WETH-USDC farm. We assume an investment of 1000 USD. To calculate daily returns from staking we apply the following formula:

$$staking\ profit = \frac{1000}{TVL} * \frac{AP}{TAP} * \frac{Sushi}{block} * \frac{blocks}{day} * Sushi\ price \tag{2.10}$$

In figure 2.3, we see that returns from staking used to be higher. Since the inclusion of more pools in the *Onsen Menu* and less Sushi being distributed, returns from staking have gone down.

Figure 2.3: Sushiswap WETH-USDC pool, daily ROI on 1000 USD invstement.



2.6.2 Curve.fi

On Curve [24] our biggest interest was in a big stable pool called *3pool*. Curve has a proprietary token called CRV, which is used to benefit the community (LPs), shareholders, employees and a community reserve [25]. CRV was launched for the first time on 13th of August in 2020. In the first year a total amount of around 1990197 CRV tokens was distributed daily. According to Curve [24] the release schedule for the community (LPs) is as follows:

Table 2.2: CRV Release Schedule.

Period	Daily CRV Release to Community
14.08.2020-13.08.2021	753262
14.08.2021-13.08.2022	633415
14.08.2022-13.08.2023	532637

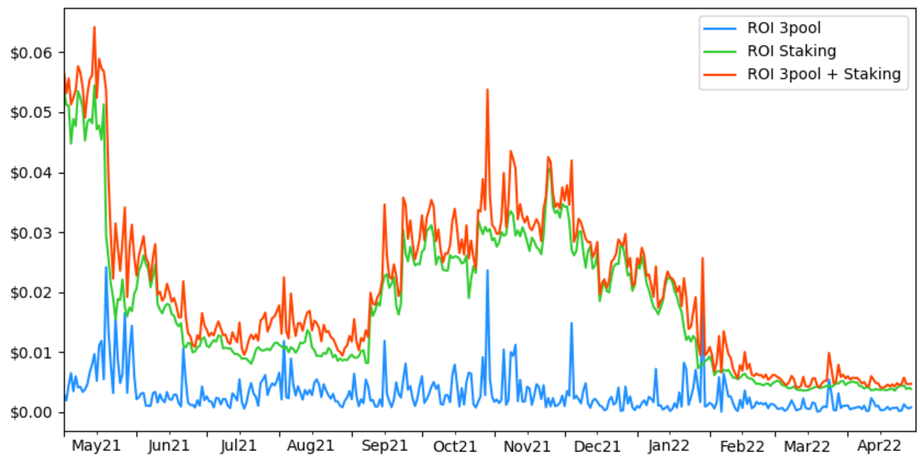
The reduction of daily CRV distributed will continue until a total supply of 3.03B CRV is reached [25][26].

On Curve the community decides how much of CRV is allocated to which pool [27]. This is done in a weekly voting process. In this process *pair gauge weight (PGW)* of each pool is determined. The value of PGW can be accessed through the gauge address in the curve subgraph. Comparing PGW with *total gauge weight (TGW)* gives us the fraction of daily CRV distributed to liquidity pools per individual pool. To calculate the daily returns from staking in the *3pool*[2], we need the price of CRV in USD and TVL of the pool. This then gives us the following equation for an investment of 1000 USD:

$$staking\ profit = \frac{1000}{TVL} * \frac{PGW}{TGW} * daily\ CRV\ amount * CRV\ price \quad (2.11)$$

For the *3pool* we were able to get the results in figure 2.4. It shows how important staking can become when distributed fees are small. Especially, in the Curve *3pool* with a distributed fee of 0.015%, returns from staking brings higher profits then providing liquidity.

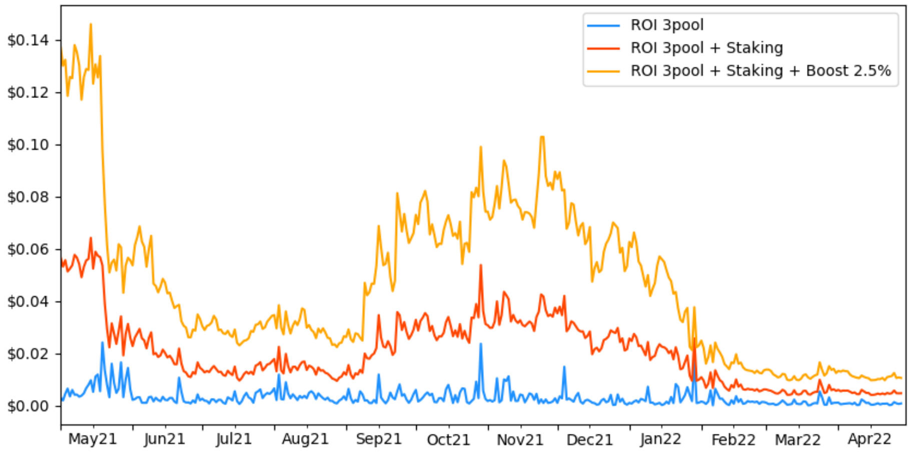
Figure 2.4: Curve.fi *3pool* daily ROI on 1000 USD invstement.



[2]pair address of *3pool*: "0xbebc44782c7db0a1a60cb6fe97d0b483032ff1c7", gauge address of *3pool*: "0xbfcf63294ad7105dea65aa58f8ae5be2d9d0952a"

Additionally, Curve allows investors to stake CRV in return for a boost on their liquidity rewards. In general we will not include the boost for our results. To illustrate the extended possibilities for investors, in figure 2.5 we show returns as if the investor would have applied the 2.5% boost on his 1000 USD daily investment.

Figure 2.5: Curve.fi *3pool* daily ROI on 1000 USD with boosting.



2.6.3 Pancakeswap & Trader Joe

On both Pancakeswap and Trader Joe it is possible to stake LPTs. Pancakeswap yields CAKE tokens. Trader Joe has a variety of staking options. However, in this bachelor's thesis we exclude staking from Pancakeswap and Trader Joe because of the difficulty to get accurate results using *the graph* and lack of documentation. Further, like on Sushiswap not all pairs have a farm. This means staking is sometimes not available for pairs we want to analyze.

Chapter 3

Metrics

Our goal is to compare returns on different DEXs. If we find an efficient market, we would see that returns should be similar. In the following sections we will cover different metrics that describe the market behaviour of the pool. Further, we introduce some metrics for market efficiency.

We do not include impermanent loss in our analysis. Impermanent loss can be significant for investors as has been shown by Heimbach et al. [3] and Aigner and Dhaliwal [5]. Especially in the case of the ETH-USDC pair this should be considered before investing as Ether is volatile. To get accurate results we only compare pools with the same pairs or stable coins, as impermanent loss should then be the same between all pools.

3.1 Overview

All DEXs provide analytical tools to investors[1]. The most common metrics are 24 hour volume and total value locked. These values are useful for estimating returns. On the other side, some DEXs provide information that is misleading. For example Curve provides information on annual percentage yield (APY), which is calculated by only considering the daily performance of a pool. On Curve and Pancakeswap, information on liquidity provider rewards is sometimes misleading. For investors it is therefore important to understand the values which are provided by DEXs.

Because of lack of good information by DEXs several third-party analytic-services provide more detailed information like Dune Analytics [30] or Guillaume Lambert's Yewbow [31] for Uniswap v3.

[1] Uniswap Analytics [28], Sushiswap Analytics [29], Pancakeswap Analytics [14], Curve Analytics [24]

3.2 Return on Investment

The most significant indicator of a successful investment is return on investment (ROI). In our analysis we focus on daily ROI. To compare between different pools and DEXs we ignore the price fluctuations of each token and analyze what happens if we would invest 1000 USD in a pool for a day. Applying the following formula gives us the daily ROI of the pool:

$$daily\ ROI = \frac{1000}{TVL} * distributed\ fee * daily\ volume \tag{3.1}$$

In some pools we also take returns from staking into consideration. In this case we get:

$$daily\ ROI = \frac{1000}{TVL} * distributed\ fee * daily\ volume + staking\ profit \tag{3.2}$$

This method of calculating ROI does not resemble the way an investor would make a profit from liquidity pools. An investor is not likely to only invest for a day due to gas fees. Nevertheless, this method allows us to compare the performance of each pool on a daily basis as well as see trends in the whole market.

