Algorithms and competition

Roundtable discussion

David Jevons
Partner

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oxera
compelling economics

Where are algorithms used?

Underlying economic problems

Pricing	General insurance	▪ compensating for risks, reducing cross-subsidisation
	Amazon Marketplace	▪ showing the best offer in the BuyBox
	Airlines	▪ managing perishable goods
	Uber	▪ adjusting short-term supply
	AirBnb	▪ maintaining a consistent price-quality trade-off
	Ad platforms	▪ encouraging truthful bids to extract best value
Matching	Amazon Marketplace	▪ matching from a wide range of products
	AirBnB	▪ ranking the options using relevant variables
	Ad platforms	▪ identifying and targeting the most relevant audience

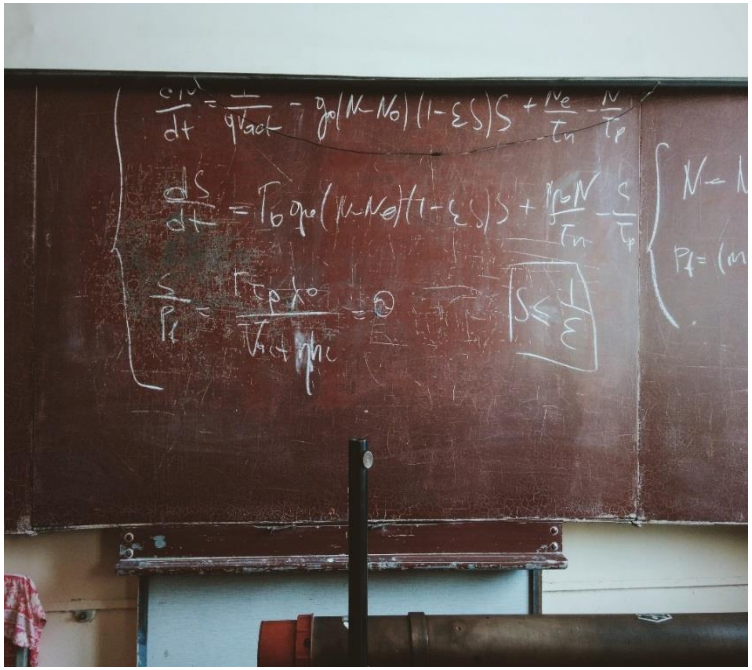
Overview

What do algorithms do?

Why algorithmic pricing?

Distributional implications

What do algorithms do?
Types of algorithmic pricing



Heuristic approach

- Simple rules
- Example: price-matching rules in online retail

Analytical approach

- Using historical data
- Example: insurance and credit for risk-based pricing

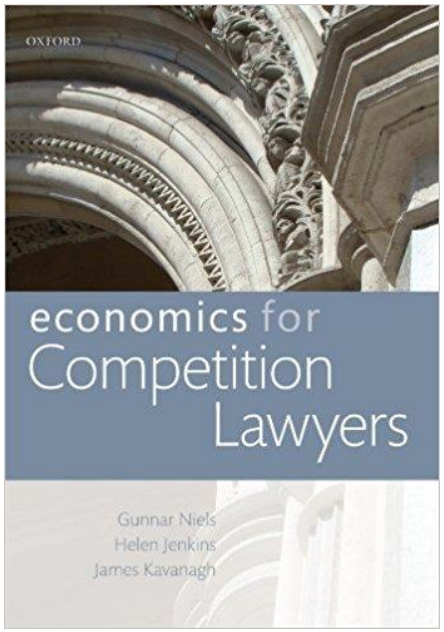
Autonomous approach

- Continuous self-updating
- Example: online ad placement

Auctions

- Interaction between multiple algorithms
- Example: online ad pricing

What do algorithms do?
Algorithms in use



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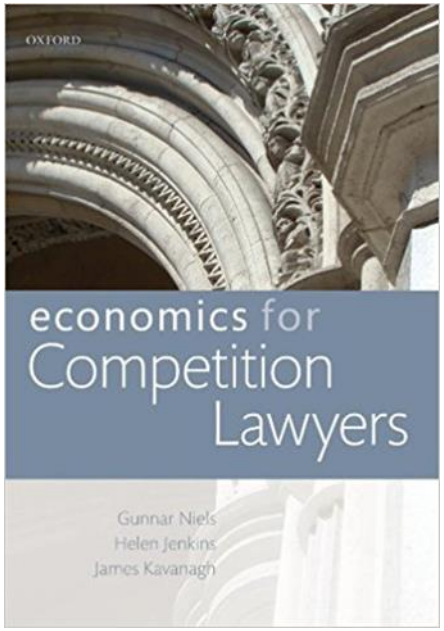
What do algorithms do?
Algorithms in use



