International Journal of Network Management

WILEY

SPECIAL ISSUE PAPER OPEN ACCESS

Option Contracts in the DeFi Ecosystem: Opportunities, Solutions, and Technical Challenges

Srisht Fateh Singh[1] | Vladyslav Nekriach[1] | Panagiotis Michalopoulos[1] | Andreas Veneris[1,2] | Jeffrey Klinck[1]

[1]Department of Electrical and Computer Engineering, University of Toronto, Toronto, Ontario, Canada | [2]Department of Computer Science, University of Toronto, Toronto, Ontario, Canada

Correspondence: Srisht Fateh Singh (srishtfateh.singh@mail.utoronto.ca)

Received: 1 September 2024 | **Revised:** 28 January 2025 | **Accepted:** 29 January 2025

Keywords: CEX | cryptocurrency | decentralized finance | DeFi | derivatives | DEX | options | volatility

ABSTRACT

This paper investigates the current landscape of option trading platforms for cryptocurrencies, encompassing both centralized and decentralized exchanges. Option contracts in cryptocurrency markets offer functionalities akin to traditional markets, providing investors with tools to mitigate risks, particularly those arising from price volatility, while also allowing them to capitalize on future volatility trends. The paper discusses these applications of option contracts in the context of decentralized finance (DeFi), emphasizing their utility in managing market uncertainties. Despite a recent surge in the trading volume of options contracts on cryptocurrencies, decentralized platforms account for less than 1% of this total volume. Hence, this paper takes a closer look by examining the design choices of these platforms to understand the challenges hindering their growth and adoption. It identifies technical, financial, and adoption-related challenges that decentralized exchanges face and provides commentary on existing platform responses. Subsequently, the paper analyzes the impact of absent options markets on the inefficiencies of automated market maker liquidity. It examines historical on-chain data for 14 ERC20 token pairs on Ethereum. The analysis shows 1143 instances in which deeper liquidity levels, as high as $\times 6$ more, could have been achieved by establishing an options market.

1 | Introduction

Option contracts are financial derivatives that give their holder the right, but not the obligation, to buy or sell an underlying asset at a predetermined price (*strike price*) until a specified date (*expiration date*) [1]. These contracts provide investors with flexibility in their investment strategies by offering a wide range of uses, including hedging, speculation, leverage, income generation, and risk management. Such features allow investors to tailor their investment approach to specific objectives and market conditions, making option contracts a valuable tool in traditional finance. Option contracts have gained significant popularity in the current decade, showing no signs of slowing down. According to the FIA, a leading global trade organization, 2023 saw a trading volume of 101 billion option contracts globally.[1] This represents a 100% growth rate compared with the previous year and a 1162% increase compared with 2013. In the remainder of this paper, we use the term "options" and option contracts interchangeably.

Like traditional assets, options are also traded for cryptocurrencies, particularly Bitcoin [2] and Ethereum [3]. Generally, the financial markets for cryptocurrencies can be classified into centralized (CeFi) and decentralized finance (DeFi). CeFi involves custodial applications and services that are managed by a registered corporation. Conversely, DeFi consists of autonomous programs, known as smart contracts, running on blockchains. These autonomous smart contracts replace central intermediaries to provide financial services. Characterized by zero market downtime, application interoperability, and permissionless access and listing, DeFi has seen rapid user adoption in recent years with over 50 million unique market participants.[2] With billions of dollars in total value locked (TVL), it has emerged as a successful alternative to "traditional" financial services. This includes automated market makers, which have replaced spot exchanges with \$19.8 billion in TVL, perpetual futures and derivatives replacing futures exchanges with \$2.7 billion in TVL, decentralized lending services taking the place of leverage trading with \$32.9 billion in TVL, and staking services substituting risk-free yield services with \$55.2 billion in TVL [4].

Apart from providing flexibility in investment strategies, the presence of options or options-like instruments in a DeFi ecosystem has the potential to mitigate many existing risks, particularly those arising from heightened volatility. Moreover, unlike traditional finance, DeFi's unique characteristics allow for novel strategies that do not exist in traditional markets. However, to the best of our knowledge, no substantial work has thoroughly examined current solutions offering options in DeFi or explored the scope of the opportunities they present. Therefore, it is crucial to assess the current landscape to understand the need and demand for options and the associated implementation challenges.

This paper extends our prior work [5] on option exchanges for cryptocurrencies. After outlining the fundamentals of options, we underscore their significance in DeFi by exploring their potential to address numerous ongoing challenges stemming from the early stage of DeFi markets, particularly focusing on mitigating the effects of increased volatility. Thereafter, we study existing option exchanges, both centralized (CEXes) and decentralized (DEXes), under three aspects: (i) how the platform(s) work, (ii) user benefits and shortcomings, and (iii) market adoption trends. Our findings demonstrate that despite harnessing the inherent advantages of blockchains, DEXes have historically captured a significantly lower market share (less than 1%) in options trading. Moreover, most of the digital assets still lack a functional and liquid options market. Nevertheless, recent advancements in option DEX protocols and user interfaces are fostering a notable improvement in this trajectory. The study employs a systematic methodology, concentrating on the four largest CEXes and the eight largest DEXes by trading volume on Ethereum. We select Ethereum because it is the largest DeFi ecosystem with over \$55.9 billions in TVL [4].

Compared with [5], this paper provides a deeper analysis of the platforms under consideration. In particular, we present an abstract design of a decentralized options exchange, with key components represented as modular units. We then analyze each of these modules across the eight DEXes under consideration. To ensure comprehensiveness, we include platforms that exhibit high trading volumes, operate with and without third-party dependencies (such as oracles), and support both traditional vanilla and exotic options designs. As a further contribution to [5], this paper demonstrates that the presence of an options market not only derives but also ensures a minimum threshold of liquidity on automated market makers (AMMs). To validate this, we analyze historical liquidity data from Uniswap [6], the largest AMM on Ethereum, comparing observed liquidity levels with our theoretically derived threshold. However, our empirical results reveal that liquidity levels can fall significantly below this threshold in the absence of an options market. By examining historical data from 14 ERC20 tokens without an options market, we identify 1143 instances where liquidity for these tokens fell below the threshold and could have been increased by up to $\times$ 6.

Lastly, the paper discusses the technical and financial challenges faced by the DEXes that hinder their mainstream adoption and various opportunities in DeFi. It is important to note that while regulatory hurdles behind options in decentralized ecosystems is an open issue,[3] our paper focuses on addressing only technical challenges. To our knowledge, this paper represents the first deep-dive investigation into the options landscape within the context of DeFi.

The paper is organized as follows: Section 2 gives preliminaries on option fundamentals, Section 3 discusses applications of options in DeFi. Section 4 gives an overview of option exchanges and Section 5 examines various design aspects of DEXes. Section 6 studies the impact of absent options market on AMM, Section 7 discusses the implementation challenges faced by a decentralized exchange, Section 8 talks about related work, and finally, the paper is concluded in Section 9.

2 | Background

This section presents the basic characteristics of options, including estimation models for determining their price. Then, we present everlasting options that will be useful for the rest of the paper.

2.1 | Option Fundamentals

An option is called a *call* or a *put* if it gives its holder the rights to buy or sell, respectively, an underlying asset at a price of K, known as the *strike* price. Let $\mathcal{S}$ denote the spot price of the underlying asset. Then, the *payoff* or intrinsic value of an option is defined as the value obtained by its holder if they exercise their rights and is determined using $\mathcal{S}$ and K. For a call option, the payoff is positive if the spot price is above the strike price when exercised, while the opposite holds for a put option:

$$\text{Payoff} = \begin{cases} \max(\mathcal{S} - K, 0), & \text{for call options} \\ \max(K - \mathcal{S}, 0), & \text{for put options} \end{cases} \tag{1}$$

The agents that commit to provide the payoff to holders are known as option sellers or option writers. Similarly, the *notional value* of an option is defined as the value of its underlying asset. For instance, if a call option for 1 ETH is created, and the price of ETH is \$1000, then the notional value of this option is \$1000. Notional values serve to quantify option trading volume, commonly referred to as notional volume. Notional volume is an important metric when evaluating an option trading platform because the fees collected by the platform are usually a fraction of the notional volume.

Apart from the payoff and notional value, options have a theoretical valuation that is harder to calculate than the previous two. The first method, introduced in 1973, for calculating the theoretical option price has been the Black–Scholes (B-S) model [7]. It assumes the asset's price follows a Geometric Brownian Motion [8], and its input parameters include the asset's spot price, its dividend yield, the risk-free interest rate of the numeraire, the option's strike price, price volatility, and time to expiration. Figures 1a,b illustrates the value of a European call and put option, respectively, calculated using numerical methods for Black–Scholes pricing [9]. Here, we assume a strike price of 100, volatility of 20% per year, a term of 1 year, and a zero interest rate. Options with zero intrinsic value (payoff) are referred to as out-of-the-money (OTM). These options are often cheaper due to their lack of immediate payoff. For example, the call option in Figure 1a with a spot price less than 100 is OTM. OTM options can be used to achieve high leverage on the underlying asset due to their low cost. Conversely, options with positive intrinsic value are referred to as in-the-money (ITM). In Figure 1a, the region with a spot price greater than 100 is ITM. Lastly, options with a spot price around their strike price are referred to as at-the-money (ATM). In Figure 1a, the region with a spot price 100 is ATM.

The B-S model is useful as it can help estimate future values for *volatility*, which represents the uncertainty in the asset's price. Mathematically, it is defined as the standard deviation of an asset's daily returns. Specifically, given that options are freely traded on exchanges, one can use their market prices as inputs to the B-S equation. Then, the volatility value that satisfies the equation serves as an estimate, commonly known as *implied volatility*. This ability to derive volatility from market prices is a distinctive feature of options derivatives that sets them apart.

