Exploring crypto derivatives

An introduction of market landscape, emerging trends, valuation and risk management

February 2024

EY
Building a better working world

The views reflected in this article are the views of the authors and do not necessarily reflect the views of Ernst & Young LLP or other members of the global EY organization.

In brief

‣ Despite the crypto recession, including high-profile crypto firm bankruptcies and the collapse in crypto asset prices since 2022, crypto derivatives markets are expected to continue to evolve with the introduction of new products and innovations in decentralized finance (DeFi) protocols.

‣ Crypto derivatives can be valued using the models with which we are familiar from traditional finance (e.g., the classical Black-Scholes model for option pricing under the condition of no arbitrage, which is widely used by options market participants), with key modeling considerations taking into account the unique characteristics of underlying crypto assets.[1]

‣ Effective risk management for crypto derivatives is crucial due to the high volatility, leverage and complexity of these instruments. It plays a pivitol role in ensuring protection against significant losses and promoting informed decision-making in a rapidly evolving market.

---

[1] In this article, crypto assets refer to private digital assets that depend on cryptograph and distributed ledger technologies or similar technologies, and hence include all cryptocurrencies (e.g., Bitcoin (BTC) and Ethereum (ETH)).

Crypto derivatives market overview

The trading volume of the crypto derivatives market has experienced substantial growth over the past few years, increasing from under US$100 billion in January 2019 to a peak of over US$4 trillion in May 2021. Despite a recent downward dip, as of September 2023, the monthly volume of crypto derivatives stands at US$1.33 trillion, which is nearly four times the size of the crypto spot market.[1] BTC and ETH are the most frequently referenced crypto assets in crypto derivatives.

The crypto derivative market can be categorized into two segments centralized and decentralized:

▸ The **centralized derivative market** is primarily composed of exchange-traded options, futures and perpetual swaps, while over-the-counter (OTC) crypto derivatives are also growing rapidly. In the case of BTC- and ETH-referenced derivatives, as of September 2023, 96.2% of monthly trading volume is attributed to futures and perpetual swaps.[2] Taking a geographic lens:

  ▸ The non-US market is the major contributor to the crypto derivative market and accounts for over 95% of the monthly derivative trading volume globally, with the top three exchanges holding a market share of 84.7%, as of September 2023. [1]

  ▸ The US market, on the other hand, accounts for the remaining less than 5% of the monthly derivative trading volume, with CME being the dominant exchange. As of September 2023, CME holds a market share of over 60% of the monthly derivative trading volume in the US.[1]

▸ The **decentralized[2] derivative market** offers a secure and more transparent alternative to the centralized counterpart, removing the need for intermediaries. While the decentralized derivative market is still much smaller compared with the centralized derivative market, it is growing rapidly. The current DeFi derivative market is largely dominated by dYdX protocol for perpetual swaps. As of September 2023, the monthly trading volume of dYdX was reported at $8.30 billion.[3]

Despite the high-profile crypto firm bankruptcies in the 2022 crypto recession, which have led to increased calls for greater regulation of the crypto asset industry, including the derivatives-trading sector, it is expected that the crypto derivatives market will continue to grow and evolve with the launch of new products that address market participants' investment and hedging needs. Noteworthy examples of such products are UpDown options launched for US users by Crypto.com,[4] Luxor's Hashprice NDF[3] [5] and FalconX's staking yield swap.[6] Moreover, the DeFi sector is expected to propel innovation in crypto derivatives (e.g., DeFi options vaults[7] and DeFi interest rate swaps (IRSs)[8]), as DeFi investors explore novel means to manage risk and generate yield.

---

2   While these markets are often referred to as decentralized, it's important to note that their level of decentralization is debatable. Many of these markets rely on automated algorithms and smart contracts rather than being fully decentralized in contrast to traditional centralized markets.

3   Luxor's Hashprice NDF references mining computation power (a commodity-like underlying) rather than a direct crypto asset.

