A Low-Volatility Strategy based on Hedging a Quanto Perpetual Swap on BitMEX

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***Abstract*—In 2016, BitMEX introduced a novel type of crypto derivates – Perpetual Swaps, i.e., futures with an infinite term. Perpetual swaps provide a new strategic risk management tool for cryptocurrencies due to their custody-free nature, high leverage, and funding mechanism, but there has been little quantitative analysis on the their benefits. In this paper, we introduce a trading strategy that combines a Quanto Perpetual Swap with a spot position to benefit from the funding mechanism. We compare our strategy with a long-only investment in the underlying cryptocurrency and a similar strategy based on Linear Perpetual Swaps to evaluate their performances in a large-scale backtest covering the years 2021 and 2022. Our analysis shows that our strategy generates positive returns in bullish market phases of the underlying with lower volatility.**

***Index Terms*—Crypto Derivatives, Risk Management, Perpetual Swaps**

I. Introduction

Since the launch of Bitcoin [1] in 2009, Bitcoin's volatile nature has led to speculating on or hedging against its future price movement, which contributed to the fast development of Bitcoin-related derivatives [2]. Starting with the offering of the first Bitcoin perpetual swap in May 2016 by the *Bitcoin Mercantile Exchange (BitMEX)* and the Bitcoin futures by *Chicago Board Options Exchange (CBOE)* in December 2017, a variety of crypto derivatives have emerged. BitMEX is among the most relevant exchanges for trading futures on cryptocurrencies. According to *CoinMarketCap*, it ranks among the top 10 exchanges based on multiple factors, including liquidity and normalized volume [3]. Since 2016, BitMEX has offered different types of *perpetual swaps* [4] with different payout profiles, amounting to daily trading volume of $100 billion[1]. Those contracts enable market participants to engage in cryptocurrencies without the need to worry about the custody of the underlying assets, thus opening up new opportunities for strategic portfolio management.

A perpetual swap is similar to a traditional futures contract, but has two main significant differences [4]. Firstly, a perpetual swap never expires and is therefore never settled. Secondly, a perpetual swap underlies a *funding mechanism*, where funding is paid from the majority to the minority position, to prevent a deviation from the underlying securities price. One idea for a trading strategy is to sell perpetual swaps, i.e., opening a short position, and hedging them by a spot position in the underlying. Ideally, this would create a market-neutral position that collects the funding rates. However, examining the effectiveness of this idea requires a detailed simulation that considers fees resulting from the trading activity.

In this work, we present a trading strategy that allocates an investment amount in two positions – a short position on quanto perpetual swaps side and a long position on the underlying spot side – and adjusts both positions depending on the price of the underlying. In a backtest, covering the years 2021 and 2022, we compare our trading strategy with a long-only investment in the underlying and an analogous strategy using the simpler linear perpetual swaps. Our analysis shows that our strategy generates positive and negative returns in bullish and bearish market phases, but to a lesser extent than a long-only strategy. In addition, our strategy is associated with lower volatility.

II. Related Work

Previous papers examined various aspects of Bitcoin derivatives. In the realm of Bitcoin futures, many of them, starting with [5], [6], focus on the Bitcoin spot and futures market relationship, i.e., price discovery, but no consensus is reached as to which leads which [7]–[9]. [10] adds that unregulated derivatives have net spillover effects on spot market. Other papers investigate the impact of Bitcoin derivative introduction on the Bitcoin spot market [11], [12], the speculation on crypto and price prediction [13]–[20], and the arbitrage opportunities [21]–[24]. We also see analysis on the participants of Bitcoin futures trading or ownership concentration of the product [21], [25].

On Bitcoin perpetual swap (XBTUSD), holistic analysis on BitMEX products [26] conclude that BitMEX derivatives could be responsible for the sudden price jumps that are often observed in Bitcoin markets and that the platform attracts diverse traders, both novices and experts.

However, there has been relatively little analysis on the mechanism of BitMEX perpetual swap. Furthermore the BitMEX website lacks detailed descriptions of their structure [2]. Of the research that exists in this vein, [27] shows the heteroskedasticity of funding rates and its causal relationship with the XBTUSD contract. Through mathematical modeling including stochastic calculus methods, [2] holistically studies the funding rate and index price characteristics, as well as the liquidation mechanism in relation to leverage. Cash flows from holding a perpetual swap position, a crucial factor in estimating the present value of a position, is not investigated either. [28]

[1] https://www.bitmex.com/app/trade/XBTUSD

formulates a theoretical model for the intrinsic value evolution, followed by [2], which provides comprehensive documentation of the cash flows for holding a long position on XBTUSD, by considering the realized profit-and-loss (PNL).

