

Algorithmic Pricing

Algorithmic Market Activity Workshop

Joe Harrington

Penn - Wharton

27 May 2021

Introduction

What is algorithmic pricing?

- Algorithmic pricing is the use of computer programs to set prices.
- It is automated price setting, which can involve
 - machine learning to estimate key input variables for the pricing algorithm.
 - a self-learning algorithm to "design" the pricing algorithm.
- Human intervention can range from
 - regular adjustment of coefficients of the pricing algorithm to
 - specifying the type of self-learning algorithm and its performance metric.

Introduction

a2i Pricecast technology "utilizes learning algorithms to construct dynamic profiles of customers and their usage patterns, as well as competitors. These systems rapidly and intelligently react to changing customer behavior, changing markets, and unexpected events."



PriceCast Technology

PriceCast-based systems deploy a novel application of Artificial Intelligence (AI), developed by a2i systems.

The systems utilize learning algorithms to construct dynamic profiles of customers and their usage patterns, as well as competitors and their strategies on both micro and macro scales. Sophisticated methods for reasoning about uncertainty and coping with incomplete data make PriceCast-based systems mimic a flexible, almost human-like, behavior.

The methods allow these systems to rapidly and intelligently react to changing customer behavior, changing markets, and unexpected events. The automated and continuous observation of the complex interactions obscured in the data result in a system with superhuman expertise. That is the key to the superior performance of PriceCast-based systems compared to less adaptable systems based on conventional technologies.

Introduction

What is algorithmic pricing?

Algorithmic pricing uses economics and technology.

- Economics focuses on goals and incentives.
- Technology focuses on constraints and implementation.
- Prices are a confluence of these forces.

Introduction

What is algorithmic pricing?

Example: price discrimination

- Economics describes how a firm should price discriminate in order to maximize its profit; how it depends on
 - consumers' willingness to pay
 - price-elasticity of demand
 - substitutability with competitors' products and competitors' prices
- Technology is the means for implementing price discrimination by
 - collecting data on consumers
 - using machine learning to identify consumers' characteristics
 - tracking competitors' prices
 - automating the setting of prices in real time.

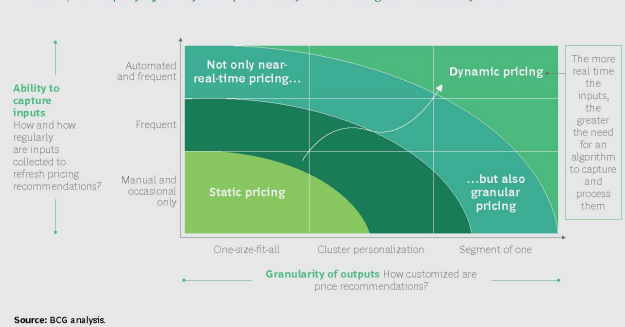
Introduction

What is algorithmic pricing?

Algorithmic pricing can affect

- prices across time ("dynamic pricing") by responding to competitors' prices, demand shocks, inventories, and other high-frequency variables
- prices across buyers ("personalized pricing") by tailoring prices to narrow market segments

EXHIBIT 1 | A Company's Journey to AI-powered Dynamic Pricing Can Take Many Forms



Introduction

Why has algorithmic pricing become more common?

- **More data** means pricing decisions can rely less on non-quantifiable information which enhances the performance of automated prices relative to humans setting prices. (higher volume and variety)
- **More data** on cost, demand, rivals' prices, etc. provides a rationale for adjusting price more frequently which enhances the performance of automated prices relative to humans setting prices. (higher velocity)
- **More data** allows self-learning algorithms to learn quicker and better which means automated pricing performs better.

Introduction

Where is algorithmic pricing occurring?

Algorithmic pricing is prevalent in retail markets (B2C) where

- demand fluctuates much more rapidly than supply; e.g., airlines, hotels, ride-hailing
- demand is very sensitive to price so responding to competitors' prices is critical; e.g., retail gasoline, Amazon Marketplace and Buy Box
- cost varies across consumers; e.g., credit, insurance
- many products need to be priced; e.g., consumer retail

Introduction

Where is algorithmic pricing occurring?

- Algorithmic pricing is less prevalent in industrial markets (B2B) because
 - prices tend to be negotiated (not posted) because of purchase size
 - rivals' prices are not easily accessible.
- But its role is increasing with a human-machine mixture
 - Example: B2B distributor in building material sector
 - Used machine learning to estimate a willingness-to-pay for each customer for each product.
 - Sales team used that recommended price when negotiating.