Crypto derivative products and valuation considerations

In this section, we will introduce the pricing methodology for three types of crypto derivatives: options, futures and perpetual swaps. Valuation of crypto derivatives is a critical prerequisite of measuring and managing financial risk, including market risk, counterparty credit risk and liquidity risk, as discussed in subsection "Crypto derivative risk types." Additionally, we will provide the overview on the most recent advancements in crypto derivative products.

Options

Crypto options offer a similar payout as traditional options, but with a crypto asset (usually a cryptocurrency or crypto index) serving as the underlying asset. Crypto option contracts can be settled either in cash or physically. The crypto options market inherits the Black-Scholes framework and quotes implied volatilities similar to traditional finance. A sample implied volatility surface on BTC as of November 10, 2023, is shown in Figure 1. This sample implied volatility surface covers a wide range of maturities (from one day to one year) and strikes (from $10,000 to $75,000).

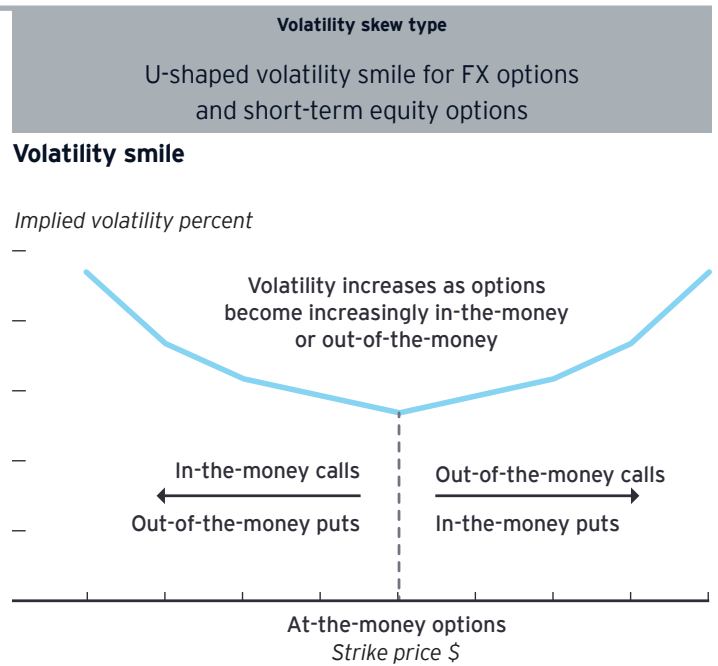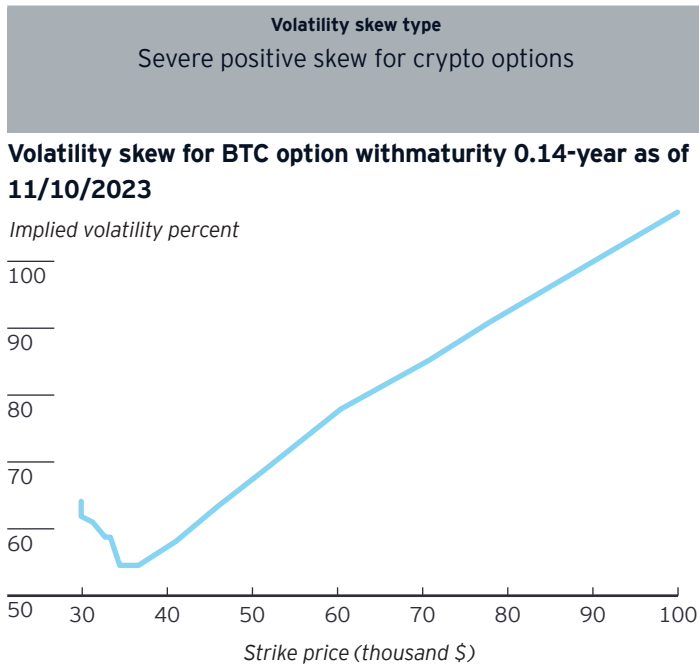**Figure 1: Sample implied volatility surface on BTC as of November 10, 2023**
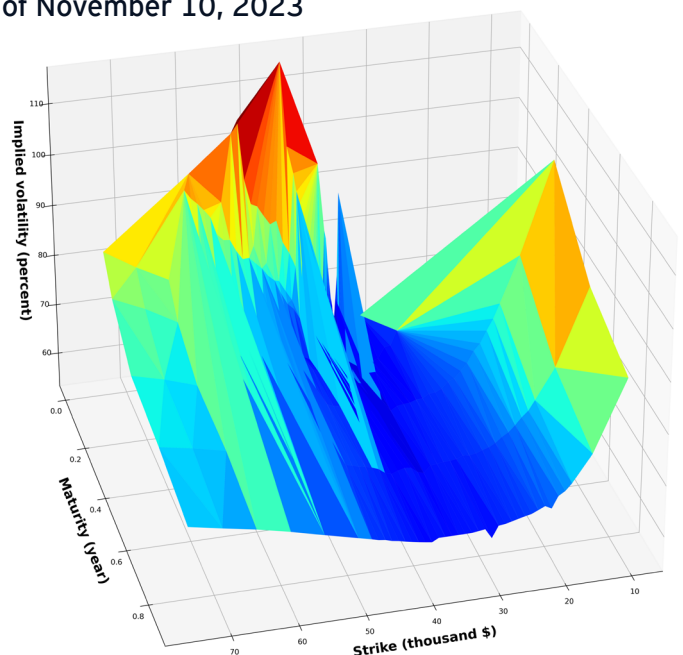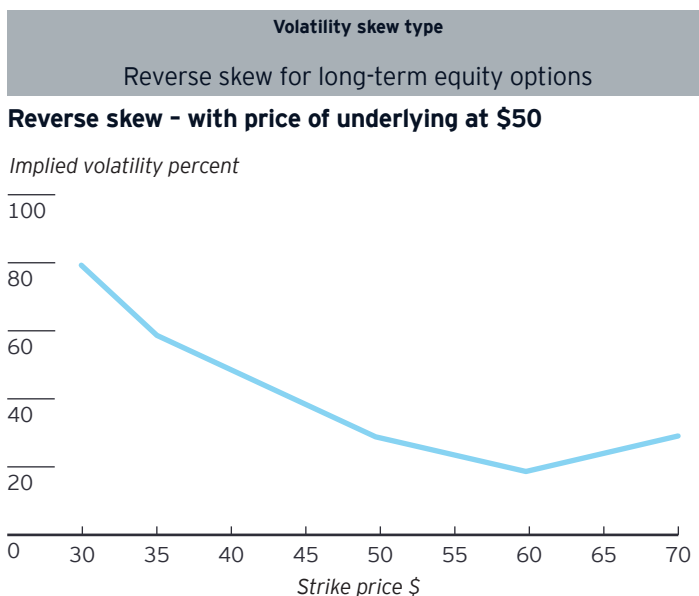

