Market Microstructure and High-Frequency Trading (MMHFT)

Lecture 1: Introduction - Financial Markets and Market Microstructure

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Albert-Ludwigs-University of Freiburg

Summer Term 2016
Contributing
Times, Dates, Points

- Lectures (Prof. Dr. Michael Stein)
  - Wednesday, 14:00 - 16:00, HS 1034, KG I
  - Thursday, 16:00 - 18:00, HS 2004, KG II
- Exercise Session (M.Sc. Andreas Kammerlander)
  - Monday, 10:00 - 12:00, HS 1243, KG I
- Trading Seminar
  - December, exact date to be announced at the latest in second week
- Credit points
  - 8 ECTS, Exam 120 minutes
Persons

• Prof. Dr. Michael Stein
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  • https://www.empiwifo.uni-freiburg.de/personen-staff/prof.-dr.-michael-stein and
    www.steinpage.com
  • Speaking hours: Thursday, 11-12, please make appointments via
    secretary office (cornelia.hupfer@vwl.uni-freiburg.de)
  • Also to be found on LinkedIn

• M.Sc. Andreas Kammerlander (Exercise Session)
  • andreas.kammerlander@vwl.uni-freiburg.de
  • https://www.empiwifo.uni-freiburg.de/personen-staff/andreas-kammerlander
Outline (ordering subject to adjustments)

1. **Introduction: Financial Markets and Market Structure**
3. Statistical Building Blocks and Econometric Basics
4. Classical Spread Component Models
5. Limit Order Book Models
6. Price Discovery and Liquidity
7. Integrated Trading Simulation Seminar (at Börse Stuttgart, seminar and travelling costs are covered)
8. Current Developments
Literature

- More literature will be announced in-course.
Important notes

• Lecture 1 covers the general nature of how exchanges work and how trading is done in specific markets. The understanding of trading mechanisms is crucial when market microstructure models are considered. Lecture 1 builds heavily on Chapter 1 of de Jong and Rindi (2009), which provides a very good overview on the topic.

• Lecture 2 introduces and reviews important aspects of financial market equilibria and asset pricing. Following a brief overview regarding asset pricing models, we again base the overview heavily on de Jong and Rindi (2009) with the derivation of equilibria under different assumptions. This provides a very useful comparison to understand the theoretical baselines of the models.

• Lecture 3 summarizes several aspects of financial data and time series analysis, where the slides can be seen merely as a backup and starting point for later inquiries related to methodology used in the respective models. This is integrated in the Exercise Sessions as well.
Important notes

- The first 3 lectures are constructed to deliver pre-requisites for understanding later sections.
- There will be an example exam later on in the semester.
- All materials are delivered via Ilias or are available at the chair.
- The integrated seminar at Börse Stuttgart contains a simulation where students need to act as competitive market makers given a simulated order book. Seminar costs are covered by Börse Stuttgart and travelling costs are covered by the University.
Motivation

- Understand how markets/exchanges work and how trades are done
- Understand how market participants act
- Understand how prices are derived
- Structure of markets relevant
- Financial markets globally important
- Interaction of market participants crucial
- Many differing models on markets and trading
- Models to be tested empirically
- Econometrics accommodate theoretical models
Trading protocols

Execution Systems

- order-driven
- direct interactions of agent’s orders
- hybrid (most commonly used today)
- quote-driven
- Interaction facilitated by market intermediaries
Market structures

**Order-driven markets**

*Auction markets*

Order matching rules: order precedence rules and trade pricing rules

- *Call (or batch) markets*
- *Oral auction (open-outcry in floors or pits)*
- *Electronic auction*
- *Continuous market (limit order book)*

*Crossing networks*

Order matching rules: order precedence rules and derivative pricing rules

**Quote-driven markets**

- *Screen-based markets – dealer markets*
- *Continuous auction markets*
- *Brokered markets*