3.2.1 Uniswap v3

For Uniswap v3 the simple method of calculating daily ROI, returns the average ROI of that day. However, in v3 users can provide liquidity in limited ranges and therefore have different returns. To allow for a comparison we apply a v2 strategy in v3. This means we invest into v3 pools like we would in Uniswap v2 (over the whole liquidity range). This is not how most investors act, but allows a reasonable comparison between returns in v2 and v3. The smart contract of Uniswap v3 makes it difficult to calculate returns on a daily basis, which is why we approximate our returns as follows.

v2 Strategy

We look at blocks which are separated by an hour and collect the values *feesUSD*, *tick* and *liquidity* from the contract. The difference in *feesUSD* between the two hours lets us derive *hourlyFees* that were distributed. Then it is assumed that the pool stayed within the given *tick* for the whole last hour. We then calculate our own liquidity at that tick. To calculate our own liquidity, we need to know the price of the current tick p_t and we apply equation 2.6:

$$our\ liquidity = \frac{500}{\sqrt{p_t}} \tag{3.3}$$

This can then be put together to derive the hourly profit:

$$hourly\ profit = \frac{our\ liquidity}{liquidity} * hourlyFees \tag{3.4}$$

We can then do this for every hour and get:

$$daily\ ROI = \sum_{i=0}^{23} hourly\ profit \tag{3.5}$$

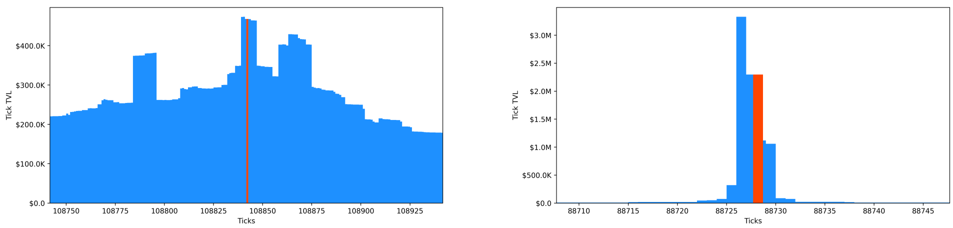
This method is used for all v3 pools. However, for stable pools it returns an unrealistic result. Investing in a stable pool like in v2 makes not much sense.

Average Strategy

As seen in figure 3.1 most liquidity in stable pools is only in a very small range of ticks compared to more volatile pools. If we invest into a stable pool with a v2 strategy, our liquidity would span the whole tick range. However, the range that is used for transaction is a lot smaller.

Figure 3.1: Comparison of the range of liquidity in 0.05% pairs on Uniswap v3. Red bar represents the current tick (02.06.2022).

a) Uniswap v3 ETH-USDC. b) Uniswap v3 USDT-USDC.



Therefore, it can make more sense to look at the average returns instead of the v2 strategy. In some comparisons we apply an average strategy which is calculated as has been shown in equation 3.1. In this case we assume the investor has been investing in a limited range around the current tick.

3.3 Total Value Locked

Total value locked (TVL) is the whole value in USD that LPs have locked in the liquidity pool. It has a direct impact on ROI, as it determines the share of distributed fees an investor receives. Further, pools with a low TVL show that investors are pessimistic to make a profit in this pool.

3.4 Volume

Volume also directly impacts ROI and shows how traders of DEXs are acting. Pools with high volume can be considered as attractive for investors. Additionally, volume can show us the movement between different pools on the same DEX.

3.5 Volatility

Volatility indicates differences in price performance between pools. It is a historical information, which represents fluctuations in price. We always calculate annualized daily volatility. We used Hull's [32] equations for volatility. We define $n + 1$ as number of observations, T_i as the token price at the end of the i-th interval and τ as length of the interval in years. In our analysis we take hourly measurements of the price giving us $\tau = \frac{1}{24*365}$. Let u_i be the change of T_i:

$$u_i = \ln\left(\frac{T_i}{T_{i-1}}\right) \tag{3.6}$$

And the average of u_i given by:

$$\bar{u} = \frac{1}{n}\sum_{i=1}^{n} u_i \tag{3.7}$$

Now we can estimate s as the standard deviation of u_i by calculating:

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(u_i - \bar{u})^2} \tag{3.8}$$

From here we find a daily estimate $\tilde{\sigma}$ of annual volatility σ as follows:

$$\tilde{\sigma} = \frac{s}{\sqrt{\tau}} = \frac{s}{\sqrt{\frac{1}{24*365}}} \tag{3.9}$$

This gives us the daily annual volatility $\tilde{\sigma}$.

3.6 Implied Volatility

To look into the future, we can analyze implied volatility which takes current values to predict market development. Guillaume Lambert who is the creator of Yewbow [31], an analytics tool for Uniswap v3 considers implied volatility an important tool for investors. He writes: *"...knowing the implied volatility should* *also help shape where liquidity is deployed in Uniswap v3 pools."* [33]. We can apply Lambert's formula for Uniswap v3 pools:

$$implied\ volatility = 2 * distributed\ fee * \sqrt{\frac{daily\ volume}{tick\ TVL}} \tag{3.10}$$

Where $tick\ TVL$ is the TVL at the current tick. For comparison we construct a similar formula for Uniswap v2 pools:

$$implied\ volatility = 2 * distributed\ fee * \sqrt{\frac{daily\ volume}{TVL}} \tag{3.11}$$

3.7 Monthly Divergence

Monthly divergence is a table to compare pools and get results on market efficiency. The idea is to show how much more returns could have been made if LPs would have invested in a different pool. First, for each comparison we define the pools to be analyzed, for example pool A and pool B. We then calculate the average returns between the pools with ROI_i and TVL_i the daily return on investment and daily total value locked as follows:

$$ROI_{average} = \frac{ROI_A * TVL_A + ROI_B * TVL_B}{TVL_A + TVL_B} \tag{3.12}$$

Then for each pool we calculate the divergence from average and sum it up over a month to get a numerical value in USD:

$$(monthly\ divergence)_A = \sum_{month} (ROI_A - ROI_{average}) * TVL_A \tag{3.13}$$

Monthly divergence shows whether a pool under- or over-performed compared to average. If we see high negative numbers we can conclude that investors in this pool could have made higher returns in other pools. Further, in an efficient market we would expect all pools to have similar returns.

The results we get from monthly divergence have to be put in to context of the whole returns in this month and not just compared to average returns. Therefore, we calculate a percentage, which looks only at the pools that outperformed average returns and put this into context with the total fees of all pools in that month. Let us assume we have three pools A, B and C. To calculate the percentage we first have to find the total positive monthly divergences as follows:

$$total\ positive\ divergence = \frac{\sum_{i \in \{A,B,C\}} |(monthly\ divergence)_i|}{2} \tag{3.14}$$

Next, we need the total fees of all pools over the whole month:

$$total\ fees = \sum_{month} ROI_A * TVL_A + ROI_B * TVL_B + ROI_C * TVL_C \tag{3.15}$$

This allows to get the percentage:

$$percentage = \frac{total\ positive\ divergence}{total\ fees} \tag{3.16}$$

3.8 Investors

To give some insight into who is providing liquidity, investors are separated into three categories in table 3.1:

Table 3.1: Type of investor.

investor	investment i in USD
small investor	$1 \leq i < 10,000$
middle investor	$10,000 \leq i < 100,000$
big investor	$100,000 \leq i$

To get data on investors we look at each individual position. A position represents the investment by a LP in the smart contract. Each position can be translated into a value in USD and then categorized into small, middle and big investors. This allows us to track who is actually providing liquidity and how different types of investors are reacting to market developments.

Additionally, we can calculate adaption rates depending on the type of investor. The adaption rate is given by looking at the TVL of two pools. For example we have pool A and pool B. Let's assume pool A has existed for longer and pool B was just launched recently. We would like to know whether investors are shifting their liquidity towards pool B. The adaption rate is given by:

$$adaption\ rate = \frac{TVL_B}{TVL_A + TVL_B} \tag{3.17}$$

This can be done for all types of investors and indicate how the respective investors adapt.

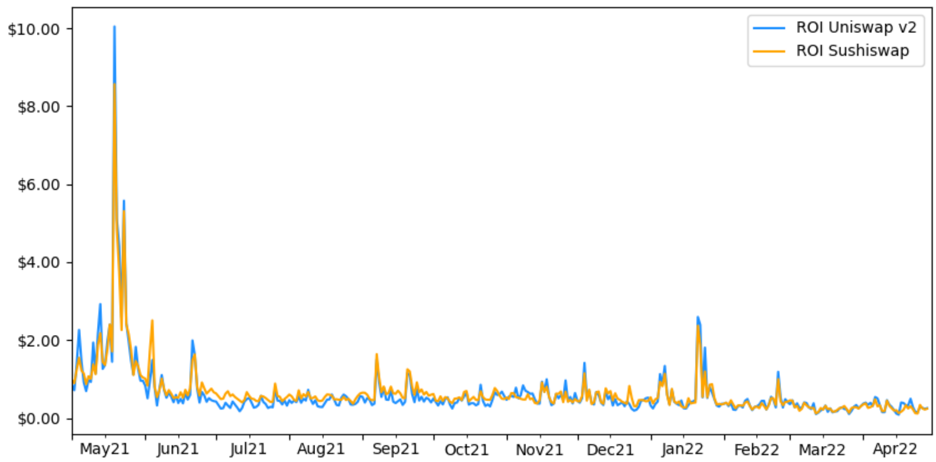
Chapter 4

Results

4.1 Uniswap v2 and Sushiswap on Etherum

First we have a look at Sushiswap and Uniswap v2 and compare the profits over a year of the ETH-USDC pool in figure 4.1.

Figure 4.1: Comparison of returns on 1000 USD investment in ETH-USDC pool on Uniswap v2 and Sushiswap (with Staking).



