The Challenge of Algorithmic Pricing for Competition Policy

Día de la Competencia
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Introduction

- *Algorithmic pricing* is when a software program processes data to set the price of a product or service.
- Algorithmic pricing can assist in profitably adjusting prices across ...
  - **time** by responding to competitors' prices, demand shocks, inventories, etc.
  - **buyers** by tailoring prices to narrow market segments.

Introduction

- Algorithmic pricing has increased in use because of
  - better computing
  - better programming
  - more data.
- More data enhances the performance of algorithmic pricing, relative to human price-setting, because
  - it substitutes for non-quantifiable (subjective) information
  - it provides a rationale for automating prices so prices can be adjusted frequently
  - it allows learning algorithms to more effectively find better pricing rules.

Introduction

Possible procompetitive efficiencies from algorithmic pricing.

- Markets clear faster as prices are more responsive to new information.
- More price discrimination can enhance welfare (price high to the rich, low to the poor).
- Savings in labor cost in the monitoring and adjusting of prices.
- Lower barriers to entry as pricing algorithms substitute for market knowledge that previously came from experience.

Introduction

Possible anticompetitive harms from algorithmic pricing.

- **Collusion** is made more likely and more effective which raises prices.
  - Humans colluding with algorithms.
  - Algorithms colluding without humans.
- **Price leadership** is facilitated which raises prices.
- **Outsourcing** pricing to a third party who may be incentivized to raise prices.

Competition Policy Challenge: *How do we prevent anticompetitive harm without interfering with procompetitive efficiencies?*

Introduction

Overview

For each of these sources of anticompetitive harm,

- describe the theory of harm
- provide some cases (when they exist)
- examine it in the context of competition law
- make policy recommendations.

Collusion

- Collusive outcome: firms coordinate on setting supracompetitive prices.
- Collusive mechanism: supracompetitive prices are sustained through a reward-punishment scheme which *rewards* a firm for abiding by those prices and *punishes* it for departing from it.
- *Cognitive collusion*
  - Algorithms assist human managers in coordinating and sustaining supracompetitive prices.
  - Managers have intent.
- *Algorithmic collusion*
  - Algorithms coordinate and sustain supracompetitive prices.
  - Managers do not have intent.

Cognitive Collusion

Effective collusion requires

- **coordinating** on a supracompetitive outcome
- **monitoring** for compliance with that outcome
- **punishing** when there is evidence of non-compliance.

Cognitive Collusion

Collusion can be more profitable and effective when firms agree on pricing algorithms, rather than prices.

- Coordinating
  - No need for many meetings.
  - Collusive price can quickly adjust to market conditions.
- Monitoring
  - Price transparency with online prices.
- Punishing
  - Immediate response to price cuts.
  - Programming "price matching" makes deviations unprofitable.

Cognitive Collusion

Cases

Wall Posters (U.S. DOJ, 2015; UK CMA, 2016)

- Retailers GB eye and Trod sold posters on Amazon Marketplace.
- GB eye internal email:

  Trod ... has agreed not to undercut us on Amazon and I have agreed to reciprocate. We will therefore be aiming to be the same price wherever possible.

- Agreement to adopt the same pricing algorithm.
  - Search for the lowest price offered by other suppliers and set price just below that level.

Cognitive Collusion

Competition policy

Coordinating pricing algorithms could make collusion more common, more durable, less detectable.

- More common because it is more profitable.
- More durable because monitoring and punishing is more effective.
- Less detectable because of fewer meetings and price wars are less frequent.

Cognitive Collusion

Competition policy

Cartel screening using online price data or auditing pricing algorithms.

- Undercutting pricing algorithm: A firm specifies a set of "rival firms" and slightly undercuts the lowest price of those rival firms subject to a minimum price.
- Collusive marker: change in pricing algorithm
  - Some firms simultaneously shift from price undercutting to price matching.
  - Some firms simultaneously raise minimum price.
- Collusive marker: exclusion of a competitor from the set of "rival firms".
  - Two firms are competitors but each excludes the other in the set of rival firms.
  - Two firms specify the same set of rivals but exclude each other.

Algorithmic Collusion

- *Cognitive collusion* is when supracompetitive prices are produced by a process "involving conscious intellectual activity such as thinking, reasoning, or remembering."
- *Algorithmic collusion* is when supracompetitive prices are produced by learning algorithms without human design to produce those outcomes.
- *Can learning algorithms learn to collude?* Yes.

Algorithmic Collusion

- An autonomous artificial price-setting agent is a software program that adapts a pricing rule to maximize profits.
- It has two components:
  - *pricing algorithm* - assigns a price to each state (i.e., environment as perceived by the algorithm)
  - *learning algorithm* - modifies the pricing algorithm based on its performance (typically, profit).