Introduction

Benefits and costs

Possible efficiencies from algorithmic pricing

- Markets clear more efficiently due to faster price adjustments
- Reduced cost from monitoring and adjusting prices
- Lower barriers to entry as third-party pricing algorithms substitute for specific market knowledge that previously came from learning-by-doing

Introduction

Benefits and costs

Possible consumer harm from algorithmic pricing

- Personalized pricing could extract surplus from high-value consumers (but also allow low-value consumers to buy)
- Reduced price competition due to more rapid monitoring and price adjustments
 - discourage price cuts
 - facilitate coordinated price increases
- Reduced price competition due to delegating pricing to third parties, such as platforms, developers.

Introduction

Overview

- 1 How can algorithmic pricing affect market performance?
 - 1 Data: Input for a pricing algorithm
 - 2 Design: Properties of the pricing algorithm
- 2 Design
 - 1 **Price leadership**
 - 2 **Third party pricing**
 - 1 **Platforms (affecting the price decision)**
 - 2 **Delegating (the price decision)**
 - 3 **Outsourcing (the pricing algorithm)**
 - 3 Collusion [covered by Giacomo Calzolari]

Price Leadership

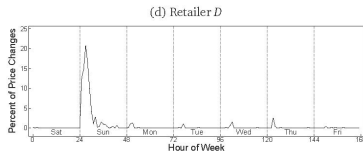
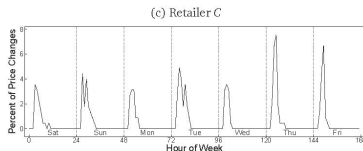
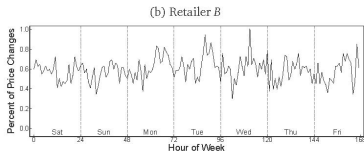
“Competition in Pricing Algorithms” (Brown and MacKay, 2020)

- Data: hourly prices for OTC allergy drugs, five largest U.S. online retailers.
 - April 10, 2018 – October 1, 2018
 - More than 3.6M price observations.
- 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)

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

Price Leadership



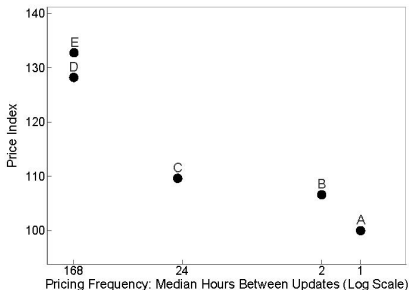
- A and B frequently adjust prices.
- C, D, E appear to be running a script at pre-specified intervals
 - C (daily between 3AM and 6AM)
 - D, E (just after midnight EDT on Sunday).

Price Leadership

Observation #2: Firms with faster pricing technology 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



Why do firms with the faster pricing technology have lower prices?

Price Leadership

- Retailers choose different frequencies to create a price leader-follower relationship.
- Two key features of algorithmic pricing are responsible:
 - ① Lowers the cost of updating prices and facilitates a regular pricing frequency.
 - ② Provides commitment to a price strategy.

Third Party Pricing

An implication of algorithmic pricing is that the algorithm can be operated or designed by a third party.

- 1 Platform sets prices or determines how prices affect market outcomes
- 2 Delegating pricing authority to a third party
- 3 Outsourcing the pricing algorithm to a developer

Third Party Pricing

Platforms

- Platform matches buyers and sellers
 - Uber: drivers and passengers
 - Airbnb: property owners and renters
 - TaskRabbit: people who need a task performed and workers
- Platforms vary in their role in pricing
 - Uber - sets prices for drivers
 - Amazon Marketplace - offers sellers a pricing algorithm
 - Airbnb - recommends prices to property owners ("Smart Pricing")
 - TaskRabbit - no role in pricing

Third Party Pricing

Platforms

Spencer Meyer v. Travis Kalanick (2016)

- Plaintiffs: "Mr. Kalanick had conspired with Uber drivers to use Uber's pricing algorithm to set the prices charged to Uber riders, thereby restricting price competition among drivers."
- Defendants: In the contract, a driver "shall always have the right to charge a fare that is less than the pre-arranged fare."
- Plaintiffs: "Though Uber claims to allow drivers to depart downward from the fare set by the algorithm, there is no practical mechanism by which drivers can do so."

Third Party Pricing

Platforms

- Should Uber be required to give pricing authority to its drivers?
- Some relevant factors
 - Market power of platform
 - Technological feasibility of decentralizing pricing authority

Third Party Pricing

Platforms

Liftago (Czech Republic)

- Driver programs in several tariffs
 - Tariff has a per kilometer fare, flagging fee, per minute waiting fee.
 - Typical driver has 5 fare combinations.
- When pinged, a driver sees the fare combinations for that ride and selects one of them.
- Customer observes for each driver: price, waiting time, car type, driver rating.

