October 4, 2023

Module: High Frequency Trading

Week 2: Market Microstructure

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Market Structure

Source: Oxera.

Latency

Latency refers to the delay between sending a message to the market and it being received and processed by the exchange.

Colocated

Being colocated means that an agent's trading system is physically housed at the electronic exchange's data centre and has a direct connection to the exchange's matching engine.

Price Movement

What happens to price in one minute?

Asset	Var	$\Delta X \neq 0$ (%)	Stats (for $\Delta X \neq 0$) P01	Q1	Q2	Q3	P99
ISNS	Bid	4.2	-43.0	-4.0	1.0	5.0	40.0
	Ask	3.4	-51.0	-4.0	-1.0	3.0	51.0
	Midprice	6.7	-25.8	-2.0	0.5	2.0	26.8
	Quoted Spread	6.7	-45.0	-5.0	-1.0	4.0	46.0
FARO	Bid	48.6	-21.0	-2.0	1.0	3.0	19.0
	Ask	49.0	-19.0	-3.0	-1.0	3.0	22.0
	Midprice	63.4	-16.0	-1.5	0.5	2.0	16.0
	Quoted Spread	60.8	-18.0	-2.0	-1.0	2.0	18.0
MENT	Bid	44.2	-5.0	-1.0	1.0	1.0	6.0
	Ask	44.1	-5.0	-1.0	-1.0	1.0	5.0
	Midprice	52.8	-4.5	-1.0	0.5	1.0	5.0
	Quoted Spread	31.1	-5.0	-1.0	-1.0	1.0	4.0

Figure: One minute changes in bid, ask, midprice, and quoted spread

Tick Size

Asset	Var	$\Delta X \neq 0$ (%)	Stats (for $\Delta X \neq 0$) P01	Q1	Q2	Q3	P99
AAPL	Bid	3.84	-17.0	-3.0	-1.0	3.0	18.0
	Ask	4.00	-18.3	-3.0	1.0	3.0	17.0
	Midprice	6.75	-11.5	-1.5	0.5	1.5	11.0
	Quoted Spread	6.69	-16.0	-3.0	-1.0	3.0	18.0
ORCL	Bid	0.41	-2.0	-1.0	-0.5	1.0	2.0
	Ask	0.40	-2.0	-1.0	1.0	1.0	2.0
	Midprice	0.47	-2.0	-1.0	0.5	1.0	2.0
	Quoted Spread	0.16	-3.0	-1.0	-1.0	1.0	2.0

Figure: One hundred ms change in bid, ask, mid price, and quoted spread

As both assets have the same minimum tick size (of one cent), this means that AAPL can experience much smaller percentage changes in its price (1 cent = 0.2 bps of \$500) than ORCL (1 cent = 2.5 bps of \$40). Thus, one would expect more frequent price movements for AAPL than for ORCL.

Daily Trading Activity

Measures of trading activities

- No. of transactions
- Volume in $
- volume in no. of shares
- share turnover

Asset	N	$V(\$)$ $(\times 10^3)$	$V(Q)$ $(\times 10^3)$	Total $V(Q)$ $(\times 10^3)$	ShrOut $(\times 10^6)$	Turnover
ISNS	14	18	3	12	5	0.62
FARO	315	1,396	34	137	17	2.04
MENT	908	3,964	204	694	112	1.56
AAPL	24,582	1,505,175	3,208	14,516	941	3.89

Figure: Daily Average Volume in 2013 for selected assets

Average Holding Period

Exchange/Exchange Group	Market cap ($B, US equiv.)	Volume ($B, US equiv.)	Annual turnover	Implied holding period (years)
New York Stock Exchange (NYSE)	24,480	9,305	0.380	2.6
Nasdaq - US	13,002	15,910	1.224	0.8
Japan Exchange Group (Tokyo)	6,191	5,099	0.824	1.2
Shanghai Stock Exchange	5,106	7,790	1.526	0.7
Hong Kong Exchanges and Clearing	4,899	1,877	0.383	2.6
Euronext	4,702	1,920	0.408	2.4
LSE Group (London)	4,183	2,000	0.478	2.1
Shenzhen Stock Exchange	3,410	11,255	3.301	0.3
TMX Group (Tornonto)	2,409	1,445	0.600	1.7

Market capitalization is as of the end of 2019. Volume reflects only EOB (electronic order book) trades.

Source: World Federation of Exchanges (http://world-exchanges.org)

Intraday Returns

Are Returns normal distributed?