Finally, options can be categorized as either fixed-term or perpetual. Fixed-term options expire on a specific date, while perpetual options have no expiration. Fixed-term options are well-studied, whereas perpetual options are less common and considered more exotic. Options can further be classified based on their exercise methods. *European* options can only be exercised at the time of expiration. Therefore, these options are always fixed-term. On the other hand, *American* options can be exercised at any time until expiration. Therefore, such options can have both fixed-term and perpetual terms.

2.2 | Everlasting Options

Everlasting options are a type of perpetual options wherein the contract holder is obligated to pay a daily *funding fee* to maintain the option's validity [10]. These options are particularly significant to holders who desire flexibility in the holding period. They serve as an alternative to continually *rolling over* multiple fixed-term options with incrementally increasing expirations. In the rollover strategy, as the option nears expiration, the holder executes a rollover by selling the existing option and purchasing a new one with a more distant expiration date. A comparison of both of these options is presented in Figure 2.

Contrary to everlasting options, the latter alternative is anticipated to incur higher costs [10]. This is due to the transactional fees associated with buying or selling an option, known as the *spread*, which are paid to market makers—agents who provide liquidity in the market. Consequently, each time the holder executes a rollover, they must bear additional fees. Furthermore, the fixed-term alternative necessitates the existence of multiple

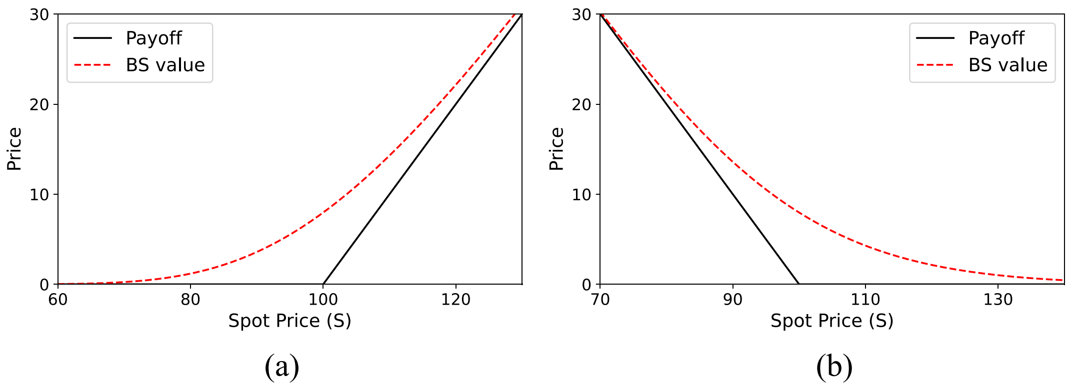


FIGURE 1 | Value of options calculated using the B-S model.

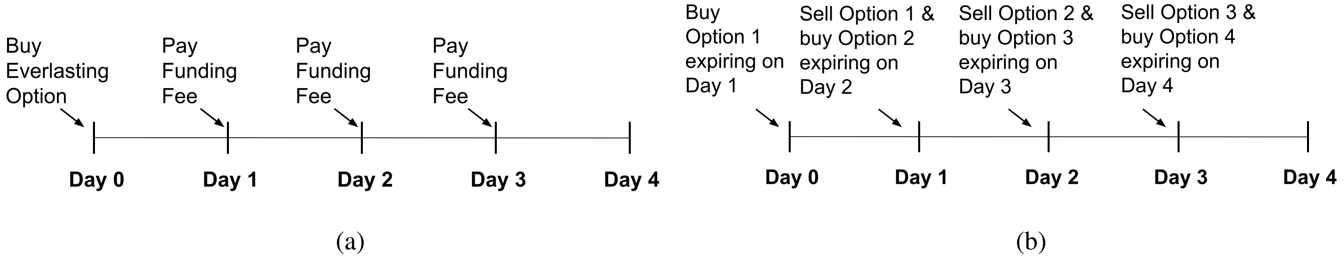


FIGURE 2 | Comparison between everlasting options and rolling daily options.

markets, each corresponding to a different expiration date. This results in greater liquidity fragmentation compared with everlasting options that rely on a single market.

The funding fee for an everlasting option is calculated once per day. It is represented as (mark − payoff), indicating the difference between the option's trading price on the exchange and its payoff, which is determined at the end of the day. An everlasting option on Day 0 is equivalent to a portfolio comprising $\frac{1}{2}$ of an option expiring on Day 1, $\frac{1}{4}$ of an option expiring on Day 2, $\frac{1}{8}$ of an option expiring on Day 3, and so forth [10]. This equivalence provides a means to price everlasting options by decomposing them into multiple fixed-term options and leveraging the accurately defined valuation provided by the B-S model.

3 | Study Motivation

Options have the potential to advance DeFi markets by bringing novel services to users to offset the risks of extreme price movements, among others. Some of these key applications are discussed below.

3.1 | Portfolio Optimization

Options are particularly useful in creating *hedging* strategies against price *volatility*. The key idea is to utilize the relationship between the option's price and the underlying asset's spot price. As illustrated by the red dashed curves in Figure 1, the price of an option, both call and put, changes non-linearly with the asset's price. This relationship provides a range of values for the δ of the option, which represents the slope of the option's value $\mathcal{V}$ with respect to the spot price, that is, $\delta = \frac{d\mathcal{V}}{dS}$. For call options, δ varies between 0 and 1, while for put options, it ranges from −1 to 0. One can use this property to construct novel portfolios consisting of assets, options, and other derivatives whose net δ is zero. Such portfolios are interesting because their net value stays the same regardless of price movements in the market and are referred to as *δ-neutral portfolios*. A simple example of such a portfolio consists of 1 ETH ($\delta = 1$), and 2 put options each with $\delta = -0.5$. The weighted δ of this portfolio turns out to be zero: $1 - 2 \cdot 0.5 = 0$.

A δ-neutral portfolio can also ensure its investors a steady income stream with minimal risk from market price fluctuations. In the context of current DeFi platforms, Rysk Finance [11] uses this strategy to offer a risk-minimized yield to its liquidity providers.

3.2 | Liquidation-Free Leverage

Leveraged returns, often provided by exchanges, occur when the investment's payoff exceeds the returns achievable solely through deposited assets or margin. Thus, a trader with a margin of 1 ETH and leverage of 2× gets a return of $2x\%$ on margin when the price of ETH changes by $x\%$. However, when the price of ETH reduces by 50%, their leveraged return becomes −100%, reducing the position size to 0 ETH. To mitigate the risk of negative returns where the trader owes the exchange, the exchange may liquidate the trader's position when the margin approaches zero.

Leverage is popular in DeFi and is implemented using overcollateralized lending and perpetual futures platforms [12, 13]. However, liquidations caused by extreme and momentary price fluctuations, which are typical in today's cryptocurrency environment [14], can be seen as unfair to traders and they remain a big issue [15]. This risk can be mitigated in some part by using options whose payoff exceeds zero (in-the-money). For call options, this means that the spot price is greater than the strike price and vice-versa for put options. To understand this, consider the example of the call option plotted in Figure 1a. Here, the strike price is \$100, and the spot price is \$120. The option's B-S value, as shown in the figure, is approximately $\$120 - 100 = 20$. For higher values of spot price, the option's value changes almost linearly with a slope of 1, that is, $\frac{d\mathcal{V}}{dS} = 1$. This means that a $x\%$ increase in the spot price increases the option's value by $120 \cdot \frac{x}{100}$ which is $\frac{120}{20} \cdot x\%$ of the option's original value. Thus, the return on the option gets levered by 6×. On the other hand, if the spot price reduces by 50%, or any larger value, the position does not get liquidated. If in the future the spot price returns to its original value, the user's position returns to its initial state without incurring any loss (neglecting any time-value decay).

Extending this idea to the out-of-the-money region, where the option value is relatively small, the amount of leverage increases further. For example, as shown in Figure 1a, if a user buys an OTM option for \$1.2 when the spot price was 80, then a 40% increase in the spot price to 120 leads to the option price of 20. This yields a return of 1566% and hence a leverage of 39×. This way OTM options also serve as high-leverage instruments.

3.3 | Liquidation-Free Loans

Over-collateralized lending protocols such as Aave [16], Compound [17], and Morpho [18] have become an established financial instrument in modern DeFi. Such protocols enable borrowing of an asset, such as ETH, by depositing different collateral, for example, USDC, of much larger value. At all times during the loan duration, the collateral must hold a larger value than the loan. Any violation of this condition, even momentarily due to a spike in the price of the underlying asset, can lead to a liquidation of the loan.

As before, such liquidations resulting from sudden price fluctuations are detrimental not only to the borrowers but also to the DeFi ecosystem as a whole due to associated systemic risks [19]. Zero liquidation loans [20] and reversible call options [21] are two solutions to this problem that use options. At a high level, the first solution requires a user borrowing 1 ETH by depositing 1000 USDC to purchase a call option with a strike price of 1000 from the lender to prevent liquidation. The second solution, on the other hand, introduces agents known as supporters who re-collateralize a loan if it gets undercollaterized and prevents liquidation. In return, supporters receive a reversible call option implicitly written by the borrower.

3.4 | Applications of Exotic Options

Apart from vanilla options, other exotic variants exist, with *binary options* being of particular interest. A unit European binary call option pays $1 if the spot price is greater than the strike price at expiration and $0 otherwise [1]. Such options can be extended to track a generalized underlying event, where the occurrence of the event pays $1 and $0 otherwise. They are often used to create insurance markets for unfavorable events [22]. Additionally, they are employed in prediction markets to estimate the likelihood of the underlying event occurring [23].

4 | Overview of Existing Option Platforms

We discuss options within the two classes of exchange platforms, namely, centralized and decentralized. The latter can be further categorized between *composable*- and *custom rollup*-based designs. Subsequent to this classification, we present an analysis of option design choices within decentralized systems.