Regarding BitMEX perpetual swap trading strategies, [29] conduct dynamic delta hedging analysis to conclude that the smile-implied hedge ratios exceed Black-Scholes delta hedging, particularly when employing perpetual swaps as a hedging tool. After acknowledging the difficulty in pricing perpetual futures due to the volatile nature of the funding rate, [30] devised a market directional high-frequency trading algorithm through volatility and mean models, which is designed with GARCH-based models [31] and support vector machine [32].

III. Preliminaries

A. Derivative Markets

Financial markets can be separated into *spot* markets and *derivatives* markets [33], [34]. In the spot market, the contract for purchasing or selling a primary financial instrument, e.g., stocks, precious metals, or bonds, is fulfilled immediately after the contract is concluded, modulo a technical deadline. In contrast, in the derivatives market, the contract is fulfilled on a forward date. A derivative's price and payout profile always refer to one or more primary assets, the *underlying* securities, and is either settled by physical delivery of the underlying or by payment of an equivalent (cash settlement) [26].

The main reasons for using derivates are hedging open positions, reducing costs, or speculating on the underlying price movement. In the case of cryptocurrencies, the custody of the underlying asset is another primary reason for using derivates, and, for example after the collapse of *FTX*, a migration from spot markets to derivatives markets was observed [35].

B. BitMEX's Perpetual Swaps

BitMEX, founded in 2014, is among the most relevant crypto derivatives exchanges. BitMEX is unregulated, that is, the exchange is not registered with the *Commodity Futures Trading Commission (CFTC)* or *Securities and Futures Commission (SFC)*. Furthermore, all margin and settlement payments are made in Bitcoin and no fiat currency is involved [10], [25]. In May 2016, BitMEX launched a new crypto derivate called perpetual swaps, futures with no expiry dates, backed by funding mechanism. There exist three products: *Inverse*, *Linear* and *Quanto* swaps. After the launch of perpetual swap by BitMEX, other exchanges such as *Bybit*, *OKEx*, *Binance*, *FTX*, and *Huobi* released their perpetual swap products [36]. Perpetual swaps differ from Bitcoin futures in terms of the denomination, settlement mechanism, high leverage, regulation, and accessibility to US citizens [25].

In the following, we present the mathematical formulation underlying BitMEX's quanto perpetual swap with Ethereum as underlying (ETHUSD). However, the formulas can be applied

TABLE I
Contract Information on BitMEX Quanto PerpetualSwap

Variable	Description
Example symbol	ETHUSD
Underlying	ETHUSD
Multiplier	0.000 001 XBT
Margin requirement	1 %
Quote Currency	USD
Settlement Currency	XBT
Margin & PNL Currency	XBT
Trading hours	Every Day
Expiry date	None
Funding Interval	Every 8 hours

to other underlying securities as well. The specifications of the contract are summarized in Table I including the multiplier and a maximum leverage (margin requirement). The payout profile of an ETHUSD contract depends on the movement of an index, which measures the price of Ethereum, and is determined by the multiplier. The multiplier specifies the amount of profit (long) or loss (short) when the index rises by one USD. The leverage determines how much margin in Bitcoin must be deposited as collateral when a position is opened. Consider n contracts are opened at $t = 0$ at the spot price Ethereum $\mathrm{ETH}_{t=0}$, then the amount of margin is given by

$$\text{margin} = \frac{|n| \cdot \mathrm{ETH}_{t=0} \cdot \text{multiplier}}{\text{leverage}} \ [\mathrm{BTC}], \tag{1}$$

where $n > 0$ if contracts are bought (long) and $n < 0$ if contracts are sold (short). No additional margin will be deposited as long as the underlying does not exceed the liquidation price. Besides the margin and the size n, each position is specified by an entry price, a value, and a liquidation price. When opening a position, the entry price is given by the spot price of the underlying, i.e.,

$$\text{entry\_price}_{t=0} = \mathrm{ETH}_{t=0} \ [\mathrm{USD}]. \tag{2}$$

The value of the entire position at time t is independent of the leverage and only depends on the number of contracts n and the entry price. It is given by

$$\text{value} = n \cdot \text{multiplier} \cdot \text{entry\_price}_t \ [\mathrm{BTC}]. \tag{3}$$