The returns of both pools have reduced significantly since May 2021. The reason for this development is the introduction of Uniswap v3 on May 5th 2021. This could also have caused the spike in that period, because a lot of trades occurred. After May the two pools have become more similar in terms of returns. Annual returns of both pools are very similar. Sushiswap returned 23.78% and Uniswap 22.5% for a 1000 USD daily investment. Further, in table 4.1 below, we show how the returns on a monthly basis have diverged from the calculated average.

Table 4.1: Monthly divergence in USD of the total pool returns of ETH-USDC pair on Sushiswap (with Staking) and Uniswap v2 compared to average.

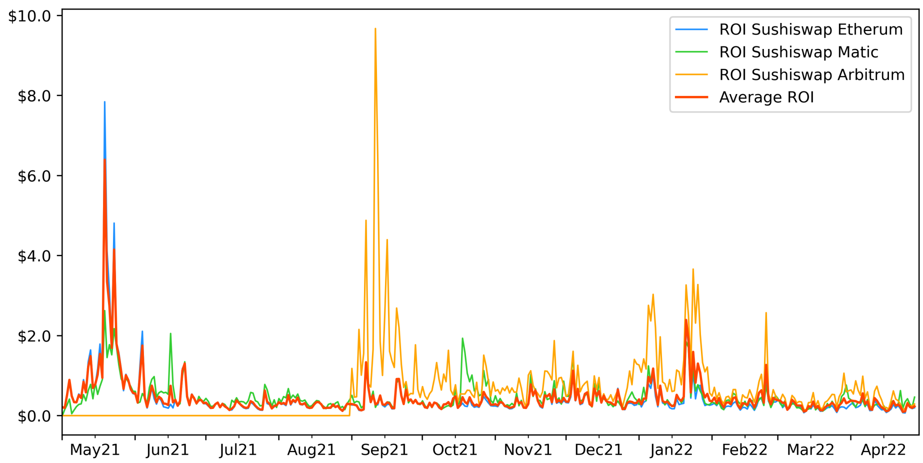
Pool	May21	Jun21	Jul21	Aug21	Sep21	Oct21
Sushiswap	-607,397	689,973	827,707	430,120	566,593	366,651
Uniswap v2	607,397	-689,973	-827,707	-430,120	-566,593	-366,651
Percentage	1.4%	4.5%	9%	4.2%	4.8%	3.8%
	Nov21	Dec21	Jan21	Feb21	Mar21	Apr22
Sushiswap	-210,057	192,452	-89,510	-23,278	8,642	-124,852
Uniswap v2	210,057	-192,452	89,510	23,278	-8,642	124,852
Percentage	2.1%	2.5%	1%	0.5%	0.3%	3.5%

The two markets have normalized over the analyzed year. The monthly divergence reduced from several hundred thousands in May 2021 to some thousand USD in March 2022. For the future we would assume these numbers to become lower as the efficiency in the market increases and more traders switch to Uniswap v3.

4.2 Sushiswap on different chains

Some DEX's are now available on different blockchains. This increases competition between exchanges but also brings uncertainty for investors. Sushiswap was originally only present on Etherum but has expanded to more blockchains like Avalanche, Arbitrum and Matic. Staking is not available on all blockchains, which is why we exclude profits from LPTs in this section. Additionally, Avalanche has only been used negligibly and is therefore excluded. The following figure 4.2 shows the profits from Sushiswap ETH-USDC liquidity pools on different blockchains.

Figure 4.2: Comparison of daily returns on 1000 USD investment in ETH-USDC pool on different blockchains on Sushiswap (without Staking).



To illustrate market efficiency we again have a look at the monthly divergence. Table 4.2 shows how the Sushiswap markets have developed.

Table 4.2: Monthly divergence in USD of the total pool returns compared to average in Sushiswap ETH-USDC pair on different blockchains.

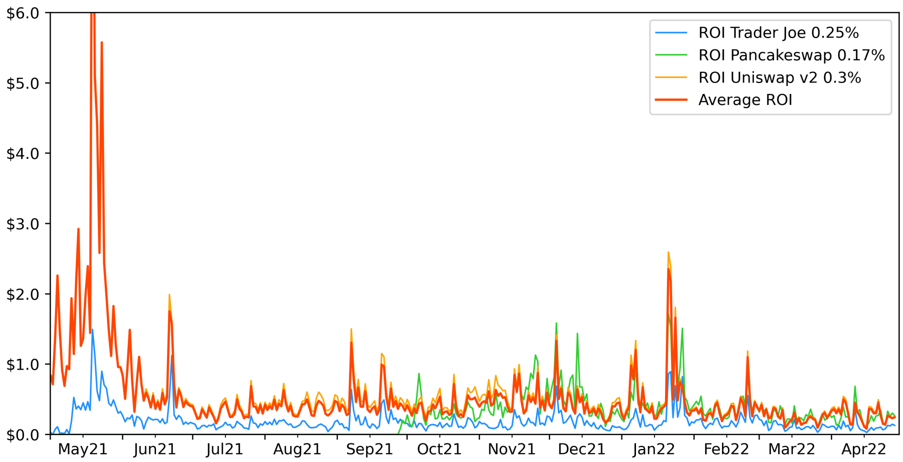
Pool	May21	Jun21	Jul21	Aug21	Sep21	Oct21
Etherum	1,473,446	-235,339	-185,445	-132,287	-175,940	-413,227
Arbitrum	-	-	-	-	136,442	99,791
Matic	-1,473,446	235,339	185,445	132,287	39,498	313,435
Percentage	8.1%	2.8%	5.3%	3.2%	3.5%	9.2%
	Nov21	Dec21	Jan22	Feb22	Mar22	Apr22
Etherum	-269,551	-206,422	-1,043,275	-581,047	-312,775	-311,488
Arbitrum	189,468	143,629	1,092,133	604,574	315,966	300,378
Matic	80,083	62,793	-48,859	-23,526	-3,191	11,110
Percentage	6.1%	4.8%	16.9%	16.3%	12.9%	15.2%

This data shows that returns from Sushiswap markets are still volatile. Especially, the data from January 2022 indicates that divergence might be increasing in the future. For investors this can be a great opportunity as investing in the right pool will bring higher returns. On the other hand, this also indicates a lot of risk as it is unclear which markets will return the highest profits. Finally, these numbers need to be taken with a grain of salt since liquidity provider rewards are not considered.

4.3 Pancakeswap and Trader Joe

Pancakeswap is running on the Binance blockchain and Trader Joe runs on Avalanche. In this section we compare ROI from Pancakeswap (ETH-USDC) and Trader Joe (WETH.e-USDC.e) with Uniswap v2 (ETH-USDC). The comparison illustrates the diversity of DEXs. In figure 4.3 results from the three pools are shown.

Figure 4.3: Comparison of daily returns on 1000 USD investment in ETH-USDC pools on Trader Joe (without staking), Pancakeswap (without staking) and Uniswap v2.



Unsurprisingly, Uniswap v2 has the the highest returns. But the results also show, that towards the end of the analyzed year, Pancakeswap is becoming more attractive. Further, because staking is not included we can assume that returns on Trader Joe and Pancakeswap will be slightly higher than in our data. As for the market as a whole, these results provide evidence that good returns are also possible on smaller DEXs like Pancakeswap. Similar conclusions can be drawn from monthly divergence which is shown inn table 4.3. We see that Trader Joe sometimes outperformed the average, which shows that small pools can potentially be profitable for investors.

Table 4.3: Monthly divergence in USD Trader Joe (without staking), Pancakeswap (without staking) and Uniswap v2.

Pool	May21	Jun21	Jul21	Aug21	Sep21	Oct21
Trader Joe	-	-	-	-	-2,807	-20,576
Pancakeswap	-205	-197,223	-303,956	-448,824	-525,934	-451,665
Uniswap v2	205	197,223	303,956	448,824	528,742	472,241
Percentage	0%	3.8%	9.3%	1.2%	13.4%	14.4%
	Nov21	Dec21	Jan22	Feb22	Mar22	Apr22
Trader Joe	2,203	26,061	-9,963	3,294	2,487	-2,577
Pancakeswap	-583,924	-285,382	-347,571	-154,016	-101,175	-143,587
Uniswap v2	581,721	259,320	357,534	150,722	98,688	146,164
Percentage	13%	7.7%	8%	6.3%	5.8%	6.7%

4.4 Stable Pools

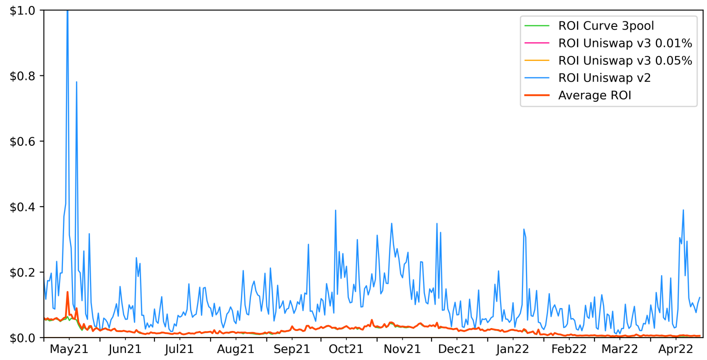
4.4.1 Development of Stable Pools

Stable pools are an easy way for inexperienced investors to enter the liquidity provider market. Most stable pools use USD as backing for all tokens in the pool. They therefore provide a low risk investment opportunity as there will be no impermanent loss compared to USD. The market for stable pools is very diverse with some additional DEXs playing an important role such as Curve. In our comparison we include the *3pool* from Curve which is composed of DAI, USDT and USDC. We compare it with a variety of newer and older pools from Uniswap as well as Sushiswap. In figure 4.4 profits from both the v2 and average strategy in Uniswap v3 are shown.

