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Uniswap

DeFi Project Deep-Dive

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1. Executive Summary

Welcome to our first Deep Dive into DeFi with our study on Uniswap.

Key Takeaways

- Uniswap is a special type of decentralized exchange (DEX) called a "token swapper" which provides a user friendly and low latency interface for direct ETH to ERC20 token swapping;

- A mechanism called "Constant Product Market Maker" is used for determining the exchange rate and price slippage, eliminating the need for an order book;

- There are 3 actors in Uniswap: Casual users, Liquidity providers, and Arbitrageur; each contribute to the system in their own way;

- Liquidity providers are incentivized to provide capital to earn transaction fees generated by casual users, and arbitrageurs are incentivized to provide external price information by earning spreads between Uniswap and other markets;

- The protocol gives regular users a passive way to earn transaction fees as liquidity providers;

- Uniswap is an important part of the developing DeFi landscape, and has already been used as a price oracle and source of liquidity for other players in the industry

2. Introduction

[Uniswap](#) is an Ethereum-based decentralized exchange (DEX) where users can trade ERC20 tokens versus Ethereum entirely on-chain using smart contracts, removing the need for order books as seen in traditional exchanges. It is a special kind of DEX called a *token swapper.*

2.1 Traditional Exchanges

Exchange and brokerage systems have been around for hundreds of years, dating back to as early as the 13th century where the merchants of Venice traded government debts and securities. Stock markets as we know them, however, first began to take form in the early 1600s in Antwerp, where the Dutch East India Company began trading on the Amsterdam Stock Exchange.

Fast forward to present day, and we now have numerous exchanges for all kinds of markets around the globe. Traditional exchanges have existed for a long time and have worked quite well thus far. So what is the need for a new system like Uniswap?

2.2 Uniswap's Origins

Uniswap was inspired by a [Reddit Post](#) from Vitalik Buterin, and founded by Hayden Adams in 2017. In August 2018, Uniswap received a $100,000 grant from the Ethereum Foundation. Subsequently, the Uniswap smart contract was launched in November 2018.

The main innovations from a protocol like Uniswap is to develop a user-friendly platform on which users can easily swap tokens without having to go through a convoluted exchange interface, while also allowing anyone to become a liquidity provider and passively earn transaction fees. It also provides benefits that a traditional DEX does, like decentralization and censorship resistance.

3.   Mechanism

In this section, we would like to highlight the key ideas on how Uniswap works, and the mechanisms behind its operation.

Order Books

Most modern exchanges run on *order books*, essentially a collection of all prices where market makers are willing to buy or sell a certain volume of each security. The difference between the lowest quoted offer and the highest quoted bid price is called the *bid-offer*, or *bid-ask spread*, which is the amount a market maker can profit while buying and selling.

The chart above is an example of a bitcoin order book in action. Market makers are willing to buy 2.006986 units at $7,900.61, 0.0002 at $7,900.37, while they are willing to sell 2.006986 units at $7,910.10, 0.0002 at $7,900.37, and so on.

When a trader wants to buy 2.1 BTC at market, they must first buy the 2.006986 units at $7,910.10, then 0.06 units at $7,910.56 and finally the remainder of their quantity at 7,910.61. The average price paid is therefore $7,910.12.

Price Slippage

The larger the order, the deeper the order book needs to be swept, which causes the price to move as trade is executed. This is called *price slippage* and is the reason why market depth and having a large pool of liquidity is important.

A classic problem with order books is that there are often "holes" in the order book where there is a lack of volume offered at specific price

points, which causes excessive price slippage on larger trades or in tokens with low liquidity. A trader not knowing this could unknowingly transact at much worse prices than the mid-price was indicating.

## 3.1 Constant Product Market Maker

To remove the need for an order book, Uniswap pools liquidity from liquidity providers who supply the system with tokens in exchange for a proportional share of transaction fees, using an automated market maker system to determine the price at which users can transact.

Uniswap uses what is called the *Constant Product Market Maker Model*, which was described first by Vitalik Buterin in a Reddit post from 2016.