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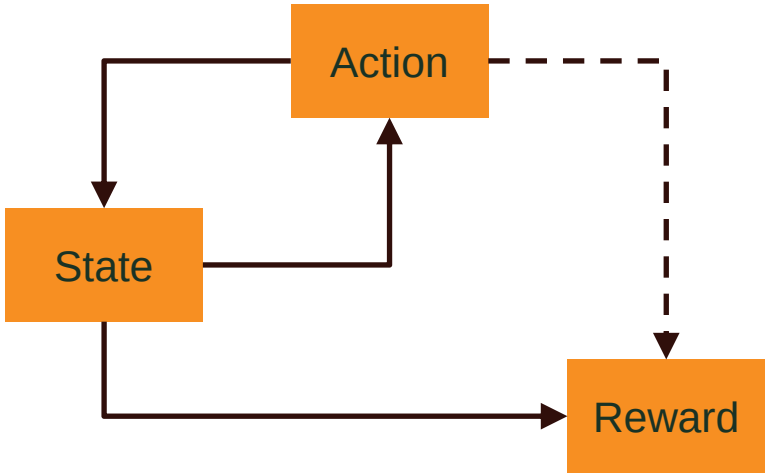
What do algorithms do?
Algorithmic learning

Reinforcement learning framework:



Source: Oxera.

What the algorithm does:

- take an objective function
  - maximise Reward (utility, revenue, profit etc.)
- start from a particular State
  - e.g. current price and quantity or capacity
- choose an Action
  - e.g. price up, include another variable
- observe Reward
  - subject to learning rate and discount factor
- iterate to maximise Reward

How algorithms learn matters…

- reinforcement learning methods approximate human learning
- Q-Learning is one example for temporal difference learning to find the optimal policy:

$$Q(s_{t+1}, a_{t+1}) = (1 - \alpha) \cdot Q(s_t, a_t) + \alpha \cdot \left[r_t + \gamma \cdot \max_a Q(s_t, a) \right]$$

- where:
  - r_t is reward from the current state, s_t
  - α is the learning rate (0 to 1), which determines the extent new information overrides old
  - γ is a discount factor (0 to 1), which trades of current rewards over future rewards

- goal is to max total reward.
  - reward is a weighted sum of expected values of all future steps, including the current step
  - initial condition (Q_0) is an arbitrary starting point. High initial seeds encourage exploration.
  - at each time, t, the algorithm chooses an action (a_t) which generates a reward (r_t) and a new state (s_{t+1})

Single and multi-agent Q-Learning

- previous slide describes naïve Q-learning
  - assumes the algorithm has no influence over the reactions of others in the system

- but in oligopoly:
  - convergence to optimal policy doesn't hold due to strategic responses
  - Nash Q-learning, which allows for joint payoff matrices
  - in theory Nash equilibria can be found using Nash Q-learning: Hu and Wellman, *JMLR* (2003)

  - other criteria still need to be met:
    - monitoring of rivals prices and total returns
    - stable supply and demand environment
    - run time
    - exploration looks like cheating so Nash equilibria may be hard to maintain

Why algorithmic pricing?
Competitive benefits

Various features help firms compete

- faster price adjustments
    - better at identifying changing market conditions, eliminating frictions
- cost reduction compared to manual price setting
    - in-house development at high upfront cost; alternatively software subscriptions
- lower barriers to entry
    - reduced need for (human) market-specific knowledge
- wide applications beyond pricing: matching offerings, understanding consumer preferences etc.

What do algorithms do for consumers?

- help inform decision-making
    - more comparison tools; but who do these algorithms work for?
    - automated switching; but does this eliminate need for consumer involvement?