Source: Deribit.

The crypto options market exhibits volatility skew. A sample of the volatility skew as of November 10, 2023, for European BTC options with a maturity of 0.14 years is shown in Table 1. This skew is characterized by a heavy right tail, which contrasts with the observed skews of traditional asset classes in Table 1. As shown in the first plot in Table 1, the largest strike with an implied volatility from the market is about 2.7 times as large as the ATM strike. This heavy right tail is believed to be due to extreme fluctuations in crypto asset prices, as well as a belief held by some investors that prices will move much higher in the next several weeks. Such a severe positive skew requires enhancements of standard volatility models to better fit the heavy tail of implied volatilities on high strikes.

Table 1: Volatility skew comparison for crypto and traditional options [9]

Sample plot

Volatility skew type
Severe positive skew for crypto options

Volatility skew type
U-shaped volatility smile for FX options
and short-term equity options

Volatility skew for BTC option with maturity 0.14-year as of 11/10/2023

Implied volatility percent

Strike price (thousand $)

Volatility smile

Implied volatility percent

Volatility increases as options
become increasingly in-the-money
or out-of-the-money

In-the-money calls ← | → Out-of-the-money calls
Out-of-the-money puts | In-the-money puts

At-the-money options
Strike price $

Sample plot

Volatility skew type
Reverse skew for long-term equity options

Volatility skew type
Forward skew for commodity options

Reverse skew – with price of underlying at $50

Implied volatility percent

Strike price $

Forward skew – with price of underlying at $50

Implied volatility percent

Strike price $

The options on more thinly traded crypto assets typically have fewer traded expiry dates. This presents a challenge when it comes to market making or valuing OTC-traded options without market quotes for specific moneyness and expiry levels. A common solution is to proxy the implied volatilities to the liquid implied volatilities of more established crypto assets, such as BTC or ETH. This is possible due to the high correlation among crypto assets. For example, if the volatility of a certain crypto asset C is not available, the implied volatility σ(C,T,K) with expiry T and strike K can be proxied using the ETH implied volatility surface and historical volatilities of ETH/C price returns. Particularly, the implied volatility of C can be calculated as follows:

Where

$$\sigma(C,T,K) := \sigma\left(ETH, T, K \cdot \frac{S_{ETH,t_0}}{S_{C,t_0}}\right) \cdot \frac{\sigma_{hist}(C,t_0)}{\sigma_{hist}(ETH,t_0)}$$

▸ S_{C,t_0}: the price (in USD) of crypto asset **C** observed at valuation time t_0

▸ $\sigma_{hist}(C,t_0)$: the standard deviation of relative daily historical price return (i.e., $\frac{S_{C,t} - S_{C,t-1}}{S_{C,t-1}}$) right before valuation time t_0 for crypto asset **C**

Note that using the above implied volatility scaling methodology can under/overestimate option prices due to the potential of a poorly established proxy relationship.

Futures

Crypto futures offer a similar payout as traditional futures, but with the underlying asset being a crypto asset (usually a cryptocurrency or crypto index). Crypto futures contracts can be settled either in cash or physically. Many crypto assets have liquid futures markets, providing valuable insight into market expectations for the underlying crypto asset's future spot price. Here are two examples:

1. As shown in Figure 2, the BTC futures market is in backwardation as of March 12, 2023, while the BTC futures market is overall in contango as of November 10, 2023. In fact, the shape of the futures curve, whether it be in a state of backwardation or contango, can provide valuable information about market sentiment and investment strategy. For instance, research[10] highlighted that crypto futures carry, the gap between futures and spot prices, can reach 60% per annum and vary greatly due to a volatile convenience yield. This is driven by smaller investors seeking leverage during booms and limited arbitrage capital in risky cash and carry positions. This dynamic, coupled with high leverage, can lead to frequent severe crypto market crashes.