Exchange rates for an ERC20 token in terms of ETH are governed by the following equation, where x and y represent the quantity of ETH and ERC20 tokens within the liquidity pool of a particular exchange, and k is a constant that does not change:

$$xy = k$$

The relationship can be summarized by the graph below:
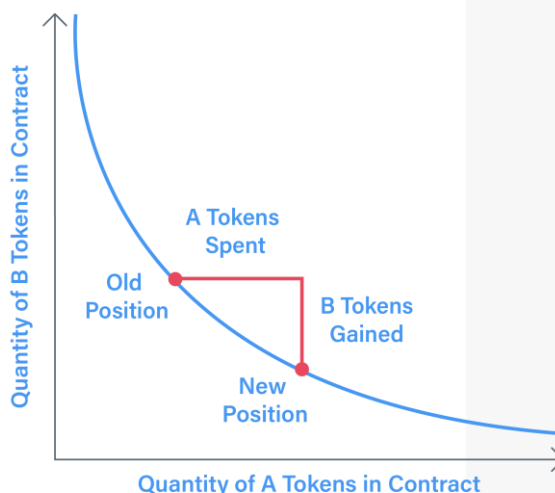
Like in a traditional exchange, the larger the amount of token A spent, the higher the marginal exchange rate paid for each additional unit of token B.

The advantage here is that it is possible for traders to know what kind of impact their order will have on the market price before accepting and executing a trade, which is preferable to unknowingly moving a market significantly like on traditional exchanges if you are not aware of the state of the order book.

Let's follow a hypothetical scenario of someone buying ETH on Uniswap ETH-DAI as an example.

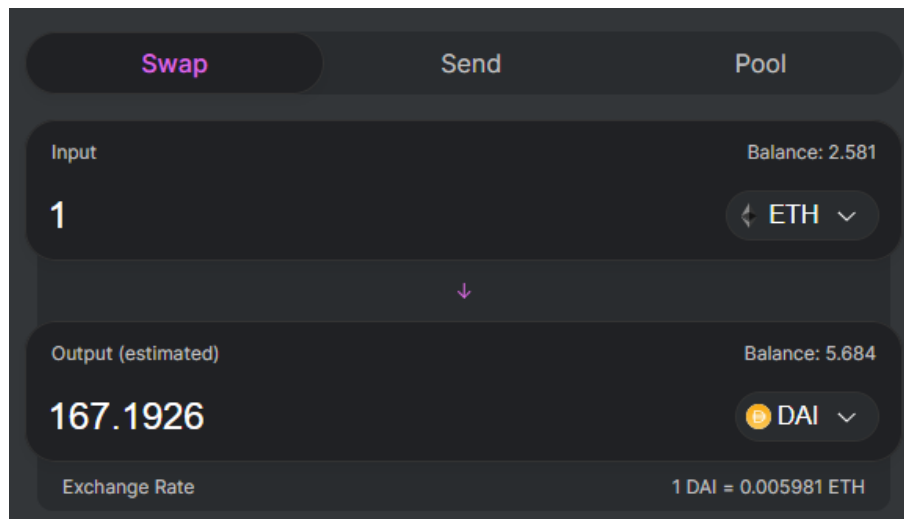|	
Initial condition of liquidity pool: • ETH: 300 • DAI: 30,000	$x = 300$ (ETH) $y = 30,000$ (DAI)
Calculate the constant k	$k = x * y = 9,000,000$
Also, we can calculate the initial exchange rate for ETH / DAI	Rate = y / x = 30,000 / 300 = 100 DAI per ETH
Someone wants to use 180 DAI to buy ETH	The DAI pool increases to 30,180
Since we know the new value of the DAI pool y_2, we can now calculate the new value of the ETH pool x_2 using the constant k to find the new level of ETH in the pool	$k = x_2 * y_2$ $x_2 = k / y_2$ $x_2 = 298.211$ ETH
The difference between the initial and new ETH liquidity pool is the amount received by the buyer	$x_1 - x_2$ = 300 – 298.211 = 1.789 ETH
We can calculate the exchange rate received by the buyer If the buyer accepts the rate, the token swap will be conducted.	Rate = 180 DAI / 1.789 ETH = 100.6
Closing condition of Liquidity Pool: • ETH: 298.211 • DAI: 30,180	298.211 (ETH) 30,180 (DAI)

3.2 Actors in Uniswap

There are three types of users of Uniswap. Casual Users, Liquidity Providers, and Arbitrageurs.

Actor	Use	Incentive	Contribution
Casual Users	Swap	Perform token swapping	Transaction fees
Liquidity Providers	Pool	Earn fees	Liquidity
Arbitrageur	Swap	Arbitrage to earn the price spread	Price oracle, Transaction fees

Casual users are those who are using Uniswap simply to exchange tokens, while liquidity providers pool their tokens onto the platform such that traders can perform token swaps. We will first go through casual users and arbitrageurs, and liquidity providers will be covered in the following section, as the mechanics are slightly more complex.

Casual Users

Casual users use Uniswap to swap tokens quickly and simply. All users have to do in the interface is connect their Web3 wallets such as Metamask, then use the 'Swap' function to select the quantity and type of token to swap. The app will give you a price quote and allow you to set some parameters like maximum slippage and so on.