Algorithmic Collusion

Reinforcement learning

1. Given the current state of the environment, each firm's algorithm chooses
   - either "best" price based on algorithm's current knowledge ("exploitation")
   - or randomly selects a price ("experimentation").
2. Profits are realized.
3. Algorithm updates its knowledge about the "best" price for a state.
4. New state is realized.
5. Process repeats until convergence of the pricing algorithm.

Algorithmic Collusion

Calvano, Calzolari, Denicolo, and Pastorello (*American Economic Review*, 2020)

- Two firms choose prices in a market with each using reinforcement learning (Q-learning).
- Result: Algorithms converge to setting supracompetitive prices.

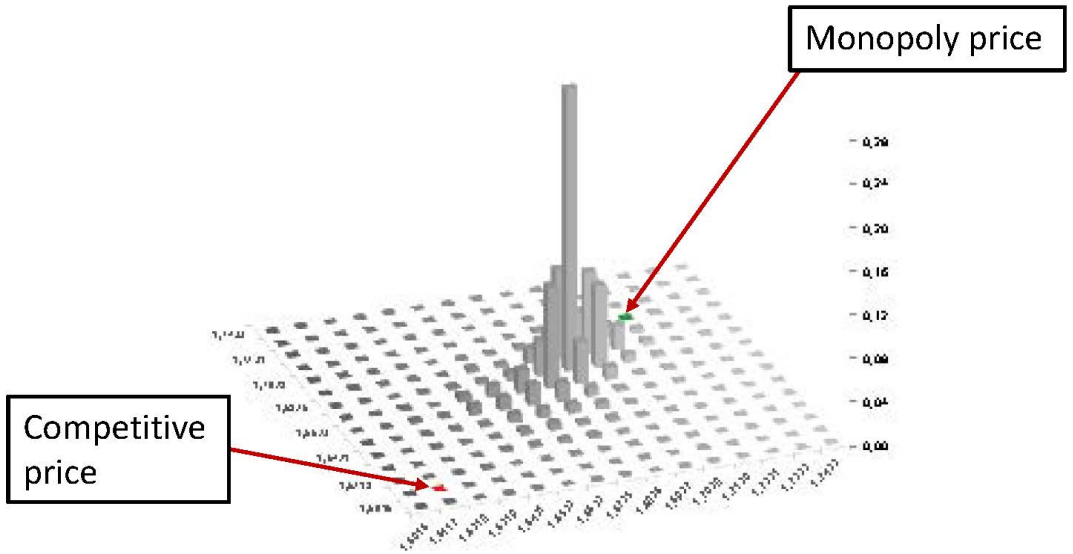


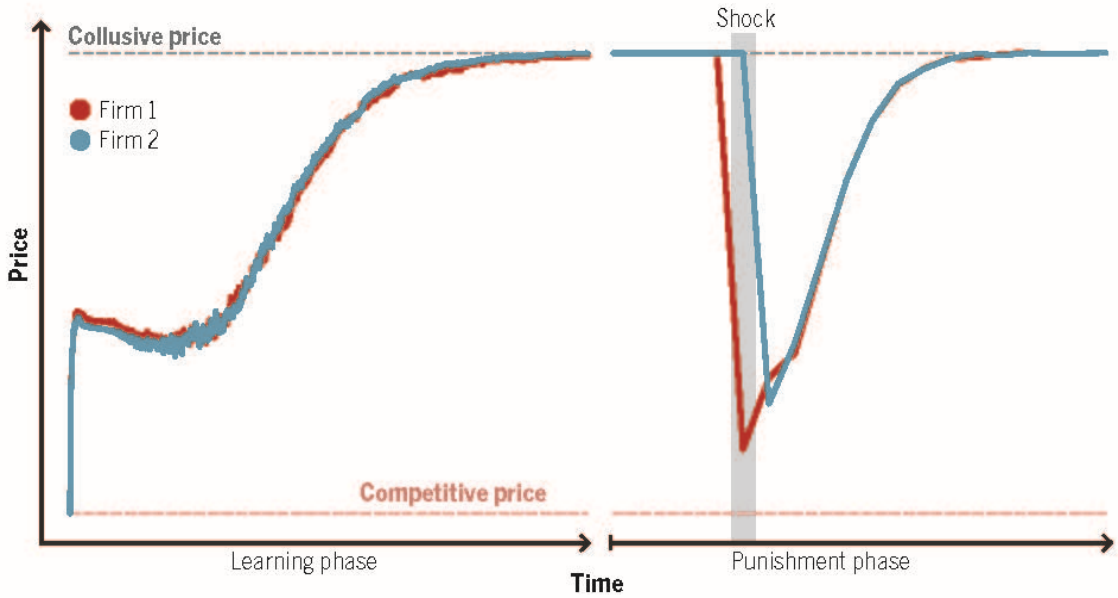
Figure 2: Histogram of states visited in the last 25,000 iterations pooling all data from 1000 sessions with $\alpha = 0.05$, $\beta = 8 \times 10^{-6}$. Green=(p^M, p^M), red=(p^N, p^N).