Why algorithmic pricing?
The likelihood of tacit collusion

Concern: inevitability of collusion

- put forward by e.g. Ezrachi/Stucke (2017) and Salcedo (2015)
- mechanisms include:
  - increased market transparency
  - more stability due to short-lived gains from deviation
- firms/programmers may or may not be aware
- hub-and-spoke facilitated by platforms

Important conditions

- market characteristics undermining collusion:
  - private prices
  - maverick firms
  - powerful customers
- algorithms' parallel understanding of:
  - each other's reward function
  - market parameters (costs, demand...)
  - dynamic changes

Limited risk given current state of algorithms (see Poster case)

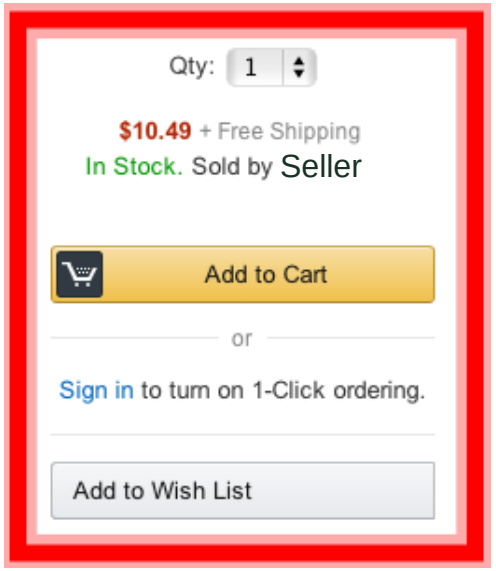
High requirements in terms of algorithms' parallel structure

Why algorithmic pricing?
Poster case: the challenge of algorithm alignment

- retailer A complained about aggressive pricing by vertically integrated poster wholesaler and retailer B
  - agreement on pricing rules to avoid mutual undercutting
- 'problem': manual monitoring not feasible for large number of products and high volatility of prices
- 'solution': algorithms in the form of re-pricing software applications
  - B only undercut A when other competitors offered a lower price than A and vice versa
  - but: fairly detailed communication on the settings of the algorithms required

Why algorithmic pricing?
Platforms and pricing: Amazon Buy Box

- the Amazon Buy Box is an example of a mechanism that interacts with re-pricing software from many providers
- a range of parameters to decide which merchant (or Amazon) gets the Buy Box:
  - price (with and without shipping)
  - customer feedback
  - shipping time
  - fulfilment method (by Amazon/merchant, Prime eligible)...
- re-pricing software allows price-setting with reference to competitor prices, advertising more sales at higher margins



"When you win the Buy Box, [software] will price up incrementally, so you can sell at higher prices."

"Push prices up! [software] will allow you to stop automated repricing for a period every day (normally the late evening and early morning when sales are lowest) and reset to maximum (if preferred), as this can often help drive prices back up across all competition."