## Uniswap Depends on Arbitrageurs

Prices on Uniswap are determined entirely by the ratio of ETH and ERC20 tokens in the pool, and this ratio does not change upon liquidity provision. The only way to alter the price in Uniswap is when a transaction (i.e. token swapping) happens.

If the Uniswap price is too low compared to the other external markets, arbitrageurs are incentivized to buy on Uniswap and sell on other exchanges, and vice versa if the price is too high. Arbitrage is usually done by automated bots.

In other words, Uniswap relies on arbitrageur as external price oracle. However, this will introduce *impermanent loss* to liquidity providers. We will discuss this more in section 3.4.
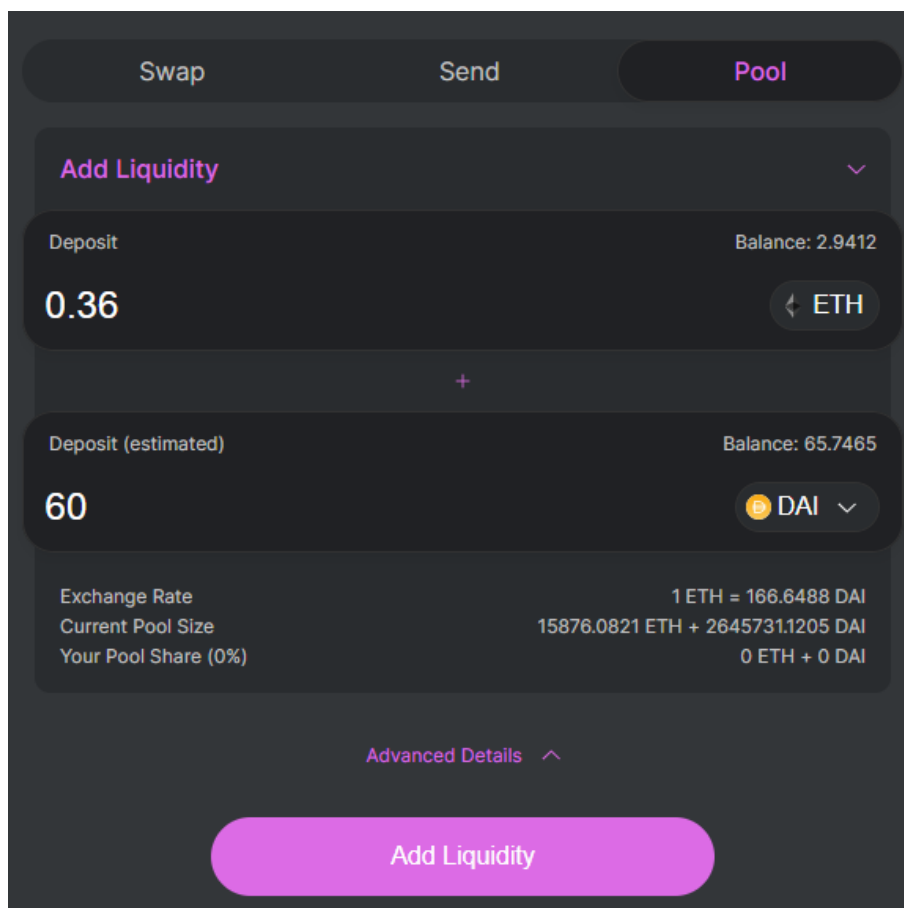
3.3 Liquidity Providers