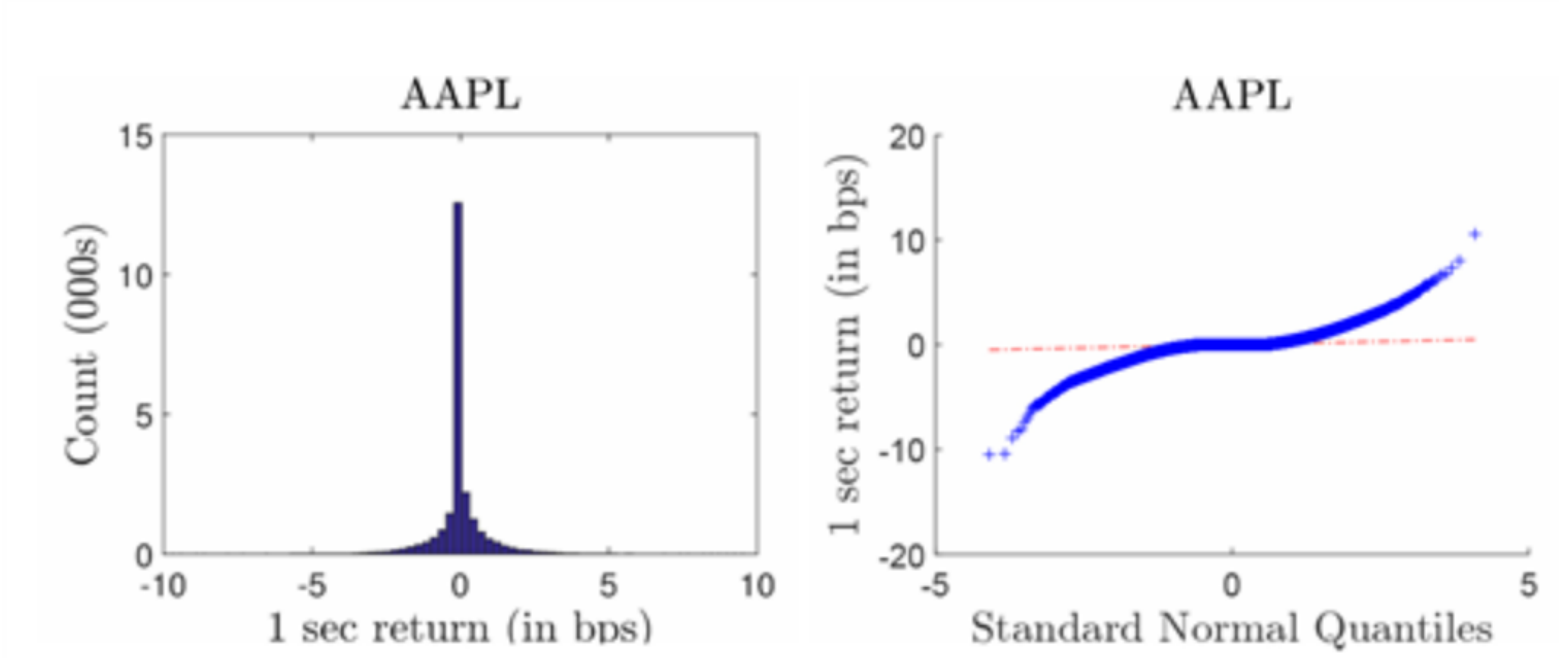


Figure: Distribution and QQ plot of the 1-second returns of AAPL on 30/07/13

Volatility

Volatility measures price fluctuations and represents a cost (i.e. low market quality) in the sense that a rapidly changing price makes it difficult to determine the actual market price of the asset.

realised volatility vs. implied volatility

Realised Volatility

The Table displays the statistical properties of realised volatility measured as σ_t^2, the standard deviation of one-minute returns over fifteen minute periods (for every day in 2013), that is, for every 15-minute period (each 15-minute period indexed by t)

$$\sigma_t^2 = \sum_{j=1}^{15} \left(r_j - \frac{1}{15} \sum_{s=1}^{15} r_s \right)^2 ,$$

Asset	Mean	StdDev	P01	Q1	Median	Q3	P99
ISNS	16.6	54.8	0.0	0.0	0.0	14.4	160.3
FARO	8.3	12.7	0.0	3.8	6.6	10.3	31.3
MENT	5.6	6.6	0.0	3.2	4.6	6.5	20.1
AAPL	5.5	4.2	1.0	3.3	4.7	6.7	18.1

Figure: Realised one-minute volatility

Liquidity

Liquidity is a broad term that summarise the level of cost and difficult that we encounter when we try to trade.

- Immediately
- Tightness
- Depth
- Resilience

Market Depth

By depth, we mean the volume posted in the LOB and available for immediate execution.