Algorithmic Collusion

- Result: Algorithms can learn to collude like humans with a reward-punishment scheme.

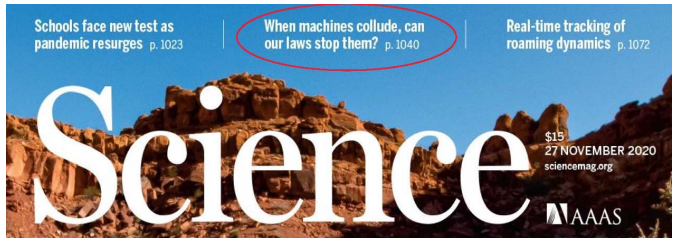
Collusive pricing rules uncovered

After the two algorithms have found their way to collusive prices ("learning phase," left side), an attempt to cheat so as to gain market share is simulated by exogenously forcing Firm 1's algorithm to cut its price ("punishment phase," right side). From the "shock" period onward, the algorithm regains control of the pricing. Firm 1's deviation is punished by the other algorithm, so firms enter into a price war that lasts for several periods and then gradually ends as the algorithms return to pricing at a collusive level. For better graphical representation, the time scales on the right and left sides of the figure are different.



Algorithmic Collusion

- *Should we be concerned?*
  - In the short term, NO.
  - In the long term, YES.
- Short term: Not a threat as algorithms have only colluded in the lab and they are slow to learn to collude.
  - Q-learning takes 100,000 periods.
  - BUT ... Generative AI (ChatGPT-4) takes only 100 periods.



INSIGHTS

POLICY FORUM

TECHNOLOGY AND LAW

Protecting consumers from collusive prices due to AI

Price-setting algorithms can lead to noncompetitive prices, but the law is ill equipped to stop it

By **Emilio Calvano[1,2], Giacomo Calzolari[2,3,4], Vincenzo Denicolò[1,3], Joseph E. Harrington Jr.[5], Sergio Pastorello[1]**

The efficacy of a market system is rooted in competition. In striving to attract customers, firms are led to charge lower prices and deliver better products and services. Nothing more pick up more market share. For example, in 1995 the CEOs of Christie's and Sotheby's hatched their plans in a limo at Kennedy International Airport, and in 1994 the U.S. Federal Bureau of Investigation secretly taped the lysine cartel as they conspired in a Maui hotel room. At those meetings, they spoke about charging higher prices and how to enforce them. Second, successful

to identify collusion. Likewise, it to assess whether the firms' rul duct are collusive because such r tent, residing in employees' head tice, we may never observe the lower prices from a firm that che though that response is there in of the employees and it is the anti such a response that sustains hig In other words, we might lack that produce the data that coul the collusive pricing rules. Fu even if one could observe what a price war, it would be difficult innocent explanations (such as in the firms' costs or a fall in dem

Given the latency of collusiv rules and the difficulty of de whether prices are collusive or co antitrust law and its enforcemer cused on the first stage: commu Firms are found to be in violation when communications (perhap mented by other evidence) are

Algorithmic Collusion

Competition Policy

- Long term: It is a threat because of AI advances and competition law is defenseless against algorithmic collusion.
- Competition law is designed for cognitive collusion.
  - The law prohibits "agreements".
  - An agreement is when firms have mutual understanding to restrain competition.
  - Evidence of an agreement is facilitating communications between firms' managers.
- Algorithmic collusion: no human intent $\Rightarrow$ no communication $\Rightarrow$ no agreement $\Rightarrow$ no violation of competition law.

Algorithmic Collusion

Competition Policy

- With cognitive collusion, the remedy is prohibiting certain communications.
- With algorithmic collusion, the remedy will be to restrict
  - how learning algorithms learn
  - the pricing algorithms that they adopt.
- Competition law will need to be revised to address algorithmic collusion.