Furthermore, the liquidation price for a short position is determined by

$$\text{liquidation\_price}_t = \text{entry\_price}_t \cdot \left(1 + \text{leverage}^{-1}\right) \ [\mathrm{USD}] \tag{4}$$

As only one position can be held for the XBTUSD contract, the entry price changes when new positions are opened. Consider m additional positions are opened at $t = 1$, then the weighted average gives the adjusted entry price for the $n + m$ contracts, i.e.,

$$\text{entry\_price}_{t=1} = \frac{n \cdot \text{entry\_price}_{t=0} + m \cdot \text{spot}_{t=1}}{n + m}. \tag{5}$$

Return on Investment (2021)

		$50,000	$100,000	$250,000	$500,000	$750,000	$1,000,000	$1,500,000	$2,500,000	$5,000,000	$7,500,000
Linear	ETHUSDT Short & ETH (4%)	-13.60%	-13.60%	-13.60%	-13.60%	-13.60%	-13.60%	-13.60%	-13.60%	-13.60%	-13.60%
	ETHUSDT Short & ETH (3%)	-15.00%	-15.00%	-15.00%	-15.00%	-15.00%	-15.00%	-15.00%	-15.00%	-15.00%	-15.00%
	ETHUSDT Short & ETH (2%)	-12.76%	-12.76%	-12.76%	-12.76%	-12.76%	-12.76%	-12.76%	-12.76%	-12.76%	-12.76%
	ETHUSDT Short & ETH (1%)	-8.28%	-8.28%	-8.28%	-8.28%	-8.28%	-8.28%	-8.28%	-8.28%	-8.28%	-8.28%
Quanto	ETHUSD Short & ETH (4%)	4.09%	7.28%	4.55%	3.89%	4.37%	4.39%	4.01%	4.30%	3.99%	3.89%
	ETHUSD Short & ETH (3%)	8.14%	9.94%	9.25%	9.20%	9.48%	9.35%	9.37%	9.36%	9.38%	9.40%
	ETHUSD Short & ETH (2%)	18.79%	15.95%	17.10%	17.18%	17.06%	16.91%	17.09%	17.08%	16.97%	17.00%
	ETHUSD Short & ETH (1%)	21.64%	23.59%	26.27%	25.25%	24.61%	25.14%	25.21%	25.06%	25.07%	25.12%

Sharpe Ratio (2021)

		$50,000	$100,000	$250,000	$500,000	$750,000	$1,000,000	$1,500,000	$2,500,000	$500,000	$7,500,000
Linear	ETHUSDT Short & ETH (4%)	-0.38	-0.38	-0.38	-0.38	-0.38	-0.38	-0.38	-0.38	-0.38	-0.38
	ETHUSDT Short & ETH (3%)	-0.46	-0.46	-0.46	-0.46	-0.46	-0.46	-0.46	-0.46	-0.46	-0.46
	ETHUSDT Short & ETH (2%)	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45
	ETHUSDT Short & ETH (1%)	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34
Quanto	ETHUSD Short & ETH (4%)	0.12	0.21	0.13	0.11	0.13	0.13	0.12	0.12	0.12	0.11
	ETHUSD Short & ETH (3%)	0.24	0.30	0.28	0.28	0.29	0.28	0.28	0.28	0.28	0.28
	ETHUSD Short & ETH (2%)	0.59	0.50	0.54	0.54	0.54	0.53	0.54	0.54	0.54	0.54
	ETHUSD Short & ETH (1%)	0.70	0.76	0.85	0.82	0.80	0.81	0.82	0.81	0.81	0.81

Fig. 1. Return on Investment and Sharpe Ratio for 2021.

