Decentralized and Centralized Options Trading: A Risk Premia Perspective

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Motivation

- There is growing interest in options contracts on cryptocurrencies.
  - In July 2023, crypto options trading reached over 3 trillion USD in notional value (accounting for 69% of the total crypto volume).
- Crypto options can be traded both on centralized limit order markets (CEX) and On-Chain on decentralized exchanges (DEXs).
  - A DEX is a decentralized p2p trading platform running on a blockchain.
  - Trading happens via an "automated market making" (AMM) mechanism (no order book or central market maker).

$\rightarrow$ What are the implications for trading options on a DEX vs. CEX?

Results Preview

- We identify larger IVs On-Chain (than Off-Chain), which
  - increases with maturity and for closer at-the-money (ATM).
- We explain the larger IVs:
  - trading volume and net demand pressure (which varies with calls and puts as retail investors prefer calls (Eaton et al. (2023))),
  - multilayered On-Chain fee structure.
- We construct a strategy to trade the differences in IV:
  - profitable net of fees in some cases.
  - connected to investors' sentiment and the price of the LYRA token.
- Results can be rationalized in a Stoll (1978) model
  - Monopolist (AMM) vs. many risk-averse dealers (CEX)

Literature Review

- **Decentralized Finance tokens, adaption, valuation, and financing**: Prat et al. (2019), Gryglewicz et al. (2021), Goldstein et al. (2023), Sockin and Xiong (2023).
- **Token trading**: Harvey et al. (2021), Härdle et al. (2020), Makarov and Schoar (2022), Aquilina et al. (2023), Barbon and Ranaldo (2021), Capponi and Jia (2024), Lehar and Parlour (2023), Park (2023), Krishnamachari et al. (2021), Xu et al. (2023), Cong et al. (2021).
- **(Off-Chain) Option pricing and retail trading**: Bollen and Whaley (2004), Gârleanu et al. (2009), Alexander et al. (2023), Eaton et al. (2023), Cao and Celik (2021), Boyle and Vorst (1992), Engle and Neri (2010), Muravyev (2016), Jameson and Wilhelm (1992), Chan et al. (2002), Cho and Engle (1999).

$\rightarrow$ We expand by comparing centralized and decentralized options trading, emphasizing option pricing and demand-side relevance.

Centralized and Decentralized Exchanges

- CEX:
  - uses a broker-dealer order system, largest options exchange is Deribit.
- DEX:
  - Trading through an (options) AMM
    - AMM aims to find the IV that balances supply and demand,
    - option price is then calculated via Black and Scholes (1973).
  - Trading happens in a liquidity pool
    - Liquidity Providers (LPs) provide liquidity in stablecoins,
    - profit from trading fees and the option price paid.
  - Pool's Risk Management of the AMM
    - risk profile is summarized by the pools' delta and vega,
    - hedges delta exposure by trading the underlying asset,
    - $+/-$ fees if the trader's position increases or decreases overall risk.

Decentralized Exchanges - AMM

- AMM aims to find the IV that balances supply and demand.
- For every standard size (SS) that the AMM buys or sells in a given expiry, the baseline IV (j:= maturity) will increase or decrease

$$IV_{new,j} = \begin{cases} IV_{old,j} + 1\% & \text{pool sells 1 SS} \\ IV_{old,j} - 1\% & \text{pool buys 1 SS} \end{cases}$$

- AMM captures the smile (i:= strike)
  - After each trade updates the Skew Ratio: $SR_{i,j} = \frac{IV_{i,j}}{IV_j}$.
- The final price of the option is then given by the $BS(IV_{i,j})$ plus fees

$$f_t = \underbrace{A \times W}_{\text{option price fee}} + \underbrace{B \times H \times VU_t + C \times S_t}_{\text{fees from risk management}}$$

  - $H = 1$ if trade increases the pool's Vega exposure (VU_t = Vega Utilization $\approx$ inventory's Vega risk),
  - $C \times S_t$: delta hedging costs,
  - A, B, and C are constants.