4.1 | Centralized Exchanges

CEXes function as custodial platforms where users' digital assets are held by the exchange. Typically, these exchanges operate using traditional limit order book designs, wherein buyers and sellers submit their price quotes, and a matching engine facilitates trades by pairing compatible orders. Currently, CEXes dominate the options trading market, with the leading players being Deribit [24], Delta Exchange [25], Binance [26], and OKX [27]. In terms of market share for notional volume, Binance and OKX each capture 6%, Delta Exchange holds 12%, while Deribit commands the largest share at 76% [28].

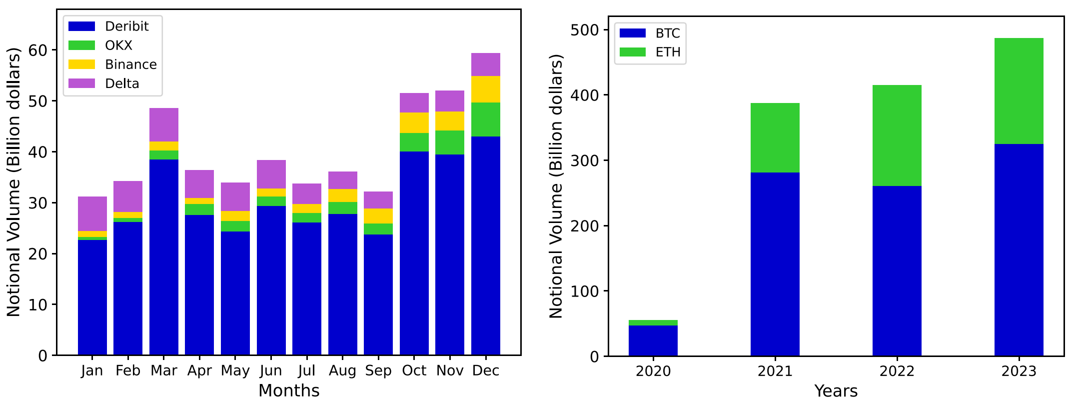
Among all cryptocurrencies, options for BTC and ETH are the most heavily traded. Figure 3 illustrates the monthly and yearly notional volume for BTC and ETH options traded on the aforementioned CEXes. In the previous year (2023), the cumulative volume of BTC options reached an impressive $325 billion, while ETH options stood at $162 billion, nearly half of BTC's volume. These figures underscore the significant demand for options within the market which has increased significantly over the recent years. In 2020, the cumulative notional for BTC and ETH together was $55.4 billion. Hence, the options market has grown by 785%. This immense growth reflects the overall advancement and acceptance of options derivatives among DeFi users. It's noteworthy that the current options market is primarily focused on BTC and ETH, indicating a substantial opportunity for the expansion of option derivatives to encompass a broader range of assets, particularly altcoins and low-liquidity ERC20 token pairs.

4.2 | Decentralized Exchanges

The following classification exists for designs of decentralized options exchange.

1. **Composable designs:** Composability in DeFi refers to the interaction between multiple applications, each benefiting from the other's permissionless and public infrastructure [29, 30]. Traditional finance has limitations on practical composability due to its permissioned nature and high barrier to entry. On the other hand, composable smart contracts serve as fundamental building blocks within the DeFi ecosystem, or money LEGOs, allowing other financial applications to be built on top of them. In the context of composable option exchanges, we consider only those design paradigms that facilitate end-to-end order execution through smart contracts on a public and permissionless blockchain (Layer-1 or -2). This entails quoting and settling of buy and sell orders entirely on the blockchain.

   Despite leveraging on the advantages of composability, this category of exchanges has struggled to gain user adoption compared with centralized exchanges. In 2023, they accounted for a cumulative volume of $1.7 billion [31], representing only 0.35% of the trading volume observed on the centralized counterparts. One of the major reasons is the difficulty posed by application development on smart contracts due to the constraints imposed by the underlying blockchain infrastructure, such as high gas cost, block delay, adherence to specific virtual machines and contract languages. These limitations can restrict flexibility in design choices, often forcing developers to adopt innovative



(a) (b)

FIGURE 3 | Notional volume of BTC and ETH options across centralized exchanges.

workarounds as discussed in Section 5. To address this, some designs opt for custom rollups, as discussed next, although this may come at the expense of composability.

2. **Custom rollup-based designs:** Layer-2 solutions are designed to enhance the scalability of blockchain networks without altering the underlying trust assumptions. These protocols operate atop Layer-1 blockchains and offer various scaling mechanisms. Among these, roll-ups are the predominant scaling solutions for DeFi protocols deployed on Ethereum [32]. Their primary objective is to alleviate the burden on the main chain by batching transaction executions off-chain and consolidating them for on-chain verification. This yields significantly reduced, between $10-20\times$, transaction costs [33].

   In the realm of decentralized finance, Layer-2 solutions tailored specifically for DeFi projects are termed *appchains* [34]. Among option appchains, AEVO (formerly known as Ribbon Finance) [35] is the most successful on Ethereum in terms of trading volume [4]. AEVO adopts an orderbook mechanism for BTC and ETH options, similar to CEXes, where buyers and sellers post their orders off-chain. Once an order is matched, settlement occurs on the AEVO rollup. Unlike CEXes, users retain custody of their assets on appchains. However, users may typically experience a waiting period of as much as 2 hours for order confirmation and/or asset withdrawal.

   Unlike composable designs, which benefit from network effects within the ecosystem, appchains are prone to isolation. Neglecting this aspect can significantly hinder the success of the protocol. One effective approach to addressing this issue is introducing multiple DeFi products on the appchain that add value to each other. This is observed in AEVO, which also operates as a perpetual futures exchange. Parameters such as *funding rates* from the futures exchange are then used to price options on altcoins in the options exchange.

   Although user adoption trends on appchains were similar to composable designs with a notional volume of $928 million in 2023, this category has seen a recent surge with $37 billion in the first six months of 2024 [31]. Although the former volume comprises 0.2%, the latter comprises 8.04% of the volume on centralized exchanges. These figures underscore a significant uptick in user interest in decentralized options trading.

5 | Design Considerations for Decentralized Options Exchanges

In this section, we study the designs of popular decentralized options exchanges, or *options DEXes*. Because each of these exchanges adopt a unique design, we abstract away from the individual details and identify a common core as shown in Figure 4. Specifically, an options DEX interacts with three kinds of users: (a) *Traders* buy an option from the exchange for a premium. Their goal is to either sell back the option at an appreciated value or exercise it for a positive payoff. Their motivation for choosing options over other products stems from its unique offerings described in Section 3 (such as leverage and hedging). (b) *Option writers* underwrite the options contract and guarantee to deliver the payoff to traders when the contract is exercised in return for the premium paid by the traders. To guarantee the promised payoff, option writers lock "sufficient" collateral with the exchange using different mechanisms ranging from partial to full collateralization. These mechanisms are studied in detail in Section 5.4. (c) *Decentralized operators* perform essential and day-to-day operations of the exchange. This includes triggering contract expiration for fixed-term options, liquidating undercollateralized writers, and so on. In some designs [36], they act as liquidity providers to bridge the gap between traders and sellers. The operators can be a set of permissioned addresses, such as members of a decentralized autonomous organization (DAO), or permissionless users trying to earn protocol incentives and rewards.

The architecture of a generic options DEX can be divided into three primary components: the *oracle*, *price*, and *collateral*

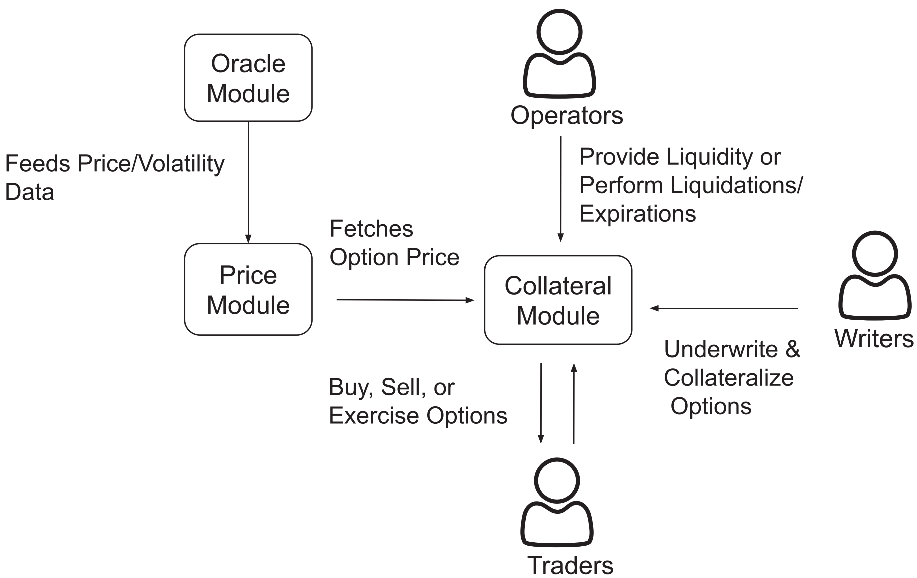


FIGURE 4 | Design abstraction for a decentralized options exchange.

modules, as shown in Figure 4. The oracle module fetches data for price and volatility feeds from on-chain and off-chain sources. These are passed as inputs to the price module to calculate the premiums of the listed options. These calculated amounts are then used by the collateral module to collect the necessary amounts from traders and pay underwriters. It also monitors the value of the deposited collateral along with its obligations to other users. This way, it performs assets' accounting while retaining their custody.

In addition to vanilla options, an options DEX may list other variants, for example, perpetual options. Thus, in the following, we discuss how different DEX designs implement the above abstract modules along with the choice of options variants they list. We analyze the following protocols: AEVO [35], DERIVE [37], DERI [38], RYSK FINANCE [11], STRYKE [39], HEGIC [40], PREMIA [41], and PANOPTIC [36]. It is worth noting that one of these eight protocols, AEVO, uses custom rollup, while the others adopt a composable design.

