High Frequency Trading

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1. Soft-dollar research

Customer, e.g., mutual fund

3. Wait for other orders

Broker Sales/Trader

2. Trading

$$$

6. Notify clients of execution

5. Exchange acknowledges order execution

4. Place order(s) on the exchange
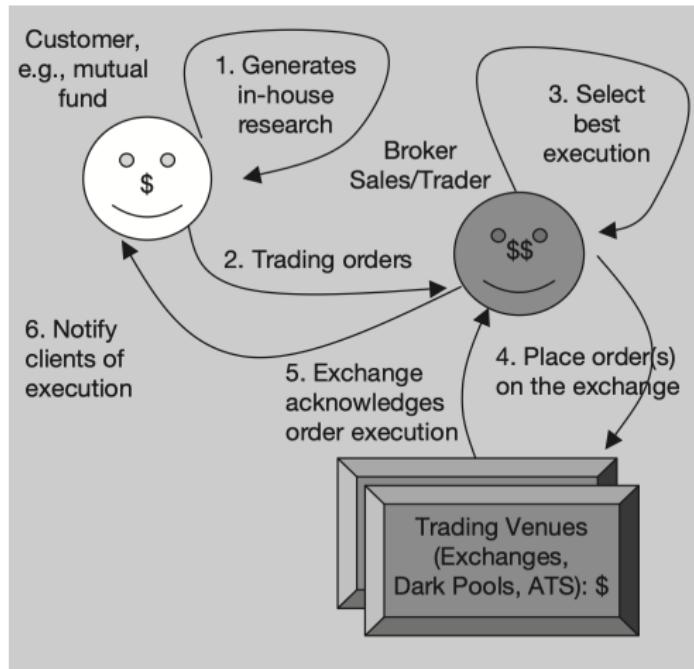
The Exchange

Overview of Past Market System

- Labor-intensive financial landscape
- High transaction costs, low turnover of securities
- Manual processing of orders (potential for error)
- Single, non-for-profit exchange in each asset class
- Traders relying on experience and intuition

Modern Investment Process

Overview of Modern Market System

- Anyone can set quotes and trade in the market
- Low transaction costs
- Automated trading, order routing, and settlement
- Alternative trading venues
- Quantitative money managers use mathematical tools for forecast prices of securities

Important Distinctions

Definition

Electronic Trading *is the ability to transmit orders electronically.*

- Fastest technology
- Co-location
- Speed and reliability
- Minimal (transaction) costs

Important Distinctions

Definition

Algorithmic Trading *is automated "best execution" process. Optimization of buy-and-sell decisions once these buy-and-sell decisions are made.*

- What exchanges/dark pools/markets?
- How to distribute order?
- When to execute order?
- How to execute order?

Important Distinctions

Definition

High-Frequency Trading *is a subset of algorithmic trading which employs algorithms for decision making, order initiation, generation, routing, or execution, for each individual transaction without human direction.*

- High-frequency data
- Automated portfolio selection
- High-volume trades
- High-speed execution / high turnover

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Trading Venues

Definition

Financial Markets *are venues for buying and selling securities.*

- Traditional exchanges have centralized limit order books (CLOBs) - "lit" market
- New exchanges - move money from brokers to investors
- Dark pools have hidden limit order books - protect information
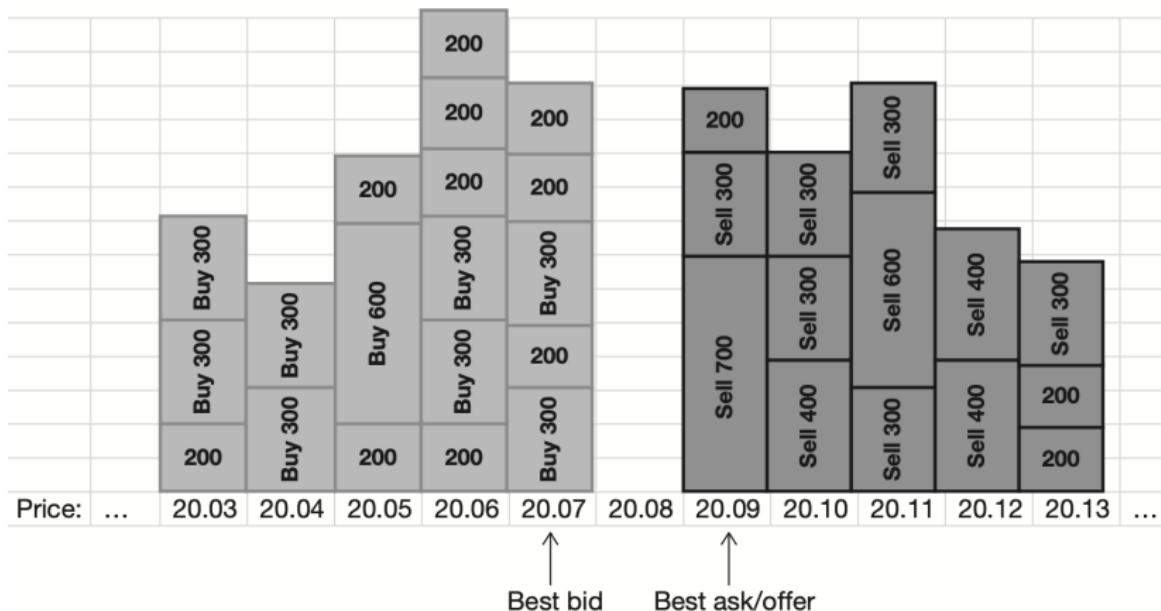
Limit Orders

