# Order Flow Analysis in Cryptocurrency Markets

Rutendo Makonise  Ndabezinhle Maphumulo

Department of Statistical Science, University of Cape Town

## Introduction

Cryptocurrency is a decentralized digital currency using encryption to secure transactions. It operates through blockchain distributed ledger technology and functions without central authorities.

**Market Evolution**

- 2010: First real-world BTC transaction: 10,000 BTC for 2 pizzas = $25
- Market capitalization grew from $12B (2014) to $831B (2018)
- Over 10,000 cryptocurrencies exist today

**Cryptocurrency market structure**

- Continuous 24/7 trading
- Liquidity fragmented across exchanges [6]
- Higher level of spoofing and order cancellations[7]
- Less regulated environment enabling manipulative practices

**Research Gap**

- Order flow analysis is extensively studied in traditional markets (equities, futures).
- Crypto markets, however, remain far less explored.
- This motivates examining whether classical order flow measures (OFI, TFI) explain short-term price changes in cryptocurrency markets.

## Methodology

**Data**

- BitMex XBTUSD contract
- Oct 1-23, 2017
- 8.5M quotes, 4.1M trades

**Variables**

- OFI: net order book events
- TFI: signed market orders
- $\Delta MP$: mid-price change in ticks

**Regression models**

$$\Delta MP_k = \alpha_{OFI} + \beta_{OFI}\, OFI_k + \epsilon_k$$

$$\Delta MP_k = \alpha_{TFI} + \beta_{TFI}\, TFI_k + \epsilon_k$$

**Time intervals (k):**1s, 10s, 1min, 5min, 10min, 1h

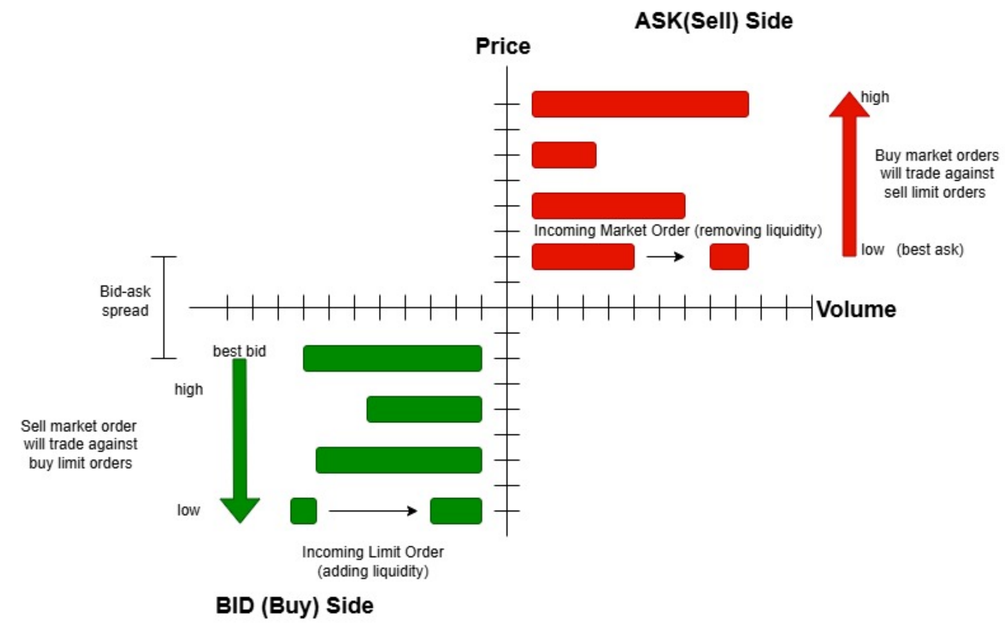
## Objectives

- Describe the order book
- Replicate Silantyev (2019) paper
- Analyse relationships between OFI/TFI and contemporaneous price changes

## The Order Book

- **Order Book (LOB):** A real time list of buy/sell orders at different price levels.
- **Order Flow:** The sequence of buy and sell orders impacting the book.
- **Order Types:**Limit orders (specify price), market orders (buy/sell at the best bid/ask), cancellations.
- **Order Flow Imbalance (OFI):** Net buying vs selling pressure at each price level.
- All trading activity occurs in the order book; order flow analysis studies these changes to anticipate short-term price movements.