Figure 2: Sample futures curves for BTC
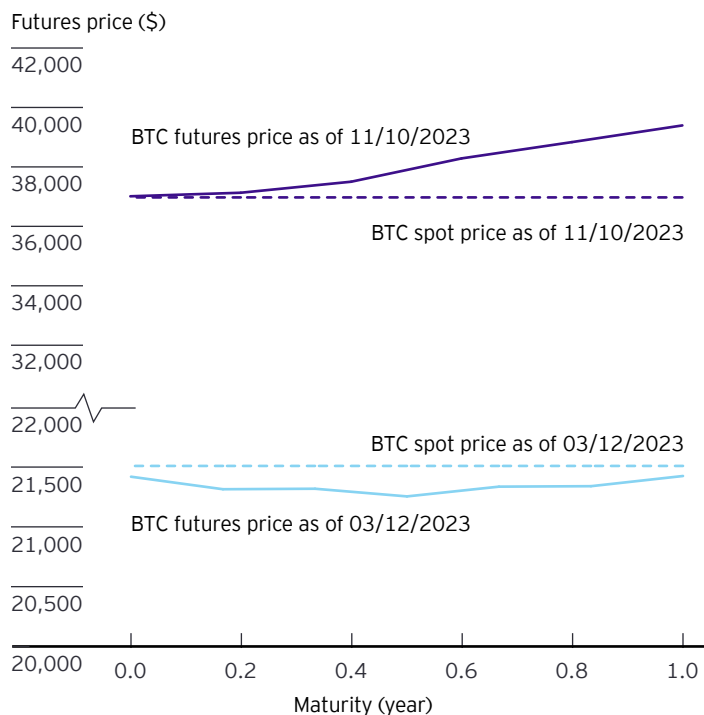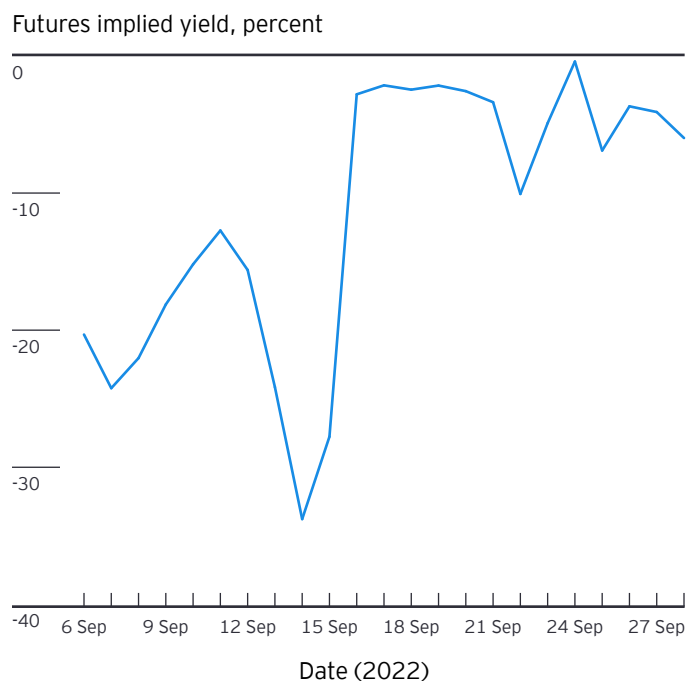
Source: Deribit.

for the perpetual swap, and this perpetual swap can be held indefinitely without any need to roll over contracts.

Although perpetual swaps were first introduced in 1992 to enable derivatives markets for illiquid assets,[11] perpetual swap markets have been developed for only crypto assets, and these markets have grown significantly since BitMex introduced crypto perpetual swaps in 2016. As of November 2023, the crypto perpetual swap is the most liquid crypto derivative with the largest market notional value.

Crypto perpetual swaps are cash-settled contracts. Traders can take long (buy) or short (sell) positions based on their market predictions. To ensure that the contract's price stays aligned with the spot market, a funding rate is introduced. This funding rate provides a mechanism for the perpetual swap to closely track its underlying crypto asset price, particularly, if the crypto perpetual swap price is higher (or lower) than the underlying crypto asset price, the funding rate is positive (or negative), and long (or short) traders would pay short (or long) traders, which incentivizes additional short (or long) position trading of perpetual swaps. In essence, this funding rate is a rebate or fee that helps to balance the short and long positions of perpetual swaps.

2. In a typical bearish crypto market, such as September 2022, a large negative ETH futures implied yield[4] was observed (as depicted in Figure 3), reflecting significant short positions and corresponding high borrowing costs. It aligns with the market's expectation for further decline in ETH prices.