As Perpetual Swaps are derivates, their PNL depends on the price movement of the underlying. At time t, the Profit-and-Loss (PNL) is given by

$$\mathrm{PNL}_t = n \cdot \mathrm{multiplier} \cdot \left(\mathrm{ETH_t} - \mathrm{entry\_price_t}\right) \ [\mathrm{BTC}], \quad (6)$$

i.e., in case of negative n, the PNL is positive when the spot price is smaller than the entry price. The price development in USD depends not only on the price development of Ethereum but also on the development of Bitcoin. To link the development of the PNL as closely as possible to the development of the underlying asset, BitMEX introduced a funding mechanism. The underlying funding rates are determined every 8 hours and paid/deducted to the holder of a contract and the counterparty. When the funding rate is positive, longs pay shorts. When it is negative, shorts pay longs. The amount of funding at time t from the perspective of a short holder is given by

$$\mathrm{funding_t} = \mathrm{funding\_rate_t} \cdot \mathrm{value_t} \ [\mathrm{BTC}]. \quad (7)$$

IV. Strategy

Our investment strategy is implemented in two phases: opening and adjustment. When opening a position, given an investment amount V in USD, half of it is invested in a Ethereum spot position at time $t = 0$, i.e.,

$$n_{\mathrm{spot},0} = \frac{V}{2 \cdot \mathrm{ETH}_0} \quad (8)$$

coins are bought. Simultaneously, perpetual swaps are sold with an value of $0.5 \cdot V$. This requires

$$n_{\mathrm{swap},0} = \frac{V}{2 \cdot \mathrm{ETH}_0 \cdot \mathrm{multiplier} \cdot \mathrm{BTC}_0} \quad (9)$$

short positions to be opened.

The positions are adjusted at time t if the difference $|\mathrm{PNL_{swap,\,t}} - \mathrm{PNL_{spot,\,t}}|$ exceeds a predefined threshold. If $\mathrm{PNL_{spot,\,t}} > \mathrm{PNL_{swap,\,t}}$, the spot position is reduced by the number of coins of value $0.5 \cdot (\mathrm{PNL_{spot,\,t}} - \mathrm{PNL_{swap,\,t}})$, and perpetual contracts are sold so that the value of the swap position rises by this amount. In the other case, contracts are closed and more coins of the underlying are bought. After the adjustment, both positions are weighted equally again, and a perfect hedge exists, i.e., we have the same situation as in the opening phase.

V. Backtest

We compare our trading strategy with the analogous version based on linear perpetual swaps. We evaluate their performances using the *Return on Investment (ROI)*, given by

$$\mathrm{ROI} = \frac{V_1 - V_0}{V_0} \quad (10)$$

where V_0 is the value of the portfolio at the beginning and V_1 is the value of the portfolio at the end. We further calculate the *Sharpe Ratio (SR)* to incorporate volatility, which is given by

$$\mathrm{SR} = \frac{V_1 - V_0}{V_0 \cdot \sigma}, \quad (11)$$

whereby we assume a risk-free interest rate of $0.00\,\%$ and σ denotes the standard deviation of the positions excess returns [37]. The backtest covers the years 2021 and 2022. Figure 1 shows the net returns, i.e., returns less trading fees, for 2021, and Figure 2 the results for the year 2022. The BitMEX pricing model is based on the trading volume, and we always assume taker orders[2]. The reference prices for Ethereum and Bitcoin are derived as the mean of best ask and best bid from order books of Binance, the most liquid spot market, collected via the *Hephaistos* system presented by Henker et al. [38]; the

[2]https://www.bitmex.com/wallet/fees/derivatives

Return on Investment (2022)

		$50,000	$100,000	$250,000	$500,000	$750,000	$1,000,000	$1,500,000	$2,500,000	$5,000,000	$7,500,000
Linear	ETHUSDT Short & ETH (4%)	-2.60%	-2.60%	-2.60%	-2.60%	-2.60%	-2.60%	-2.60%	-2.60%	-2.60%	-2.60%
	ETHUSDT Short & ETH (3%)	-3.13%	-3.12%	-3.13%	-3.13%	-3.13%	-3.13%	-3.13%	-3.13%	-3.13%	-3.13%
	ETHUSDT Short & ETH (2%)	-6.65%	-6.65%	-6.65%	-6.65%	-6.65%	-6.65%	-6.65%	-6.65%	-6.65%	-6.65%
	ETHUSDT Short & ETH (1%)	-7.10%	-7.10%	-7.10%	-7.10%	-7.10%	-7.10%	-7.10%	-7.10%	-7.10%	-7.10%
Quanto	ETHUSD Short & ETH (4%)	-31.27%	-31.09%	-31.05%	-30.93%	-31.24%	-30.93%	-30.93%	-30.95%	-30.94%	-30.94%
	ETHUSD Short & ETH (3%)	-31.59%	-31.34%	-31.24%	-31.19%	-31.17%	-31.11%	-31.11%	-31.11%	-31.12%	-31.12%
	ETHUSD Short & ETH (2%)	-31.96%	-32.13%	-31.69%	-31.56%	-31.76%	-31.62%	-31.59%	-31.66%	-31.65%	-31.64%
	ETHUSD Short & ETH (1%)	-33.53%	-33.49%	-32.93%	-32.92%	-32.92%	-33.09%	-33.02%	-33.01%	-32.97%	-33.00%