Price Leadership

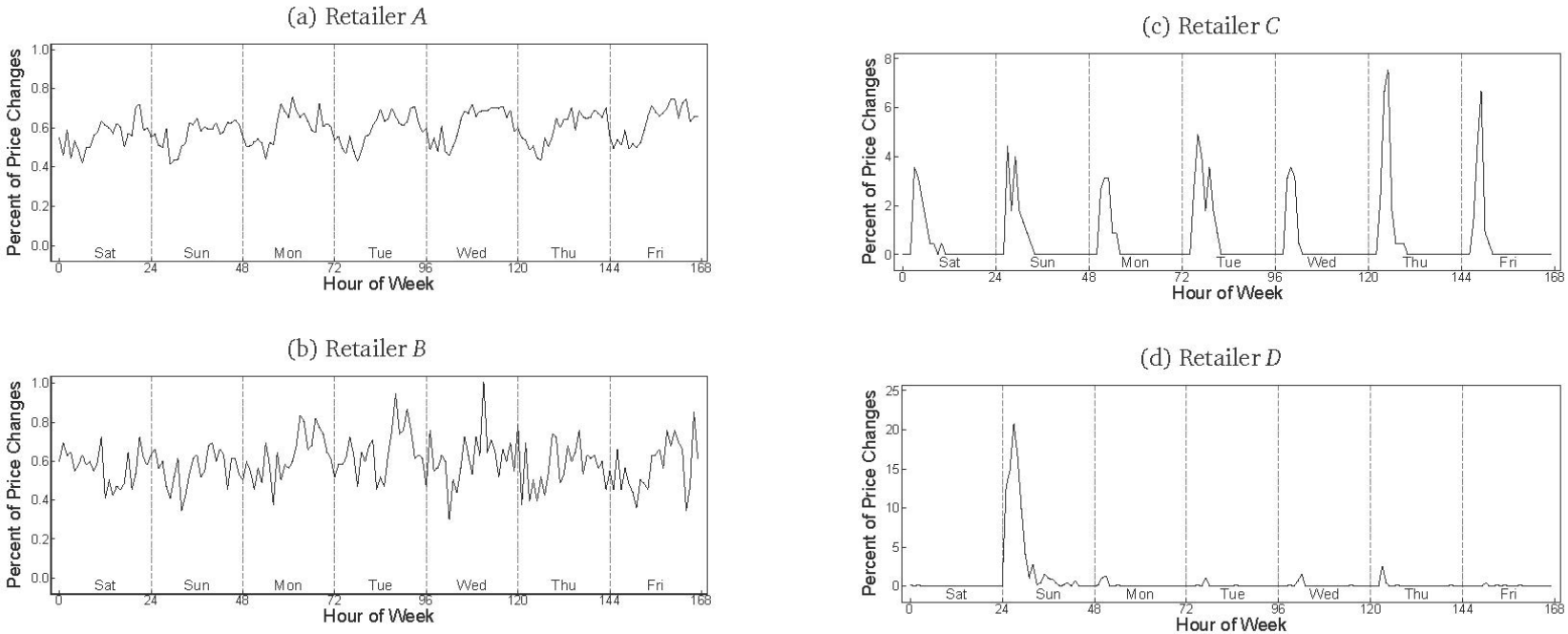
Harm: Algorithms can raise prices by facilitating price leadership.

- Assume firms independently choose their pricing algorithms (no collusion).
- Brown and MacKay (*American Economic Journal: Microeconomics*, 2023)
  - Data: hourly prices for over-the-counter allergy drugs for five largest U.S. online retailers.
  - Observation #1: Online retailers update prices at regular intervals, which differs widely across firms.

Percentage of products whose prices are changed on a given day (on average)

Retailers				
A	B	C	D	E
37.3%	8.9%	0.8%	2.0%	2.4%

Price Leadership



Percent of products with price changes over a week

- Retailers A and B frequently adjust prices over the day.
- Retailer C adjusts price daily between 3AM and 6AM.
- Retailers D, E adjust price just after midnight on Sunday.

Price Leadership

Observation #2: Firms with more frequent price adjustments have lower prices for identical products.

- Relative to retailer A
  - B's prices are 6.6% higher
  - C's prices are 9.6% higher
  - D's prices are 28% higher
  - E's prices are 33% higher

Price Leadership

- Retailers choosing different updating frequencies create a price leader-follower relationship.
  - Retailer who updates weekly knows that retailers who update daily will respond to its prices.
  - Weekly-updating retailers charge higher prices to induce daily-updating retailers to charge higher prices.
- Critical features of algorithmic pricing
  - Low cost of updating prices.
  - Committing to a pricing frequency.

Price Leadership

Competition Policy

- Price leadership is harmful but lawful because there is no remedy.
  - Judge Stephen Breyer (*Clamp-All*, 1988) – "*How does one order a firm to set its prices without regard to the likely reactions of its competitors?*"
- Practices that facilitate a price leadership agreement can be unlawful.
  - Prohibit a firm from sharing features of its pricing algorithm with competitors.
  - Prohibit public announcements where a firm announces that it will lead or follow.