Why algorithmic pricing?
Challenges to competition law enforcement

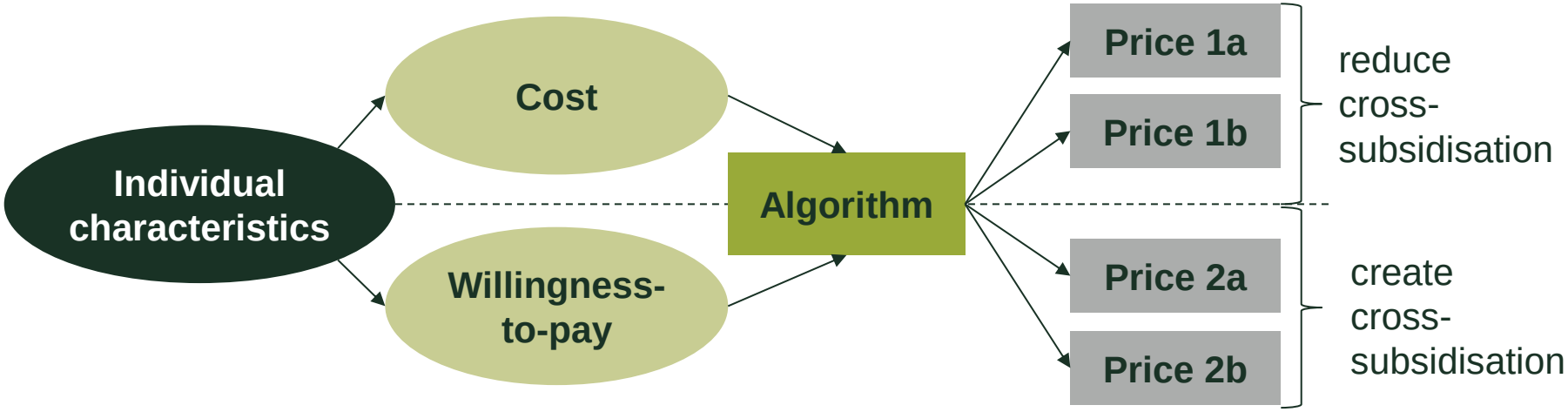
Concerns

- detection and legal instruments: coordination easier to establish without paper trail
- liability: parallel behaviour may even be possible without explicit knowledge of the firms involved
- role of platforms: can they coordinate pricing?

Potential actions

- more widespread, interdisciplinary understanding of algorithm workings
    - increase in transparency for regulators (but not among firms)
- simulation rather than attempting to understand full algorithm history
    - mergers: observe algorithm interaction in test environments
    - market investigations: test different pricing strategies and market shocks

Distributional implications
Personalised pricing



- personalised prices may increase economic efficiency
  - but: possibly undesirable implications for some consumer groups (vulnerable)
  - but: discrimination (e.g. based on race or gender) difficult to stop
    - algorithms can use other variables that are highly correlated with banned observables
    - learning on/use of historical data can reinforce past biases
- personalisation generally unpopular, but can be hidden (e.g. vouchers)

Distributional implications
Challenges for competition authorities

Lack of transparency

- for consumers
  - am I seeing the price or one of many?
  - what variables are used for pricing? should I be able to control what can be used?
- for external observers: price (changes) can indicate whether a market is working well

Lack of consensus

- what are socially acceptable variables for price discrimination?
  - some illegal (race, gender etc.)
  - how to define vulnerable consumers?
- what are socially acceptable limits to price discrimination?
  - sector regulators looking at price variation for the same good
  - when is cross-subsidisation considered fair?

Suggested reading

- OECD (2017), 'Algorithms and collusion: Competition policy in the digital age'.
- Ezrachi, A. and Stucke, M.E. (2016), 'Virtual Competition: The Promise and Perils of the Algorithm-Driven Economy', Harvard University Press
- Ittoo, Ashwin and Petit, Nicolas, 'Algorithmic Pricing Agents and Tacit Collusion: A Technological Perspective' (October 2, 2017).
- Oxera (2017), 'When algorithms set prices: winners and losers'

Contact:
David Jevons
+44 (0)1865 253 033
david.jevons@oxera.com

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Questions for discussion

What economic problem do pricing algorithms solve?

- Can it be efficient for individual suppliers to set their own prices manually, when others use algorithms?
- Is the adoption game of pricing algorithms a prisoner's dilemma?
- How do pricing and matching algorithms interact?

Questions for discussion

How does algorithmic pricing affect competition?

- What is the competitive counterfactual for collusive algorithms—manual pricing, 'competitive' algorithms, or something else?
- Is algorithmic pricing likely to render RPM and MFNs anticompetitive more or less often?
- Is there a scenario that would clearly require regulatory intervention? If so, what aspects should guide any intervention? For example, might it be appropriate to prohibit a certain fee structure?
- What environment might make collusion by algorithms less probable? Could asymmetric information between suppliers, heterogeneity of goods, outside options, or non-transparent pricing impede the tendencies of algorithms to collude?
- How do fee structures affect the incentive for platforms to recommend higher or lower prices to users?
- What would be an effective enforcement framework for algorithmic collusion? If intent is no longer relevant, is it possible to define market outcomes that would be considered illegal?
- As a firm using algorithmic pricing, how might you test that your algorithm was behaving in line with competition law?

Questions for discussion

What are the distributional implications of pricing algorithms?

- When trying to prevent illegal discrimination, what measures might be effective if prices are set by algorithms? Should there be a move to more outcome-oriented assessment?
- How might regulators address the tension between the benefits of algorithmic pricing in cost-reflectivity, and the social objective of achieving certain types of fairness in pricing outcomes?
- How might vulnerable consumers be protected from algorithmic discrimination without unintended consequences elsewhere?
- How might a firm test whether its algorithmically determined personalised pricing is predicated on consumers' behavioural biases?
- Our discussion is primarily focused on the impact of algorithmic pricing on end-users. How could algorithmic pricing that affects intermediate users in the value chain affect price discrimination?