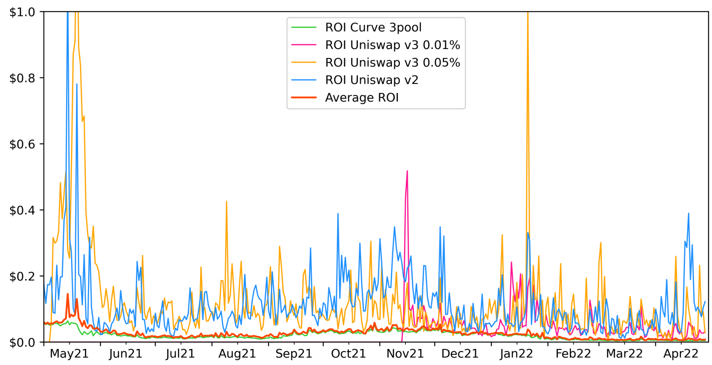
Looking only at the average strategy we calculate annual returns for all four pools. The most profitable pool is Uniswap v3 pool with a distributed fee of 0.05% which returned 4.44% in the analyzed period. Closely behind is the Uniswap v2 pool with an annual return of 4.15%. The v3 pool with a distributed fee of 0.01% returned 0.95% but was launched later. Curve had an annual return of 0.75%.

Figure 4.4: Comparison of USDT-USDC stable pools and 3pool.

a) Daily returns on 1000 USD investment of Curve (with Staking), Uniswap v2, Uniswap v3 (v2 strategy) and volume adjusted average. Uniswap v3 pools are not visible because their returns in the v2 strategy are very low.



b) Daily returns on 1000 USD investment of Curve (with Staking), Uniswap v2, Uniswap v3 (average strategy) and volume adjusted average.



c) Daily pool volumes in USD.

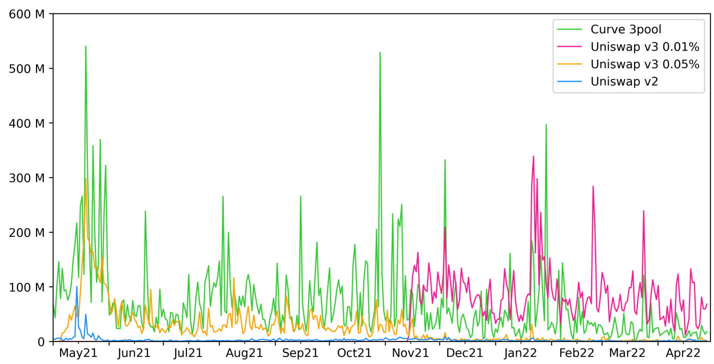


Figure 4.4 shows that the *3pool* is dominating this market. This is illustrated by the volume comparison in figure 4.4 c). Traders on DEXs prefer pools which have low fees, as is the case on Curve and the newer Uniswap v3 pools. The introduction of the v3 0.01% pool took away almost all trade volume from the v3 0.05% pool. In a nutshell, we will likely see more low fee pools emerging on DEXs, which will make it more difficult for investors to receive high fees. Nevertheless, it is still possible to make slightly higher returns by choosing Uniswap v2 which has lower volume but high distributed fees. The monthly divergence of the four pools is given in table 4.4.

Table 4.4: Monthly divergence in USD of the total pool returns compared to average in Uniswap v2 (USDC-USDT), Uniswap v3 (USDC-USDT, Average) and *3pool* (USDC-USDT-DAI) on Curve.

Pool	May21	Jun21	Jul21	Aug21	Sep21	Oct21
Curve 3pool 0.03%	-1,914,590	-608,336	-385,851	-573,724	-576,344	-457,034
Uniswap v3 0.01%	-	-	-	-	-	-
Uniswap v3 0.05%	1,116,099	506,137	293,416	419,806	399,252	254,864
Uniswap v2 0.3%	798,491	102,200	92,435	153,917	177,092	202,171
Percentage	27.3%	22%	21.2%	27.1%	20.7%	12.1%
	Nov21	Dec21	Jan22	Feb22	Mar22	Apr22
Curve 3pool 0.03%	-569,993	-294,903	-411,821	-281,500	-294,478	-275,811
Uniswap v3 0.01%	78,421	109,194	215,747	180,513	196,898	127,928
Uniswap v3 0.05%	173,004	25,780	60,698	27,838	30,630	26,454
Uniswap v2 0.3%	318,568	159,929	135,376	73,149	66,950	121,429
Percentage	13.7%	8.6%	15.6%	25.9%	32.2%	33.6%

4.4.2 Extended Stable Pool Comparison

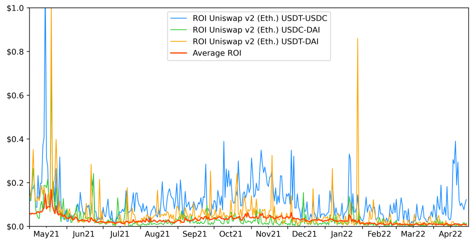
In the extended stable pool comparison we compare 22 pools that contain only stable pools pegged to USD. All pools contain USDT, USDC or DAI. The pools run on five different blockchains: Etherum, Arbitrum, Optimism, Matic (Polygon) and Binance. Most pools were launched in the last year. We show returns in figure 4.5 and monthly divergence in table 4.5.

The results show that the choice of investment opportunities for stable pools lead to very different returns depending on pool. First, the average return is heavily influenced by Curve. This weakens the results, because we do not include all returns from Curve. It could be that with boosting, returns from Curve are higher in reality. Second, some blockchains have similar results in most pools like for Uniswap v3 on Etherum as can be seen in 4.5 b). In other cases, like on Uniswap v3 on Arbitrum, returns vary a lot between pools. This indicates market inefficiencies. On Arbitrum where all pools have a distributed fee of 0.05% we would expect similar returns for all stable pools. Third, comparing the results from all pools together it is likely that investors do not have all necessary information to select the best investment. This is most likely due to the young market. New pools are launched on a regular basis and the market is constantly adapting to these changes, as can been in all the spikes in figure 4.5.

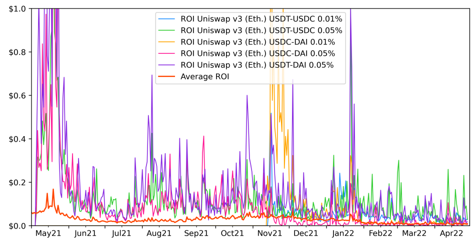
The highest annual returns were made in Uniswap v3 on Arbitrum, despite the late launch in fall. The USDT-DAI 0.05% pool annually returned 17.11%. Followed by USDT-USDC 0.05% pool with an annual return of 10.04%.

Figure 4.5: Extended comparison of stable pools. We calculate daily returns on 1000 USD investment. For Uniswap v3 pools we use the average Strategy. For Sushiswap and Pancakeswap we display results without staking. For Curve staking is included.

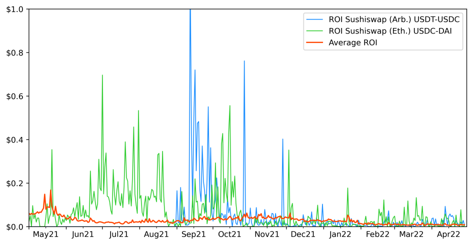
a) Uniswap v2



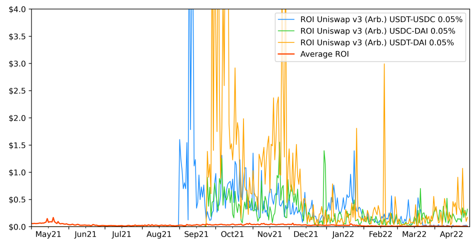
b) Uniswap v3 (Eth.)



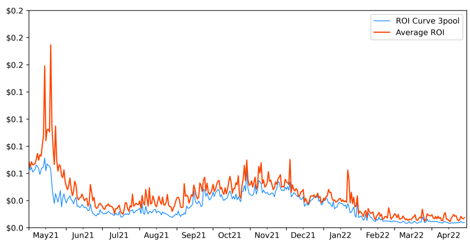
c) Sushiswap



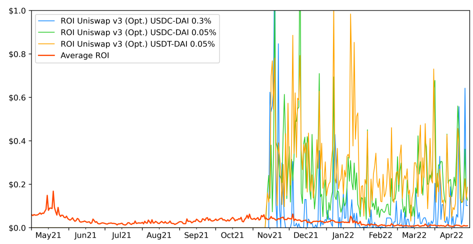
d) Uniswap v3 (Arb.)