The screenshot shows the Liftago app interface for selecting a taxi. At the top, it says "Základní služba" (Basic service), "13:39", and "97%". The main heading is "Vyberte si taxi" (Choose your taxi) with a "Zrušit" (Cancel) button. Below are four driver options:

Driver	Car Model	Rating	Dojezd (min)	Odhad (Kč)
Miloš K.	Skoda Superb 2011	5.0	13 min	369 Kč
Josef H.	Skoda Superb II Facelift	5.0	10 min	476 Kč
Petr G.	Hyundai i 30 combi / 2015	5.0	6 min	539 Kč
Ladislav M.	Skoda Octavia II 2010	4.8	13 min	521 Kč

Third Party Pricing

Platforms

- Is it or should it be illegal for a platform to control the prices at which the two sides of the platform transact?
- Is it or should it be illegal for competing suppliers (drivers) to allocate pricing authority to a common third party (Uber)?
- Should there be restrictions on how a platform prices? on the objective given to the pricing algorithm?
 - Suppose Airbnb were to adopt Uber's approach to pricing?
 - Would it matter if Airbnb's pricing algorithm was designed to maximize property owners' revenue?
 - But would it do so? Would that maximize the platform's profit?

Third Party Pricing

Platforms

"Dominant platforms have a responsibility to ensure that their rules do not impede free, undistorted, and vigorous competition."

*- J. Crémer, Y.-A. de Montjoye, and H. Schweitzer,
"Competition Policy for the Digital Era," Report for the
European Commission, 2019*

- When a platform does not set price, can it set rules to promote better outcomes?
- How does the platform profit-maximizing rule compare with what maximizes social welfare?

Third Party Pricing

Platforms

“Platform Design When Sellers Use Pricing Algorithms” (Johnson et al, 2020)

- Consider a setting like Amazon Marketplace, Booking.com, eBay
 - brings together sellers and buyers
 - sellers set their prices
- What are platform rules that could encourage price competition and discourage price collusion?
- Price-directed prominence
 - There are n sellers and buyers only observe the k ($< n$) sellers with the lowest prices.
 - Even with differentiated products, all firms price at cost.
 - As k is smaller, product variety goes down which harms consumers.
 - If k/n is large enough then consumer welfare is higher.

Third Party Pricing

Platforms

- Rule to destabilize collusive price setting.
- Dynamic price-directed prominence
 - Only the seller with the lowest price is shown to buyers.
 - That seller is given an advantage in the next period: It will be the only seller shown to buyers as long as
 - it does not raise price and
 - its price does not exceed the lowest price of other sellers by more than some specified amount.
- Under this rule, collusion can be made unstable.
 - The rule accentuates the profit advantage to undercutting a collusive price.

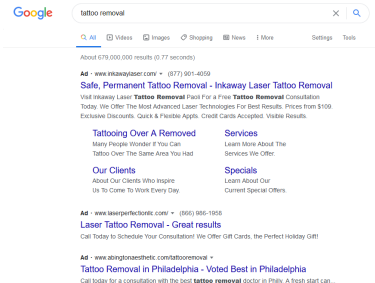
Third Party Pricing

Delegation

"From Mad Men to Maths Men: Concentration and Buyer Power in Online Advertising" (Decarolis and Rovigatti, *American Economic Review*, forthcoming)

Sponsored search auctions

- For a keyword, an advertiser submits a bid amount and a budget.
- Each time a user queries a keyword, an auction is run to allocate slots based on bid and "ad quality".
- Payment occurs when the user clicks on the ad.
- Cost-per-click: mean = \$2.34, median = \$0.90