Asset	Mean	StdDev	P01	Q1	Median	Q3	P99
ISNS	619	787	51	150	300	750	3,250
FARO	142	125	14	86	122	171	484
MENT	661	694	117	351	527	784	2,852
AAPL	189	169	64	127	161	210	662

Figure: Average Depth and the Bid and Ask

Trade Size

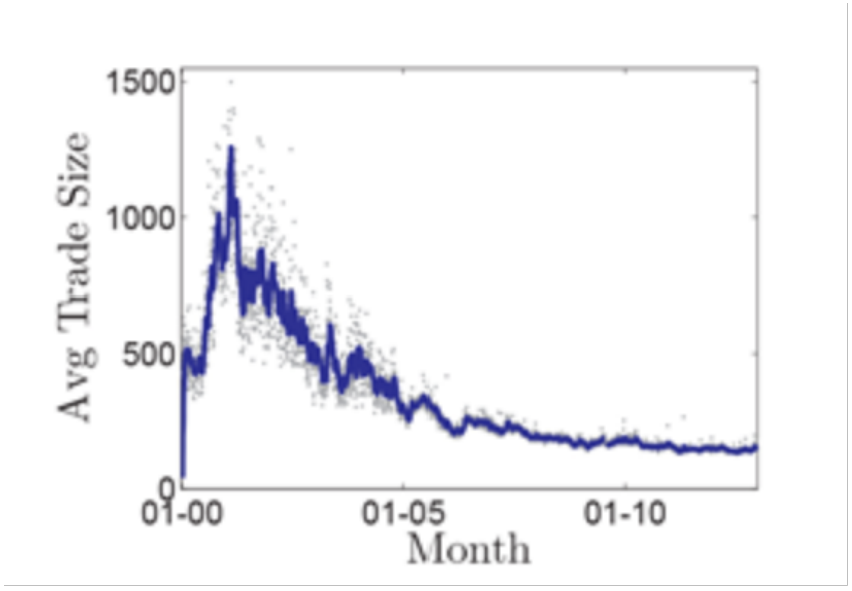


Figure: Average Depth and the Bid and Ask

Depth and trade size are not independent of one another If the depth is thin (few orders resting in the LOB), MOs will be small –which implies that in thin markets, relatively urgent large orders that would walk the LOB need to be broken up into smaller MOs which are then sequentially executed over a period of time.

Price Impact

A main concern for participants that wish to execute a large order is that the order will have an adverse price impact: increasing the price when buying aggressively and lowering it when selling. There are several variables that can be used to measure the price impact of an order.

- measuring depth
- measuring the impact on price from buying/selling each share

Order Flow

- Order flow is a very important concept in trading because information infuses into price through orders.
- Order flow in dealer's market can be easily defined because it is easy to tell which side is the liquidity provision side.
- More generally, order flow can be defined as the difference between the volumes of buy and sell MOs during a period.

Permanent Price Impact

We first estimate the permanent price impact by looking at the impact of order flow on the change in price over five-minute intervals.
Let $\Delta S_n = S_n - S_{(n-1)\tau}$ be the change in the midprice during the time interval $[(n-1)\tau, n\tau]$, where $\tau = 5$ minutes.
Let μ_n be the net order flow during the same time interval.
We then estimate the permanent price impact as the parameter b in the following robust linear regression:

$$\Delta S_n = b\mu_n + \epsilon_n$$

where ϵ_n is the error term (assumed normal). This model is estimated every day, using winsorized data, excluding the upper and lower 0.5 % tails.

Temporary Price Impact

We assume that temporary price impact is linear in the volume traded. Specifically, the difference between the execution price that the investor receives and the best quote is kQ, where Q is the total volume traded.
To perform the estimation, we take a snapshot of the LOB each second, determine the price per share S_i^{exec} for various volumes $\{Q_1, Q_2, \ldots, Q_N\}$ (by walking the LOB), compute the difference between the execution price per share and the best quote at that time, and perform a linear regression. That is, we regress,

$$S_{i,t}^{exec,bid} = S_t^{bid} - k^{bid} Q_i + \varepsilon_{i,t}^{bid}, \qquad S_{i,t}^{exec,ask} = S_t^{ask} + k^{ask} Q_i + \varepsilon_{i,t}^{ask}$$

where $\epsilon_{i,t}$ represents the estimation error of the i-th volume for the t-th timestamp.
The slope coefficient of the linear regression, denoted as k, is an estimate of the temporary price impact per share at that time.