5.1 | Choice of Option Variant

As described in Section 2.1, options can be categorized as either fixed-term or perpetual. Market participants, including option writers and traders, have long favored fixed-term options due to their established track record and familiarity. Consequently, an extensive body of literature exists on financial strategies utilizing fixed-term options [1]. Despite their popularity, fixed-term on-chain options present numerous implementation challenges, including constant market renewals after each expiration, which results in higher gas costs that can be particularly problematic for short-term options. Additionally, liquidity fragmentation among different expiration terms contributes to an overall low liquidity for each duration. Nevertheless, six of eight on-chain protocols—namely, AEVO, DERIVE, RYSK FINANCE, STRYKE, HEGIC, and PREMIA—offer fixed-term options, underscoring the industry's emphasis on standardization.

On the other hand, DERI and PANOPTIC are some of the few exchange designs to offer perpetual options. DERI implements everlasting options, described in Section 2.2, as its underlying financial instrument. Although exotic, this variant has gained significant traction, making DERI the largest composable design in terms of total value locked. Unlike everlasting options, PANOPTIC implements a different variant known as Panoptions. Instead of paying a daily funding fee as in everlasting options, the holder of a panoption pays a stream of continuous and dynamic premiums. This payment stream equates to the trading fees earned by liquidity providers on the corresponding Uniswap pair [6]. Utilizing the composable interactions with Uniswap makes PANOPTIC's design familiar to the existing users on Uniswap.

Apart from these, other variants of perpetual options have also been proposed [42]. However, despite being innovative, they are relatively new and thus present a lack of research on strategies for various participants, particularly option writers, who may be hesitant to participate significantly due to under-confidence in assessing their risks and incentives.

5.2 | Oracle Choices

Because blockchains operate as isolated systems, they lack direct access to real-world (off-chain) data. However, decentralized derivatives applications often require continuous monitoring of the underlying asset, such as its spot price. In these scenarios, oracles, which are third-party data providers, play a crucial role as data sources that bridge smart contracts with the outside world [43]. They are widely utilized in DeFi protocols to fetch various types of data, including spot price, trading volume, and price volatility.

Despite their utility, oracles introduce several challenges to DeFi projects. Both centralized and decentralized oracle designs are susceptible to malfunctions and manipulations, as witnessed in past exploits [44]. Such incidents can have a significant impact on DeFi applications unless preemptive mitigation strategies are adopted [45, 46].

Decentralized option exchanges typically rely on oracle sources for fetching either price feeds, volatility feeds, or both. Some applications, including RYSK FINANCE, AEVO, and DERIVE, also fetch parameters such as risk-free interest rate, forward rate, and so on. These parameters are often used for option pricing, as discussed in the subsequent text or to monitor collateral requirements for option writers. Table 1 presents the oracle feeds used by major on-chain option protocols. Notably, decentralized oracle services such as Chainlink [47], Pyth [48], Oraclum [49], and DIA [50] are mostly utilized for spot price feeds except AEVO which uses weighted prices from 10 exchanges. This choice is more robust than the former but incurs higher operation and management costs. On the other hand, API feeds from centralized exchanges such as Deribit or services like Block Scholes [51] are used for implied volatility data. Additionally, designs like PREMIA allow for permissionless integration of third-party oracles for spot price feeds. This approach is noteworthy as each oracle has its own benefits and limitations, and having a permissionless design allows protocols to leverage the strengths of multiple oracles.

TABLE 1 | List of oracle feeds used by onchain exchanges.

Protocol	Price feed oracle	Volatility feed oracle
AEVO	Weighted price from CEXes	Pyth, Deribit
DERIVE	Block Scholes	Block Scholes
DERI	Oraclum, Pyth	Oraclum, Pyth
RYSK FINANCE	Chainlink	Deribit (Offchain)
STRYKE	Chainlink, DIA	Deribit (Offchain)
HEGIC	Chainlink	Chainlink
PREMIA	Permissionless	Amberdata/Deribit
PANOPTIC	—	—

While access to external data via oracles broadens the scope of protocol design, reliance on third-party services poses operational limitations. For instance, protocols using Deribit volatility feeds are restricted to listing assets traded on the Deribit exchange (BTC and ETH), limiting the scalability of the options protocol. To address such concerns, PANOPTIC eliminates reliance on oracle services. Instead, it uses the trading fees on Uniswap as its only external input. As a result, permissionless options markets can be created for any token pair that trades on Uniswap. Finally, it is worth mentioning that although this design removes dependencies on third-party oracles, it generates dependencies between Panoptic and Uniswap.

5.3 | Choice of Price Discovery Mechanism

This aspect examines how different protocols quote options prices to traders. Price discovery mechanisms can be classified into three categories: (a) *market-based* where the price is determined by the demand and supply of the option, (b) *model-based*, where option prices are calculated by the protocol using established financial models, and (c) *hybrid* where a combination of both is used. In the following, we provide a brief description of each.

1. **Market-based:** This category of price discovery uses mechanisms such as order book-based markets, automated market makers (AMM), or on-chain auctions. Of the seven protocols, AEVO and DERIVE use order books for price discovery, with the former using this only for BTC and ETH options. On the other hand, PREMIA employs an AMM-based scheme where they create a concentrated AMM pool for each strike price of an option. This allows the protocol to discover the price for each strike independently.

2. **Model-based:** This pricing category is the most prevalent among existing on-chain option designs. Vanilla pricing models such as standard Black–Scholes, as used by STRYKE and HEGIC, require input values for spot price, implied volatility, and interest rates. On the other hand, advanced models like SABR [52], as used by AEVO over-the-counter (OTC) [53] and RYSK FINANCE, require additional parameters such as the forward price. While spot price oracles are readily available, sources for other parameters such as implied volatility are scarce. This scarcity is attributed to the immaturity and illiquidity of the options market, especially for altcoins. To confront this challenge, designs like AEVO and RYSK FINANCE use implied volatility and funding fees from off-chain exchanges for BTC and ETH which are then used to derive any additional parameters. Moreover, AEVO calibrates these input parameters to determine volatility for other altcoins. Others like STRYKE and HEGIC use historical volatility feeds and neglect other parameters like interest rates, resulting in approximated outputs.

   Unlike the above, PANOPTIC does not charge an upfront premium. Instead, it charges a streaming premium every time the spot price crosses the strike price (from above or below) on Uniswap, which amounts to the corresponding trading fees. This makes the premium dependent on the price path, making it stochastic. Assuming a Geometric Brownian model for the price, PANOPTIC numerically proves that around 33% of the time, the streaming premium on its 7-day option is zero [36]. Moreover, around 16% of the time, the streaming premium is twice as large as the theoretical B-S premium. However, the streaming premium converges to the B-S premium as the holding duration becomes sufficiently long. Therefore, the pricing of these options can deviate significantly for a shorter holding duration.

   A key observation on exchanges solely dependent on model-based pricing is that they sometimes do not allow option traders to sell their positions while it is out-of-the-money. This is observed in the STRYKE, HEGIC, and PANOPTIC protocols, which only allow buyers to exercise their positions if they become in-the-money. This condition may not be acceptable for some option holders because restricting the sale of out-of-the-money options might limit their flexibility compared with other DEX designs that allow selling at any time.

3. **Hybrid:** This pricing category is used by DERI for determining the mark price of its everlasting options. DERI uses a mechanism called proactive market-making (PMM) that uses a liquidity pool but functions as an order book against which the users' market orders are filled. That is why it is also referred to as a *virtual orderbook*. To achieve this, PMM uses two parameters: the initial mid-price of the order book and the shape of the order book. To calculate the first parameter, that is, the option's theoretical value, the spot price, and volatility are fetched from the oracle feed, and the final value is calculated using the pricing formula for everlasting options derived in [38]. The protocol manager controls the second parameter, shaping the order book accordingly.

5.4 | Collateralization Choices

To understand collateralization, consider an example of a European call option on the ETH/USD pair and a strike price of \$100. If the price of ETH, p, at the time of expiration is greater than \$100, then the option writer pays \$$(p - 100)$ to the holder. As, theoretically, the ETH price does not have an upper bound, the writer can end up owing an unbounded amount to the holder. To guarantee that option holders will be paid, exchanges often require writers to deposit collateral. In the above example, if the writer deposits 1 ETH as collateral, then its change in value will always cover the payoff. If the option in the previous example is a put, then the payoff is \$$(100 - p)$ when the ETH price is below \$100. In this case, a deposit of \$100 fully collateralizes the option. This is the scenario of a *fully collateralized* call option.

Conversely, in the *partial* collateralization case, a writer deposits its collateral that is less than the amount written in the option. Such collateralization benefits the option writer as less capital is needed to underwrite an option. However, this method poses the risk of a writer not fulfilling their payoff commitment. For example, if only 0.5 ETH supports the call option in the example above, then an ETH price above \$200 would make the collateral less valuable than the payoff. To prevent such an event, partially collateralized options are liquidated before the collateral value falls below the payoff value, leading to the seizure of the deposited collateral. Hence, partial collateralization presents a trade-off between lower capital requirements and the risk of liquidation.

Considering the above, an options DEX designed to eliminate liquidation complexities would require full collateralization. Such complexities include monitoring the value of the collateral, dependencies on price oracle, incentivizing users that perform liquidation, and maintaining insurance funds to cover liabilities from unsuccessful liquidations, which can occur during extreme volatility periods [54]. This is why three protocols, namely, Stryke, Hegic, and Premia only support full collateralization. On the other hand AEVO, Derive, Deri, Panoptic, and Rysk Finance support partial collateralization. In the latter case, option writers often must deposit initial collateral, known as the *initial margin*, and maintain a lower *maintenance margin* over time. Table 2 summarizes the four design choices discussed for the seven protocols.