The screenshot shows a Google search for "tattoo removal". The search bar is at the top with the Google logo on the left and search, all, videos, images, shopping, news, and more icons on the right. Below the search bar, it says "About 679,000,000 results (0.77 seconds)". The first search result is an advertisement for "www.inkawaylaser.com" with the headline "Safe, Permanent Tattoo Removal - Inkaway Laser Tattoo Removal". The ad text includes "Visit Inkaway Laser Tattoo Removal Paoli For a Free Tattoo Removal Consultation Today. We Offer The Most Advanced Laser Technologies For Best Results. Prices from \$100. Exclusive Discounts. Quick & Painless Apprx. Credit Cards Accepted. Visible Results." Below the ad text are four columns of links: "Tattooing Over A Removed" (with subtext "Many People Wonder If You Can Tattoo Over The Same Area You Had"), "Our Clients" (with subtext "About Our Clients Who Inspire Us To Come To Work Every Day"), "Services" (with subtext "Learn More About The Services We Offer"), and "Specials" (with subtext "Learn About Our Current Special Offers"). Below this ad is another ad for "www.laserperfectonics.com" with the headline "Laser Tattoo Removal - Great results" and subtext "Call Today to Schedule Your Consultation! We Offer Gift Cards, the Perfect Holiday Gift!". The third ad is for "www.abingtonaesthetic.com/tattooremoval" with the headline "Tattoo Removal in Philadelphia - Voted Best in Philadelphia" and subtext "Call today for a consultation with the best tattoo removal doctor in Philly. A fresh start can...". At the bottom of the page, there are navigation icons for back, forward, and search.

Third Party Pricing

Delegation

Many advertisers delegate bidding authority to an intermediary.

- Advertisers run marketing campaigns through a digital marketing agency (DMA).
- Most DMAs delegate bidding to a "network".
- Seven networks submit bids for advertisers.
- Efficiency rationale: Networks have more data and more sophisticated algorithms.
- Competitive concern: DMA and the network it uses is contracted to set the prices of competitors
 - Aegis-Dentsu's clients included Dell, Samsung, Apple, HP, IBM/Lenovo, Intel

Third Party Pricing

Delegation

Policy issues

- If the third party chooses bids to maximize a joint objective, is this a violation of competition law?
- Should a third party be prevented from handling competitors' prices?
- Should there be firewalls when handling competitors' accounts?

Third Party Pricing

Outsourcing

- A firm buys a pricing algorithm from a third party software developer because it has
 - more expertise, experience, data
 - stronger incentive to invest in creating a better pricing algorithm
- *How do the design incentives of a firm which is to sell the algorithm differ from the design incentives of a firm which is to use the algorithm?*
- The firm that sells it will want to take into account that its algorithm may "compete against itself."
- A third party may make its pricing algorithm less competitive so that it performs better when multiple firms in a market adopt it.

Third Party Pricing

Outsourcing

- **UK Competition & Markets Authority** (2018): “If a sufficiently large proportion of an industry uses a single algorithm to set prices, this could result in ... the ability and incentive to increase prices.”
- **OECD** (2017): “Concerns of coordination would arise if firms outsourced the creation of algorithms to the same IT companies and programmers.”
- What are the rights and responsibilities of a third party developer in the context of competition law?
- Can there be collusive pricing without a conspiracy among competitors?

Third Party Pricing

Outsourcing

Algorithm may be designed to compete less aggressively

- Bad third party design property: search for the lowest competing price and then undercut it.
 - Mutual adoption results in a price war and low profits.
- Third party developers advertise their algorithms do not price aggressively.
 - Feedvisor: "How to avoid price wars and maintain market share."
 - RepricerExpress: "There are features to help sellers detect and avoid a price war."

Third Party Pricing

Outsourcing

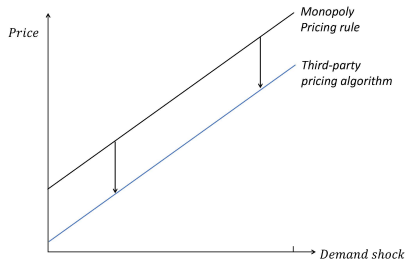
"The Effect of Outsourcing Pricing Algorithms on Market Competition"
(Harrington, 2021)

- Pricing algorithm allows a firm to respond to high-frequency demand shocks.
- Third party chooses the *design* to
 - maximize the incremental value of adoption (as that maximizes expected demand, for a given fee).
 - make adoptions strategic complements (which encourages more adoptions).
- Monopoly price function is not optimal because
 - while it maximizes the profit when adopting (given rival firms adopt)
 - it makes it very profitable not to adopt (given rival firms adopt and thus set a very high average price).

Third Party Pricing

Outsourcing

- Design challenge: *How to make the pricing algorithm profitable to adopt without making it exploitable by a firm that does not adopt?*
- Third party pricing algorithm has price *respond* to the high-frequency demand shock so as to maximize joint profits - makes it profitable when both firms adopt.
- Average price is not higher - not exploitable by a non-adopting firm.
- Price is more variable than when pricing algorithm is not outsourced - harms consumers.



Concluding Remarks

- Algorithmic pricing can deliver efficiencies but also raises some concerns related to competition.
- Does current competition law adequately address these concerns?
- How might competition law be modified to address them?