Permanent and Temporary Price Impact

	FARO	SMH	NTAP	ORCL	INTC
$\hat{b}$	1.41×10^{-4}	5.45×10^{-6}	5.93×10^{-6}	1.82×10^{-6}	6.15×10^{-7}
	(9.61×10^{-5})	(4.20×10^{-6})	(2.31×10^{-6})	(7.19×10^{-7})	(2.16×10^{-7})
$\hat{k}$	1.86×10^{-4}	8.49×10^{-7}	3.09×10^{-6}	8.23×10^{-7}	2.50×10^{-7}
	(2.56×10^{-4})	(8.22×10^{-7})	(1.75×10^{-6})	(3.78×10^{-7})	(1.25×10^{-7})
$\widehat{b/k}$	1.02	7.43	2.04	2.28	2.55
	(0.83)	(6.24)	(0.77)	(0.74)	(0.70)

Figure: Permanent and temporary price impact of NASDAQ stocks 2013

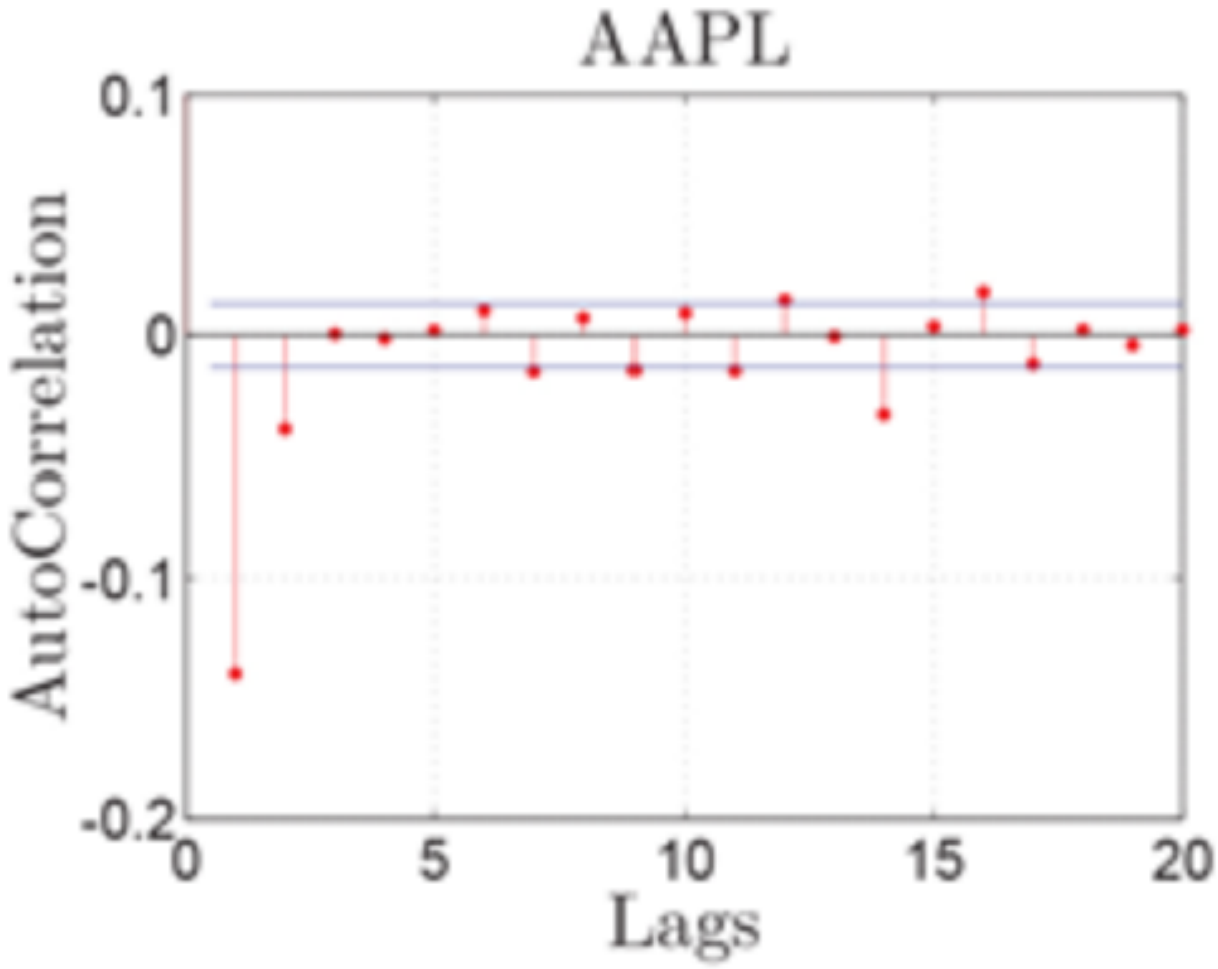
Order Imbalance

We define order imbalance ρ_t at time t as the ratio of the quoted volume imbalance to the total quoted volume, i.e.,

$$\rho_t = \frac{V_t^b - V_t^a}{V_t^b + V_t^a},$$

Here, V_t^b denotes the volume of limit orders posted on the bid side of the LOB, and V_t^a denotes the volume of limit orders posted on the ask side of the LOB.

Return ACF



Python Application

- import libraries
- loading data as arrays
- calculate midprice, microprice, spread and order imbalance etc. with LOB information
- plot
- calculate order or return autocorrelation