6 | Consequences of Missing Options Market

In this section, we study how the absence of an options market can affect the liquidity of tokens on an AMM. More specifically, in a market with tradeable options, if the liquidity on an AMM is below a specific threshold, such that the trading fees per liquidity are greater than the premium of a put option, then a risk-free investment opportunity arises. Assuming a fixed trading fee in a time window (i.e., constant AMM trading volume), a user can start with a cash position, purchase the asset, add liquidity to the AMM to earn fees, and simultaneously buy a put option to cover their loss if the asset's price falls. As the fees are enough to pay for the option, the user earns a positive return without bearing any risk. This continues until the liquidity level reaches a threshold such that the trading fees equal the premium. We refer to this process as *zero-loss liquidity provision*.

In the absence of an options market, this incentive is not present, and hence, the liquidity can fall below the aforementioned threshold. The degree to which it reduces is evaluated in our experiments through analysis of historical on-chain data for tokens without an options market. In the following, we briefly explain the workings of liquidity provision on AMMs and derive an expression for the threshold level of liquidity.

6.1 | Concentrated Liquidity Provision

Concentrated liquidity automated market makers, introduced by Uniswap v3 [6], constitute a decentralized design for a spot exchange. The AMM consists of a collection of liquidity pools for trading token pairs, denoted by T/U, where T is the asset token and U is the numeraire, such as USD. Agents known as *liquidity providers*, or LPs, deposit both the asset and the numeraire in a liquidity pool in a specific price range. They serve as counterparties to traders and are subject to loss, also known as impermanent loss, that can be as high as the LP's total position as a result of significant price movements. On the other hand, LPs are incentivized to participate by earning trading fees for each trade executed on the AMM. Consider a pool for the pair T/U and let p denote the spot price of T in terms of U. As described in Uniswap v3 [6], the position of an LP providing l units of liquidity in the price range $[p_a, p_b]$ consists of the following units of T and U, respectively:

$$\begin{aligned} T:&\quad \max\left(\frac{l}{\sqrt{p}}-\frac{l}{\sqrt{p_b}},0\right)\\ U:&\quad \max\left(l\left(\sqrt{p}-\sqrt{p_a}\right),0\right)\end{aligned} \tag{2}$$

When the spot price is outside the above range, the position becomes inactive, and the amounts of T and U do not change. Therefore, the payoff of the above position calculated in units of numeraire U is

$$\begin{cases} p\left(\dfrac{l}{\sqrt{p}}-\dfrac{l}{\sqrt{p_b}}\right)+l\left(\sqrt{p}-\sqrt{p_a}\right) & \text{if}\quad p_a\le p\le p_b\\ p\left(\dfrac{l}{\sqrt{p_a}}-\dfrac{l}{\sqrt{p_b}}\right) & \text{if}\quad p\le p_a\\ l\left(\sqrt{p_b}-\sqrt{p_a}\right) & \text{if}\quad p_b\le p\end{cases} \tag{3}$$

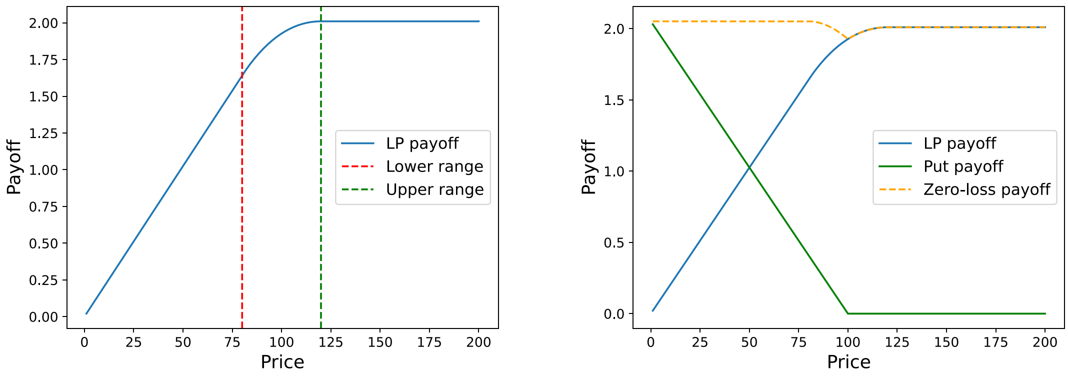
Figure 5a shows the plot of the above position versus the spot price of T where $p_a = 80$ and $p_b = 120$.

6.2 | Zero-Loss Liquidity Provision

In a scenario where an options market is available to users, an LP with l units of liquidity can hedge their payoff below the

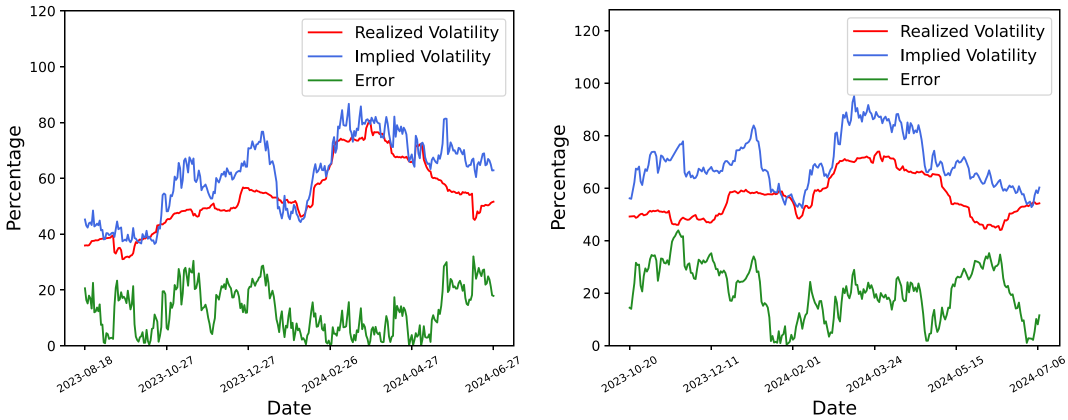
TABLE 2 | Options design choices in decentralized protocols.

Protocol	Option variant	Oracle type	Pricing mechanism	Collateralization
AEVO	Fixed	CEX	Market-based	Partial
Derive	Fixed	Centralized	Market-based	Partial
Deri	Perpetual	Decentralized	Hybrid	Partial
Rysk Finance	Fixed	Decentralized/CEX	Model-based	Partial
Stryke	Fixed	Decentralized/CEX	Model-based	Full
Hegic	Fixed	Decentralized	Model-based	Full
Premia	Fixed	Permissionless	Market-based	Full
Panoptic	Perpetual	—	Model-based	Partial



(a) (b)

FIGURE 5 | Illustration of payoff in concentrated liquidity provision and zero-loss liquidity provision strategy.



(a) (b)

FIGURE 6 | The fit and standard error between realized and implied volatility of ETH and BTC during the last year.

entry price by buying $\frac{l}{\sqrt{p_a}} - \frac{l}{\sqrt{p_b}}$ units of a put option with strike price equal to the entry price. The payoff of such a put option is shown in Figure 5b, where the entry price is 100. As a result, their hedged payoff becomes a flat line, as shown in Figure 5b by the dashed line. For this strategy to be profitable, the total liquidity should be below the threshold L^*, assuming uniform liquidity in the price range. Let f denote the total fees earned for the duration the LP holds the option and p_{put} denote the premium of the put option, then the following expression derives the threshold liquidity by equating fees per unit liquidity with the cost of the associated units of put option:

$$\frac{f}{L^*} = p_{put}\left(\frac{1}{\sqrt{p_a}} - \frac{1}{\sqrt{p_b}}\right) \tag{4}$$

In the next section, we find historical instances where the liquidity was less than the above threshold.

6.3 | Evaluation

In this section, we examine historical instances where, hypothetically, a zero-loss liquidity provision was feasible. Specifically, we focus on instances where the trading fees earned per unit liquidity provision exceeded the cost of the put option premium. Our analysis is centered on ERC20 token pairs for which option derivatives have not yet been developed.

Methodology: We consider a strategy where a user provides unit liquidity, that is, $l = 1$ for a pair T/U on Uniswap v3 for a period of n weeks. The lower and upper range of the liquidity is the minimum and maximum price of T in the subsequent n week window. Simultaneously, the user buys $\frac{1}{\sqrt{p_a}} - \frac{1}{\sqrt{p_b}}$ units of a put option with a strike price equal to the entry price.

To calculate the price of the put option, we use the historical realized volatility as an estimate for implied volatility. The realized volatility is calculated by taking the standard deviation of the logarithm of daily returns of prices over a rolling window that spans 22 before and 21 days after the day of interest. These window sizes were found by minimizing the $L2$ error between realized volatility and implied volatility of BTC and ETH. Figure 6 shows a plot of the fit between realized and implied volatility and the corresponding error with a worst-case value of 30%. The price of the at-the-money put option p_{put} (since strike price equals spot price at the beginning of the month) is then calculated using the approximate expression:

$$p_{put} = 0.4 p_e \sigma_r \sqrt{\frac{n}{52}} \tag{5}$$

where σ_r is the realized volatility and $\frac{n}{52}$ is the time to expiration in years [55]. As the price of the put option is linear to the volatility, we increment σ_r by 30% while calculating p_{put} to account for the worst-case error during volatility.

To calculate the historical fees earned per unit of liquidity over n weeks, we use the Dune Analytics [56] API, with the corresponding code available on Github.[4] Subsequently, we compare the ratio of fees earned to the worst-case price of the put option to determine profitable opportunities.

Setup: We performed three experiments, each corresponding to $n = 4$, 6, and 8 weeks, respectively, and analyzed the historical data for the past three years. For each experiment, we check the profitability of a strategy starting at the beginning of every week. We investigated altcoins on the Ethereum [3], Arbitrum [57], and Polygon [58] blockchains for which profitable strategies exist. Of the pairs available with Dune API, we shortlisted the ones shown in Table 3 and more specifically: Chainlink [47] (LINK), Uniswap [6] (UNI), Ethereum Name Service [59] (ENS), Arbitrum [57] (ARB), Polygon [58] (MATIC), DIMO [60], AAVE [16], Vulcan Forged [61] (PYR), Curve Finance [62] (CRV), and Lido Finance [63] (LDO).