## Definition

*A **limit order** is an order to buy or sell a stock with a restriction on the maximum price to be paid (with a buy limit) or the minimum price to be received (with a sell limit).*

- The **best bid** is the highest buy limit available
- The **best ask/offer** is the lowest market sell limit available
- No assurance of execution
- Can be placed during extended hours

Limit Orders

Liquidity

Definition

Liquidity is the cumulative trade size of all limit orders available at any given time on a specific trading venue.

- Higher number of limit orders - more liquidity
- Larger size of each order - more liquidity

Market Orders

Definition

A **market order** *is an order to buy or sell a stock at the market's best available price.*

- Market **buy orders** meet best ask/offer
- Market **sell orders** meet best bid
- Only placed during market hours for immediate execution

Stop Orders

Definition

*A **stop order** is an order to buy or sell a stock at the market price once the stock has traded at a specified price (the "stop price").*

- Sell order is used as a "stop-loss" signal to minimize losses or protect unrealized gains
- Buy order is used as a "buy" signal to prevent the stock from getting away from you
- Designed to limit risk
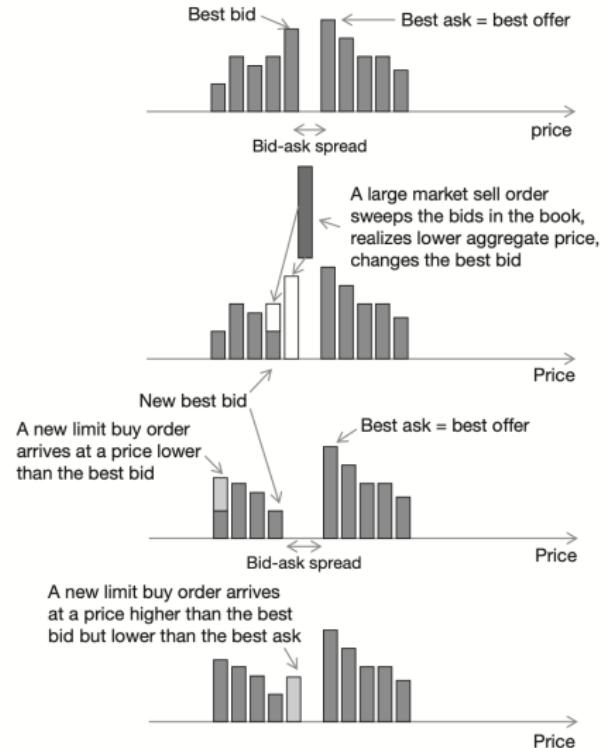
Limit Order Book

Definition

*A **limit order book** is a real-time record of all limit buy and sell orders in a market, organized by price levels.*
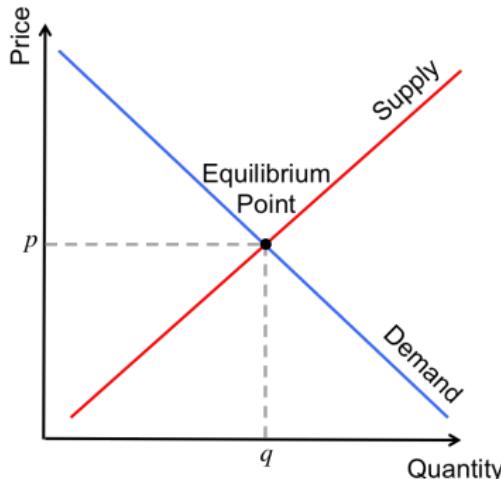
- Any new limit order is placed into a limit order queue corresponding to its price
- The aggregate size is reported as the best bid (sell) size
- FIFO matching process - "continuous double-sided auction"
- Pro-rata matching - fixed proportion of each limit order is matched
- Encourages larger limit orders