Data

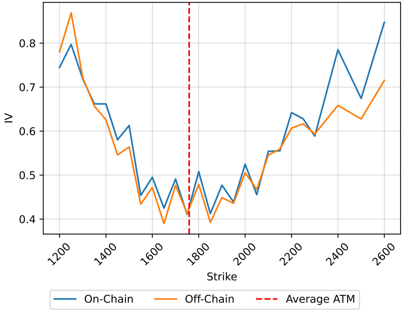
- Analyze a cross-section of trades (tick level) and quotes (hourly):
  - European out-of-the-money (OTM) options,
  - BTC and ETH,
  - maturities (7-30 days),
  - On-Chain: Lyra V2 on Arbitrum (now Derive.xyz) as DEX, obtained via the Graph
  - Off-Chain: Deribit as CEX, obtained from amberdata.io.
- The On-Chain and Off-Chain options are matched based on their:
  - underlying, time to expiry, strike price, type, and observation time.

On-Chain and Off-Chain - IVs

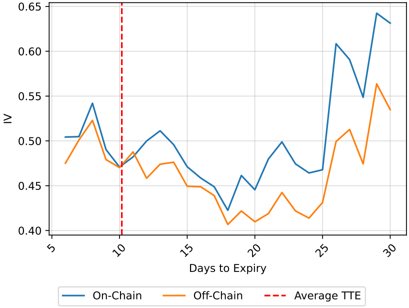
- The figures show the difference between On-Chain and Off-Chain IVs.

→ IV begins to diverge for low and high strike prices and is widening for longer maturity options.

(a) ETH Trades: IV-Strike



(b) ETH Trades: IV-Maturity



On-Chain and Off-Chain - IVs

- Explain the difference between On-Chain and Off-Chain IVs using key characteristics (type, maturity, moneyness, delta, vega)

$$\text{Diff IV}_{i,t} = \beta_0 + \beta_1 \text{Call}_i + \beta_2 \text{Maturity}_{i,t} + \beta_3 \text{Mness}_{i,t} + \epsilon,$$
$$\text{Diff IV}_{i,t} = \beta_0 + \beta_1 \text{Abs. Delta}_{i,t} + \beta_2 \text{Vega}_{i,t} + \epsilon.$$

On-Chain and Off-Chain - IVs

Variable	Diff IV	Diff IV
Panel B: ETH		
Intercept	-0.35380	-0.04622
	(0.00000)	(0.00000)
Call	0.01167	
	(0.00000)	
Maturity	0.00194	
	(0.00000)	
Mness	0.36788	
	(0.00000)	
Abs. Delta		0.13586
		(0.00000)
Vega		0.00031
		(0.00000)
Adj. R-squared	0.0843	0.1910
Observations	146438	146438

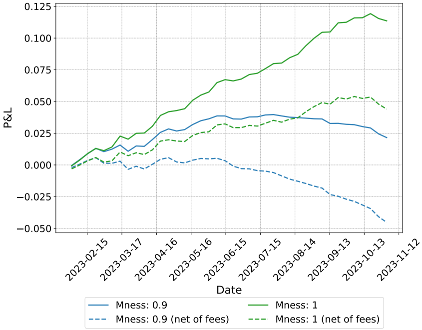
Table 1: Regression results for options trades on ETH.

→ The difference in IV tends to increase for calls, longer-dated options, and options closer to ATM.

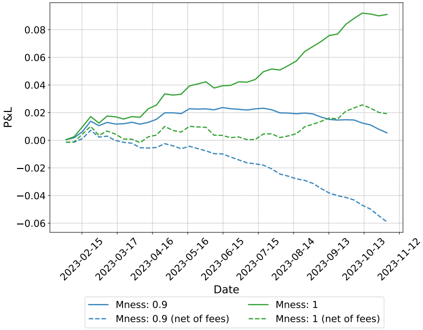
→ An increase in abs. Delta and Vega widen the IV gap.

- Buy 1 Off-Chain option and sell 1 On-Chain option, consider different: maturities, moneyness, puts, calls.
- Without fees $\approx$ profit of 0.01 ETH per month
- With fees: profit halves and sometimes non-profitable at all.

(a) ETH: IV-Maturity (15d), Calls



(b) ETH: IV-Maturity (15d), Puts



Trading Strategy - On-Chain and Off-Chain

- Exchange-related variables cannot explain the strategy's returns.

