

# Lecture 15

Markets, Mechanisms and Machines

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# Online advertising

- Many online platforms use economic mechanisms to determine market outcomes
  - Online advertising
  - Online search "verticals" (travel, jobs, real estate)
  - Online retail



# Features of online marketplaces

- Dynamic environments
  - Composition of the marketplace, demand and supply change
- Limited information available to market designers
  - Have to rely on inference to make allocations and predict behavior of players
- Difficult for bidders to properly form expectations about the future
  - Need to rely on adaptive learning
  - May have much more information relative to static environments

# Selling advertising slots

- Traditional model: direct negotiation with advertisers
  - **Pro's :** Predictable outcomes and allocations; direct relationship between platform and advertisers
  - **Con's :** Advertiser behavior cannot respond to changing demand; hard to change prices and allocations if tastes or volumes change
- Market-based model: auction or other similar market mechanism that “automates” pricing and allocations
  - **Pro's :** Responds to changing demand through competition of advertisers; more inclusive for new or smaller advertisers
  - **Con's :** Market participants need to know how to play; harder to predict the market

# Prediction of online advertising marketplaces in equilibrium

- **Assumption:** bidders know their objective functions and can optimize them.
- **Equilibrium:** bidder's bid must be best response to competing bid distribution.
- **Observation:** competing bids distribution is observed in data.
- Approach to recover primitives:
  1. given bid distribution, solve for bid strategy
  2. invert bid strategy to get bidder's value for item from bid.
- **Solution:** using values predict outcome of new mechanism

# Prediction of online advertising marketplaces in equilibrium

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Internal preview Help improve Bing

# Auction for keywords

- The ads are allocated and priced for each user query
- Pricing and allocation decisions are combined and fully automated by an “auction”:
  - Real-time
  - Pay per click
  - Score-weighted
  - Generalized second price (GSP)
  - With possible reserve prices and thresholds

# Allocating and pricing multiple heterogeneous objects



Need to allocate and price multiple heterogenous objects (slots) at the same time with little computation

# N-pirate problem

- Need to allocate and price multiple heterogenous objects (slots) at the same time with little computation
- Imagine  $N$  pirates that need to split a heterogeneous treasure
- If one pirate is accused of claiming an unfair share of the treasure, he gets thrown overboard
- Easiest to imagine solution for 2 pirates and generalize
- Leads to the envy free refinement of Nash equilibrium in multi-unit auction: no bidder benefits from switching bid with any other bidder

# GSP auction

- Components of the auction
  - Bids of bidders
  - Payment per click
  - Model for user clicks (multiplicative)
    - Position effect
    - Advertiser effect (score)
  - GSP payment and allocation rule:
    - bidders ranked by score-weighted bids
    - expected payment of each bidder proportional to score-weighted bid of the bidder ranked below

