

Outcomes of multiagent learning dynamics

AIM Pitch

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Setting

- Companies outsource sequential-decision making to algorithms.
- They learn and optimize in the presence of other learning algorithms.
- Captured in the framework of Markov games.
- The different equilibria of this joint learning process, may lead to drastically different outcomes for society.
- There are results proving convergence of algorithms to an equilibrium
- There are results proving convergence to 'joint optimal outcome'

But what if the objectives of the firms aren't aligned with those of society?

Example from Assad et al. 2024 (JPE)

Abstract

Economic theory provides ambiguous and conflicting predictions about the association between algorithmic pricing and competition. In this paper we provide the first empirical analysis of this relationship. We study Germany's retail gasoline market where algorithmic-pricing software became widely available by mid-2017, and for which we have access to comprehensive, high-frequency price data. Because adoption dates are unknown, we identify gas stations that adopt algorithmic-pricing software by testing for structural breaks in markers associated with algorithmic pricing. We find a large number of station-level structural breaks around the suspected time of large-scale adoption. Using this information we investigate the impact of adoption on outcomes linked to competition. Because station-level adoption is endogenous, we use brand headquarter-level adoption decisions as instruments. Our IV results show that adoption increases margins by 9%, but only in non-monopoly markets. Restricting attention to duopoly markets, we find that market-level margins do not change when only one of the two stations adopts, but increase by 28% in markets where both do. These results suggest that AI adoption has a significant effect on competition.

This is one of a number of articles providing evidence of such phenomena.

Relevant Contexts

- pricing (Cournot)
- quantity (Bertrand)
- inventory management
- recommender systems
- trading (e.g. energy markets)
- financial markets
- auctions
- platform design
- common resource management

The preferred outcome for society is not always competition, but could also be cooperation among firms, for example, to preserve a common resource.

Goal

Societal

Inform policymakers and regulators by answering:

- How do algorithms learn undesirable outcomes? (What should we forbid?)
- How can we detect such algorithms? (How can we detect transgressions?)

Beneficiaries: AFM, ACM, CBS. (I am already in contact with all three.)

Mathematical

- Develop methods for quantifying the probability with which undesirable outcomes are learned.
- Identify algorithmic mechanisms leading to undesirable outcomes.
- Design statistical tests for detecting the use of such mechanisms.

Envisioned approach

Idealized process + Noise

- Proofs for convergent algorithms rely on showing that an idealized process is approximated arbitrarily well in the limit of some algorithmic parameter.
- First: understand probability of different outcomes in the idealized process.
- Second: characterize the noise due to true learning dynamics.
- Third: study how noise changes probability.

Given the non-stationarity inherent in the types of contexts (e.g. changes in cost of raw materials), algorithms used in practice, will likely not reduce exploration indefinitely.

(Some examples of) Required expertise

- reinforcement learning/stochastic optimization/approximate dynamic programming
- deep learning theory
- stochastic approximation
- dynamical systems theory
- basin of attraction analysis
- game theory
- statistics
- stochastic stability
- multiagent learning
- Bayesian learning

Preliminary Results

Decentralized Q-learning

- RL algorithm
- convergent in weakly acyclic games
- idealized process: Best-response strategy adjustment process
- method for quantifying probability of outcomes under BRSAP
- to-do: analysing effect of noise

Interested?

- Contact: j.m.meylahn@utwente.nl
- Would be open for a number of funding opportunities:
 - ▶ Open Competition M-2
 - ▶ ELSA Lab from AINed (together with Economists and Legal Scholars)
 - ▶ Funding together with AFM/ACM/CBS?
 - ▶ Any other ideas you might have.