Sharpe Ratio (2022)

		$50,000	$100,000	$250,000	$500,000	$750,000	$1,000,000	$1,500,000	$2,500,000	$500,000	$7,500,000
Linear	ETHUSDT Short & ETH (4%)	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18
	ETHUSDT Short & ETH (3%)	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24
	ETHUSDT Short & ETH (2%)	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52
	ETHUSDT Short & ETH (1%)	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64
Quanto	ETHUSD Short & ETH (4%)	-0.77	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76
	ETHUSD Short & ETH (3%)	-0.81	-0.79	-0.79	-0.79	-0.79	-0.79	-0.79	-0.79	-0.79	-0.79
	ETHUSD Short & ETH (2%)	-0.84	-0.85	-0.84	-0.83	-0.84	-0.83	-0.83	-0.84	-0.84	-0.84
	ETHUSD Short & ETH (1%)	-0.96	-0.97	-0.94	-0.94	-0.94	-0.95	-0.95	-0.95	-0.95	-0.95

Fig. 2. Return on Investment and Sharpe Ratio for 2022.

funding rates are publicly available from BitMEX[3]. Our data, implementation, and result files are available as a GitHub[4] repository to guarantee reproducibility.

In 2021, Ethereum had a return of ROI = 413.5 % (SR = 3.79). The implementation of the strategy based on the linear perpetual swap generated a negative ROI in the same period, whereas the strategy based on the quanto perpetual swap generated a positive ROI. Of particular relevance here is the selected threshold $\theta = (|\text{PNL}_{\text{swap, t}} - \text{PNL}_{\text{spot, t}}|)/V$, above which adjustments are made. The lower the threshold selected, the higher the ROI and the higher the SR. With a fixed threshold, both the ROI and the SR remained constant regardless of the investment volume. In 2022, Ethereum had a negative return of ROI = -57.3 % (SR = -0.77). Both strategies also show a negative ROI, independent of the investment amount at a constant threshold, which is not a surprise as the funding rates changed sign due to the market environment. Unlike in 2021, however, a lower value for θ harms both the ROI and the SR.

VI. Discussion

Our results can be summarized as follows: by hedging a quanto perpetual swap, a strategy that achieves positive (negative) returns in bullish (bearish) market phases, but to a lesser extent than a long-only strategy, can be implemented. Furthermore, the SR shows that our strategy has a lower volatility. Therefore, our strategy represents an opportunity to participate in the performance of the underlying, but with a lower risk.

Our results are prone to different threats to validity. Though our analysis incorporates trading fees as "explicit costs" that reduce the return, so-called "implicit costs" are neglected. Implicit costs mean deviations from the assumed price of the underlying that arise from the order book [39]. Those implicit costs can rise dramatically, especially in "extreme" market scenarios, e.g., significant events [40]. However, this effect mainly depends on the order size, and as we recommend using a small threshold, the overall trend should not change [41]. Furthermore, funding rates might change by participating in the market, especially when placing large volumes. Our analysis relies on historical data, so this effect can not be incorporated.

[3]https://www.bitmex.com/app/fundingHistory
[4]https://github.com/atzberger/Hedging_Quanto_Perpetual_Swaps

VII. Conclusions

Derivatives on cryptocurrencies enable market participants to manage their risk and speculate on price movements. BitMEX's perpetual swaps are among the most popular products in the crypto domain, as they never expire, require a low margin, and do not require fiat currencies. Furthermore, by introducing a funding mechanism, the contracts trade close to the underlying. We proposed a trading strategy that combines a short position of quanto perpetual swap and a spot position in the underlying and evaluated its performance in a backtest covering 2021 and 2022. Our results revealed that this strategy allows traders to participate in the price movement of the underlying but with lower volatility, thus lower risk. We presume that our strategy would be an opportunity for diversification in the current changing market environment, as short positions receive funding.

We see different directions for future work: First, we plan to address the threats to validity by considering entire order books in our backtest to incorporate implicit costs, which requires a more performant implementation. Secondly, we see great potential in combining our strategy with a market-making algorithm to generate another income stream, as maker orders are rewarded in contrast to taker fees. Furthermore, it would also be interesting to analyze the ROI and SR in terms of other cryptocurrencies instead of USD.