	Call		Put	
Variable	7	15	7	15
Delta (Pool)	0.1321	-0.2335	-0.0507	0.9077
	(0.434)	(0.771)	(0.468)	(0.287)
Vega (Pool)	0.0038	-0.0096	0.0021	0.0088
	(0.094)	(0.301)	(0.151)	(0.343)
Underlying Volume	0.0000	0.0000	0.0000	0.0000
	(0.296)	(0.268)	(0.235)	(0.886)
NBP call ATM	22.4574	-79.8933	-	-
	(0.327)	(0.319)	-	-
NBP put ATM	-	-	-4.0583	8.6164
	-	-	(0.570)	(0.780)
Rsquared	0.13	0.10	0.13	0.03
Adj. R-squared	0.03	-0.00	0.02	-0.08
Observations	39.00	39.00	38.00	39.00

Trading Strategy - On-Chain and Off-Chain

- Profitability rises with LYRA price, reflecting future protocol profits.
- Profitability increases with negative cryptocurrency sentiment (Fear), higher On-Chain trading compensation.

	Call		Put	
Variable	7	15	7	15
LYRA	537.1840	-1304.7638	361.9476	2098.1037
	(0.010)	(0.259)	(0.000)	(0.012)
TxGrowth	-0.0000	0.0001	0.0000	-0.0001
	(0.136)	(0.146)	(0.353)	(0.205)
# Contracts	-0.0494	0.3492	-0.0443	-0.4930
	(0.557)	(0.255)	(0.200)	(0.040)
FearGreed	-0.2818	-0.8912	-0.1999	0.2921
	(0.041)	(0.152)	(0.010)	(0.538)
Rsquared	0.48	0.21	0.66	0.54
Rsquared Adj	0.42	0.12	0.62	0.48
Nobs	39.00	39.00	38.00	39.00

VAR Model - AMM Mechanism

- We estimate a Vector Autoregressive Model (VAR) to compare the pricing mechanism of the DEX and CEX

$$y_t = c + A_1 y_{t-1} + \ldots + A_p y_{t-p} + e_t.$$

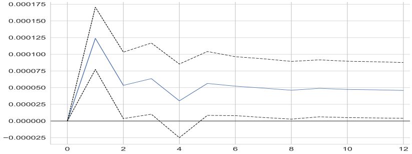
- The endogenous variables are for On-Chain options,
  - IV, Fees (Option Price Fee, Spot Price Fee, Variance Fee, Vega Fee), Volume.
- for Off-Chain options,
  - IV, Bid-Ask Spread, Volume.

VAR Model - AMM Mechanism

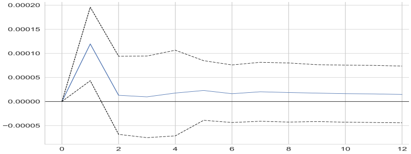
- IRFs: ETH IV on the Volume for (long) options.

$\rightarrow$ On-Chain IV is positively affected by the volume (Off-Chain is not).

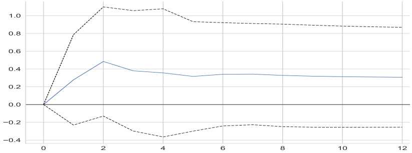
(a) On chain, Call: Volume $\rightarrow$ IV



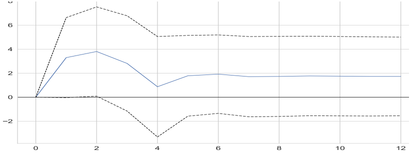
(b) On chain, Put: Volume $\rightarrow$ IV



(c) Off chain, Call: Volume $\rightarrow$ IV



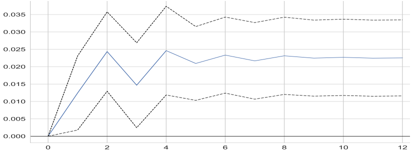
(d) Off chain, Put: Volume $\rightarrow$ IV



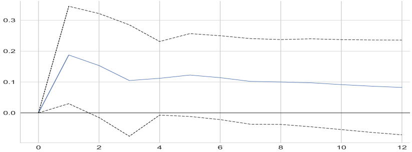
- IRFs: ETH IV on the fees for (long) calls.

→ On-Chain call IVs are affected by the fees.

