Empirical Game-Theoretic Analysis of Algorithmic Trading Scenarios

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Modeling Algorithmic Trading

• Research agenda
  • Implications on market performance
  • Separate distinct algo roles & tactics
  • Evaluating market and regulation designs

• Approach: Agent-based simulation
  – Comprehensive modeling of financial market ecosystem
  – Capturing heterogeneity, microstructure, fine-grained information flows
  – Combine with game-theoretic analysis

Example studies:
• Latency arbitrage and frequent call markets
• Strategic market choice
• Market making
• Strategic shading
• Market manipulation

This talk:
• Spoofing
• Trend following and market stability
Levels of Agent (ARB-BOT) Behavior

1. Passive search for arbitrage opportunities
2. Attempts to amplify arb opps through purposeful instigation of market movements (e.g., spoofing)
3. Attempts to create new arb opps
   • new financial instruments
   • deliberate fragmenting
4. Malicious subversion of markets
Level 2: Market Manipulation

• SEC Definition: Intentional conduct designed to deceive investors by controlling or artificially affecting the market for a security

• Spoofing
  • Dodd-Frank defn: bidding or offering with the intent to cancel the bid or offer before execution
  • Widely known strategies, several recent prosecutions

• Recent work: Agent-Based Model of Spoofing
  • Wang & W., AAMAS-17
  • Key idea: Rational investors learn from market prices under normal conditions, vulnerable to spoofing
Spoofing refers to the practice of submitting large spurious orders to buy or sell some security to mislead other traders’ beliefs.
An example of Mr Coscia's trading (00:00:00.000 to 00:00:00.609)

- True buy order
- True sell order
- Spoofing buy order
- Spoofing sell order

Source: Financial Conduct Authority, Animated Example of Mr Coscia’s Trading
Spoofing Study

Motivating Questions

• Can we model a market where spoofing effectively manipulates rational traders’ beliefs about prices?

• What is the impact of spoofing on market performance and trading behavior? Can we quantify the effect of spoofing?
Estimating an Empirical Game
Agent Strategic Choices - EGTA (HBL, ZI)

When spoofing is absent, investors generally have incentives to make bidding decisions based on order book information.
HBL Improves Price Discovery - EGTA (HBL, ZI) vs EGTA (ZI)

(a) $N = 28$

(b) $N = 65$
HBL Improves Market Surplus - EGTA (HBL, ZI) vs EGTA (ZI)

(a) \( N = 28 \)

(b) \( N = 65 \)
A Spoofable Market with HBL Traders

Amplified (diminished) spoofing effect in markets with more HBL (Z1).
In a market with spoofing, ZI benefits from HBL’s spoofed beliefs.
When re-equilibrating games with spoofing, HBL often remains in mixed equilibria but with smaller proportions.
The presence of spoofing generally decreases market surplus.
Spoofing: Ongoing Research Questions

1. What are some of the general characteristics of market environments subject to spoofing?
2. Are there more robust ways for exchanges to disclose order book information?
   • Yes: *cloaking* mechanisms [Wang, Vorobeychik, W., IJCAI-18]
3. Are there strategies by which traders can exploit order book information but in less vulnerable ways?
   • Yes: *price blocking* or *offset* strategies [Wang, Hoang, W., ICML-19 workshop]
4. Based on a model of this kind, can we design effective spoofing detection methods?
EGTA Investigation of Financial Market Stability

• Under what conditions might a market shock be amplified?
• Trend-following agents
  • A simple “technical” trading strategy
  • Can be profitable given market frictions
  • Effect on market stability and performance

Erik Brinkman
Effect of Price Shock in a Model where Agents Observe Current Fundamental

Shock: exogenous insertion of large sell order

Market stabilizes quickly, as agent beliefs unaffected by prices
Effect of Shock with Noisy Observation of Fundamental

Agent beliefs influenced by prices, so shock has more persistent effect.
Market Frictions Contribute to Mispricing

Fundamental Mispricing

Suggests long trends signal profit opportunities
High Frequency Trend Follower

1. Continually looks for monotonic trends in transaction prices (fundamental shift)
2. Take best price in direction of trend, and resubmit for a more extreme price
3. Withdraw if un-transacted for a long period of time

TF strategy present in equilibrium, given model with noisy observations
Shock with Trend Followers

Price - μ

Price - Without TFs

Fundamental

Price - With TFs

Time

[Graph showing price fluctuations over time with and without trend followers.]
TFs Reduce Mispricing during Trends

![Graph showing the reduction of fundamental mispricing with TFs during trends. The graph plots trend length against fundamental mispricing. Without TFs, mispricing increases rapidly with trend length. With TFs, mispricing is significantly lower, maintaining a more stable and lower level.]
TFs Crowd Out Use of Transaction Price Information

<table>
<thead>
<tr>
<th></th>
<th>Fraction using transaction information</th>
</tr>
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<tbody>
<tr>
<td>Without TFs</td>
<td>100%</td>
</tr>
<tr>
<td>Without TFs</td>
<td>54%</td>
</tr>
<tr>
<td>With TFs</td>
<td>23%</td>
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</table>
Trend Following Exacerbates Shock Impact

Graph showing the impact of trend following on shock magnitude. The graph compares 'With TFs' and 'Without TFs' scenarios, with the 'With TFs' line showing a greater increase in shock magnitude compared to the 'Without TFs' line.

- **Max Difference**: The difference in shock magnitude between 'With TFs' and 'Without TFs' is significant.
- **Num Shock Orders**: The x-axis represents the number of shock orders, ranging from 0 to 100.

The graph indicates that trend following significantly increases the shock impact compared to not using trend following.
Trend Following Helps Recovery

RMSD

Shock Magnitude

Without TFs

With TFs
TFs Reduce Market Efficiency

<table>
<thead>
<tr>
<th></th>
<th>Without TFs</th>
<th>With TFs</th>
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<tbody>
<tr>
<td>Efficiency</td>
<td>50.7%</td>
<td>40.6%</td>
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**Why?**
- Crowding out use of price information
- Increasing adverse selection
Conclusions: Trend Followers & Market Stability

• TF can be rational given standard market frictions
  • Imperfect fundamental information
  • Delayed market access

• TF affect on market performance
  • Less price-awareness
  • More adverse selection
  • Reduced efficiency

• TF affect on shock response
  • Amplified magnitude, shorter duration
  • Representative of flash crashes
EGTA & Algorithmic Trading: Conclusions

Closing Thoughts
• Algorithmic trading at the leading edge for application of autonomous agents
  • Is algorithmic manipulation the next frontier?
  • Is stability at risk?
  • Can AI be part of the solution?
• Computational strategic reasoning a useful tool for understanding financial settings, design for market quality and stability

Our other AI/Finance Study Areas
• (more on algorithmic trading)
  • Financial credit networks
    • Strategic payment routing
    • Intermediation
    • Network formation
• Bank leverage regulation