Results: Figure 7 plots the ratio of fees earned versus the put option price for the above tokens. The markers above 1 indicate a profitable opportunity. For some pairs such as LINK/ETH, UNI/ETH, MATIC/PYR, MATIC/LIDO, ETH/ENS, the zero-loss LP strategy had more profitable opportunities for longer periods, namely, 6 and 8 weeks when compared with 4 weeks. Table 3 presents the range of the fee-to-option price ratios for each pair under the three holding periods along with the number of profitable opportunities. For the period of 4 weeks, the ratio went as high as 6.31 for the MATIC/PYR pair on the Polygon blockchain. The same pair demonstrated the highest ratio for the 6 and 8 weeks periods, as well, reaching 6.11 and 6.69, respectively. Similarly, the MATIC/AAVE pair observed 51 profitable instances, which is the highest in a 4-week window. The pair with the most profitable instances for the 6 and 8 week windows was MATIC/PYR with 51 and 57 instances, respectively.

6.4 | Discussion

Over the past three years, we identified 1143 zero-loss liquidity provision opportunities (as shown in the last row of Table 3) across the 14 token pairs listed above, spanning three blockchains. The number of such instances could be even higher if more token pairs on various other AMM platforms, such as Uniswap v2, Sushiswap, and so on, and across different layer-1 and layer-2 blockchains were considered. The ratio of fees to option premium represents the factor by which the existing liquidity levels were lower than the minimum threshold. This factor is well above one for every altcoin, and for some, is over six. The inferences from this are twofold. First, the presence of altcoin options could have reduced the cost of liquidity provision, leading to significantly higher liquidity. Second, there is a substantial need for altcoin options in the DeFi markets. However, this need was never served due to the lack of a well-functioning options trading platform where users can create and trade options on arbitrary token pairs.

TABLE 3 | Range of fee to option premium ratio along with the number of profitable instances for a window size of 4, 6, and 8 weeks, respectively.

Token pair (Pair_Fee_Chain)	4 weeks (min, max, data points)	6 weeks (min, max, data points)	8 weeks (min, max, data points)
LINK_ETH_0.3%_ETH	(1.01, 4.23, 46)	(1.01, 2.96, 46)	(1.0, 2.5, 52)
UNI_ETH_0.3%_ETH	(1.03, 1.8, 13)	(1.05, 2.57, 23)	(1.03, 2.4, 27)
ETH_ENS_0.3%_ETH	(1.32, 3.74, 3)	(1.04, 5.28, 6)	(1.1, 6.03, 10)
ARB_USDC_0.05%_ARB	(1.1, 1.26, 4)	(1.01, 1.4, 8)	(1.23, 1.69, 6)
MATIC_DIMO_1.0%_POLY	(1.14, 2.04, 11)	(1.02, 1.91, 11)	(1.02, 1.71, 8)
MATIC_AAVE_0.3%_POLY	(1.0, 2.23, 51)	(1.0, 1.93, 47)	(1.01, 2.12, 37)
MATIC_PYR_1.0%_POLY	(1.12, 6.31, 47)	(1.09, 6.11, 51)	(1.03, 6.69, 57)
MATIC_BTC_0.05%_POLY	(1.01, 1.67, 4)	(1.02, 1.41, 3)	(1.11, 1.27, 3)
MATIC_CRV_0.3%_POLY	(1.02, 4.23, 47)	(1.01, 4.51, 46)	(1.0, 4.24, 48)
LINK_ETH_0.3%_POLY	(1.0, 3.0, 36)	(1.02, 1.74, 37)	(1.0, 1.9, 25)
ETH_AAVE_0.3%_POLY	(1.04, 2.81, 41)	(1.03, 3.27, 51)	(1.01, 3.7, 44)
USDC_LINK_0.3%_POLY	(1.01, 1.49, 24)	(1.0, 1.51, 20)	(1.01, 1.43, 16)
MATIC_UNI_0.3%_POLY	(1.05, 5.56, 31)	(1.02, 6.05, 29)	(1.01, 2.11, 25)
MATIC_LDO_0.3%_POLY	(1.13, 2.06, 10)	(1.07, 2.86, 15)	(1.01, 2.57, 24)
Total Data Points	368	393	382
Grand total		**1143**	

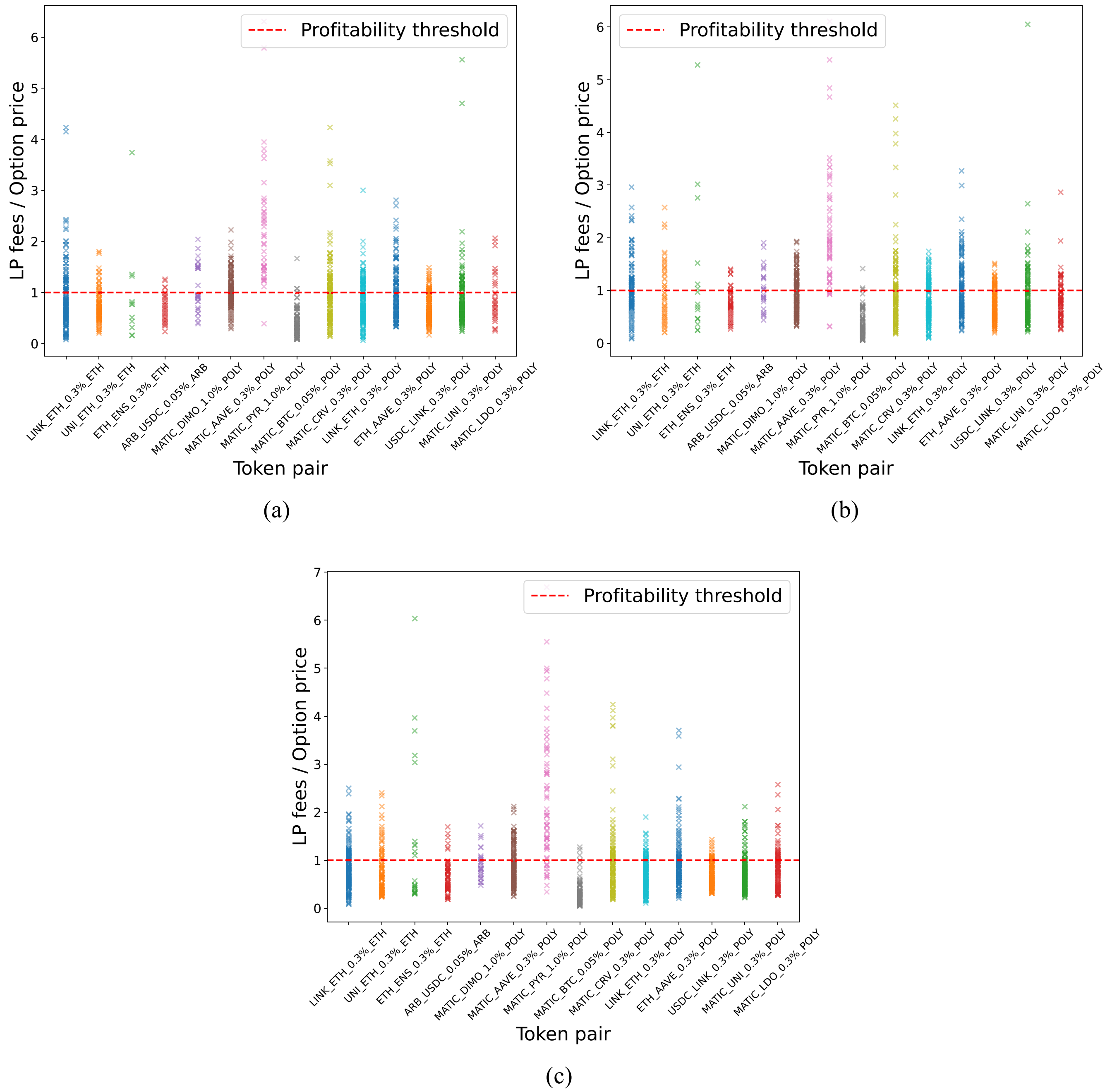


FIGURE 7 | The ratio of LP trading fee to option premium of different trading pairs for periods of 4, 6, and 8 weeks, respectively.

7 | Challenges

The substantial notional volume of options traded on CEXes highlights their strong demand and importance within the cryptocurrency markets. Yet, despite this, DEXes collectively own only a small share of the options market. Thus, it is important to understand the challenges that need to be addressed for option DEXes to gain traction.

- *Liquidity fragmentation:* Options with fixed-term expiration dates necessitate the creation of separate markets for each combination of strike price and expiry date. This segmentation leads to liquidity fragmentation, making it difficult to aggregate sufficient liquidity in any single market. One solution is perpetual options as they use a single market for multiple periods. However, they come with their issues, as discussed next.
- *Research gap for non-vanilla options:* Non-vanilla options, including innovative designs like everlasting options, are intended to address the technical limitations inherent in traditional vanilla fixed-term options. These new designs introduce unique features that may require a different approach to price modeling, risk assessment, and the development of trading strategies. However, the literature reveals a significant research gap in these areas. The lack of comprehensive studies and robust models for these non-standard options could lead to uncertainty among traders. Without a solid understanding of the pricing dynamics, potential

risks, and effective trading strategies, serious traders may hesitate to allocate substantial capital to these financial instruments, potentially hindering the adoption and growth of the protocol.