Third-Party Pricing Algorithms

Harm: Outsourcing pricing to a third party who may be incentivized to raise prices.

- Third party designs a pricing algorithm for a particular class of markets.
  - Subscribing firms share their data with the third party.
  - Data analytics company trains a pricing algorithm based on subscribing firms' data and other data.
  - Data analytics company inputs current data into the pricing algorithm to recommend prices.
  - Subscribing firms decide whether to implement recommended prices.

Third-Party Pricing Algorithms

- Apartment rentals - United States (RealPage, Yardi)
- Gasoline or petrol - Brazil, Germany (a2i Systems, Kalibrate)
- Hotels - United States (IDeAS, Rainmaker)

Third-Party Pricing Algorithms

- Efficiencies from outsourcing
  - Third party has more experience and expertise.
  - Third party has more data.
  - Third party has stronger incentives to invest in development.
- Fundamental tension for competition policy
  - There are efficiencies from a firm outsourcing its pricing algorithm to a third party.
  - A common third party recommending prices to competitors creates the risk of anticompetitive harm.

Third-Party Pricing Algorithms

Competition authorities and international organizations

OECD: *"Concerns of coordination would arise if firms outsourced the creation of algorithms to the same IT companies."*

A third party "knows or accepts [it] could contribute to a collusive market outcome [and] it is even conceivable that [they] see such a contribution as an advantage, as it makes the algorithm more attractive for users."

Monopolkommission

Third-Party Pricing Algorithms

Private litigation (U.S.)

- Private litigants claim a price-fixing agreement between a data analytics company and subscribing firms.
  - Apartments - private, U.S. Dept of Justice (Antitrust Division)
  - Hotels - private
  - Health services - private

Company That Makes Rent-Setting Software for Apartments Accused of Collusion, Lawsuit Says

Texas-based RealPage worked with some of the nation's largest landlords to create a cartel to raise rents, says a lawsuit filed just days after ProPublica published its investigation into the company.

MONEYWATCH ›

Vegas hotel giants MGM, Caesars, Wynn and Treasure Island sued for "algorithmic-driven price-fixing"

MONEY WATCH JANUARY 27, 2023 / 9:54 AM / AP

Third-Party Pricing Algorithms

Empirical Studies

Assad, Clark, Ershov, and Lu (*J. of Political Economy*, 2024) - retail gasoline (Germany)

- Many stations adopted in mid-2017.
- Average price-cost margin increased by 12%.
- Duopoly markets (only two stations are within 1 km of each other)
  - One station adopted: no effect.
  - Both stations adopted: margin increased by around 30%.