Limit Order Book Dynamics

Best bid

Best ask = best offer

price

Bid-ask spread

A large market sell order sweeps the bids in the book, realizes lower aggregate price, changes the best bid

Price

New best bid

A new limit buy order arrives at a price lower than the best bid

Best ask = best offer

Bid-ask spread

Price

A new limit buy order arrives at a price higher than the best bid but lower than the best ask

Price

Supply and Demand

- Many market buy orders "eat" the best ask orders, until the higher price limit orders become the new best offers - higher demand increases price!
- Many market sell orders "eat" the best bid orders, until the lower price limit orders become the new best bids - lower demand decreases price!

Bittrex ETH/BTC order book

- x-axis is the unit price of Ethereum in terms of Bitcoin
- y-axis is cumulative order depth in Bitcoin

Aggressive vs Passive Execution

- Passive order: low-priced buy order, high-priced sell order
- Aggressive order: near the market price
- Extremely aggressive orders that "cross the spread" behave as *market* orders - immediately matched with the best-priced limit order on the opposite side of the limit order book

Trading Complexity

- Market orders automatically cross the spread (and thus pay the cost)
- "Slippage" of price - largest cost in today's market
- Limit orders do not have price risk but have execution risk
- **Privacy:** Iceberg orders hide true size of order, Hidden orders are not displayed at all
- **Speed:** Market-on-close order, Match-midpoint orders cross half the spread (negotiate)
- **Time to market:** Fill-or-kill, Day, Extended Hours, Good-till-canceled
- Quantitative triggers (e.g. volatility) or order-slicing **(HFT)**

Regulation

- **National Best Bid and Offer** (NBBO): NBBO quote is aggregated and disseminated through Security Information Processors (SIP) using all exchanges - the smallest spread available
- SEC passed the **Regulation National Market System** (Reg NMS) in 2005
- Brokers are required to find and execute the NBBO or better for equities - Exchanges are required to route orders if this is not possible
- Access rule and Sub-penny rule
- Prevent broker incentivization and protect retail traders

Front-Running

- NBBO hard to enforce or check
- HFT firms are faster than SIP because of technology, infrastructure, and co-location etc.
- Anticipate NBBO before investors become aware - latency between calculation of the NBBO and its publishing
- Traders profited by as much as $21 billion by taking advantage of this latency (University of Michigan, 2013)
- Mint small but sure profit
- "Flash Boys: A Wall Street Revolt" by Micheal Lewis

Fragmentation in Equities

- 22% of equity volume in dark pools, 78% on exchanges (Pragma Securities, 2011)
- Dark pools exempt from NBBO
- **Normal Exchanges** compete to attract NBBO limit orders
- **Inverted Exchanges** compete to attract market orders and place proprietary NBBO limit orders
- **Rebates** are negative transaction costs - structure varies exchange to exchange
- Competition between exchanges; total volume captured, rebate and fee structures etc
- Fragmentation in other asset types (options, futures, forex, fixed income etc.)

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What is High-Frequency Data?

Definition

High-Frequency Data *("tick data") is a record of the live market activity.*

- The "last trade price" and the "last trade size" are defined by the most recently matched market order

Tick Data

Includes:

- **A timestamp**
- **A financial security identification code**
- **An indicator of what information it carries:**
    - Bid price
    - Ask price
    - Available bid size
    - Available ask size
    - Last trade price
    - Last trade size
- **Security-specific data**, such as implied volatility for options
- **The market value information**, such as the actual numerical value of the price, available volume, or size

Level 1 Tick Data

Timestamp	Last Traded Price	Best Bid Price	Best Ask Price	Trade Volume
2024-09-25 09:30:15.123	97.29	97.25	97.93	2000

- Lowest volume (single best bid/ask prices)
- Quick snapshot of current market conditions
- Used by retail traders for basic strategies

Level 2 Tick Data

T	Bid L1	Bid L2	Bid L3	Ask L1	Ask L2	Ask L3	Volume
T1	97.25	97.24	97.23	97.93	97.94	97.95	2000
T2	97.26	97.25	97.24	97.94	97.95	97.96	2200
T3	97.27	97.26	97.25	97.95	97.96	97.97	2400

- Higher volume (multiple bid/ask prices)
- Used for in-depth analysis of liquidity and order flow
- Used by HFT firms and professional traders

Level 3 Tick Data

T	Order ID	Bid/Ask	Price	Quantity	Trader ID
T1	1001	Bid	97.25	500	Trader X
T2	1002	Ask	97.93	300	Trader Y
T3	1003	Bid	97.24	200	Trader Z