- *Advantage over centralized exchanges:* While decentralized exchange solutions offer significant benefits such as self-custody, which ensures users retain control over their assets, and full transparency, which allows for open verification of transactions and protocols, they often fall short in providing a clear financial advantage over their centralized counterparts. Unlike AMMs, which allow for the permissionless listing of tokens for any trading pair, many current option DEX solutions are constrained by their reliance on price and volatility oracles. This dependency limits their ability to offer similar flexibility and responsiveness, especially in markets with high volatility or illiquid assets.
- *Difficulty of price discovery:* Price discovery in decentralized options markets faces challenges with both market-based and model-based approaches. In market-based discovery, time value decay complicates matters as the continuously changing option value requires frequent updates to order books or AMM reserve states, leading to significant gas costs. On the other hand, model-based discovery struggles with the complexity of non-linear pricing models, making accurate and affordable on-chain calculations difficult. Moreover, these models only provide rough estimates, and there is no universally accepted "best" model. Therefore, innovative solutions are needed to address these challenges in option price discovery.
- *Oracle vulnerabilities:* Almost all decentralized designs depend on oracle feeds for price and volatility, which raises several operational and efficiency challenges. Operational challenges include the inability to list arbitrary assets caused by the lack of volatility feeds for these assets. On the other hand, efficiency challenges are inherent to oracle design and manifest as oracle malfunction and manipulation. By addressing these concerns or completely removing oracle dependency with "oracle-less" designs as in PANOPTIC, DeFi options can reach their next phase of adoption.
- *Illiquid altcoin markets:* The options market for altcoins is still in its early stages and lacks liquidity across all exchanges. This absence of liquidity results in a scarcity of volatility feeds, which in turn discourages other platforms from entering this sector. Although solutions like AEVO aim to address these challenges by calibrating such markets to BTC and ETH using correlated models, they come with their own limitations. These include invalidity of the model for longer-term options and inaccuracies in correlation assumptions [53].
- *Unresolved regulatory issues:* Although the observations of this paper are only technical, the DeFi sector is characterized by uncertainties surrounding regulatory issues around many of its activities. Consequently, developers are compelled to adhere to subjective "best practices," resulting in a deterrent effect on participation [64], which is also a pillar behind the technical observations of this work.

8 | Related Work

DeFi applications design survey: Several works investigate designs of popular and fundamental DeFi applications, including decentralized exchanges, decentralized debt markets, derivatives, on-chain asset management protocols, and so on [65–68]. In these works, the study of derivative protocols is limited to tokens whose price depends on real-world assets or events. This includes perpetual futures and prediction markets but does not include designs for options. Other studies [44, 69] investigate the design of DeFi applications from a security point of view. Lastly, there is a set of works that focuses on vertical analysis of specific DeFi categories, for example, decentralized exchanges [70], yield generating protocols [71], and lending [72]. However, none of them investigates the designs of the options protocols. Our work fills this gap by investigating the smart contract designs of the major decentralized options protocol.

DeFi options survey: While several studies have explored the derivatives landscape in DeFi, few have specifically concentrated on options derivatives. One study [69] examines various DeFi protocols and highlights their vulnerabilities to exploits. It includes a brief discussion on the current state of options derivatives in DeFi, addressing challenges such as high collateralization requirements, managing time-value decay in pricing, and liquidity constraints. Similarly, another study [73] discusses various financial "legos" of DeFi and briefly mentions options derivatives. Unlike these works, our work provides an extensive examination of the options landscape in DeFi, elaborating on the designs of existing platforms, and their shortcomings.

Inefficiencies in AMM: There have been several works that characterize inefficiencies in AMM. One category of work studies inefficiencies in price execution that are unfavorable to traders [74, 75]. Another category studies inefficiencies in liquidity provision arising due to increased risk and lower rewards [76–78]. Similarly, some works study the historical behavior of liquidity providers [79]. Lastly, a category of work investigates optimal liquidity provision strategies for optimal LP returns under different market conditions [80–83]. Unlike these, our work presents a historical analysis of AMM inefficiency through lower liquidity or higher fees that could be offset with an options market.

9 | Conclusion and Future Work

Option derivatives are fundamental instruments in both financial literature and traditional financial markets, primarily due to their unique characteristics, such as non-linear delta and value dependency on market volatility. The non-linear delta allows for the creation of highly leveraged positions, particularly through out-of-the-money options and enables delta-neutral portfolio optimization. The value dependency on market volatility allows traders to capitalize on insights into future market conditions.

The traditional finance sector has seen a significant surge in the options market over the past decade, with trading volumes growing more than tenfold. This gradual adoption reflects the advanced nature of these instruments. Similarly, in decentralized finance markets, which have only been around for about a decade, options on digital assets are gradually being adopted by traders with significant year-on-year growth. However, the market share of decentralized exchanges for options remains extremely small compared with centralized exchanges. This disparity can be attributed to several challenges, particularly stemming from technical, adoption, and research issues, that hinder the success of DEXs. The root of these lies in offering a significant value proposition that CEXs do not provide. For example, the value addition in decentralized spot markets was the permissionless listing of arbitrary token pairs, a feature not currently available in options platforms due to their reliance on third-party oracles.

One consequence of the absence of options markets is the low liquidity on AMMs. As presented in this work, numerous tokens oversaw significantly low liquidity on AMMs and the existence of an options could have allowed users to increase liquidity in risk-free manner. Such an opportunity, along with innovations like liquidation-free loans, has the potential to advance the DeFi landscape significantly.

While investigating the impact of options market on DeFi, this study only focuses on the prevalent platform, namely, concentrated liquidity AMM, omitting other platforms such Uniswap v2, lending platforms, and so on. Future research endeavors could explore historical opportunities on these unexplored platforms to further validate the need for decentralized options. Other future research directions include analyzing designs of prominent oracle-less DeFi derivatives protocols to propose oracle-less options exchange solutions. Another avenue is investigating exotic options in the traditional finance literature to address adoption challenges for DeFi options, such as modeling complex payoffs and enhancing user-friendliness.

Endnotes

[1] https://www.fia.org/fia/etd-tracker.

[2] https://dune.com/rchen8/defi-users-over-time.

[3] https://www.forbes.com/sites/digital-assets/2023/07/09/sec-regulation-of-defi-could-box-out-diverse-entrepreneurs-and-impact-projects/.

[4] https://github.com/ukitta555/LP_Options_Hedge_Backtest.

References

1. J. Hull, *Options, Futures, and Other Derivative Securities*, Vol. 7 (Englewood Cliffs, NJ: Prentice Hall, 1993).

2. S. Nakamoto, “Bitcoin Whitepaper,” (2008), https://bitcoin.org/bitcoin.pdf.

3. V. Buterin, “Ethereum: A Next-Generation Smart Contract and Decentralized Application Platform,” (2014), https://ethereum.org/en/whitepaper/.

4. “Total Value Locked in DeFi,” (2024), https://defillama.com/.

5. S. F. Singh, P. Michalopoulos, and A. Veneris, “Option Contracts in the DeFi Ecosystem: Motivation, Solutions, & Technical Challenges,” in *2024 IEEE International Conference on Blockchain and Cryptocurrency (ICBC)* (IEEE, 2024), 1–7.

6. H. Adams, N. Zinsmeister, M. Salem, R. Keefer, and D. Robinson, “Uniswap v3 Core,” Tech. rep. Uniswap, (2021).

7. F. Black and M. Scholes, “The Pricing of Options and Corporate Liabilities,” *Journal of political economy* 81, no. 3 (1973): 637–654.

8. D. Duffie, *Dynamic Asset Pricing Theory* (Princeton University Press, 2010).

9. N. Cantarutti, “Financial-Models-Numerical-Methods,” https://github.com/cantaro86/Financial-Models-Numerical-Methods/.

10. D. White and S. Bankman-Fried, “Everlasting Options,” (2019), https://www.paradigm.xyz/static/everlasting-options.pdf.

11. “Rysk Finance,” (2024), https://docs.rysk.finance/.

12. J. Xu and N. Vadgama, “From Banks to DeFi: The Evolution of the Lending Market,” in *Enabling the Internet of Value: How Blockchain Connects Global Businesses* (2022), 53–66.

13. G. Angeris, T. Chitra, A. Evans, and M. Lorig, “A Primer on Perpetuals,” *SIAM Journal on Financial Mathematics* 14, no. 1 (2023): SC17–SC30.

14. D. G. Baur and T. Dimpfl, “The Volatility of Bitcoin and Its Role as a Medium of Exchange and a Store of Value,” *Empirical Economics* 61, no. 5 (2021): 2663–2683.

15. K. Qin, L. Zhou, P. Gamito, P. Jovanovic, and A. Gervais, “An Empirical Study of DeFi Liquidations: Incentives, Risks, and Instabilities,” in *Proceedings of the 21st ACM Internet Measurement Conference*, (2021): 336–350.

16. E. Frangella and L. Herskind, “Aave v3 Technical Paper,” (2021), https://github.com/aave/aave-v3-core/blob/master/techpaper/Aave_V3_Technical_Paper.pdf.

17. R. Leshner and G. Hayes, “Compound: The Money Market Protocol,” (2019), https://compound.finance/documents/Compound.Whitepaper.pdf.

18. M. G. Delaunay, Q. Garchery, P. Frambot, M. Égalité, J. Thomas, and K. Babbar, “Morpho V1 Yellow Paper,” (2023).

19. A. Lehar and C. A. Parlour, “Systemic Fragility in Decentralized Markets,” (2022), Available at SSRN.

20. A. Sardon, “Zero-Liquidation Loans: A Structured Product Approach to DeFi Lending,” (2021), arXiv preprint arXiv:2110.13533.

21. K. Qin, J. Ernstberger, L. Zhou, P. Jovanovic, and A. Gervais, “Mitigating Decentralized Finance Liquidations With Reversible Call Options,” (2023), arXiv preprint arXiv:2303.15162.