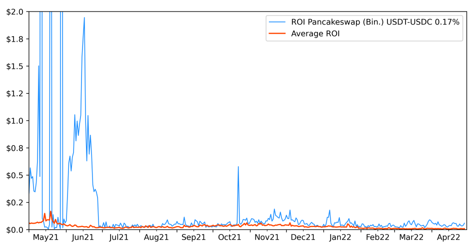
e) Curve



f) Uniswap v3 (Opt.)



g) Pancakeswap



h) Uniswap v3 (Mat.)

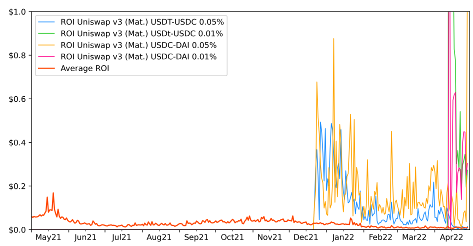


Table 4.5: Monthly divergence in USD of the total pool returns compared to average for all stable pools.

DEX	Pair	Fee	May21	Jun21	Jul21	Aug21	Sep21	Oct21
Uni. v2	USDT-USDC	0.3	758,043	92,964	88,818	145,631	167,874	195,464
Uni. v2	USDC-DAI	0.3	52,242	13,882	4,709	-18,392	-2,942	-19,284
Uni. v2	USDT-DAI	0.3	51,363	8,899	3,077	5,362	6,402	6,835
Sushiswap(Arb.)	USDT-USDC	0.25	-	-	-	-	83	24
Sushiswap(Eth.)	USDC-DAI	0.25	-93	171	534	302	70	399
Uni. v3(Eth.)	USDT-USDC	0.01	-	-	-	-	-	-
Uni. v3(Eth.)	USDT-USDC	0.05	1,087,860	480,886	283,752	403,651	382,271	239,942
Uni. v3(Eth.)	USDC-DAI	0.01	-	-	-	-	-	-
Uni. v3(Eth.)	USDC-DAI	0.05	515,548	302,969	122,930	270,718	266,200	245,462
Uni. v3(Eth.)	USDT-DAI	0.05	300,875	96,942	48,848	111,920	96,210	81,793
Uni. v3(Arb.)	USDT-USDC	0.05	-	-	-	-	7,683	11,293
Uni. v3(Arb.)	USDC-DAI	0.05	-	-	-	-	42	1,457
Uni. v3(Arb.)	USDT-DAI	0.05	-	-	-	-	10	2,770
Uni. v3(Opt.)	USDC-DAI	0.3	-	-	-	-	-	-
Uni. v3(Opt.)	USDC-DAI	0.05	-	-	-	-	-	-
Uni. v3(Opt.)	USDT-DAI	0.05	-	-	-	-	-	-
Uni. v3(Mat.)	USDT-USDC	0.05	-	-	-	-	-	-
Uni. v3(Mat.)	USDT-USDC	0.01	-	-	-	-	-	-
Uni. v3(Mat.)	USDC-DAI	0.05	-	-	-	-	-	-
Uni. v3(Mat.)	USDC-DAI	0.05	-	-	-	-	-	-
Pancakeswap	USDT-USDC	0.17	1,095	6,788	39,848	49,070	60,273	74,788
Curve	3pool	0.015	-2,766,933	-1,003,500	-592,516	-968,260	-984,176	-840,943
Percentage			34%	30%	26.9%	35.9%	28.5%	19.1%

DEX	Pair	Fee	Nov21	Dec21	Jan22	Feb22	Mar22	Apr22
Uni. v2	USDT-USDC	0.3	313,515	156,393	129,356	71,610	65,136	119,832
Uni. v2	USDC-DAI	0.3	-47,448	-30,472	14,387	271	-3,282	4,517
Uni. v2	USDT-DAI	0.3	5,146	347	7,788	3,032	1,477	867
Sushiswap(Arb.)	USDT-USDC	0.25	-3	-19	-7	-1	0	1
Sushiswap(Eth.)	USDC-DAI	0.25	-48	7	-8	7	15	5
Uni. v3(Eth.)	USDT-USDC	0.01	74,560	100,781	199,285	175,134	189,185	119,197
Uni. v3(Eth.)	USDT-USDC	0.05	165,488	24,237	59,125	27,453	30,116	25,781
Uni. v3(Eth.)	USDC-DAI	0.01	51,268	95,810	125,573	-15,144	10,792	455
Uni. v3(Eth.)	USDC-DAI	0.05	47,475	-50,915	6,337	-694	-2,450	6,552
Uni. v3(Eth.)	USDT-DAI	0.05	77,354	44,681	58,025	27,089	15,594	7,246
Uni. v3(Arb.)	USDT-USDC	0.05	9,179	6,104	15,702	11,530	10,153	2,946
Uni. v3(Arb.)	USDC-DAI	0.05	1,723	1,839	6,781	4,691	2,953	3,082
Uni. v3(Arb.)	USDT-DAI	0.05	2,152	1,951	315	791	219	589
Uni. v3(Opt.)	USDC-DAI	0.3	1,815	-128	393	27	192	780
Uni. v3(Opt.)	USDC-DAI	0.05	4,404	15,451	14,343	9,131	12,962	17,490
Uni. v3(Opt.)	USDT-DAI	0.05	9,432	9,798	10,017	7,095	7,770	7,020
Uni. v3(Mat.)	USDT-USDC	0.05	-	4,090	24,068	12,762	7,619	6,530
Uni. v3(Mat.)	USDT-USDC	0.01	-	-	-	-	-	1,701
Uni. v3(Mat.)	USDC-DAI	0.05	-	1,156	4,788	3,384	3,863	4,726
Uni. v3(Mat.)	USDC-DAI	0.05	-	-	-	-	-	733
Pancakeswap	USDT-USDC	0.17	105,545	67,837	60,219	35,450	57,721	79,105
Curve	3pool	0.015	-821,556	-449,152	-736,487	-373,619	-410,035	-409,156
Percentage			17.8%	13.5%	22.5%	28.4%	34.6%	36.9%

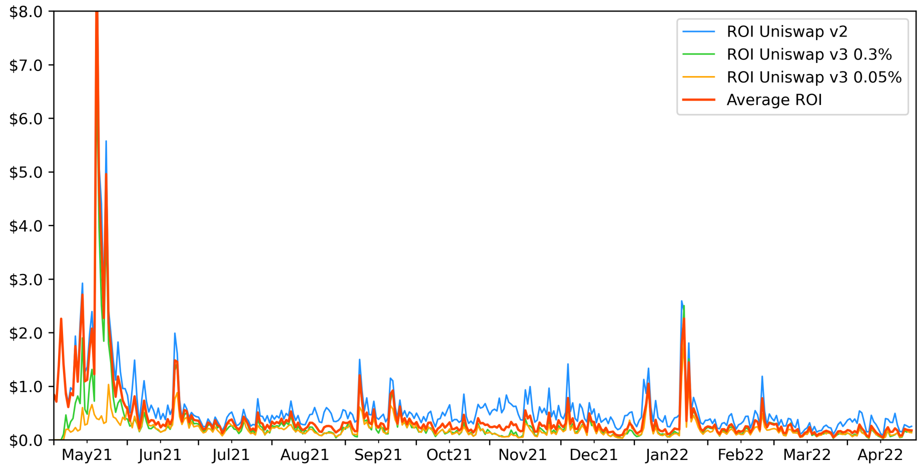
4.5 Uniswap

Uniswap is one of the biggest DEXs in the world of DeFi with over 20 billion USD locked [1]. Because Uniswap is the biggest DEX and Uniswap v3 has brought big changes, we will make a range of comparisons in the next sections.

4.5.1 v2 and v3

To analyze this market we compare the returns from v2 and v3 in the USDC-ETH pool. To allow for some comparison we try to emulate investing in the v3 pool like it would be a v2 pool by using the v2 strategy. On Uniswap version 3, we have two pools with a 0.3% and 0.05% distributed fee respectively. The returns are shown in figure 4.6 and monthly divergence is given in table 4.6.

Figure 4.6: Comparison of daily returns on 1000 USD investment in ETH-USDC pools on Uniswap v2 and v3 (v2 Strategy) to volume adjusted average.



The results show a fast adaption of Uniswap v3 from May to June 2021. The market shifted from v2 with 0.3% distributed fee to the v3 pool with a 0.3% distributed fee. It took a while until traders started using the v3 pool with a 0.05% distributed fee, which can be observed in the monthly divergence. Interestingly, the older v2 pool still makes higher returns than newer v3 pools. One would except that traders prefer the pool with the lowest fee, in our case the 0.05% pool. Therefore, the difference between v2 0.3% and v3 0.05% pools, shows that some traders are not acting in the most efficient way. It is difficult to find an explanation for this discrepancy. One reason could be that other DeFi applications use Uniswap v2 in their smart contract and have not been updated since the introduction of v3. Although returns in v2 are lower in April 2022 than in June 2021, this market inefficiency can still be exploited by investors.

Table 4.6: Monthly divergence in USD of the total pool returns compared to average in ETH-USDC pools on Uniswap v2 and v3 (v2 Strategy).

