Lecture 24:
Market Microstructure

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Types of Buy/Sell Orders

Brokers can typically perform the following buy/sell orders for exchange traded assets:

- *Market orders* request the trade happen immediately at the best current price.
- *Limit orders* demand a given or better price at which to buy or sell the asset. Nothing happens unless a matching buyer or seller is found.
- *Stop* or *stop-loss order* becomes a market order when a given price is reached by the market on the downside. This enables an investor to minimize losses in a market reversal, but does not guarantee the given price.

- *Market-if-Touched order* (MIT) becomes a market order when a given price is reached by the market on the upside. This enables an investor to take profits when they are available, but does not guarantee them the given price.

The volume and distribution of stop and limit orders in principle contains information about future price movements. Theory argues against making such orders as giving away an option for no payoff, however, such orders are useful particularly for modest-sized investments.

The computational and financial details of trading are called *market microstructure*.

Market Order Book

The priority queues of open limit orders form the *order book*.

MSFT Microsoft Corp

NYSE Arca. MSFT Go» New Window

Bid				Ask			
ID	Price	Size	Time	ID	Price	Size	Time
ARCA	19.89	1077	09:06:05	ARCA	19.92	1992	09:13:39
ARCA	19.84	500	08:42:38	ARCA	19.93	400	09:10:45
ARCA	19.83	100	08:54:39	ARCA	19.94	922	09:09:36
ARCA	19.82	2500	08:30:00	ARCA	19.95	309	08:40:49
ARCA	19.80	1000	08:33:48	ARCA	20.00	500	09:05:52
ARCA	19.76	600	08:28:35	ARCA	20.23	100	08:17:13
ARCA	19.75	5500	09:06:55	ARCA	20.28	100	08:06:38
ARCA	19.65	5000	08:01:53	ARCA	20.35	1100	09:11:55
ARCA	19.62	1000	09:02:58	ARCA	20.70	2000	08:54:12
ARCA	19.57	100	08:06:48	ARCA	20.92	500	09:11:07
ARCA	19.56	100	08:00:35	ARCA	20.97	1000	08:40:41
ARCA	19.55	1000	08:01:53	ARCA	21.07	2500	08:52:20
ARCA	19.53	1100	09:07:04	ARCA	21.17	100	04:15:03
ARCA	19.51	1000	08:02:52	ARCA	21.50	300	08:30:01
ARCA	19.50	300	09:13:22	ARCA	21.74	100	04:15:03
ARCA	19.43	100	08:00:17	ARCA	22.00	8000	06:42:11

http://www.tradingday.com/cgi-bin/stock_quotes_charts.cgi?s=MSFT

Properties of the Order Book

Orders with the same price are prioritorized by arrival time.
The difference between bid and ask is called the *spread*. The last executed price is the *ticker* price.
Market orders are matched with the most competitive limit orders in the opposing book.
Orders can be cancelled up until the moment they are matched, and often are.
The party who placed the order is not publicly revealed.
The limit orders in a book are often publicly available and (1) provide clues to market sentiment, and (2) guidence for order placement, such as stepping in front of an order by a fractional amount.

Electronic Crossing Networks

NASDAQ is an entirely electronic exchange, so a computer executes all matches between buyers and sellers.

NASDAQ permits multiple *Electronic Crossing Networks* (e.g. Island, Instinet, Archipelago) providing essentially independent, competing markets for NASDAQ stocks.

Many ECNs reveal their order books to traders, but others (called *dark pools*) don't.

ECNs account for about 75% of NASDAQ market volume.

Island ECN accounts for roughly one in seven NASDAQ trades.

Finding the best price for an order involves search across all of these networks.

Scale of Trading Operations

The New York Stock Exchange handled a volume of over 4 billion shares on Feburary 27, 2007.

That presumably works out to over 10 million transactions, or almost 500 transactions per second – not counting unmatched orders.

Further, trade volumes spike in times of stress, so they must be able to handle even larger volumes.

Massive amounts of computer technology are necessary to make such systems work reliably.

Transaction Costs

According to Kissell and Glantz, “Optimal Trading Strategies”, transaction costs on U.S. range from 87-134 basis points on average orders, 101-152 basis points on large orders (250,000+ shares), and 232-282 basis points during adverse price movements.

The most important costs factors are invisible, due to price changes and market impact.

	Fixed	Variable
Visible	Commissions	Taxes
	Fees	Spreads
Non-transparent		Delay cost
	n/a	Price appreciation
		Market impact
		Timing risk
		Opportunity cost

Trade slowly, and the price will drift from the target.

Trade rapidly, and the price will be impacted.