**Hybrid markets**

**Source:** De Jong and Rindi (2009)
Order-driven markets

- Investors’ buy and sell orders are matched directly, no intermediaries except brokers.
- No market makers, liquidity resulting from steady and constant flow of orders from market participants.
- Brokers transmit orders but do not maintain own positions.
- Rules for order matching are imposed, can be auction or crossing network markets.
Auction markets

- Dominant type in leading markets
- Call/batch auction characterized by simultaneous order submissions
- Call/batch auction can take place at opening, during trading day and at closing time
- Continuous auction characterized by possibility to submit at any time during trading phase
- Two types of orders in auction markets: market orders and limit orders
Market orders vs limit orders

- **Market:**
  - Executed at market price, only buy/sell and quantity is specified
  - Executed with high probability, as long as demand and supply are present
  - Favorable for traders needing immediate transactions
  - Price at execution is not limited and therefore unknown

- **Limit:**
  - Executed only when limit price is met or below for buy orders (met or above for sell orders)
  - Specification of buy/sell, quantity and limit price
  - Guaranteed price, but execution depends on availability of orders on other side (either limit order of opposite direction and limit price within, or market order in opposite direction)
  - Favorable for price-sensitive traders not in urgent need of execution
  - Not executed orders placed in limit order book (LOB) until execution or cancellation
Communication in call auctions

*Oral auction (open-outcry auction)*
- Rules of pre-trade transparency
- Order precedence rules (time and price priority, public precedence)
- Trade pricing rules governed by the best quoted prices

*Electronic call auction, continuous auction and crossing networks*
- *Order precedence rules*
  - Time priority
  - Price priority
  - Visibility and size restriction
- *Trade pricing rules*
  - Uniform price (electronic call)
  - Discriminatory price (continuous call)
  - Derivative price (crossing network)

**Source:** De Jong and Rindi (2009)
Oral call auction

- Market participants physically present at trading floor
- Crying out of buy and sell offers directly
- Prices and executions open, public and transparent
- Price priority: highest bid and lowest ask preferred
- For given prices, those who bid first are preferred: time priority
  \[\text{Price priority dominant over time priority}\]
- Additional rules possible
- Equilibrium price determined either by auctioneer or by brokers
Electronic auctions

- Electronic call auctions characterized by pre-determined time period, all submitted orders are traded at the same time at the same equilibrium price given limits
  >>> uniform pricing rule

- Electronic continuous auction characterized by trading sequentially over time, with market participants observing order flow, mainly automated trading

- Electronic continuous auctions most frequent for stocks and derivatives and common form of order-driven markets, structured as open limit order book (OLOB)

- Accumulation of limit orders and traded as described above

- "at best" execution means that traded at best price in LOB for orders fulfilling limit

- Precedence rules applied, price > time > others
Crossing networks

- No price priority, only time priority
- Call system that crosses prices several times per day
- Primary stock markets are indicative for prices that are determined
- Finding of prices through derivative pricing rules
- No equilibrium price, prices found through rules
- Differing rules and differing assets traded lead to different actual crossing networks
Quote-driven market

- Market-makers/dealers specify prices
- Monopoly of market-makers, they are liquidity providers
- Market-makers act on own account, but can act as brokers as well
- Trading done on prices and volumes as quoted by market-makers
- Low transparency, market-makers make price based on supply, demand and their risk of involuntarily having large inventory
- Negotiation possible
Transparency

- Markets and types of trading lead to differing levels of transparency
- Differentiation between pre-trade and post-trade transparency
- Strategies affected by structure of transparency and information