Pool	May21	Jun21	Jul21	Aug21	Sep21	Oct21
v3 0.3%	-1,987,680	-1,456,344	-480,668	-802,260	-698,935	-868,501
v3 0.05%	-42,721	-139,541	-226,190	-437,688	-349,678	-384,635
v2 0.3%	2,030,401	1,595,885	706,859	1,239,948	1,048,613	1,253,136
Percentage	8.5%	17.3%	13.1%	20.2%	14.3%	24.1%
	Nov21	Dec21	Jan22	Feb22	Mar22	Apr22
v3 0.3%	-1,228,010	-841,171	-594,707	-245,190	-217,124	-581,489
v3 0.05%	-976,394	-669,996	-847,748	-550,773	-367,265	-412,571
v2 0.3%	2,204,404	1,511,166	1,442,455	795,963	584,389	994,060
Percentage	34.8%	21.5%	14.4%	14.4%	13.4%	23.1%

4.5.2 ETH-USDC in v3

A deeper focus was given to ETH-USDC pool throughout this whole bachelor's thesis. The following results focus on Uniswap v3.

Different Blockchains

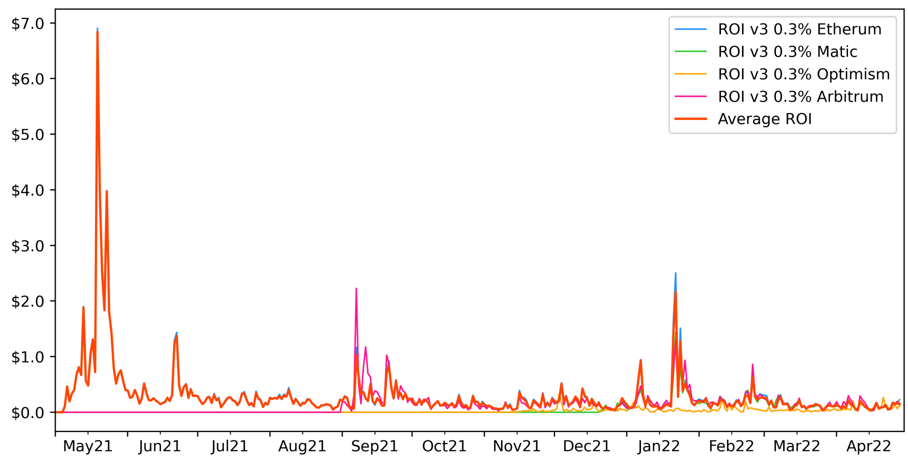
We have a look at the performance of ETH-USDC pools in Uniswap v3 on four different blockchains. Since September 2021 Uniswap v3 is available on Arbitrum and later in the fall it was launched on Matic and Optimism. The returns are shown in figure 4.7. In table 4.7 monthly divergence is displayed.

The results indicate a higher return for 0.3% pools at the beginning of the year. However returns are slowly getting higher in the 0.05% pool. On Etherum this is seen in April 2022, where for the first time the 0.05% pool is performing above average and the 0.3% pool below average. Difference in returns between 0.3% and 0.05% pools on Etherum are studied in depth in section 4.5.2.

All pools except for pools on Optimism have very similar returns. This is a good sign for market efficiency. It shows that investors as well as traders operate similarly on different blockchains and therefore the difference between blockchains does not have a significant impact on returns on Uniswap v3.

Figure 4.7: ETH-USDC in v3 on Etherum, Arbitrum, Matic and Optimism.

a) Daily returns on 1000 USD investment in Uniswap v3 (v2 Strategy) 0.3% ETH-USDC pools on different block chains and compared to volume adjusted average of all v3 ETH-USDC pools.



b) Daily returns on 1000 USD investment in Uniswap v3 (v2 Strategy) 0.05% ETH-USDC pools on different block chains and compared to volume adjusted average of all v3 ETH-USDC pools.

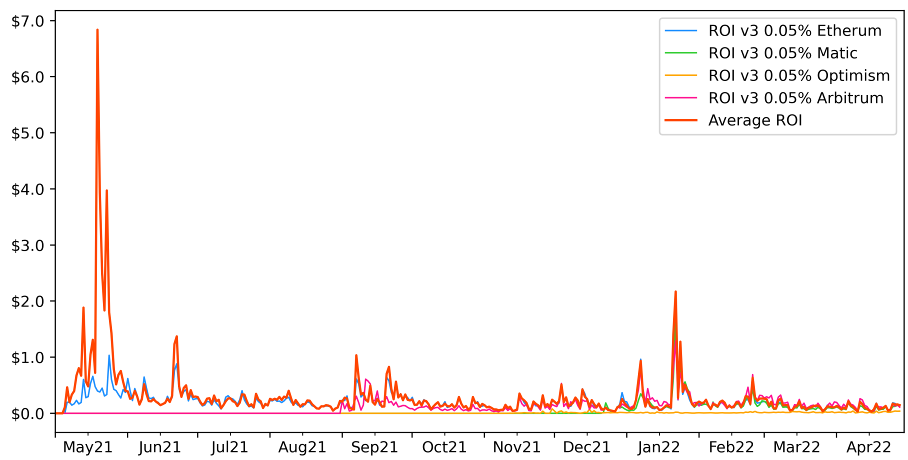


Table 4.7: Monthly divergence in USD of the total pool returns compared to average in ETH-USDC pools on Uniswap v3 (v2 Strategy) on different block chains. We look at Etherum (Eth.), Matic (Mat.), Optimism (Opt.) and Arbitrum (Arb.).

Pool	May21	Jun21	Jul21	Aug21	Sep21	Oct21
0.3% Eth.	24,782	45,961	49,086	88,860	71,257	21,097
0.3% Mat.	-	-	-	-	-	-
0.3% Opt.	-	-	-	-	-	-
0.3% Arb.	-	-	-	-	19,188	-3,579
0.05% Eth.	-24,782	-45,961	-49,086	-88,860	-89,467	5,722
0.05% Mat.	-	-	-	-	-	-
0.05% Opt.	-	-	-	-	-	-
0.05% Arb.	-	-	-	-	-977	-23,241
Percentage	0.5%	1.1%	2.1%	3.3%	2.4%	1.1%
	Nov21	Dec21	Jan22	Feb22	Mar22	Apr22
0.3% Eth.	130,226	101,912	274,989	207,569	118,198	-1,638
0.3% Mat.	-	68	-8,959	-118	245	-368
0.3% Opt.	-3,345	-4,478	-12,835	-7,511	-6,931	-1,467
0.3% Arb.	-2,815	-2,576	-3,642	2,997	1,281	2,644
0.05% Eth.	-98,125	-73,404	-222,393	-194,127	-113,343	3,739
0.05% Mat.	-	-92	-17,755	-11,232	-14,122	-11,456
0.05% Opt.	-173	-869	-1,372	-618	-500	-1,526
0.05% Arb.	-25,768	-20,562	-8,033	3,041	15,173	10,072
Percentage	5.7%	2.7%	4.5%	6.1%	4.6%	0.7%

Different Fees

The ETH-USDC pair in Uniswap v3 on Etherum in May 2022 is available in all distributed fee options of v3: 1%, 0.3%, 0.05% and 0.1%. We compare return on investment in all four pools on Etherum with the v2 strategy in figure 4.8.

The results show how the 0.3% pool and 0.05% are the most used pools. Despite the 1% pool not seeing regular volume, when swaps happen within the pool, returns are high. This explains some of the spikes in November and December. In table 4.8 our results show that the four pools perform similar, except when the 1% pool performs well. The results from the 0.3% and 0.05% pool allow us to show development in the market. The 0.5% made a higher profit in April 2022 than the 0.3%. In the next comparison we will go into a deeper analysis of the two most used pools.

Figure 4.8: Comparison of daily returns on 1000 USD investment in ETH-USDC pools on Uniswap v3 (v2 Strategy) to volume adjusted average.

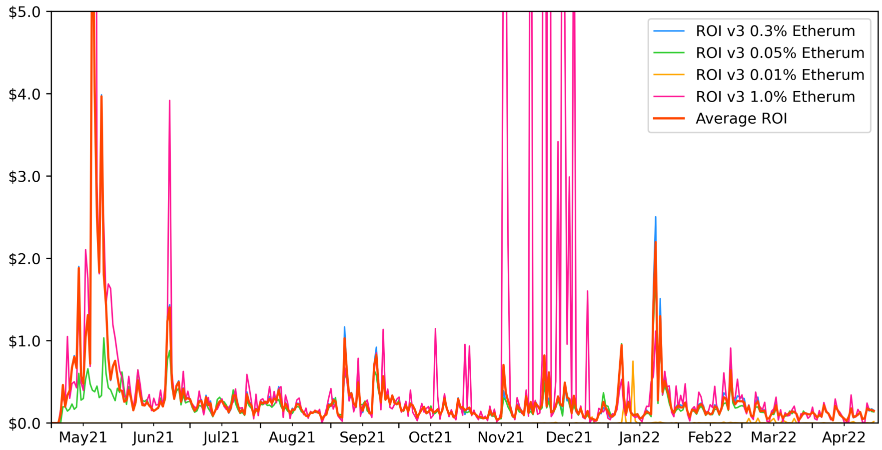


Table 4.8: Monthly divergence in USD of the total pool returns compared to average in ETH-USDC pools on Uniswap v3 (v2 Strategy) with different distributed fees on Etherum (Eth.).