In addition, despite the fact that crypto asset is generally a lightweight asset without any material storage cost, there are some unique costs associated with crypto assets, such as counterparty risk to the exchanges.
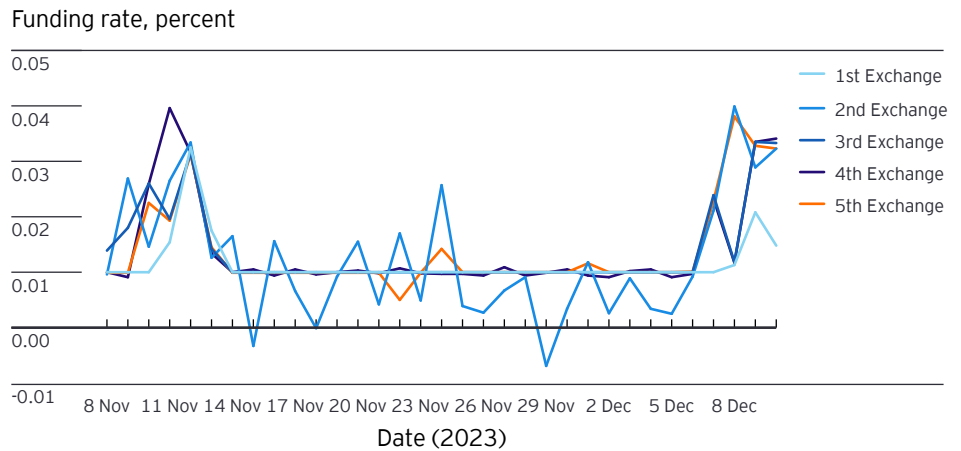
Perpetual swaps

A perpetual swap, also known as a "perpetual futures contract," is an agreement to non-optionally buy or sell the underlying asset at an unspecified future point. Similar to a futures contract, it allows traders to speculate on the future crypto asset price movements. However, compared with regular futures, there is not any prespecified expiration date

---

4   Defined as $\frac{1}{t}log(F_t/S_0)$, where F_t is the crypto future price with maturity t and S_0 is the crypto asset spot price.

Figure 3: Daily futures implied yields for ETH futures with maturity September 30, 2022, in September 2022

Futures implied yield, percent

Date (2022)

Source: Deribit.

The funding rate is generally calculated over a fixed time interval using the price difference between the crypto perpetual swap and the underlying crypto asset, and the funding fee (as the product of dollar position value and funding rate) is generally settled every eight hours. The recent funding rates for BTC perpetual swaps are presented in Figure 4 for the top five exchanges in terms of daily trading volume as of December 10, 2023. Due to the different calculation methods on funding rate and long/short trading positions by exchanges, this funding rate at a fixed time point can be positive for some exchanges but negative for other exchanges.

Figure 4: Sample funding rates for BTC perpetual swap

Funding rate, percent

Source: Coinglass.

New derivative product innovation

In addition to options, futures and perpetual swaps, several novel derivative products that have no counterpart in traditional assets have emerged in recent years. Although the valuation methodology for these products is still in the early stages of development, it is expected that the trend of meeting market participants' hedging and investment needs through such innovation will continue to flourish. Below, we discuss three notable examples:

1

UpDown option [4]
This is a Commodity Futures Trading Commission (CFTC)-regulated product listed on Crypto.com Derivatives North America, a US-regulated exchange. As a unique type of option, the UpDown option automatically expires when the underlying asset price reaches a predetermined target or stop price. These options offer several benefits, such as potentially limiting losses, providing full exposure to asset price fluctuations at a reduced cost and facilitating tailored hedging strategies. Nevertheless, UpDown options also possess certain drawbacks, which may include capped profit potential and a heightened risk of premature termination in turbulent market conditions.

2

Bitcoin Hashprice non-deliverable forward (NDF) [5]
Hashprice quantifies how much a bitcoin miner can expect to earn from a specific quantity of hashrate (i.e., compute power). Given the volatility of bitcoin price, the NDF provides bitcoin miners with a much-needed tool to hedge their mining operations by selling the contract to lock in bitcoin mining revenue. In the meantime, contract buyers can participate in the potential upside of bitcoin mining with nonphysical exposure. The valuation of the NDF contract depends on forward-looking market expectations of block subsidy, transaction fees, network difficulty and bitcoin price.

3

Staking yield swap [6]
Interest rate swaps have long been a fundamental building block in traditional, fixed-income derivative markets. Such an instrument has been reinvented for the crypto world, where the staking yield swap is introduced to exchange fixed payments for floating payments (or vice versa) based on variable fees earned from staking ETH. In addition to providing synthetic access to staking yields, the staking yield swap allows for more intricate trading strategies for hedging and investing, as well as facilitating the introduction of structured product innovations.