# GSP auction

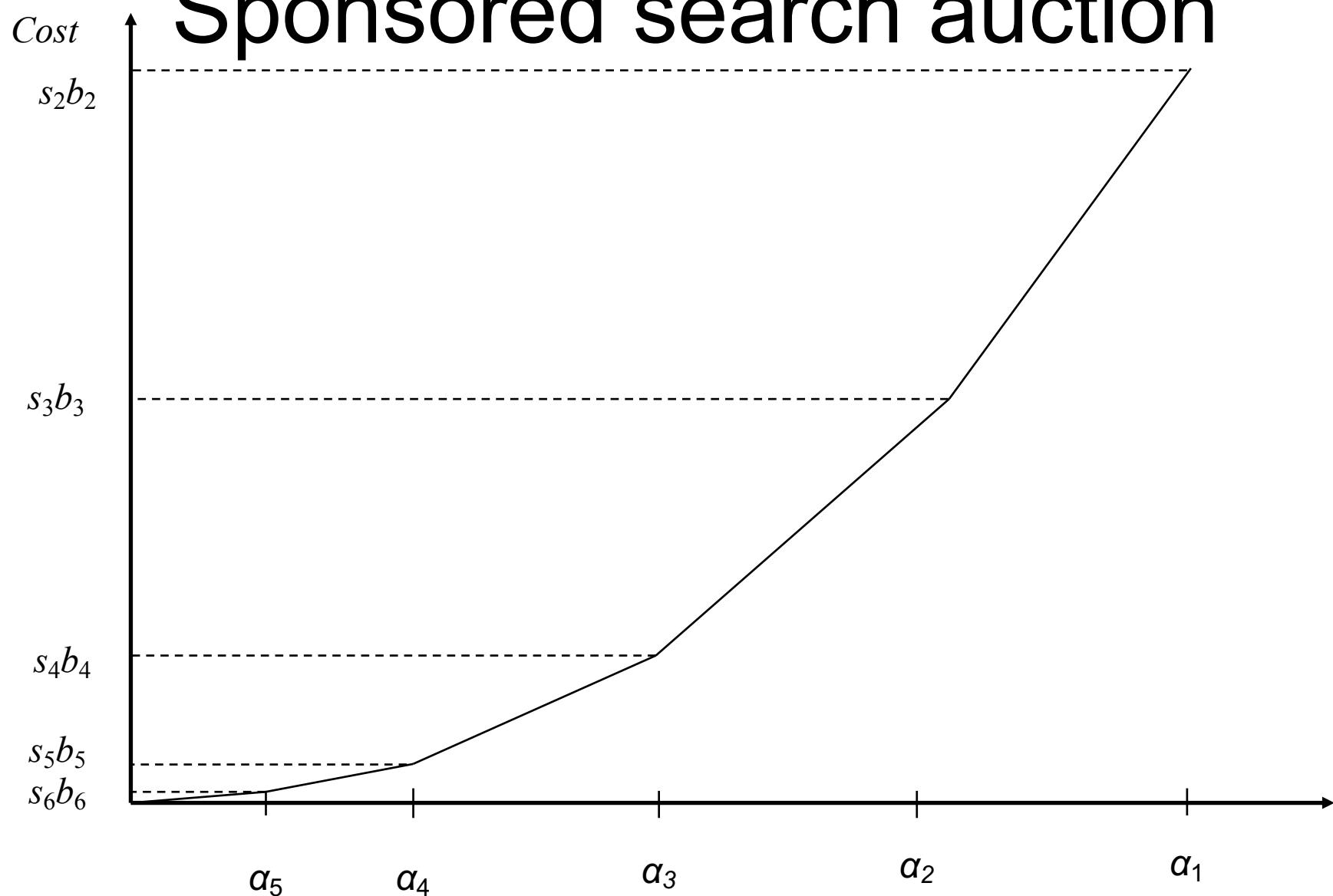
- Example: 4 bidders, 3 slots, reserve price  $R$

<i>Bid</i>	<i>Score</i>	<i>Slot clickthrough rate</i>	<i>Score-weighted bid</i>	<i>Price</i>	<i>Expected payment per search</i>
$b_1$	$s_1$	$\alpha_1$	$s_1 b_1$	$s_2 b_2 / s_1$	$\alpha_1 s_2 b_2$
$b_2$	$s_2$	$\alpha_2$	$s_2 b_2$	$s_3 b_3 / s_3$	$\alpha_2 s_3 b_3$
$b_3$	$s_3$	$\alpha_3$	$s_3 b_3$	$\min \{s_4 b_4 / s_3, R\}$	$\alpha_3 \min \{s_4 b_4, s_3 R\}$
$b_4$	$s_4$	0	$s_4 b_4$	0	0

# Sponsored search auction

- Assume that bidders can interact with high frequency: by changing bids sufficiently can learn own and opponent scores as well as bids
- This game has complete information
- Moreover, with high frequency assumption can focus on the *ex-post refinement*: bidders are happy with how they bid after they learned what their opponents bids
- Best response constructed by considering incremental cost per click: how much more bidder  $i$  needs to pay to get an extra click?

# Sponsored search auction



- Cost of bidder  $i$  as a function of her score-weighted bid
- It is a convex function: look at the marginal cost

# Sponsored search auction

- In a Nash equilibrium with ex-post refinement

$$\alpha_i \left( v_i - \frac{s_k b_k}{s_1} \right) \geq \alpha_l \left( v_i - \frac{s_m b_m}{s_1} \right), \quad l = m - 1 \geq i = k - 1$$
$$\alpha_i \left( v_i - \frac{s_k b_k}{s_1} \right) \geq \alpha_l \left( v_i - \frac{s_m b_m}{s_1} \right), \quad i + 1 = k \geq m = l + 1.$$

or

$$\min_{l < i} \frac{s_l b_l \alpha_i - s_{i+1} b_{i+1} \alpha_l}{\alpha_l - \alpha_i} \geq s_i v_i \geq \max_{l > j} \frac{s_{i+1} b_{i+1} \alpha_j - s_{l+1} b_{l+1} \alpha_l}{\alpha_i - \alpha_l}.$$