Source: De Jong and Rindi (2009)
# Global market structures

<table>
<thead>
<tr>
<th>Stock exchange</th>
<th>Structure</th>
<th>Call market, Market on close (MoC), Cross (Cr)</th>
<th>Pre-trade transparency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mkt opening Mkt closing Intraday (trading halts)</td>
<td>Limit order book Members Investors Identities of liquidity providers Members Investors Hidden orders Anonymity</td>
</tr>
<tr>
<td>Borsa Italiana (Bit)</td>
<td>AOD</td>
<td>yes yes yes</td>
<td>Full Book 5 Best B/A no no yes yes</td>
</tr>
<tr>
<td>Euro next</td>
<td>AOD</td>
<td>yes yes yes</td>
<td>Full Book 5 Best B/A no no yes yes</td>
</tr>
<tr>
<td>Frankfurt Stock Exchange (XETRA and Floor)</td>
<td>AOD/AOD</td>
<td>yes yes yes</td>
<td>Full Book Full Book no no yes yes</td>
</tr>
<tr>
<td>London Stock Exchange (SEt)</td>
<td>AOD</td>
<td>yes yes yes</td>
<td>Full Book Full Book no no yes yes</td>
</tr>
<tr>
<td>London Stock Exchange (SEAQ-I)</td>
<td>SBQD</td>
<td>no yes (Cr) yes (2 Cr)</td>
<td>Best B/A Best B/A yes no no no no</td>
</tr>
<tr>
<td>NASDAQ (Integrated Single Book)</td>
<td>AOD</td>
<td>yes (Cr) yes (Cr) yes</td>
<td>Full Book 5 Best B/A no no yes yes</td>
</tr>
<tr>
<td>NYSE Hybrid Market (SuperDot)</td>
<td>AOD</td>
<td>yes yes yes</td>
<td>Full Book Full Book no no yes yes</td>
</tr>
<tr>
<td>NYSE (Floor)</td>
<td>FBQD</td>
<td>yes (MoC) yes (MoC) yes</td>
<td>Full Book Full Book yes no yes yes yes</td>
</tr>
<tr>
<td>Swiss Exchange (SWX)</td>
<td>AOD</td>
<td>yes yes yes</td>
<td>Full Book Best B/A no no yes yes yes</td>
</tr>
<tr>
<td>Tokyo Stock Exchange (STP)</td>
<td>AOD</td>
<td>yes yes yes</td>
<td>5 Best B/A 5 Best B/A no no no no yes yes</td>
</tr>
<tr>
<td>Toronto Stock Exchange (TOREX)</td>
<td>AOD/AOD</td>
<td>yes no yes</td>
<td>Full Book Full Book no no yes yes</td>
</tr>
</tbody>
</table>

*Note: AOD = Automated order-driven; AQD = Automated quote-driven; SBQD = Screen-based quote-driven; FBQD = Floor-based quote-driven; B/A = Bid/ask.*

**Source:** De Jong and Rindi (2009)
Orders and order properties

Price instructions
Limit order (marketable if at or beyond the best bid offer (BBO))
Market order
Order at the auction price

Maturity instructions
Day order (valid for the day)
Good-till-cancel (valid until cancelled)
Market-on-open and market-on-close (valid at the opening or closing auction)

Quantity instructions
Fill or kill = All-or-nothing (valid if completely filled at submission)
Minimum-or-none (valid if filled for a minimum specified quantity)
Fill & Kill (valid only for the quantity filled at submission)
Hidden (valid for a disclosed and an undisclosed quantity)

Source: De Jong and Rindi (2009)
Orders and order properties

Table 1.4. Order classification
This table reports different types of orders classified from the most to the least aggressive; examples refer to the state of the limit order book shown in Table 1.8

Aggressive orders
Type 1a. Market order that can walk up the book for a size greater than the cumulative quantity at the best price on the opposite side of the order book, e.g. Market buy 20.
Type 1b. Limit orders improving on the best price on the opposite side of the order book with associated size greater than the cumulative quantity at the best price on the opposite side of the order book, e.g. Limit buy 70 @ 51.00.
Type 2. Market order for a size equal to the cumulative quantity at the best price on the opposite side of the order book, e.g. Market buy 5.
Type 3a. Market order that cannot walk up the book for a size greater than the cumulative quantity at the best price on the opposite side of the order book, e.g. Market buy 20.
Type 3b. Limit order with price improving on the best price on the opposite side of the order book and for a size smaller than the cumulative quantity at the best price on the opposite side of the order book or market order for a size smaller than the cumulative quantity at the best price on the opposite side of the order book, e.g. Limit buy 4 @ 50.50 or Market buy 4.