Crypto derivative risk management

Crypto derivatives have gained popularity in recent years, providing investors with an opportunity to gain exposure to crypto assets without actually holding the underlying assets. However, like other financial products, these derivatives also carry various types of risks that need to be understood and managed carefully.

Crypto derivative risk types

The lifecycle of trading crypto derivatives primarily encompasses the following risk types:

‣ **Market risk** stems from the potential financial loss due to unfavorable fluctuations in market prices. Accurate valuation of crypto derivatives is vital for calculating real-time or daily profit and loss (P&L) and estimating value at risk (VaR) or expected shortfall. Such measures help estimate losses associated with market movements corresponding to a high percentile (e.g., 99%). Emphasizing extreme crypto asset volatility, market participants must remain vigilant and incorporate strategies to manage the heightened market risk in the inherently volatile crypto landscape.

‣ **Counterparty credit risk (CCR)** is the risk of financial loss due to a counterparty's unwillingness or inability to fulfill their obligations. Models measuring counterparty credit risk typically involve simulating market factors using Monte Carlo approaches and accurate valuation along time points in each simulated path to compute potential future exposures. In addition, properly capturing collateral requirements for variation margin (VM) and initial margin (IM) is crucial for CCR calculation.

‣ **Liquidity risk** can manifest in two forms: **funding liquidity risk** and **market liquidity risk**. Funding liquidity risk refers to potential financial losses stemming from an inability to meet liabilities. Market participants should address funding liquidity risk by factoring in the funding costs associated with posting collateral throughout the duration of the derivatives contract. This is commonly known as a "funding valuation adjustment" (FVA). Market liquidity risk arises when difficulties in selling assets at current market prices lead to losses. Participants should take this into account as a liquidity valuation adjustment (LVA).

‣ **Operational risks** in trading and managing crypto derivatives are diverse and complex:

 ‣ One critical consideration is the management of margin requirements imposed by trading venues, such as dealers or exchanges. This aspect can present various challenges, including potential margin calls, abrupt increases in margin requirements and other operational hurdles. Traders should have a thorough understanding of these margin requirements and maintain sufficient collateral buffers to handle potential market fluctuations.

 ‣ Technological vulnerabilities inherent in blockchain systems and smart contracts, coupled with cybersecurity threats, further complicate the risk landscape. Failures or malfunctions in trading platforms can lead to substantial losses, and the rapid pace of crypto markets introduces execution risks. The reliance on third-party services, such as wallet providers, adds another dimension of risk.

‣ **Legal and compliance risk** pertains to potential financial or other losses stemming from non-compliance with laws or regulations. This risk is amplified within cryptocurrency markets due to their decentralized and global structure coupled with inconsistent regulatory frameworks across jurisdictions. Certain crypto assets and activities face

ongoing regulatory, legislative, and judicial uncertainties, including in major economies like the United States. Moreover, many active crypto derivative exchanges operate outside prominent jurisdictions, hence lacking the stringent regulatory oversight demanded by agencies like the U.S.'s CFTC, and posing additional risks to market participants.

All of these factors emphasize the crucial need for robust controls and a comprehensive risk management approach when trading and managing crypto derivatives.

Crypto derivative-specific risk modeling considerations

In comparison with traditional asset risk modeling, crypto derivative-specific risk modeling considerations pose unique challenges. These challenges stem from the characteristics of the underlying crypto assets and the crypto markets in which they trade. Six key aspects to consider when developing risk models for crypto derivatives are:

1. **High volatility:** Crypto assets tend to exhibit higher volatility than traditional assets, which can result in large price swings. This necessitates the incorporation of higher volatility estimates in market risk models to accurately capture the potential losses and risks associated with these instruments.

2. **Continuous trading:** Crypto markets operate on a 24/7 basis, unlike traditional financial markets, which have set trading hours. This continuous trading can lead to nonuniform price movements and liquidity changes over time. Risk models should account for this by adjusting the frequency of P&L calculations and considering intraday risk measures.