- Highest volume (full order book)
- Granular data
- Used for advanced trading strategies
- Used by market making institutions

Properties of High-Frequency Data

Property	Description	Pros	Cons
Voluminous	Each day = 30 years of data.	Lots of information.	Difficult to handle manually.
Bid-Ask Bounce	Tick data has bid/ask prices and sizes.	Supply-demand information.	Hard to model spread/jumps.
Non-Normal	Tick returns are not normal OR lognormal.	Opportunity to explore new models.	Traditional pricing models fail.
Irregular Timing	Tick data arrive at uneven intervals.	Inter-arrival times may be informative.	Transformation to regular intervals.
No Trade Direction	Lacks info on whether a trade is buyer/seller initiated.	Difficult for bystanders to extract.	Trade direction is key for many models.
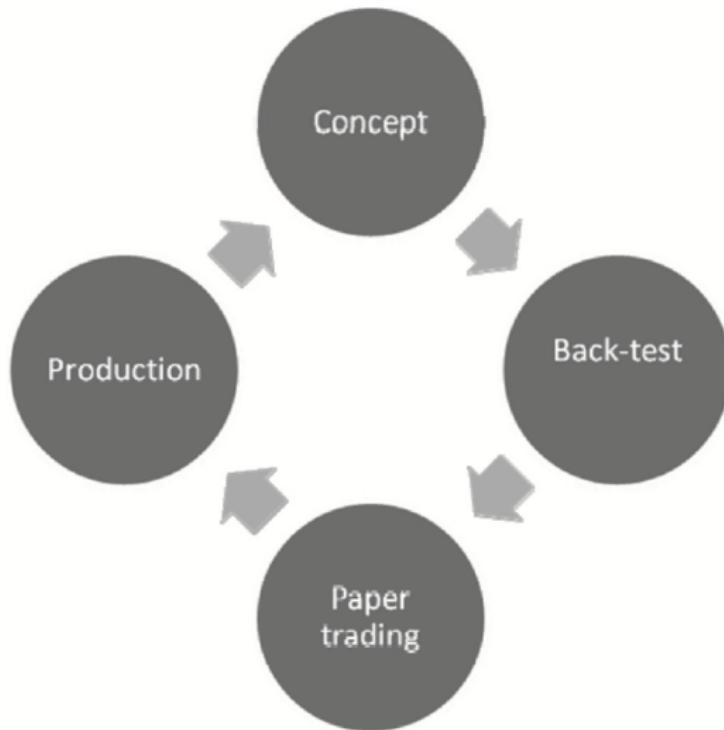
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Types of HFT Traders

- **Statistical Arbitrage Traders** - market orders for fast-dissolving price discrepancies, limit orders to capture misvaluations
- **Directional Traders** - estimate the direction of an impending market move (typically execute "aggressive" orders)
- **Liquidity Traders** - aim to profit from providing liquidity

Directional-Based Traders

- Determine (repetitive) events - economic news, market disruptions
- Identify portfolios that profit during time window of event
- Open portfolio ahead of / just after event, and fully liquidate shortly after

Automated Market Making

- Most modern exchanges have CLOBs - automated market-making technology is extremely portable
- Market maker's bids "hit" by market sell orders, asks/offers "lifted" by incoming market buy orders
- Market makers collect the spread as a compensation for providing limit orders (liquidity) to traders placing market orders (liquidity takers)
- Tightness of bid-ask spread reflects degree of competition among limit order–placing traders

HFT Arbitrage (Generally Legal)

- **Latency Arbitrage** - use high speeds to exploit where Law of One price fails
- **Spread Scalping** - repeatedly capture tiny profits from bid-ask spread
- **Rebate Capture** - profit from exchanges paying rebates for posting limit orders
- **Quote Matching** - track/mimic orders from institutional investors and ride the market impact (generally infeasible)
- **Machine Learning** - learn patterns from historical data

HFT Arbitrage (Generally Illegal)

- **Layering** - place limit orders away from market price - create illusion of market interest, then cancel the orders
- **Ignition** - trigger volatility with aggressive orders to cause sudden price movement - profit from overreaction
- **Pinging / Sniping / Sniffing** - "phish" for hidden liquidity - if small order gets filled instantly, there's more hiding there
- **Quote Stuffing** - submit and cancel thousands of orders per second - overload/clog market data feeds
- **Spoofing** - place large, visible orders without intent to trade (fake demand) and cancel after influencing price direction
- **Pump and Dump** - artificially inflate asset prices, sell at peak

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References

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