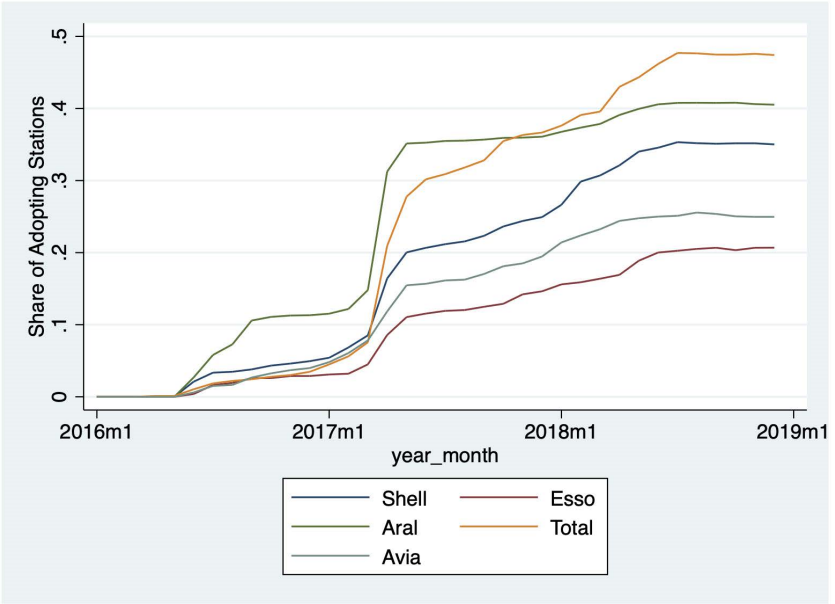


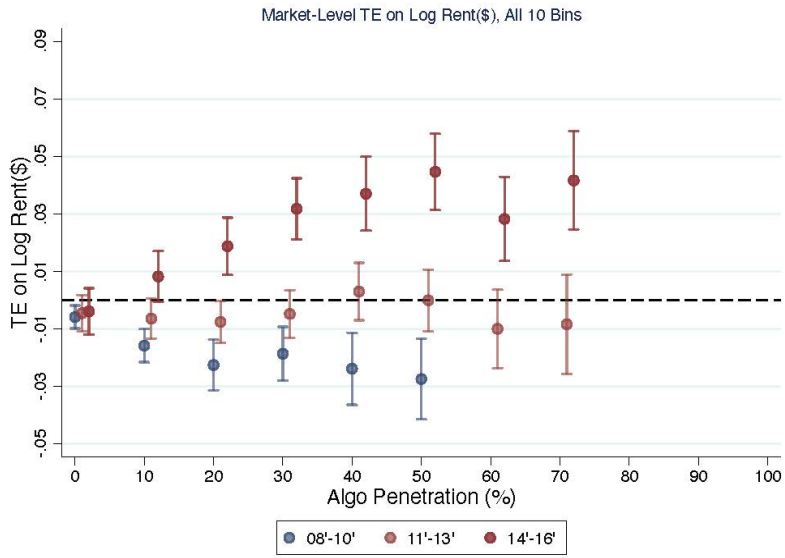
Figure 6: Share of AI Adopters Among Top 5 Brands

Third-Party Pricing Algorithms

Empirical Studies

Calder-Wang and Kim (working paper, 2024) - apartment rentals market with RealPage (United States)

- Evidence of procompetitive effect: Compared to non-adopters, adopters had higher (lower) prices when demand is strong (weak).



- Evidence of anticompetitive effect
  - Estimation supports RealPage engaging in joint-profit maximization.
  - Estimated markup of $53 per unit per month.

Third-Party Pricing Algorithms

Anticompetitive harm

Sources of anticompetitive harm from a third party recommending prices to competitors.

1. Agreement between the third party and subscribing firms to set supracompetitive prices.
   - Illegal by the per se (by object) rule.
2. Agreement or concerted practice to share information which results in supracompetitive prices.
   - Illegal by the per se rule or the rule of reason (by effect).
3. Unilateral conduct by the third party which results in supracompetitive prices.
   - Illegality is unclear.

Third-Party Pricing Algorithms

Anticompetitive harm: Price-fixing agreement

- Complaints claim a price-fixing agreement
  - Apartments: "RealPage provides software and data analytics to Lessors [and] has [been] facilitating an agreement not to compete on price."
  - Hotels: "Operator Defendants have agreed to outsource their independent pricing decision-making to a single, common pricing manager - IDeaS, which has willingly facilitated and enforced the conspiracy."
- Bill Baer in Congressional testimony noted that "antitrust jurisprudence describes this behavior as a hub and spoke conspiracy."
- But commentators do not appreciate the distinctive implications when the hub is supplying a pricing algorithm.

Third-Party Pricing Algorithms

Anticompetitive harm: Price-fixing agreement

- More difficult to prove an agreement.
  - With the usual upstream supplier, evidence of an agreement ("rim") comes from bilateral communications with downstream firms about their prices.
  - With a data analytics company as the upstream supplier, such communications is part of delivering a legitimate service.
- More difficult to design a remedy.
  - With the usual upstream supplier, prohibiting communications with downstream firms about downstream prices comes at no cost.
  - With a data analytics company as the upstream supplier, such a prohibition interferes with procompetitive efficiencies.

Third-Party Pricing Algorithms

Anticompetitive harm: Price-fixing agreement

"Hub-and-Spoke Collusion with a Third-Party Pricing Algorithm" (Harrington, working paper, 2024)

- Third party's efficiency
  - Price can condition on a varying demand state.
  - Efficiency is greater when market demand is more variable.
- Collusive agreement
  - Third party designs the pricing algorithm to maximize adopters' profits.
  - But it must incentivize firms to adopt the pricing algorithm.

Third-Party Pricing Algorithms

Anticompetitive harm: Price-fixing agreement

"Hub-and-Spoke Collusion with a Third-Party Pricing Algorithm" (Harrington, working paper, 2024)

- Factors in a firm's adoption decision.
  - Adopting means being able to condition price on the demand state.
  - Not adopting allows a firm to undercut the high average (collusive) price of adopting firms.
- Result: The greater is the third party's efficiency, the higher is the supracompetitive markup and the more profitable is collusion.
- Implication: Markets with larger procompetitive efficiencies have a higher risk of an anticompetitive agreement.

Third-Party Pricing Algorithms

Anticompetitive harm: Information exchange

- Agreement among firms to share confidential, commercially sensitive data with the third party.
- DOJ Complaint against RealPage (Aug 2024)
  - "Landlords have agreed with one another to exchange nonpublic, competitively sensitive data through RealPage's revenue management software."
- DOJ must prove
  1. subscribing firms are sharing information through RealPage
  2. subscribing firms have an agreement to share information
  3. agreement is anticompetitive.