3. **Legal enforceability:** The absence of a standardized legal framework for the netting and margining of crypto assets increases CCR for crypto derivatives. This uncertainty should be factored in when calculating margin requirements and exposure aggregation.

4. **Crypto collateral:** Crypto assets are often used as collateral for derivative transactions; however, there is limited historical data on the liquidation costs of these collaterals during stress periods. This introduces additional uncertainty in the liquidity risk modeling process, which requires considering incorporating alternative stress scenarios or applying conservative assumptions to account for this limitation.

5. **Regulatory considerations:** The regulatory environment for crypto derivatives is still evolving, and it is crucial to be cognizant of potential changes in regulations that could impact risk modeling assumptions or methodologies. Regular updates and reviews of the models should be conducted to ensure compliance with any regulatory changes.

6. **Market concentration:** Crypto markets can be characterized by a high degree of market concentration, with a few dominant players or exchanges exerting significant influence. Risk models should account for potential risks arising from this concentration, such as increased vulnerability to market manipulation or abrupt liquidity shifts.

How we can help

Ernst & Young LLP offers extensive support for crypto derivatives valuation and risk modeling and management, adhering to industry practices and regulatory requirements.

Our services encompass:

▸ Development, enhancement and implementation/integration of models

▸ Testing and documentation of models

▸ Validation and ongoing monitoring of models

▸ Dynamic lifecycle transformation of models, including optimizing strategies and adopting agile modeling approaches

▸ Regulation compliance support

▸ Risk identification, measurement, management and reporting

References

[1] *Exchange Review*, Cryptocompare, September 2023.

[2] *Bitcoin futures charts: open interest and exchange volumes*, The Block, theblock.co/data/crypto-markets/futures.

[3] dYdX Perpetual Trade Volume, CoinGecko, dYdX Perpetual Trade Volume, Trade Pairs & Trust Score | CoinGecko.

[4] *What Are UpDown Options?*, Crypto.com.

[5] *OTC Trading Desk for Bitcoin Mining Derivatives: Live Hashprice Chart*, Luxor, https://luxor.tech/derivatives.

[6] *FalconX Executes First-Ever Staking Yield Swap with Figment, Unlocking New Opportunities By Pioneering a Brand New Crypto Derivatives Market*, news release, May 9, 2022, FalconX.

[7] *An Explanation of DeFi Options Vaults (DOVs)*, QCP Capital, December 12, 2021.

[8] Jones, Simon and Begyan, Artur, *An Automated Market Maker for Interest Rate Swaps*, Voltz Protocol, December 2021 (website-files.com).

[9] *Volatility Smiles & Smirks*, The Options & Futures Guide (theoptionsguide.com).

[10] Schmeling, Maik, Schrimpf, Andreas and Todorov, Karamfil, *BIS Working Papers No 1087: Crypto carry*, BIS website, April 2023, bis.org/publ/work1087.pdf.

[11] Shiller, Robert J. *Measuring Asset Values for Cash Settlement in Derivative Markets: Hedonic Repeated Measures Indices and Perpetual Futures*, Journal of Finance, July 1993.

Contact us

Authors

Ming Shi
Managing Director,
Quantitative Advisory Services
Ernst & Young LLP
ming.shi@ey.com

Donald Cheng
Senior Manager,
Quantitative Advisory Services
Ernst & Young LLP
donald.cheng@ey.com

Seha Islam
Senior Manager,
Financial Risk Management
Ernst & Young LLP
seha.islam@ey.com

Yang Yang
Senior Manager,
Quantitative Advisory Services
Ernst & Young LLP
yang.yang4@ey.com

EY | Building a better working world

EY exists to build a better working world, helping to create long-term value for clients, people and society and build trust in the capital markets.

Enabled by data and technology, diverse EY teams in over 150 countries provide trust through assurance and help clients grow, transform and operate.

Working across assurance, consulting, law, strategy, tax and transactions, EY teams ask better questions to find new answers for the complex issues facing our world today.

ey.com