Modeling Transaction Costs

The implementation shortfall methodology breaks transaction costs into visible and invisible components.

$$\mathrm{TC}(\$) = \underbrace{\underbrace{\left(\sum_{j-1}^{n} x_j\right)(P_d - P_0)}_{\text{Delay cost}} + \underbrace{\sum_{j-1}^{n} x_j p_j - \sum_{j-1}^{n} x_j P_0}_{\text{Trading related}} + \underbrace{\left(X - \sum_{j-1}^{n} x_j\right)(P_n - P_d)}_{\text{Opportunity cost}}}_{\text{Non-transparent transaction costs}}.$$

Delay cost reflects price movement from decision to order placement.

Trading related costs deviations between realized and original prices.

Opportunity costs measure the lost profits from trades that could not get made.

Modeling Market Impact

The Almgren and Chriss model is based on random walks integrating permanent and temporary impack with price drift:

$$P_n = P_0 + \underbrace{\sum_{j=1}^{n} \Delta p_j}_{\text{Price appreciation}} + \underbrace{\sum_{j=1}^{n} \kappa(x_j) e^{-(n-j)c}}_{\text{Temporary market impact}} + \underbrace{\sum_{j=1}^{n} f(x_j)}_{\text{Permanent market impact}} + \underbrace{\sum_{j=1}^{n} \varepsilon_j}_{\text{Price volatility}} .$$

Temporary market impact decays exponentially with time.

Once you can model transaction costs, you can design trading strategies to optimize them.

The Penn-Lehman Automated Trading Project

M. Kearns and L. Ortiz, IEEE Intelligent Systems, 2003.

The Penn Exchange Simulator (PXS) merged client orders with real-world, real time data.

Dealing with market impact is particularly critical in high-frequency, high-volume trading.

PXS got the top 15 limit orders via the web every three seconds; simulated trades were integrated into the order book.

Backtesting Environments

Trading strategies requires proper *backtesting*, performance evaluation on historical data, before cutting them loose with real money.

Simulators that use price but not order data fail to factor in market impact, unless they use a fill or execution model.

Long histories are needed for statistical significance, but are often not available or irrelevant because of market changes (e.g. decimalization, ECNs)

Out-of-sample testing is needed for proper testing, yet signals have a finite lifetime before others discover them.

The Penn Competitions

To test effectiveness of PXS and various trading strategies, three formal competitions were held between automated clients.

Limited trading to one stock, Microsoft.

Limited positions to $\pm 100,000$ shares, then at about \$25 a share.

PPC 2003 divided the 14 entrant strategies into Blue and Red pools, to ensure enough liquidity, and ran for ten business days during business hours.

Points were awarded for daily profit/loss, consistency of P/L, daily position reversals (going both long and short), robustness to market variation, daily risk saturation (achieving large position), and daily position unwinding.
There were no explict transaction costs such as commissions or tax charges.

Strategies Employed

Several strategies (9 of 14) employed variants of Static Order Book Imbalance (SOBI) to anticipate price movements bases on volume/price imbalances between buy and sell order books.

Some used machine learning techniques, some technical indicators (MoneyFlow, OBCrossover, and OBBbreakout)

Some employed market-marking strategies seeking to profit from price volatility instead of overall movement. Like pairs trading, these use simultaneous buy / sell orders at below / above the current price. E.g. place the orders immediately in front of the nth order in the book.

Some strategies were simple (e.g. Contrarian)

Results

Table 1. 2003 Platinum Platter Competition clients.

Client	Description	Performance
CBR-SOBI	Case-based reasoning applied to the Static Order Book Imbalance strategy's parameters	First in the Blue pool; statistically significant profitability
MoneyFlow	A predictive strategy using money flow (price movement times volume traded) as a trend indicator	Second in the Blue pool
OBMM	A market-maker that positions orders in front of the *n*th orders on both books	Third in the Blue pool
CReaTiv	Capitalization on Real Time Volatility—SOBI modified by recent volatility	Fourth in the Blue pool
OBCrossover	Exponential Moving Average crossover strategy moderated by confirmation of order book quartile volume-weighted average prices	Tied for fifth in the Blue pool
OBBreakout	A breakout strategy applied to trend lines on the volume-weighted average prices of buy and sell books	Tied for fifth in the Blue pool
RaSTa	Resistance and Support Trading Agent—computes support and resistance levels on the basis of peaks in the order book volume	Seventh in the Blue pool
DAMM-STAT	A Mixture of a Dynamically Adjusted Market-Maker that calibrates by recent volatility and a trend-based predictive strategy	First in the Red pool; stellar position management
Contrarian	Sells on rising prices, buys on falling prices	Second in the Red pool
OBSigma	Trades on the basis of relative spreads in the buy and sell books, interpreting a small standard deviation as a sign of confidence	Third in the Red pool
OBVol	A simple predictive strategy using total volumes in buy and sell books	Fourth in the Red pool; highest Sharpe ratio and statistically significant profitability
RapidMM	A market-maker with rapid revision of quotes based on the current inside market	Fifth in the Red pool
CIA	Central Intelligent Agent—a predictive strategy applying boosting to order book snapshots	Sixth in the Red pool
SimpleTrend	A simple trend prediction strategy	Seventh in the Red pool; statistically significant negative earnings

The Winners

CBR-SOBI won the blue pool largely based on raw profitability. It sells when the volume-weighted price average of the buy-book is further from the the last price than that of the sell-book.

