Learning Algorithms and Market Manipulation

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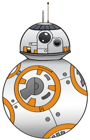
Rough evolution of trading

- Open outcry to electronic trading
- Rise in **computing power** (and internet)
  - Electronic trading
  - Algorithmic trading
- More data and more computing power
  - **Alternative data** sets
- **Learning algorithms**
  - Versatile and adaptive data-driven trading algorithms

Artificial intelligence learning algorithms and electronic trading

- Benefits: one expects
  - Improve price efficiency
  - Lower costs of trading (e.g., tighter spreads)
  - Decisions driven by data (no emotions)
  - Detect risks and exposures

- Risks and **unintended** behaviour
  - **manipulate** electronic order book
  - **coordinate** with other algorithms to manipulate electronic book
  - **signal** to enhance coordination
  - **collude** to widen the spreads (away from competitive spread)



What is a learning algorithm?

A learning algorithm consists of

- An **objective**, e.g., maximise profits, minimise costs.
- A **set of actions**, e.g., buy, sell, do nothing, make liquidity
- **Rules** to decide how to choose actions
- **Rules** to update **rules** with
  - performance of current and past actions
  - new data
- How to exploit or explore actions
  - **Exploit**: stick to actions that deliver good historical performance
  - **Explore**: try new or seldom used strategies

Right or wrong?

The learning algorithm is not endowed with a **moral compass**

Learning to learn

- How does one train an algorithm?
  - Offline with historical data
  - Online as market evolves
  - Both: offline and online
- What key aspects affect the performance of the learnt strategies?
  - One directly controls
    - Information/features fed to the algorithm
    - Exploitation and exploration
    - Initial conditions, i.e., algorithm needs to start learning from somewhere
  - One cannot (directly) control
    - Competition with other learning algorithms
    - Competition with traditional participants
    - Stability of the environment

Manipulation, collusion, and signalling in electronic markets

- **Manipulation**: algorithms learn
  - how predictive signals work and will learn how manipulate these signals to their advantage
  - how other algorithms react to actions and will learn how to entice other market participants to react to certain actions
- **Collusion**: algorithms learn
  - to coordinate actions that achieve **supracompetitive outcomes**
  - to sustain outcomes with a **reward-punishment mechanism**
- **Signaling**: algorithms learn
  - to communicate relevant information to obtain **supracompetitive outcomes**

How likely is manipulation and collusion in electronic markets?

The following have a significant effect on the chances of a manipulative/collusive outcome

- **Data** used by the algorithm
  - Offline with historical data
  - Online as market evolves
  - Both: offline and online
- **Exploration** and **exploitation** used by the algorithm
- Optimise choice of initial conditions in **backtesting**
- **Algorithms** used by competitors
- Number of **competitors**

Research output: algorithmic collusion and manipulation

- Learning algorithms often learn to quote a wider (supracompetitive) spread. paper
- Learning algorithms can learn to collude. paper
- Learning algorithms can learn to spoof/manipulate the book. paper
- Market makers signal themselves to each other.

Spreads in LOBs: Collusive/supracompetitive

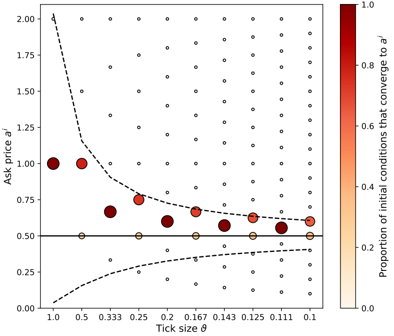
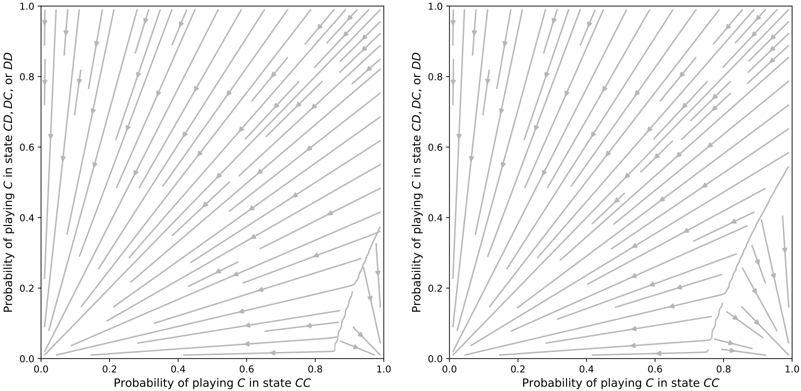


Figure: Proportion of initial conditions that converges to a certain action as a function of tick size. The horizontal black line is the Bertrand–Nash equilibrium offer. The offers between the bounds (dashed lines) are the elements of the set of symmetric pure strategy Nash equilibria from the stage game with a discrete action space. The circles indicate the price grid, and the size and colour represent the proportion of initial conditions converging to the equilibrium offer.

Folk Theorem: learn to collude



(a) Patient

(b) Very patient

Figure: Basins of attraction to collusive equilibrium (bottom right) and competitive equilibrium (bottom left).

Quote-based manipulation and spoofing in electronic books

- Algorithms will **learn dynamics of signals**, e.g., demand and supply pressure
- Algorithms will **manipulate and spoof** buy and sell pressure in book
  - Entice other market participants to act on rigged signals
- Derive **conditions** for limit orders books where algorithms will learn to manipulate buy and sell pressure signals
  - Nasdaq's LOB is conducive to quote-based manipulation and spoofing

Signalling

- Market makers use excessively large limit orders to **signal** themselves.
- **Signaling**: the book is not anonymous.
- Market makers almost never trade with each other when signalling.
  - In ETFs, $< 1\%$ of trades initiated by a market maker is with another market maker.
  - In shares, $\approx 50\%$ of trades initiated by a market maker is with another market maker.
- Market makers **snipe benign retail flow**.

Thank you!