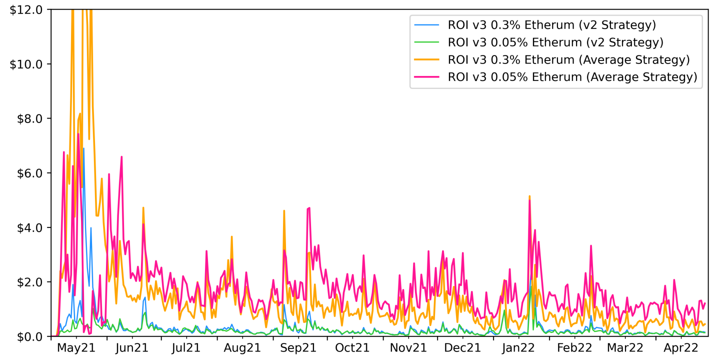
Pool	May21	Jun21	Jul21	Aug21	Sep21	Oct21
1.0% Eth.	19,925	18,903	2,432	1,662	-575	7,302
0.3% Eth.	4,975	29,085	47,349	87,650	85,394	-2,298
0.05% Eth.	-24,900	-47,988	-49,781	-89,312	-84,819	-5,003
0.01% Eth.	-	-	-	-	-	
Percentage	0.5%	1.2%	2.1%	3.3%	2.3%	0.3%
	Nov21	Dec21	Jan22	Feb22	Mar22	Apr22
1.0% Eth.	352,516	704,954	-17,435	24,805	4,347	3,465
0.3% Eth.	-97,527	-354,499	255,462	185,970	112,904	-5,066
0.05% Eth.	-252,813	-350,439	-237,704	-210,714	-117,177	1,689
0.01% Eth.	-2,176	-16	-322	-61	-73	-88
Percentage	13.1%	15.8%	4.3%	6.2%	4.2%	0.2 %

0.3% and 0.05%

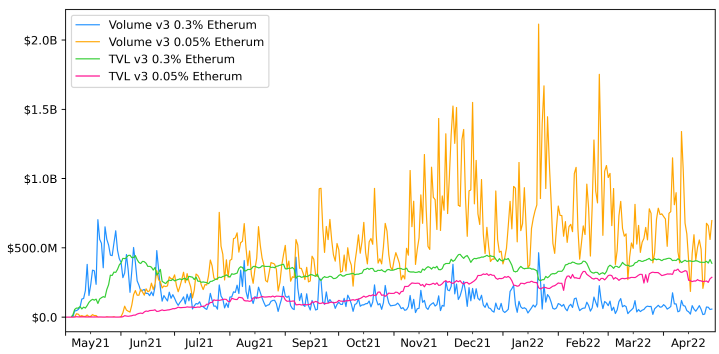
The ETH-USDC 0.3% and 0.05% pools in v3 have some of the highest daily volumes and TVL of all pools on Uniswap v3. Since their launch they have replaced the 0.3% pool on Uniswap v2. An interesting question is, which pool has performed better in the analyzed period. Our results are inconclusive but show some trends in the market. In figure 4.9 a) ROI of both the v2 strategy and the average strategy are shown. As expected the average strategy yields a higher profit for both pools. But the v2 strategy was more profitable in the 0.3% pool. This is not the case for average strategy, as the 0.05% pool constantly outperformed the 0.3% pool. This indicates that for most investors the 0.05% pool will be the better option as they provide liquidity in a limited range and their returns will be closer to the average strategy than the v2 strategy.

Figure 4.9: ETH-USDC in v3.

a) Daily returns on 1000 USD investment in Uniswap v3 (v2 Strategy and Average Strategy) ETH-USDC pools with 0.3% and 0.05% distributed Fees.



b) Daily Volume and TVL of 0.3% and 0.05% ETH-USDC pools in Uniswap v3 on Etherum.



Because of the difference between the two strategies, one can look at alternative metrics to get insights into the market. In figure 4.9 b) we show volumes and TVL of both pools. The results indicate a general preference in the 0.05% pool by traders of Uniswap. It is not surprising as they have to pay a lower fee to swap tokens in this pool. We reveal that the TVL of both pool has become very similar in recent months. If the TVL is the same, the 0.05% pool will make higher returns in the average strategy if it sees six-times more volume than the

0.3% pool. As we saw in table 4.8, April 2022 marked the first month where the 0.05% outperformed the 0.3% pool with the v2 strategy. Finally, these results indicate the difficulty of investing in Uniswap v3. It is not always clear which strategy performs best and for example high changes in daily volume can make predictions uncertain.

4.6 Liquidity Providers in Uniswap v3

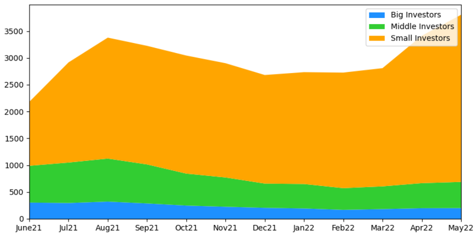
One question regarding DeFi applications is how decentralized they are. In this section we show who is providing liquidity on Uniswap v3 on Etherum. We separate liquidity positions in the smart contract into the three categories: small, middle and big (from table 3.1). We exclude positions that are below 1 USD.

In figure 4.10 results from four pools on Uniswap v3 are shown. Sub-figures a), c), e) and g) show how many investors of which category are providing liquidity to the pool. The results indicate that big and middle investors are reacting more to the market then small investors. This can be see in plot 4.10 a): In June 2021 the pool had 303 big LPs, but because of lower returns in the 0.3% pool, liquidity was shifted such that in May 2022 only 200 big LPs were left in the pool. On the other hand, the number of small investors grew from 1192 in June 2021 to 3115 in May 2022. Most likely big investors moved their liquidity to the 0.05% pool. It saw growth of big investors from 2 in June 2021 to 151 in May 2022. Similar observations can be made for the two USDT-USDC pools. Therefore we see the expected market adaption in middle and big LPs but not with small investors. This is further illustrated by the adaption rates in figure 4.11. It shows how much TVL of both pools is applied in the 0.05% pool. The adaption rate of big investors is the steepest of all investors. This provides evidence that big investors react more efficiently than small investors as they are likely to have a higher profit in the 0.05% pool as shown in section 4.5.2.

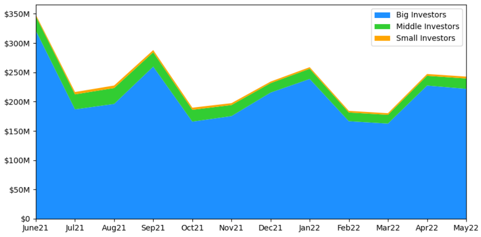
Somewhat surprising is the fact that liquidity on a DEX is not provided by the community and instead by a a small group of big investors. The best example of this is 4.10 h). In May 2022 there were 27 big investors in the USDT-USDC 0.01% pool on Uniswap v3. The 27 investors provided 99.5% of the TVL, which is around 215 million USD.

Figure 4.10: How much liquidity do investors provide? We compare four pools on Uniswap v3 on Etherum. The investors plots shows how many investors of each category were investing in the given month. The TVL plots illustrate who is providing how much liquidity in USD to the pool.