22. S. F. Singh, P. Michalopoulos, and A. Veneris, “Bakup: Automated, Flexible, and Capital-Efficient Insurance Protocol for Decentralized Finance,” in *2024 IEEE International Conference on Blockchain and Cryptocurrency (ICBC)* (IEEE, 2024), 235–239.

23. “Polymarket,” https://docs.polymarket.com/.

24. “Deribit,” (2024), https://www.deribit.com/.

25. “Delta Exchange,” (2024), https://www.delta.exchange/.

26. “Binance,” (2024), https://www.binance.com/en.

27. “Okx,” (2024), https://www.okx.com/.

28. “The Block,” (2024), https://www.theblock.co/data/crypto-markets/options.

29. “DeFi's Permissionless Composability Is Supercharging Innovation,” (2023), https://chain.link/education-hub/permissionless-composability.

30. M. Knecht and B. Stiller, “Cusc: Composable User-Centric Smart Contracts,” in *2023 5th Conference on Blockchain Research & Applications for Innovative Networks and Services (Brains)* (IEEE, 2023), 1–4.

31. “Options Volume,” (2024), https://defillama.com/options.

32. “Layer-2 TVL,” https://l2beat.com/scaling/tvl.

33. “Transaction Fees in Layer-2,” (2024), https://l2fees.info/.

34. J. Surmont, W. Wang, and T. Van Cutsem, "Static Application Security Testing of Consensus-Critical Code in the Cosmos Network," in *2023 5th Conference on Blockchain Research & Applications for Innovative Networks and Services (Brains)* (IEEE, 2023), 1–8.

35. "Aevo Exchange," (2024), https://docs.aevo.xyz/.

36. G. Lambert and J. Kristensen, "Panoptic: A Perpetual, Oracle-Free Options Protocol," (2022), arXiv preprint arXiv:2204.14232.

37. S. Dawson, D. Romanowski, and V. Cheng, "Derive Protocol," (2023), https://www.derive.xyz/files/v2-whitepaper.pdf.

38. 0xAlpha, F. D, and R. Chen, "The Exchange Protocol for Everlasting Options," https://github.com/deri-protocol/whitepaper/blob/master/deri_everlasting_options_whitepaper.pdf.

39. "Stryke," (2024), https://docs.stryke.xyz/.

40. "Hegic," (2021), https://github.com/jmonteer/hegic-resources/tree/main/docs.

41. "Premia," https://docs.premia.blue/.

42. J. P. Madrigal-Cianci and J. Kristensen, "Time-Efficient Decentralized Exchange of Everlasting Options With Exotic Payoff Functions," in *2022 IEEE International Conference on Blockchain (Blockchain)* (IEEE, 2022), 427–434.

43. B. Liu, P. Szalachowski, and J. Zhou, "A First Look Into DeFi Oracles," in *2021 IEEE International Conference on Decentralized Applications and Infrastructures (DAPPS)* (IEEE, 2021), 39–48.

44. L. Zhou, X. Xiong, J. Ernstberger, et al., "Sok: Decentralized Finance (DeFi) Attacks," in *2023 IEEE Symposium on Security and Privacy (SP)* (IEEE, 2023), 2444–2461.

45. X. Deng, S. M. Beillahi, C. Minwalla, H. Du, A. Veneris, and F. Long, "Safeguarding DeFi Smart Contracts Against Oracle Deviations," in *46th International Conference on Software Engineering (ICSE 2024)* (ACM, 2024), 1–12.

46. A. T. Aspembitova and M. A. Bentley, "Oracles in Decentralized Finance: Attack Costs, Profits and Mitigation Measures," *Entropy* 25, no. 1 (2022): 60.

47. L. Breidenbach, C. Cachin, B. Chan, et al., "Chainlink 2.0: Next Steps in the Evolution of Decentralized Oracle Networks," *Chainlink Labs* 1 (2021): 1–136.

48. pyth data association, "PYTH Network: A First-Party Financial Oracle," (2023), https://pyth.network/whitepaper_v2.pdf.

49. "Oraclum," https://oraclum.io/.

50. "Dia," https://docs.diadata.org.

51. "Blockscholes," https://www.blockscholes.com/.

52. P. S. Hagan, D. Kumar, A. S. Lesniewski, and D. E. Woodward, "Managing Smile Risk," *Best of Wilmott* 1 (2002): 249–296.

53. team A, "AEVO OTC," https://docs.aevo.xyz/aevo-otc/.

54. "The Market Collapse of March 12-13, 2020: How It Impacted Makerdao," (2020), https://blog.makerdao.com/the-market-collapse-ofmarch-12-2020-how-it-impacted-makerdao/.

55. M. Brenner and M. G. Subrahmanyan, "A Simple Formula to Compute the Implied Standard Deviation," *Financial Analysts Journal* 44, no. 5 (1988): 80–83.

56. "Dune Analytics," https://dune.com/.

57. H. Kalodner, S. Goldfeder, X. Chen, S. M. Weinberg, and E. W. Felten, "Arbitrum: Scalable, Private Smart Contracts," in *27th Usenix Security Symposium (Usenix Security 18)* (2018), 1353–1370.

58. "Polygon," https://polygon.technology/.

59. "Ethreum Name Service," https://docs.ens.domains/.

60. "Dimo," https://dimo.co/.

61. "Vulcan Forged," https://vulcanforged.com/.

62. M. Egorov and C. Finance, "Automatic Market-Making With Dynamic Peg," (2021), retrieved Dec 2021.

63. "Lido Finance," https://lido.fi/.

64. Y. Y. Park, "Legal Issues in Designing DeFi Regulation," *Journal of East Asia & International Law* 16, no. 2 (2023): 283.

65. F. Schär, "Decentralized Finance: On Blockchain-and Smart Contract-Based Financial Markets," *Federal Reserve Bank of St. Louis Review*, Second Quarter (2021): 153–174.

66. B. Sriman and S. G. Kumar, "Decentralized Finance (DeFi): The Future of Finance and DeFi Application for Ethereum Blockchain Based Finance Market," in *2022 International Conference on Advances in Computing, Communication and Applied Informatics (ACCAI)* (IEEE, 2022), 1–9.

67. R. Auer, B. Haslhofer, S. Kitzler, P. Saggese, and F. Victor, "The Technology of Decentralized Finance (DeFi)," *Digital Finance* 6, no. 1 (2024): 55–95.

68. K. Gogol, C. Killer, M. Schlosser, T. Bocek, B. Stiller, and C. Tessone, "Sok: Decentralized Finance (DeFi)–Fundamentals, Taxonomy and Risks," (2024), arXiv preprint arXiv:2404.11281.

69. S. M. Werner, D. Perez, L. Gudgeon, A. Klages-Mundt, D. Harz, and W. J. Knottenbelt, "Sok: Decentralized Finance (DeFi)," (2021), arXiv preprint arXiv:2101.08778.

70. J. Xu, K. Paruch, S. Cousaert, and Y. Feng, "Sok: Decentralized Exchanges (DEX) With Automated Market Maker (AMM) Protocols," *ACM Computing Surveys* 55, no. 11 (2023): 1–50.

71. S. Cousaert, J. Xu, and T. Matsui, "Sok: Yield Aggregators in DeFi," in *2022 IEEE International Conference on Blockchain and Cryptocurrency (ICBC)* (IEEE, 2022), 1–14.

72. L. Gudgeon, S. Werner, D. Perez, and W. J. Knottenbelt, "DeFi Protocols for Loanable Funds: Interest Rates, Liquidity and Market Efficiency," in *Proceedings of the 2nd ACM Conference on Advances in Financial Technologies* (2020), 92–112.

73. S. Kitzler, F. Victor, P. Saggese, and B. Haslhofer, "Disentangling Decentralized Finance (DeFi) Compositions," *ACM Transactions on the Web* 17, no. 2 (2023): 1–26.

74. J. A. Berg, R. Fritsch, L. Heimbach, and R. Wattenhofer, "An Empirical Study of Market Inefficiencies in Uniswap and SushiSwap," in *International Conference on Financial Cryptography and Data Security* (Springer, 2022), 238–249.

75. L. Heimbach, E. Schertenleib, and R. Wattenhofer, "Exploring Price Accuracy on Uniswap v3 in Times of Distress," in *Proceedings of the 2022 ACM CCS Workshop on Decentralized Finance and Security* (2022), 47–53.

76. L. Heimbach, E. Schertenleib, and R. Wattenhofer, "Risks and Returns of Uniswap v3 Liquidity Providers," in *Proceedings of the 4th ACM Conference on Advances in Financial Technologies* (2022), 89–101.

77. R. Fritsch, "Concentrated Liquidity in Automated Market Makers," in *Proceedings of the 2021 ACM CCS Workshop on Decentralized Finance and Security* (2021), 15–20.

78. R. Fritsch and A. Canidio, "Measuring Arbitrage Losses and Profitability of AMM Liquidity," in *Companion Proceedings of the ACM on Web Conference 2024* (2024), 1761–1767.

79. L. Heimbach, Y. Wang, and R. Wattenhofer, "Behavior of Liquidity Providers in Decentralized Exchanges," (2021), arXiv preprint arXiv:2105.13822.

80. Z. Fan, F. Marmolejo-Cossio, D. J. Moroz, M. Neuder, R. Rao, and D. C. Parkes, "Strategic Liquidity Provision in Uniswap v3," (2021), arXiv preprint arXiv:2106.12033.

81. A. Cartea, F. Drissi, and M. Monga, "Decentralized Finance and Automated Market Making: Predictable Loss and Optimal Liquidity

Provision," *SIAM Journal on Financial Mathematics* 15, no. 3 (2024): 931–959.

82. Y. Bar-On and Y. Mansour, "Uniswap Liquidity Provision: An Online Learning Approach," in *International Conference on Financial Cryptography and Data Security* (Springer, 2023), 247–261.

83. A. Khakhar and X. Chen, "Delta Hedging Liquidity Positions on Automated Market Makers," (2022), arXiv preprint arXiv:2208.03318.