REFERENCES

[1] Satoshi Nakamoto. Bitcoin: A peer-to-peer electronic cash system, 2009.

[2] Yue Wu. A quantitative analysis on BitMEX perpetual inverse futures XBTUSD contract. *Undergraduate Economic Review*, 17(1), 2020. Article 12.

[3] CoinMarketCap. Top cryptocurrency derivatives exchanges. 2023. URL: https://coinmarketcap.com/rankings/exchanges/derivatives/.

[4] BitMEX. Perpetual contracts guide. 2023. URL: https://www.bitmex.com/app/perpetualContractsGuide.

[5] Tatja Karkkainen. Price discovery in the bitcoin futures and cash markets. In *The Routledge Handbook of FinTech*. Taylor & Francis, 2021.

[6] Dirk G. Baur and Thomas Dimpfl. Price discovery in bitcoin spot or futures? *Journal of Futures Markets*, 39(7):803–817, 2019.

[7] Toshiko Matsui and Lewis Gudgeon. The speculative (in)efficiency of the CME bitcoin futures market. In *Mathematical Research for Blockchain Economy*, pages 91–103, Cham, 2020. Springer International Publishing.

[8] Erdinc Akyildirim, Shaen Corbet, Paraskevi Katsiampa, Neil Kellard, and Ahmet Sensoy. The development of bitcoin futures: Exploring the interactions between cryptocurrency derivatives. *Finance Research Letters*, 34:101234, 2020.

[9] Arun Narayanasamy, Humnath Panta, and Rohit Agarwal. Relations among bitcoin futures, bitcoin spot, investor attention, and sentiment. *Journal of Risk and Financial Management*, 16(11), 2023.

[10] Carol Alexander, Jaehyuk Choi, Heungju Park, and Sungbin Sohn. BitMEX bitcoin derivatives: Price discovery, informational efficiency, and hedging effectiveness. *Journal of Futures Markets*, 40(1):23–43, 2020.

[11] Ruozhou Liu, Shanfeng Wan, Zili Zhang, and Xuejun Zhao. Is the introduction of futures responsible for the crash of bitcoin? *Finance Research Letters*, 34:101259, 2020.

[12] Patrick Augustin, Alexey Rubtsov, and Donghwa Shin. The impact of derivatives on spot markets: Evidence from the introduction of bitcoin futures contracts. *Management Science*, 69(11):6752–6776, 2023.

[13] Evita Stenqvist and Jacob Lönnö. Predicting bitcoin price fluctuation with twitter sentiment analysis. Bachelor's thesis, KTH, School of Computer Science and Communication, Stockholm, Sweden, 2017.

[14] Jethin Abraham, Daniel Higdon, John Nelson, and Juan Ibarra. Cryptocurrency price prediction using tweet volumes and sentiment analysis. *SMU Data Science Review*, 1(3), 2018.

[15] Sean McNally, Jason Roche, and Simon Caton. Predicting the price of bitcoin using machine learning. In *Proceedings of the 26th Euromicro International Conference on Parallel, Distributed and Network-based Processing*, PDP '18, pages 339–343. IEEE, 2018.

[16] Jim Liew, Richard Ziyuan Li, Tamás Budavári, and Avinash Sharma. Cryptocurrency investing examined. *The Journal of The British Blockchain Association*, 2(2), 2019.

[17] Shubhankar Mohapatra, Nauman Ahmed, and Paulo Alencar. KryptoOracle: A real-time cryptocurrency price prediction platform using twitter sentiments. In *Proceedings of the International Conference on Big Data*, BigData '19, pages 5544–5551. IEEE, 2019.

[18] Kin-Hon Ho, Tse-Tin Chan, Haoyuan Pan, and Chin Li. Do candlestick patterns work in cryptocurrency trading? In *Proceedings of the International Conference on Big Data*, BigData '21, pages 4566–4569. IEEE, 2021.

[19] Gil Cohen. Intraday algorithmic trading strategies for cryptocurrencies. *Review of Quantitative Finance and Accounting*, 61(1):395–409, 07 2023.

[20] Toshiko Matsui and William J. Knottenbelt. Optimal hedge ratio estimation for bitcoin futures using kalman filter. In *International Conference on Blockchain and Cryptocurrency*, ICBC '23, pages 1–5. IEEE, 2023.