DAMM-STAT was barely profitable but won the red pool based on adherence to good trading practices.

OBVol performed well monitarily but lost points for failing to saturate allowed risk.

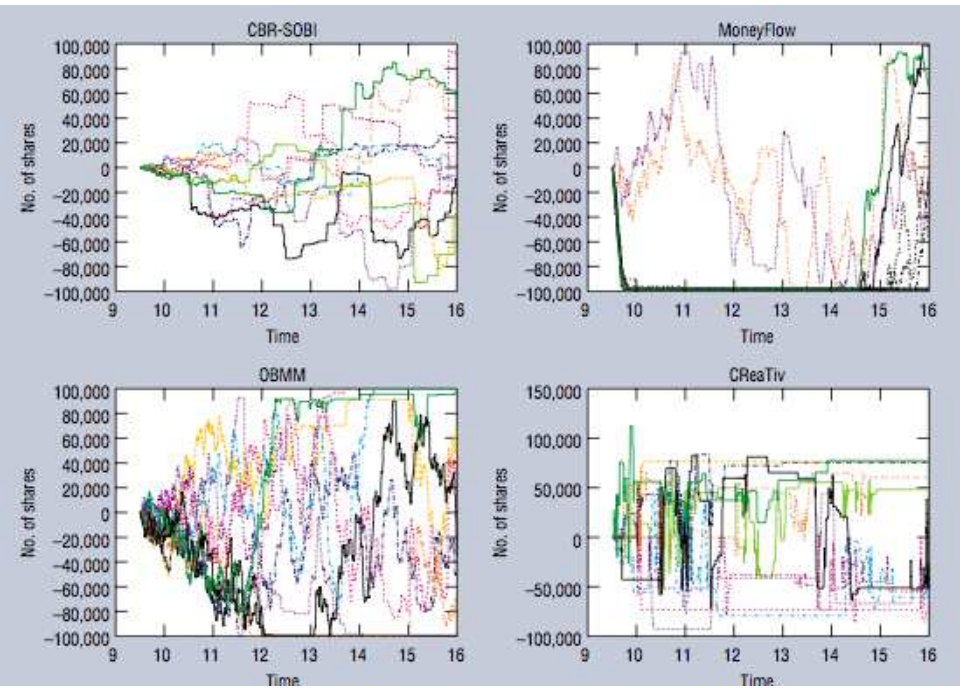
CBR-SOBI and OBVol had statistically significant Sharpe ratios.

Correlation between point totals and P/L was 0.41, so profit was important but not dominant.

The Scoreboard

Strategy	Pool	Rank	Total points	Points for: Daily profit & loss	Daily risk saturation	Daily position unwinding	Daily intraday position reversal	Consistency of P&L	Robustness to market variation	Avg. P&L ($)	95% confidence interval	10-day Sharpe ratio
CBR-SOBI	Blue	1	74	9	18	2	10	15	20	4,187	± 3,733	0.70
MoneyFlow	Blue	2	69	15	20	0	4	15	15	2,007	± 15,692	0.08
OBMM	Blue	3	46	8	20	0	8	0	10	258	± 7,909	0.02
CReaTiv	Blue	4	42	7	20	0	10	0	5	(2,410)	± 6,770	(0.22)
OBCrossover	Blue	5	33	6	6	0	6	0	15	3,242	± 4,220	0.45
OBBreakout	Blue	5	33	10	18	0	0	0	5	3,680	± 7,963	0.29
RaSTa	Blue	7	21	5	2	0	4	0	10	1,182	± 2,441	0.30
DAMM-STAT	Red	1	65	6	20	14	10	0	15	685	± 5,195	0.08
Contrarian	Red	2	55	6	20	2	12	0	15	2,022	± 3,658	0.34
OBSigma	Red	3	54	8	20	6	10	0	10	1,649	± 2,382	0.43
OBVol	Red	4	53	14	0	0	4	15	20	4,037	± 1,900	1.32
RapidMM	Red	5	50	10	20	0	10	0	10	3,649	± 9,121	0.25
CIA	Red	6	30	13	12	0	0	0	5	(1,451)	± 9,822	(0.09)
SimpleTrend	Red	7	27	3	20	2	2	0	0	(24,467)	± 17,974	(0.84)

Characteristics of Different Strategies



Momentum Trading Strategies

If you expect that current trends will continue, it pays to invest in the stock/fund which showed the best recent returns, a *momentum strategy*.

A study by Conrad and Kaul, Rev. Financial Studies, 1998 show that momentum and contrarian strategies are equally likely to be successful, unless conditioned on the return horizon.

Momentum is usually profitable in a 3 to 12 month horizon, while contrarian strategies are better long term.