Next, let's dive into how liquidity provision works in Uniswap. The diagram below shows a high level view of how it works. We will delve deeper into the mechanics of each step below.
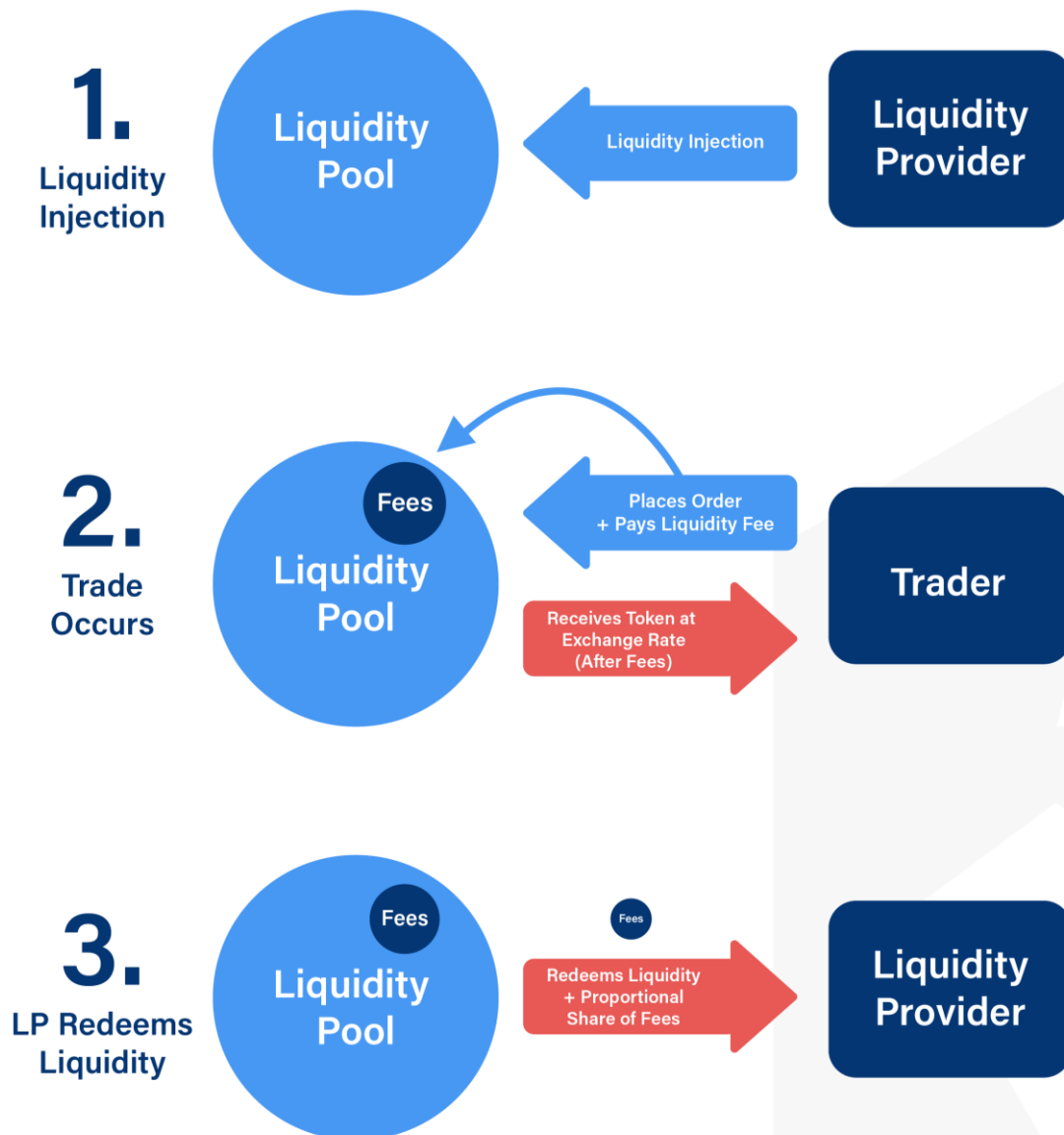
Step 1: Liquidity Injection

Liquidity providers (LPs) deposit tokens into the liquidity pool. The LP receives newly minted liquidity tokens to represent their share of the total liquidity pool.

Note that the LP does not have the ability to set the price of his liquidity injection, as the price is determined by the constant product, i.e. the ratio of assets in the pool at the time of injection. As a result, liquidity must be provided in pairs.

In the Uniswap interface, liquidity injection is done with the 'Pool' function. Once there, you can enter any quantity of any token in each pair, and it will automatically calculate an equivalent value of the other token in the pair. Note that you must have the required amount of each token in your wallet before you can perform this operation – if you do not have enough of one particular token, you can use 'Swap' to exchange some first.

Step 2: Trade Occurs

When casual users perform token swapping, a 0.3% liquidity fee is charged. The fees will then remain in the liquidity pool as a dividend to liquidity providers when they redeem their tokens.

Step 3: Liquidity Redemption

When an LP redeems their liquidity, their tokens are returned to them, and the liquidity token that was minted on injection is then burned, and the LP receives the amount of fees they are entitled to depending on their share of the liquidity pool. Below is a screenshot showing the interface for removing liquidity we have pooled into the ETH-DAI pool.

Factors Affecting LP Returns

As LPs are providing capital to the system, they will not do this for free. The system needs to provide an incentive for them, which comes in the form of transaction fees.

There are two main factors that affect the amount of fees generated by a single liquidity provider in a Uniswap pool: 1) the total size of the liquidity pool, and 2) the volume of trades that occurs in that pool.

As the liquidity pool grows larger, the proportional share of fees owed to the LP decreases. On the other hand, higher trading volumes will increase the amount of fees generated.