[21] Igor Makarov and Antoinette Schoar. Trading and arbitrage in cryptocurrency markets. *Journal of Financial Economics*, 135(2):293–319, 2020.

[22] Andrei Shynkevich. Bitcoin arbitrage. *Finance Research Letters*, 40:101698, 2021.

[23] Yoontae Jeon, Laleh Samarbakhsh, and Kenji Hewitt. Fragmentation in the bitcoin market: Evidence from multiple coexisting order books. *Finance Research Letters*, 39:101654, 2021.

[24] Ivan Vakhmyanin and Yana Volkovich. Price arbitrage for DeFi derivatives. In *International Conference on Blockchain and Cryptocurrency*, ICBC '23, pages 1–4. IEEE, 2023.

[25] Alex Ferko, Amani Moin, Esen Onur, and Michael Penick. Who trades bitcoin futures and why? *Global Finance Journal*, 55:100778, 2023.

[26] Kyle Soska, Jin-Dong Dong, Alex Khodaverdian, Ariel Zetlin-Jones, Bryan Routledge, and Nicolas Christin. Towards understanding cryptocurrency derivatives: A case study of BitMEX. In *Proceedings of the Web Conference*, WWW '21, pages 45–57. ACM, 2021.

[27] Sai Srikar Nimmagadda and Pawan Sasanka Ammanamanchi. BitMEX funding correlation with bitcoin exchange rate, 2019. arXiv:1912.03270 [q-fin.ST].

[28] Jun Deng, Huifeng Pan, Shuyu Zhang, and Bin Zou. Optimal Bitcoin trading with inverse futures. *Annals of Operations Research*, 304(1):139–163, September 2021.

[29] Carol Alexander and Arben Imeraj. Delta hedging bitcoin options with a smile. *Quantitative Finance*, 23(5):799–817, 2023.

[30] Avinash Malik. A comparison of machine learning and econometric models for pricing perpetual bitcoin futures and their application to algorithmic trading. *Expert Systems*, 40(10):e13414, 2023.

[31] Tim Bollerslev. Generalized autoregressive conditional heteroskedasticity. *Journal of Econometrics*, 31(3):307–327, 1986.

[32] Kyoung-jae Kim. Financial time series forecasting using support vector machines. *Neurocomputing*, 55(1):307–319, 2003.

[33] John C. Hull. *Options, futures, and other derivatives*. Pearson Prentice Hall, 6. edition, 2006.

[34] Philip J. Hunt and Joanne E. Kennedy. *Financial derivatives in theory and practice*, volume 556 of *Wiley Series in Probability and Statistics*. John Wiley and Sons, 2004.

[35] Robin Wigglesworth. What does crypto look like after FTX? 2022. URL: https://www.ft.com/content/6874a389-0b9f-4b32-aba6-622f7137bbe4.

[36] Henri Arslanian. Crypto exchanges. In *The Book of Crypto: The Complete Guide to Understanding Bitcoin, Cryptocurrencies and Digital Assets*, pages 335–350. Springer International Publishing, Cham, 2022.

[37] William F Sharpe. The Sharpe ratio. *Streetwise – The Best of the Journal of Portfolio Management*, 3:169–85, 1998.

[38] Robert Henker, Daniel Atzberger, Jan Ole Vollmer, Willy Scheibel, Jürgen Döllner, and Markus Bick. Hephaistos: A management system for massive order book data from multiple centralized crypto exchanges with an internal unified order book. In *Proceedings of the 1st International Workshop on Cryptocurrency Exchanges*, CryptoEx '23. IEEE, 2023.

[39] Peter Gomber and Uwe Schweickert. The market impact-liquidity measure in electronic securities trading. *Die Bank*, 7(1):485–489, 2002.

[40] Adrian Jobst, Daniel Atzberger, Robert Henker, Jan Ole Vollmer, Willy Scheibel, and Jürgen Döllner. Examining liquidity of exchanges and assets and the impact of external events in centralized crypto markets: A 2022 study. In *Proceedings of the 1st International Workshop on Cryptocurrency Exchanges*, CryptoEx '23. IEEE, 2023.

[41] Martin Angerer, Marius Gramlich, and Michael Hanke. Order book liquidity on crypto exchanges. In *Proceedings of the 3rd Crypto Asset Lab Conference*, CAL '21. Crypto Asset Lab, 2021.