Patient orders
Type 4a. Limit orders with price strictly inside the BBO, better than best price on its own side, but worse than the best price on the opposite side of the order book, e.g. Limit buy 10 @ 49.50.
Type 4b. Limit orders with price equal to the best price on its own side. The order stays on the BBO: best bid if it is a buy order, best offer if it is a sell order, e.g. Limit buy 10 @ 49.00.
Type 4c. Limit orders with price worse than the best price of its own side of the order book; if it is a buy (sell) order, the price is below (above) the best bid (ask), e.g. Limit buy 20 @ 48.50.

Source: De Jong and Rindi (2009)
Example: Batch opening and closing auctions

- Opening auctions with pre-opening period
- Traders submit their orders
- Equilibrium price determined, four crucial rules apply:
  1. maximize trading volume
  2. minimize trading imbalances
  3. highest (lowest) price as equilibrium call price when prices based on 1) and 2) exhibit surplus buy (sell) volume
  4. reference price used when equal buy and sell imbalances are present, but only if between limits
Example: Batch opening and closing auctions

This table shows a list of proposals submitted to the pre-auction phase

<table>
<thead>
<tr>
<th>Time</th>
<th>Trader</th>
<th>Orders</th>
<th>Size</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.01</td>
<td>Alan</td>
<td>Buy</td>
<td>20</td>
<td>48.00</td>
</tr>
<tr>
<td>8.02</td>
<td>Fred</td>
<td>Sell</td>
<td>20</td>
<td>47.50</td>
</tr>
<tr>
<td>8.04</td>
<td>Art</td>
<td>Buy</td>
<td>30</td>
<td>47.50</td>
</tr>
<tr>
<td>8.06</td>
<td>Tom</td>
<td>Sell</td>
<td>40</td>
<td>51.00</td>
</tr>
<tr>
<td>8.09</td>
<td>Mike</td>
<td>Buy</td>
<td>40</td>
<td>46.00</td>
</tr>
<tr>
<td>8.15</td>
<td>Lucy</td>
<td>Sell</td>
<td>30</td>
<td>51.50</td>
</tr>
<tr>
<td>8.30</td>
<td>James</td>
<td>Buy</td>
<td>15</td>
<td>49.00</td>
</tr>
<tr>
<td>8.34</td>
<td>Guy</td>
<td>Sell</td>
<td>20</td>
<td>49.50</td>
</tr>
<tr>
<td>8.37</td>
<td>Larry</td>
<td>Buy</td>
<td>40</td>
<td>51.00</td>
</tr>
<tr>
<td>8.38</td>
<td>Pete</td>
<td>Sell</td>
<td>25</td>
<td>48.50</td>
</tr>
<tr>
<td>8.40</td>
<td>Phil</td>
<td>Sell</td>
<td>10</td>
<td>50.00</td>
</tr>
<tr>
<td>8.42</td>
<td>Nick</td>
<td>Sell</td>
<td>10</td>
<td>50.00</td>
</tr>
<tr>
<td>8.43</td>
<td>Rob</td>
<td>Buy</td>
<td>30</td>
<td>Market</td>
</tr>
<tr>
<td>8.44</td>
<td>Gene</td>
<td>Sell</td>
<td>15</td>
<td>50.00</td>
</tr>
<tr>
<td>8.45</td>
<td>Andrew</td>
<td>Buy</td>
<td>20</td>
<td>48.50</td>
</tr>
<tr>
<td>8.50</td>
<td>Luke</td>
<td>Sell</td>
<td>40</td>
<td>Market</td>
</tr>
<tr>
<td>8.55</td>
<td>Frank</td>
<td>Buy</td>
<td>20</td>
<td>50.50</td>
</tr>
<tr>
<td>8.56</td>
<td>Chris</td>
<td>Buy</td>
<td>20</td>
<td>50.00</td>
</tr>
<tr>
<td>8.57</td>
<td>Tito</td>
<td>Sell</td>
<td>15</td>
<td>50.50</td>
</tr>
<tr>
<td>8.58</td>
<td>Ingrid</td>
<td>Buy</td>
<td>40</td>
<td>50.00</td>
</tr>
<tr>
<td>8.59</td>
<td>Ale</td>
<td>Sell</td>
<td>15</td>
<td>49.00</td>
</tr>
</tbody>
</table>

Source: De Jong and Rindi (2009)
Example: Batch opening and closing auctions

This table shows the order book, where orders have been organized according to the price and time priority rules.