## Order Book schematic




Limit order book schematic. *A market buy order is about to hit the best ask, removing liquidity, while a limit buy order is simultaneously being added to the bid side, increasing the book's depth (liquidity)*

**Mathematical Definitions**

$$OFI_k = \sum_{n=N(t_{k-1})+1}^{N(t_k)} e_n$$

$$e_n = I_{\{P_n^B \geq P_{n-1}^B\}} q_n^B - I_{\{P_n^B \leq P_{n-1}^B\}} q_{n-1}^B - I_{\{P_n^A \leq P_{n-1}^A\}} q_n^A + I_{\{P_n^A \geq P_{n-1}^A\}} q_{n-1}^A$$

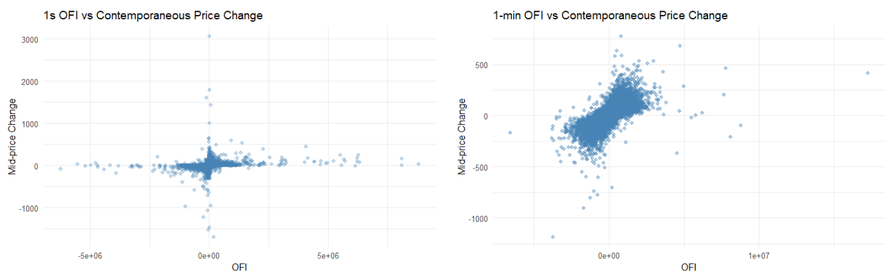
$$TFI_k = \sum_{n=N(t_{k-1})+1}^{N(t_k)} s_n v_n$$

$$s_n = \begin{cases} +1 & \text{buyer-initiated} \\ -1 & \text{seller-initiated} \end{cases}$$

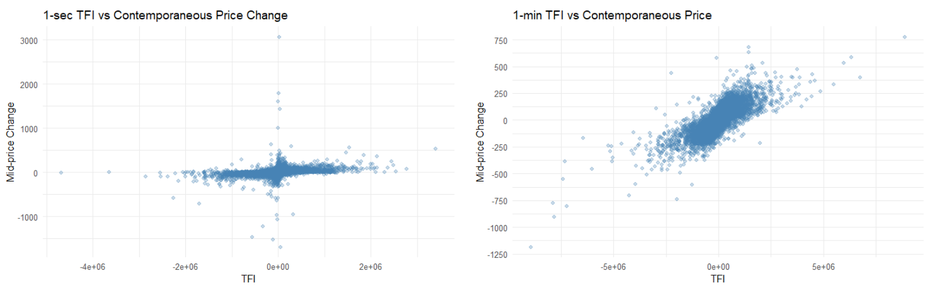
$P_n^B, P_n^A$ best bid/ask prices, $q_n^B, q_n^A$ volumes, $v_n$ trade size.

## Results

Order Flow Imbalance (OFI)




Trade Flow Imbalance (TFI)




- Short intervals: noisy, non-linear
- Longer intervals: linear trends, TFI outperforms OFI.
- Strong linear relationship with midprice changes as the sampling window (k) increases. eg for OFI $R^2$ grows from 7.4% (1s) $\rightarrow$ 55.4% (1min)
- All $\beta_{OFI}$ and $\beta_{TFI}$ significant, ($p < 0.01$)

| Interval | OFI | | | TFI | | |
|---|---|---|---|---|---|---|
| | $\alpha$ | $\beta$ | $R^2$ | $\alpha$ | $\beta$ | $R^2$ |
| 1s | 0.0013 | 4.5e-5 | 7.40% | 0.0122 | 7.7e-5 | 13.3% |
| 10s | -0.0036 | 7.7e-5 | 40.9% | 0.0290 | 1.1e-4 | 37.5% |
| 1min | -0.277 | 8.4e-5 | 55.4% | 0.1300 | 1.8e-4 | 58.5% |
| 5min | -0.840 | 7.2e-5 | 52.1% | 0.9100 | 1.0e-4 | 69.0% |
| 10min | -1.330 | 6.8e-5 | 49.8% | 2.0500 | 9.2e-5 | 70.7% |
| 1h | -6.160 | 6.4e-5 | 51.2% | 13.2500 | 8.6e-5 | 75.1% |

model parameter estimations

## Discussion

- Short-term: OFI provides early signals, but noisy.
- Long-term: TFI has stronger relationship with price changes.
- Aggregation of sampling windows smooths noise; linear trends emerge.
- Microstructure (depth, spread, liquidity) shapes price response.
- Ephemeral liquidity reduces OFI informativeness.

## Conclusion

- Both Order Flow Imbalance (OFI) and Trade Flow Imbalance (TFI) have statistically significant associations with price changes.
- TFI outperforms OFI, especially over longer time intervals.
- Market microstructure explains weaker OFI in cryptocurrency

## Further Work

- Analyse additional cryptocurrencies and longer time intervals.
- Address autocorrelation in OFI/TFI (lagged terms or Newey-West errors).
- Test predictive power of OFI/TFI for short-horizon forecasting.
- Apply advanced models eg Hidden Markov Models (HMMs)

## References

[1] Silantyev, E. (2019). Order flow analysis of cryptocurrency markets.

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[4] Hasbrouck (1991).Measuring the information content of stock trades.

[5] Chordia, Roll & Subrahmanyam (2002). Order imbalance, liquidity, and market returns.

[6] Jeon et al. (2021). Liquidity aggregation in cryptocurrency markets.

[7] Hafner et al. (2021). Order cancellation patterns in crypto markets.