If there are fewer liquidity providers pooling capital on a Uniswap exchange relative to the trade volume executed, then LP returns in that pool will be higher, making it more attractive for liquidity providers. Hence, in an efficient market, the activity in a Uniswap contract should be linked closely with the amount of liquidity LPs are willing to provide.

Snapshot of Liquidity Provider Returns

So what type of returns might we expect from providing liquidity to Uniswap and locking up our precious crypto? Below is a snapshot from pools.fyi showing the current state of the top 5 liquidity pools and the ETH returns seen over the prior 30-day period:

	Pool			Liquidity	Price	Volume (24h)	Annualized Returns (ETH, 30d)	
1		Uniswap ETH-sETH Synth sETH	STABLE INCENTIVIZED	$14,868,542	$196	$147,362		2.0%
2		Uniswap ETH-HEX HEX		$5,608,762	$0.00025	$227,098		-12.0%
3		Uniswap ETH-DAI Dai Stablecoin		$5,150,236	$1.01	$4,378,854		42.8%
4		Uniswap ETH-MKR Maker		$4,698,366	$523	$421,087		7.9%
5		Uniswap ETH-REP Reputation		$3,773,385	$12.3	$510,445		0.4%

Note that the returns shown above are based on historical transaction data and fees, and do not represent future obtainable returns.

3.4 Impermanent Loss

When Uniswap was first created and the first liquidity providers began pooling their capital to earn transaction fees, many users discovered on liquidity redemption that the value of their redemptions was less than the amount they would have had they instead held onto those tokens. If liquidity providers are earning fees, how could this be?

It turns out that any deviation in price from the initial price at the time of liquidity injection can cause losses to the LP. This is caused by the mathematical relationship in the constant product equation, where the total value of the liquidity pool when measured in ETH or the ERC20 token changes as the price changes. This is called *impermanent loss* (a term coined in this article) as losses are not realized until liquidity redemption, but if the price at any point returns to its initial state, this loss disappears.

Below is a graph showing how the value of LP tokens changes as the price moves. The blue line shows the value of the tokens had the liquidity provider held onto those tokens, while the red line shows the value of those tokens in Uniswap.

Token Value of HODL vs Uniswap Pool
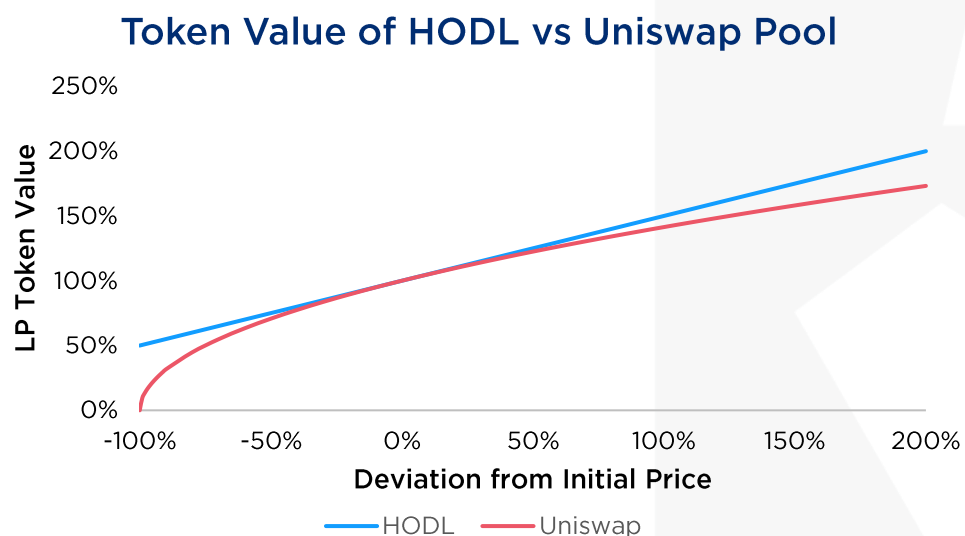
To view it another way, liquidity providers' losses relative to HODL:

Liquidity Provider Losses Relative to HODL
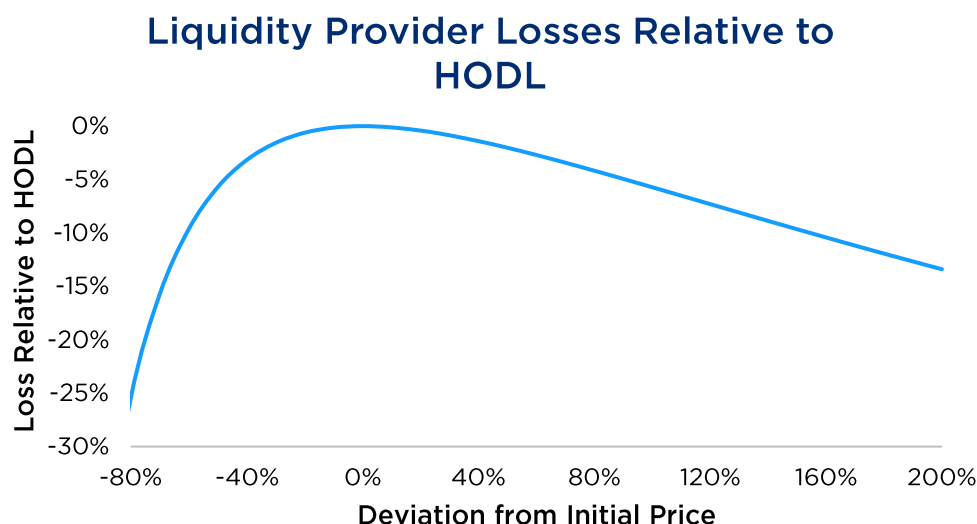
Conceptually, you can understand impermanent loss in terms of opportunity cost. A user providing liquidity into a pool could have held onto their tokens, but instead chose to pool these tokens on Uniswap and subject the proportion of their tokens to change as per the constant product model.

Although impermanent loss sounds scary, the impact of impermanent loss in reality is relatively small within a reasonable range of price movements. A 25% price increase only results in a 0.6% loss relative to HODL, while a 100% price increase only results in a 5.7% loss relative to HODL. If transaction fees are high enough, this could offset any impermanent losses.

Arbitrageurs Profit from Liquidity Provider's Losses

So if liquidity providers incur losses as price moves, who reaps the gains? The answer is arbitrageurs, who perform the essential function of price oracle for Uniswap.

So you can actually see impermanent loss as a fee paid by liquidity providers to arbitrageurs for their value in providing external price information. Arbitrageurs are able to profit from the fact that liquidity providers cannot change the price at which they provide liquidity.

4. Analysis

Now that we understand what Uniswap is and what it does, let's explore some of the advantages and disadvantages for Uniswap.

Below is a summary:

Advantages	Disadvantages
Highly Decentralized and Autonomous	Inability for Market Participants to Set Prices
High Degree of Anonymity	Lack of Variable Liquidity Fees
Open Source	Smart Contract Risk
Lower Gas Fees	Front Running
User Friendly Interface	

4.1 Advantages of Uniswap

Highly Decentralized and Autonomous

Uniswap operates without any centralized service provider or middle-man, and since all transactions happen on-chain, cannot be halted as long as Ethereum is functional.

High Degree of Anonymity

Since there are no user accounts to log into and anyone with an Ethereum address can use Uniswap, there is a high degree of anonymity. There is also no KYC process before using Uniswap, unlike in many other exchanges.

Open Source

Uniswap is an public, open-source application, which means in the future, if the Uniswap team leaves the project for any reason, the Uniswap community can still maintain the project and develop new functionality.

Lower Gas Fees

According to Uniswap, due to its minimalist design and mechanism, it is more gas efficient than its decentralized exchange counterparts.

Exchange	Uniswap	EtherDelta	Bancor	Radar Relay (0x)	IDEX	Airswap
ETH to ERC20	46,000	108,000	440,000	113,000*	143,000	90,000
ERC20 to ETH	60,000	93,000	403,000	113,000*	143,000	120,000*
ERC20 to ERC20	88,000	no	538,000	113,000	no	no

*wrapped ETH

User Friendly Interface

Uniswap has provided a very user-friendly interface. Even people new to crypto can easily swap their desired ERC20 tokens in just a few clicks. Because of the simple UI and lack of order books, Uniswap has also greatly reduced loading times, an issue that has plagued other DEXs.

The interface even allows traders to set slippage limits, and order timers such that orders are canceled if not executed within a time limit, which helps to mitigate front running.

4.2 Disadvantages of Uniswap

Inability for Market Participants to Set Prices

Perhaps the greatest disadvantage of Uniswap's system is that users are unable to use limit orders to set the prices at which they would like to buy or sell, but are instead subject to the price as dictated by the constant product algorithm. Although this can be beneficial for small traders who do not need or wish to use limit orders, traders transacting in large sizes may find this feature undesirable.

Furthermore, due to the inherent way in how the constant product works, liquidity providers must pay arbitrageurs for price information via impermanent losses.