Third-Party Pricing Algorithms

Anticompetitive harm: Information exchange

- Assume each subscribing firm knows competitors are also sharing their data with a third party.
- *Are subscribing firms sharing information with each other?*
  - Third party is not directly sharing information: It uses shared data to make private price recommendations.
  - Third party may not be indirectly sharing information.
    - Is a firm able to infer other firms' shared data from its price recommendations?
  - "Using data across all your customers for research does not plausibly suggest that one customer has access to the confidential information of another customer." Judicial opinion from Hotels case

Third-Party Pricing Algorithms

Anticompetitive harm: Information exchange

- *Do subscribing firms have an agreement to share information with the third party?*
  - Third party's efficiency makes it in a firm's interest to share data even if other firms do not.
  - Mutual adoption is not evidence of an agreement.
- *Is an agreement to share information anticompetitive?*
  - DOJ: "it removes competitive uncertainty and allows [firms] to agree with recommendations by RealPage that they increase rents."
  - Cannot be presumed to have anticompetitive effect because there are efficiencies.
  - Must show there are minimal efficiencies or higher prices.

Third-Party Pricing Algorithms

Anticompetitive harm: Information exchange

- Concerted practice is "a form of coordination that, without reaching a formal agreement, knowingly substitutes cooperation for competition."
- European Commission guidance (2023) on the exchange of commercially sensitive information via a third party.
  - Competitors are liable if they are aware of the third party using the information to pursue an anticompetitive objective.
  - Third party is liable if it intends to contribute to or was aware of or could reasonably have foreseen anticompetitive effect.
- This legal path may be effective if it can be shown
  - the third party has an anticompetitive objective
  - the subscribing firms have knowledge of this anticompetitive objective.

Third-Party Pricing Algorithms

Anticompetitive harm: Unilateral conduct

- A third party is interested in creating value for subscribing firms.
- Possible sources of value
  - Efficiencies
  - Higher prices
- Questions
  - Does the third party have an incentive to build in a supracompetitive markup?
  - If it does, what are possible remedies?

Third-Party Pricing Algorithms

Anticompetitive harm: Unilateral conduct

Harrington (*Management Science*, 2022)

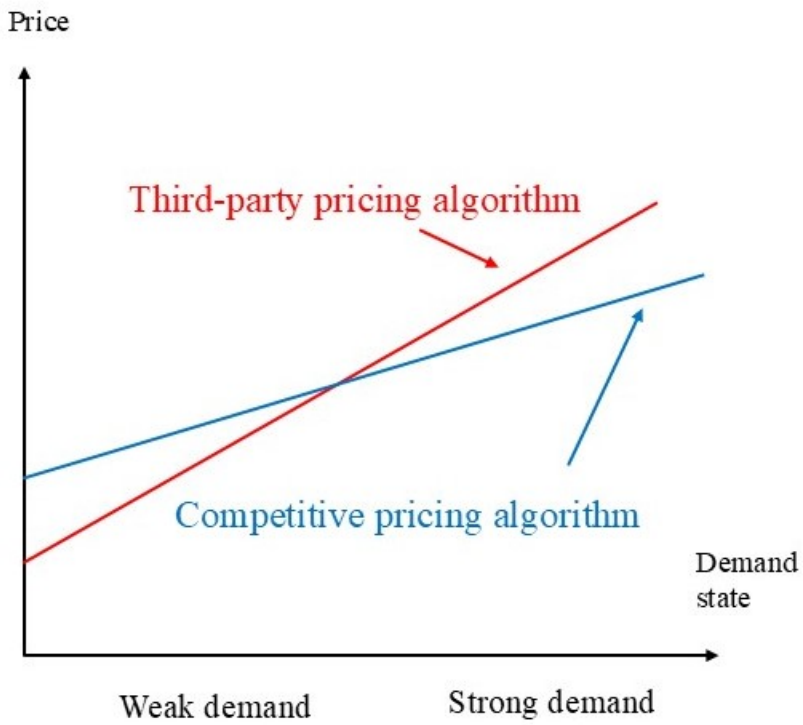
- Third party's efficiency: pricing algorithm allows price to respond to varying demand.
- Third party's objective is to maximize its profit from selling the pricing algorithm
  - Design of pricing algorithm maximizes a firm's willingness-to-pay = profit from adopting minus profit from not adopting.
  - No collusive agreement so it is not assumed to maximize adopters' profits.
  - But it does take into account that its algorithm will "compete against itself".