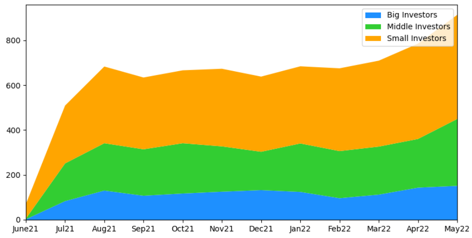
a) ETH-USDC 0.3% investors



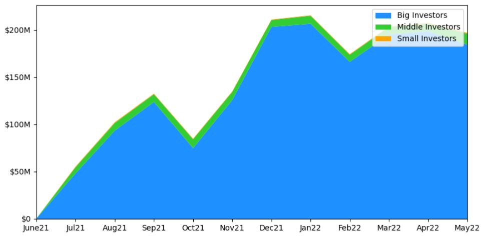
b) ETH-USDC 0.3% TVL



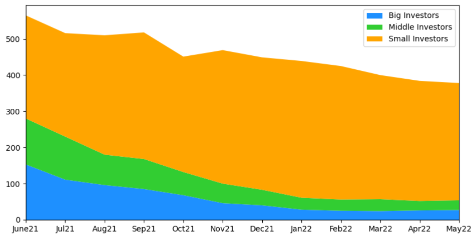
c) ETH-USDC 0.05% investors



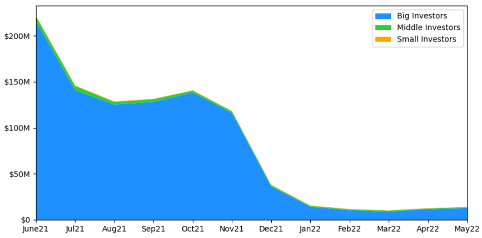
d) ETH-USDC 0.05% TVL



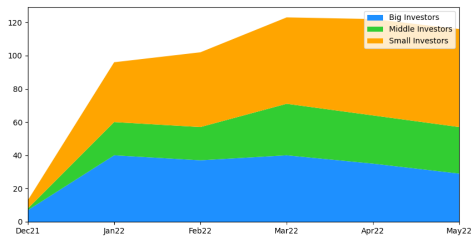
e) USDT-USDC 0.05% investors



f) USDT-USDC 0.05% TVL



g) USDT-USDC 0.01% investors



h) USDT-USDC 0.01% TVL

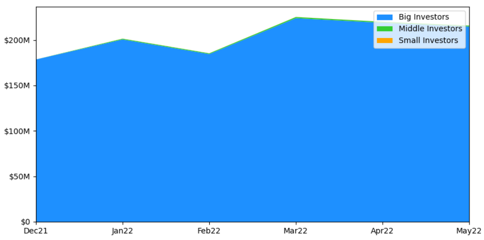
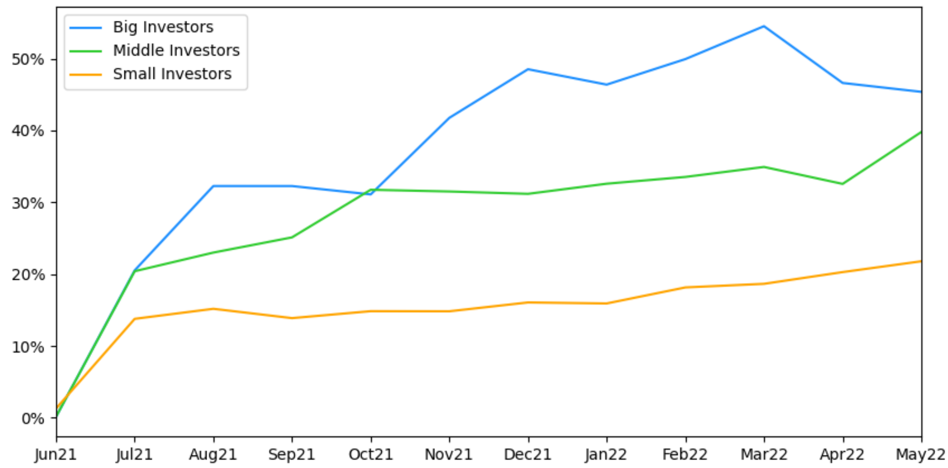


Figure 4.11: Adaption rate of 0.05% ETH-USDC pool compared to 0.3% pool on Uniswap v3 on Etherum. Equation 3.17 is applied for each type of investor.

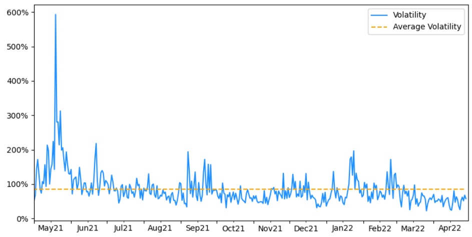


4.7 Volatility & Implied Volatility

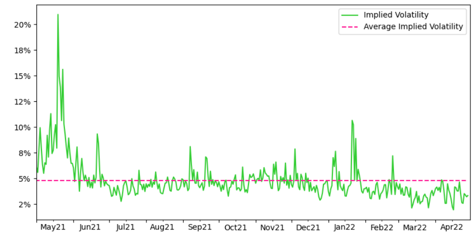
To illustrate whether the same pools on different blockchains adapt to the market as expected, we can look at volatility and implied volatility. We show annualized volatility and implied volatility of ETH-USDC pools with a distributed fee of 0.3% in figure 4.12. The results are as expected. The average volatility of a pool, which is only based on prices is for all pools around 60-80%. This shows that all pools follow the price development in a similar fashion. Implied volatility indicates market opportunities and we see that v2 has a lower implied volatility than the v3 pools. This is as expected because in v2 we calculate implied volatility with the total value locked of the whole pool, as explained in section 3.6. Further, for v3 we see a similar pattern for all pools. When comparing Arbitrum and Optimism, results show an average implied volatility of around 70% for both.

Figure 4.12: Volatility and implied volatility of ETH-USDC pools with fee of 0.3%. We look at Uniswap v2 and Uniswap v3 pools on Etherum, Arbitrum and Optimism. The orange line represent the average volatility or implied volatility of the respective pool.

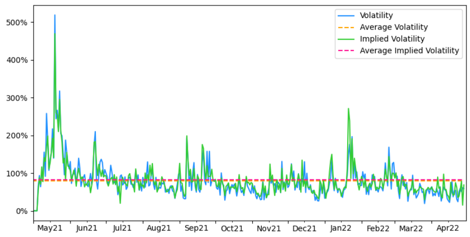
a) Uniswap v2 volatility



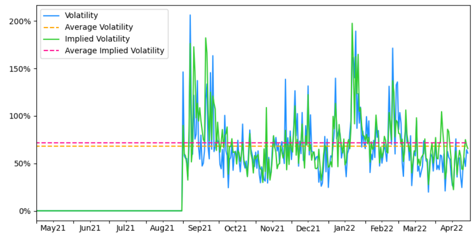
b) Uniswap v2 implied volatility



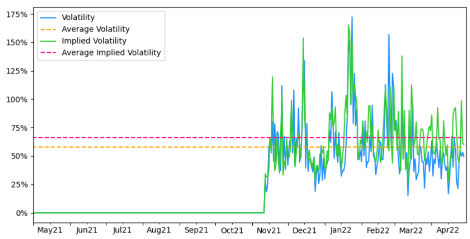
c) Uniswap v3 (Eth.)



d) Uniswap v3 (Arb.)



e) Uniswap v3 (Opt.)



Chapter 5

Conclusion

This bachelor's thesis focused on return on investment of liquidity pools, different DEXs which run on a variety of blockchains and market efficiency. Our results vary a lot depending on which liquidity pools were selected. Our data was collected between May 2021 to April 2022 from *the graph* [1]. We can draw three conclusions. First, returns from long existing liquidity pools tend to become more similar, which is an indicator that markets are efficient. Second, new features, launches and in general the development in DeFi still causes high fluctuations and volatility. DEXs are therefore an uncertain environment for investors. Third, our results show different investor behaviours depending on the amount of liquidity provided. Lack of access to good information and documentation can be a contributor to inefficient markets. This is particularly true for small investors.

Older liquidity pools have more similar returns and develop more steadily than newer pools. Results (section 4.1) show how returns from ETH-USDC pools on Uniswap v2 and Sushiswap have become very similar. For stable pools (section 4.4.1) we observe that returns on investment resemble each other more in April of 2022 than in the first months after the introduction of Uniswap v3. Returns (section 4.5.2) from the same ETH-USDC pools on different blockchains on Uniswap v3 are becoming more similar despite initial larger differences.

The majority of pools in this bachelor's thesis were launched within the analyzed year. Most pools have an unstable start, which comes with fluctuations in returns, daily volume and TVL. The launch of DEXs on a new blockchain like Uniswap v3 on Arbitrum in September 2021 caused the whole market to become more volatile. Investors and traders first have to figure out the potential of newly created exchanges. Several comparisons show volatility after the introduction of new pools (section 4.4.1 and 4.5.2). It is difficult to find a clear increase in market efficiency over all of our data. This can be illustrated by simple observations. Why does Uniswap v2 (section 4.4.1 and 4.5.1) still has such a high volume and returns despite cheaper options being available for traders? These findings indicate that the whole market is still away from efficient trader behavior. This can be exploited by investors. On Uniswap v3 our results are contradicting. The introduction of a stable pools with a lower distributed fee on Uniswap v3 (section

4.4.1), makes traders switch to the new pool, which can be observed when looking at the daily volume. On the other hand shows how a 1% pool made some of the highest profits in some months (section 4.5.2). This should not be the case as there exists cheaper pools for traders. Different strategies delivered different results in Uniswap v3. Returns will therefore depend on the applied strategy and the state of the market in general. These factors make it difficult to draw a clear conclusion about market efficiency on Uniswap v3 as well as the whole market of DEXs.

Significant differences in returns in our extended stable pool comparison (section 4.4.2) suggest insufficient information of investors as well as traders. The lack of big comparisons like in this bachelor's thesis make it difficult for investors to choose the right pools. Based on our results, some smaller investors choose in which pool to invest at random or with bad information. This gives power to the DEXs which are the main source of market analysis as well as big investors with more information. Our exploration of different DEXs calls into question the trustworthiness of certain players. Issues include the in-transparency of how liquidity provider rewards exactly work and misleading information on APY on some platforms. Our analysis of investors (section 4.6) show how few players are providing most of the liquidity on DEXs.

Future work could focus on the impact big investors have on DEXs. This would be especially interesting on DEXs like Curve where big investors have more voting power. More metrics to analyze market efficiency would be needed. Additionally, more DEXs could be included to provide an even broader overview of the whole market. Staking returns from Pancakeswap and Trader Joe could be added. To provide better information, the development of a website with live data from different DEXs could be a useful tool for smaller investors. Finally, in this bachelor's thesis we introduced new metric to analyze DEXs. Applying the same metrics in a years time could bring more detailed findings. Revisiting established liquidity pools should deliver more conclusive results on market efficiency.

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