Lack of Variable Liquidity Fees

Although the way Uniswap handles liquidity fees is simple, the lack of a constantly changing bid-ask spread is a detriment. In traditional markets, the bid-ask spread changes with the state of liquidity in the market. In Uniswap, however, all trades are charged a flat 0.3% liquidity fee, which means that traders could be overpaying even when liquidity is abundant.

Smart Contract Risk

In general, DEX removes risks associated of custodial arrangements. However, they introduce a new risk: smart contract risk. If the smart contracts that Uniswap is built upon have any vulnerabilities, users and liquidity providers may suffer from loss, and they are irreversible due to blockchain's immutability.

Front Running

Although this disadvantage is not limited to Uniswap, it still deserves a mention. Front runners and malicious miners can detect large transactions and place orders immediately before and after the trade is executed to profit at the expense of the trader. This process is written about by Vitalik Buterin on Ether Research here.

4.3 Interactions with Other Protocols

Uniswap has grown tremendously since it launched, and currently boasts a liquidity pool of more than 260,000 ETH, or US$45 million. How does Uniswap tie into the wider world of crypto and DeFi?

Uniswap as a Price Oracle

Because of Uniswap's growing liquidity and ability to handle different pairs, it has becoming popular to use the protocol as a price oracle for a multitude of purposes, since it is theoretically expensive to significantly manipulate the price of a pair on Uniswap for a large period of time, *given a sufficiently deep liquidity pool* (see [this research piece](#)).

bZx, a margin lending DeFi platform, had been relying on Kyber (thus indirectly, Uniswap) as a price oracle to determine the value of collateral. On 18/02/2020, an attacker utilized flash loans to borrow 7,500 ETH on bZx, then traded 3,517 ETH for sUSD, a stablecoin that should be pegged to USD. Next, the attacker used 900 ETH to purchase sUSD on Kyber and Uniswap, which temporarily pumped the price of sUSD to over 2.5 times the market rate. With the now-inflated value of sUSD, the attacker took out another loan on bZx and repaid the original flash loan, netting a profit of 2,378 ETH.

Because the attack happened within a single block, and bZx was relying on just short-term Uniswap and Kyber prices to determine collateral values, the attacker was able to very briefly manipulate the price oracle and borrow more than they should have been able to, leaving bZx with an undercollateralized loan.

This incident highlighted the importance of using high quality price information, ideally over multiple time frames and sources, such that the attacks, as they were carried out, would be much harder to do so in the future. It also emphasized the importance of having large enough liquidity pools to make it more costly for attackers to manipulate market prices. Since the attack, bZx has made the decision to team up with decentralized oracle network Chainlink for additional external price information.

Uniswap as Primary Source of Liquidity for sETH

In order to increase sETH (Synthetic ETH) liquidity, Synthetix, a synthetic asset platform providing on-chain exposure to various real world and crypto-related instruments, implemented a new program in mid-2019 to offer SNX as an incentive for liquidity providers in the ETH-sETH Uniswap contract.

sETH liquidity is of great importance to Synthetix's platform, since sETH acts as the on- and off-ramp for users depositing into and withdrawing from Synthetix's exchange. Due to insufficient liquidity in the past, users experienced significant slippage when trading sETH.

Since the launch of the Uniswap ETH-sETH pool, sETH liquidity has increased significantly. As of 01/03/2020, the value of tokens staked on the ETH-sETH contract stood at 35,124 ETH, or US$15.2 million.

Curve Finance

In January 2020, Curve Finance launched curve.fi, a stablecoin swapping protocol designed to offer extremely low slippage and transaction fees (currently 0.04%).

Curve's automated market maker sets prices in a similar way to Uniswap in that prices are determined by a curve, except curve.fi's is called "StableSwap" since it is designed to remain very flat within a certain price range as opposed to Uniswap's (thus lowering slippage), and also allows liquidity injections in single tokens instead of forcing liquidity to be injected in pairs. This algorithm works especially well for swapping stablecoins since stablecoin prices should remain within a very close bound of each other.

This protocol was developed to address users' pain point of often high slippage when transacting in stablecoins. The demand for this product is seen by the rapid growth of Curve, which has already attracted almost US$10 million in stablecoin liquidity within just two months since launch.

5. Summary

5.1 Conclusion

In conclusion, Uniswap allows casual users to swap tokens easily and earn passive income by participating as liquidity providers. The user interface is easy to use, and making trades is only a few clicks away.

Uniswap may not completely replace traditional exchange or DEX due to its unsuitability for performing large volume trades, but it has provided an interesting alternative that is beneficial for casual usage. Moving forward, it is exciting to see how Uniswap evolves and grows as the DeFi space matures.