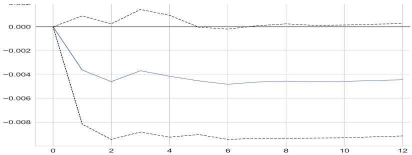
(a) Option Price Fee → IV



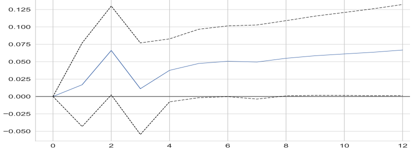
(b) Spot Price Fee → IV



(c) Variance Fee → IV



(d) Vega Fee → IV



Net Buying Pressure (NBP)

- Relation between NBP (Bollen and Whaley (2004)) and the option's IV (as volume does not reflect potential trade flow imbalance).

$$\text{Delta IV}_t = \beta_0 + \beta_1 \text{Underlying Return}_t + \beta_2 \text{Underlying Volume}_t + \beta_3 \text{NBP}_t + \beta_4 \text{Delta IV}_{t-1} + \epsilon.$$

- Where the NBP for a given type and moneyness is defined as,

$$\text{NBP}_t = \frac{(\text{Buy Volume}_t - \text{Sell Volume}_t) \times \text{Abs Delta}_t}{\text{Total Volume}_t}.$$

- All variables are standardized to have unit root and zero mean.

- Options are divided into tertiles from deep OTM (q1) to ATM (q3).

Net Buying Pressure (NBP) - Calls

→ Changes in IV are directly linked to NBP from public order flow.

	On-Chain			Off-Chain		
	Call_{q1}	Call_{q2}	Call_{q3}	Call_{q1}	Call_{q2}	Call_{q3}
Variable	Delta IV	Delta IV	Delta IV	Delta IV	Delta IV	Delta IV
Intercept	-0.00000	0.00000	0.00000	0.00000	0.00000	-0.00000
	(1.00000)	(1.00000)	(1.00000)	(1.00000)	(1.00000)	(1.00000)
Underlying Return	0.20923	0.10629	-0.01384	0.18794	0.14044	0.10529
	(0.00062)	(0.12235)	(0.85556)	(0.01728)	(0.05408)	(0.16253)
Underlying Volume	0.14831	0.20361	0.20261	0.18251	0.23946	0.27212
	(0.03731)	(0.00106)	(0.00155)	0.01279)	(0.00028)	(0.00003)
Net Buying Pressure	0.20254	0.17446	0.11149	0.11686	0.07664	0.02076
	(0.00103)	(0.00896)	(0.10900)	(0.01430)	(0.21876)	(0.65818)
Delta IV L1	-0.21543	-0.14118	-0.19513	-0.03295	-0.01458	-0.03800
	(0.00246)	(0.15091)	(0.03951)	(0.56779)	(0.77410)	(0.48544)
Rsquared	0.15	0.10	0.09	0.10	0.10	0.09
Rsquared Adj	0.14	0.08	0.07	0.09	0.09	0.08
Nobs	218	231	217	280	314	314

- NBP only significant for far OTM puts (On-Chain and Off-Chain)

Appendix

Theoretical Explanation

- Adapting Stoll (1978) model with inventory.
- DEX/AMM: Monopolistic dealer who offers investors immediate liquidity.
- CEX: LOB with (M) risk-averse dealers.
- We show that the price On-Chain excess the price Off-chain if:

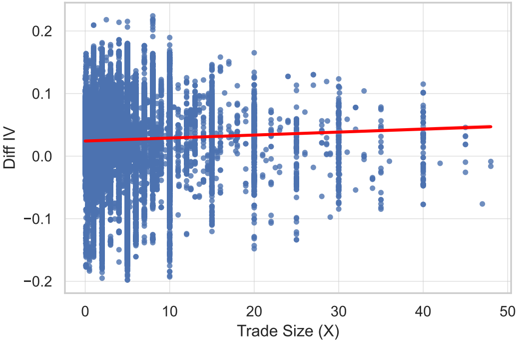
$$p_{DEX} \geq p_{CEX} \quad \Leftrightarrow \quad x \geq \left(W_0 + \frac{1}{2}I - \bar{I}\right)\frac{2M}{M-2} := \text{Lower Bound}$$

- I denotes the monopolist's inventory, $\bar{I}$ the average inventory of the M dealers, W_0 the monopolist initial wealth, we set $x = x_{AMM} = x_{CEX}$.