<table>
<thead>
<tr>
<th>Buyers</th>
<th>Order price</th>
<th>Sellers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seller</td>
<td>Size</td>
<td>Price</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rob</td>
<td>30</td>
<td>Market buy</td>
</tr>
<tr>
<td>Larry</td>
<td>40</td>
<td>51.00</td>
</tr>
<tr>
<td>Frank</td>
<td>20</td>
<td>50.50</td>
</tr>
<tr>
<td>Chris</td>
<td>20</td>
<td>50.00</td>
</tr>
<tr>
<td>Ingrid</td>
<td>40</td>
<td>50.00</td>
</tr>
<tr>
<td></td>
<td>50.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>49.50</td>
<td></td>
</tr>
<tr>
<td>James</td>
<td>15</td>
<td>49.00</td>
</tr>
<tr>
<td>Andrew</td>
<td>20</td>
<td>48.50</td>
</tr>
<tr>
<td>Alan</td>
<td>20</td>
<td>48.00</td>
</tr>
<tr>
<td>Art</td>
<td>30</td>
<td>47.50</td>
</tr>
<tr>
<td>Mike</td>
<td>40</td>
<td>Market sell</td>
</tr>
</tbody>
</table>

Source: De Jong and Rindi (2009)
Example: Batch opening and closing auctions

This table shows how the equilibrium price is selected in a call market.

<table>
<thead>
<tr>
<th>Price</th>
<th>Aggregate demand schedule</th>
<th>Aggregate supply schedule</th>
<th>Trading volume</th>
<th>Excess demand order imbalance</th>
<th>Market pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>51.50</td>
<td>30</td>
<td>240</td>
<td>30</td>
<td>-210</td>
<td>Sell</td>
</tr>
<tr>
<td>51.00</td>
<td>70</td>
<td>210</td>
<td>70</td>
<td>-140</td>
<td>Sell</td>
</tr>
<tr>
<td>50.50</td>
<td>90</td>
<td>170</td>
<td>90</td>
<td>-80</td>
<td>Sell</td>
</tr>
<tr>
<td>50.00</td>
<td>150</td>
<td>155</td>
<td>150</td>
<td>-5</td>
<td>Sell</td>
</tr>
<tr>
<td>49.50</td>
<td>150</td>
<td>120</td>
<td>120</td>
<td>30</td>
<td>Buy</td>
</tr>
<tr>
<td>49.00</td>
<td>165</td>
<td>100</td>
<td>100</td>
<td>65</td>
<td>Buy</td>
</tr>
<tr>
<td>48.50</td>
<td>185</td>
<td>85</td>
<td>85</td>
<td>100</td>
<td>Buy</td>
</tr>
<tr>
<td>48.00</td>
<td>205</td>
<td>60</td>
<td>60</td>
<td>145</td>
<td>Buy</td>
</tr>
<tr>
<td>47.50</td>
<td>235</td>
<td>60</td>
<td>60</td>
<td>175</td>
<td>Buy</td>
</tr>
<tr>
<td>46.00</td>
<td>275</td>
<td>40</td>
<td>40</td>
<td>235</td>
<td>Buy</td>
</tr>
</tbody>
</table>

Source: De Jong and Rindi (2009)
References

Mandatory: F. de Jong and B. Rindi
*The Microstructure of Financial Markets*. Chapter 1

The references in the de Jong and Rindi chapter contain many interesting articles for further reading!