Key Takeaways

- Uniswap is a special type of decentralized exchange (DEX) called a "token swapper" which provides a user friendly and low latency interface for direct ETH to ERC20 token swapping;

- A mechanism called "Constant Product Market Maker" is used for determining the exchange rate and price slippage, eliminating the need for an order book;

- There are 3 actors in Uniswap: Casual users, Liquidity providers, and Arbitrageur; each contribute to the system in their own way;

- Liquidity providers are incentivized to provide capital to earn transaction fees generated by casual users, and arbitrageurs are incentivized to provide external price information by earning spreads between Uniswap and other markets;

- The protocol gives regular users a passive way to earn transaction fees as liquidity providers;

- Uniswap is an important part of the developing DeFi landscape, and has already been used as a price oracle and source of liquidity for other players in the industry

5.2 Statistics

Below are some numbers to put Uniswap's scale into perspective. The amount of Ethereum pooled on Uniswap contracts as of March 2020 was more than 270,000 ETH, or US$59 million. This puts it at 5th place on DeFi apps, according to DeFi Pulse.

**Pooled Liquidity on Uniswap
(ETH, thousands)**
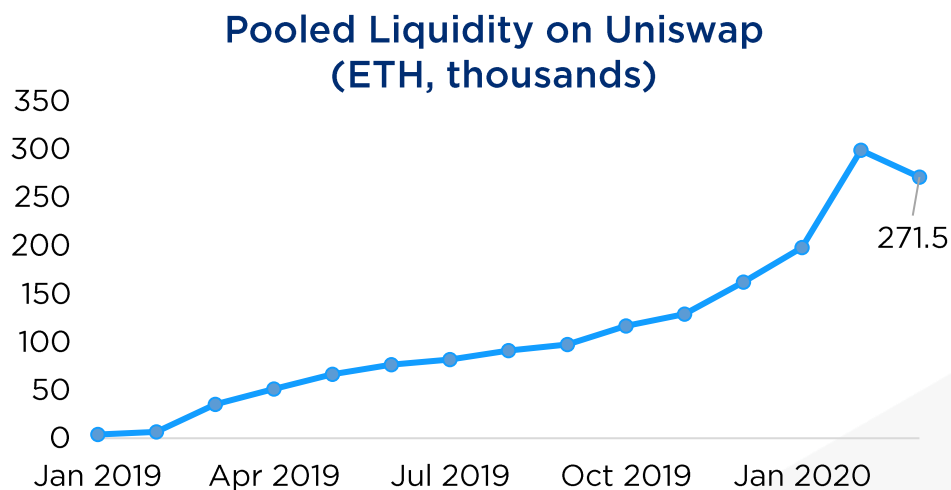
The trading volumes on Uniswap have also been rising steadily, with average daily trading volume of more than 20,000 ETH (around US$5 million) in February, a significant increase from the average daily volume of 6,000 ETH (around US$ 1.1 million) for 2019.

**Average Daily Volume by Month
(ETH, thousands)**
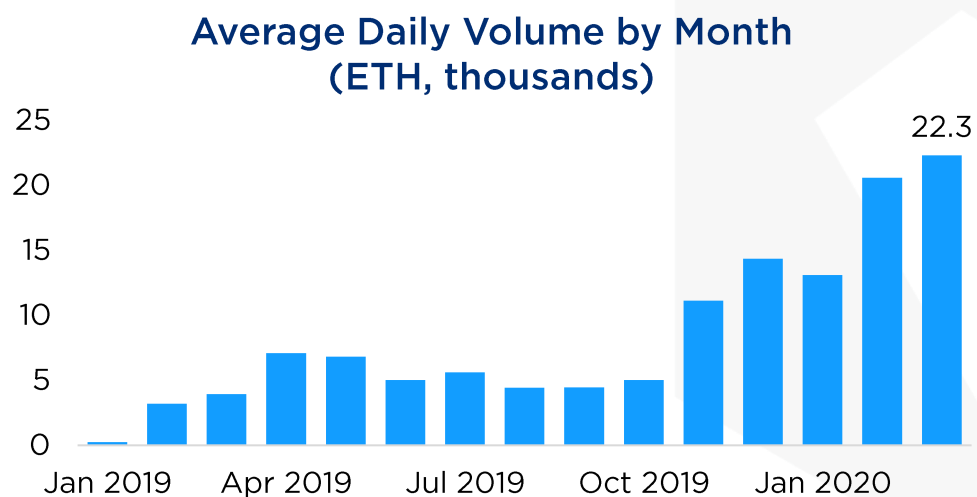
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