Model Implications - Empirical Investigation

- Select trades at the same time with similar size ($x = x_{AMM} = x_{CEX}$).
- Larger difference in IV for larger trade size (Lower Bound).
- Regression confirms visual evidence (red line's slope is significant).

(a) Difference in IV and trade size



Robustness

- DEX:
  - Lyra V1 and V2 on Optimism
  - Aevo
- CEX:
  - OKX
  - Bitcom
- Placebo test: No difference in IVs for CEX (Deribit) vs. CEX (OKX)

→ Findings confirm IV larger On-Chain across all exchanges.

Concluding Remarks

- On-Chain options provide a decentralized way to trade options.
- On-Chain options have higher IVs,
  - which increase with maturity and proximity to being ATM.
  - A profitable trading strategy that captures this difference (profitable net of fees only in some cases).
- We explain the difference between On-Chain and Off-Chain IVs:
  - fee structure, trading volume, and net buying pressure.
  - NBP is more relevant for On-Chain calls (as compared to Off-Chain).
- Theoretical explanation rationalizes the results
  - larger difference in IV for larger trade size

→ Many more results in the paper! `https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4822783`

$t^h a_n (k)\ \ y_o [u]$!

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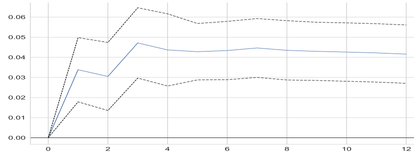
Appendix

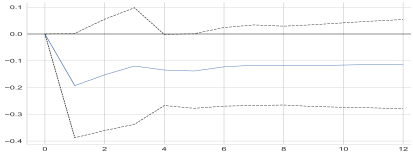
- The figures display the ETH IV IRFs on the fees for puts (long).

→ On-Chain put IVs are affected by the fees.

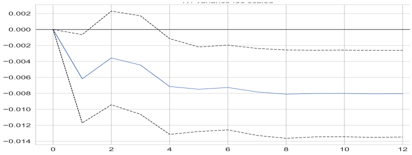
(a) Option Price Fee → IV



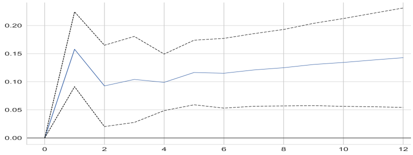
(b) Spot Price Fee → IV



(c) Variance Fee → IV



(d) Vega Fee → IV



Net Buying Pressure (NBP) - Puts

◂ Back

→ Changes in IV are directly linked to NBP from public order flow.

	On-Chain			Off-Chain		
	Put_{q1}	Put_{q2}	Put_{q3}	Put_{q1}	Put_{q2}	Put_{q3}
Variable	Delta IV	Delta IV	Delta IV	Delta IV	Delta IV	Delta IV
Intercept	-0.00000	-0.00000	-0.00000	0.00000	-0.00000	-0.00000
	(1.00000)	(1.00000)	(1.00000)	(1.00000)	(1.00000)	(1.00000)
Underlying Return	-0.07028	-0.20387	-0.10626	-0.15940	-0.14408	-0.06815
	(0.15953)	(0.00057)	(0.16138)	(0.01762)	(0.02295)	(0.31587)
Underlying Volume	-0.04285	0.07001	0.13182	0.13846	0.22159	0.27903
	(0.49937)	(0.19978)	(0.02651)	(0.08290)	(0.00155)	(0.00003)
Net Buying Pressure	0.21193	0.07766	0.02543	0.10604	0.07079	0.05494
	(0.00016)	(0.28345)	(0.73659)	(0.02835)	(0.26291)	(0.23911)
Delta IV L1	-0.16986	-0.20931	-0.23899	-0.11189	-0.07044	-0.03010
	(0.00646)	(0.00104)	(0.00571)	(0.06088)	(0.19280)	(0.61805)
Rsquared	0.08	0.10	0.08	0.06	0.07	0.08
Rsquared Adj	0.06	0.08	0.06	0.05	0.06	0.07
Nobs	219	229	182	297	314	314

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