Third-Party Pricing Algorithms

Anticompetitive harm: Unilateral conduct

Compared to the pricing algorithm that firms would independently design, the third party's pricing algorithm

- is more sensitive to the demand state
- but average price is the same - no supracompetitive markup.



Third-Party Pricing Algorithms

Competition policy: Unilateral conduct

- Suppose a third party does make the pricing algorithm supracompetitive without the request, approval, or knowledge of the subscribing firms.
- German Monopolies Commission (2018): "*Liability gaps can open up if the IT service provider brings about a collusive market outcome without the approval of the parties involved*."

Third-Party Pricing Algorithms

Competition policy: Unilateral conduct

What are some possible remedies?

1. Restrictions on who the third party can supply.
   - Prohibit a third party from supplying its pricing algorithm to more than one firm in a market.
2. Restrictions on data sharing.
   - "Preventing Algorithmic Collusion Act" (U.S.)
3. Restrictions on the pricing algorithm.

Third-Party Pricing Algorithms

Competition policy: Unilateral conduct

"Preventing Algorithmic Collusion Act" (U.S. Senate, proposed 2024)

- A third party and subscribing firms have an unlawful agreement when the third party's pricing algorithm is trained on or conditions on nonpublic competitor data.
- Prohibits the "sharing" of nonpublic competitor data.

Third-Party Pricing Algorithms

Competition policy: Unilateral conduct

Prohibiting a third party's pricing algorithm from using nonpublic competitor data.

- Flaw #1: Harms procompetitive efficiencies
  - Prohibition makes it difficult to distinguish market-wide and firm-specific demand changes.
  - Prohibition puts a new firm at a disadvantage.
- Flaw #2: May not prevent anticompetitive harm.
  - When past prices are public information, a third party can produce supracompetitive prices without using nonpublic competitor data.
  - Source of harm is a shared objective, not shared data.

Third-Party Pricing Algorithms

Competition policy: Unilateral conduct

Desiderata of a remedy

1. Remedy applies to unilateral conduct.
   - Third party may be the only one with intent.
   - Even when there is an agreement, it may be difficult to prove.
2. Remedy does not regulate the design of the pricing algorithm.
   - We do not know enough to effectively regulate.
   - With more knowledge and experience, a regulatory remedy may be feasible in the future.

Third-Party Pricing Algorithms

Competition policy: Unilateral conduct

Proposed Remedy: *Advising companies on their pricing when it is reasonably foreseeable that it may substantially lessen competition is unlawful.*

- Applicable to data analytics companies but also management consultancies, information aggregators, trade associations, and marketplace platforms.
- Open a case based on evidence of effect using market data.
  - Adopters' prices exceed non-adopters' prices.
  - Average price is increasing in the adoption rate.
- Prosecute a case based on evidence of intent to substantially lessen competition.
  - Internal documents
  - Program code

Third-Party Pricing Algorithms

Competition policy: Unilateral conduct

Evidence of anticompetitive intent: internal documents

- Expressing a goal or plan to maximize subscribers' joint profits.
- Expressing a goal or plan to reduce competition (e.g., avoid price wars).

Third-Party Pricing Algorithms

Competition policy: Unilateral conduct

Evidence of anticompetitive intent: program code

- Program's objective is anticompetitive.
  - With an optimization algorithm, the objective is to maximize subscribing firms' joint profits.
  - With a reinforcement learning algorithm, the performance metric is subscribing firms' joint profits.
- Experiments with common price changes for subscribing firms.
- Distorts the pricing algorithm to result in supracompetitive prices.
  - Uses an inflated cost.
  - Asymmetric overrides; e.g., overrides an algorithm's recommendation when prices are below average but not when above average.

Summary of Practices and Challenges

- Firms' managers coordinate pricing algorithms.
  - Status: practice exists though not many documented episodes.
  - Liability: per se violation of competition law.
  - Policy response: develop detection methods using online data.
- Firms' learning algorithms autonomously collude.
  - Status: theoretical, does not yet exist in practice.
  - Liability: not a violation of competition law.
  - Policy response: need to modify competition law.

Summary of Practices and Challenges

- Firms independently adopt pricing algorithms that reduce price competition (create a leader-follower arrangement).
  - Status: practice exists and likely to be growing.
  - Liability: not a violation of competition law
  - Policy response: like tacit collusion, do we just accept it? could we restrict pricing algorithms?
- Firms adopt a pricing algorithm from the same third party.
  - Status: practice exists and likely to be growing.
  - Liability
    - violation of competition law when there is an agreement
    - problematic when there is no agreement.
  - Policy response: new competition law designed to address a third party's unilateral anticompetitive conduct while taking account of procompetitive efficiencies.