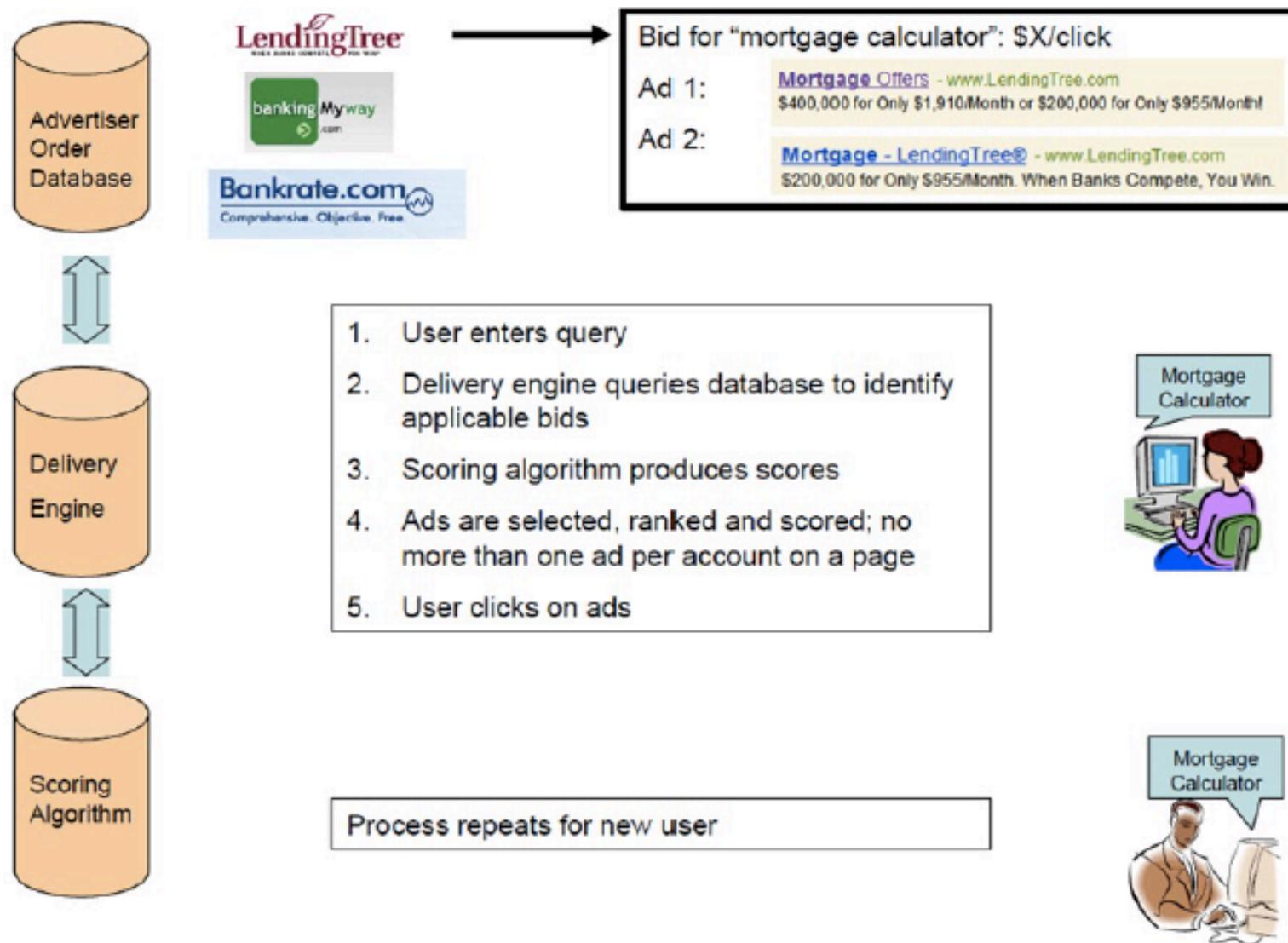
- Each bidder sets her bid to have score weighted value between marginal cost needed to decrease and increase clicks at the margin
- There are multiple Nash equilibria

# Sponsored search auction

- Edelman, Ostrovsky, Schwartz (2007) show that equilibrium always exists
- There is an equilibrium where bidders pay Vickrey payoffs
- This equilibrium generates the lowest revenue to the auctioneer
- However, this auction is not truthful: bidders have incentive to shade their bids

# Sponsored search auction

- In reality users arrive at high rate with little feedback to bidders



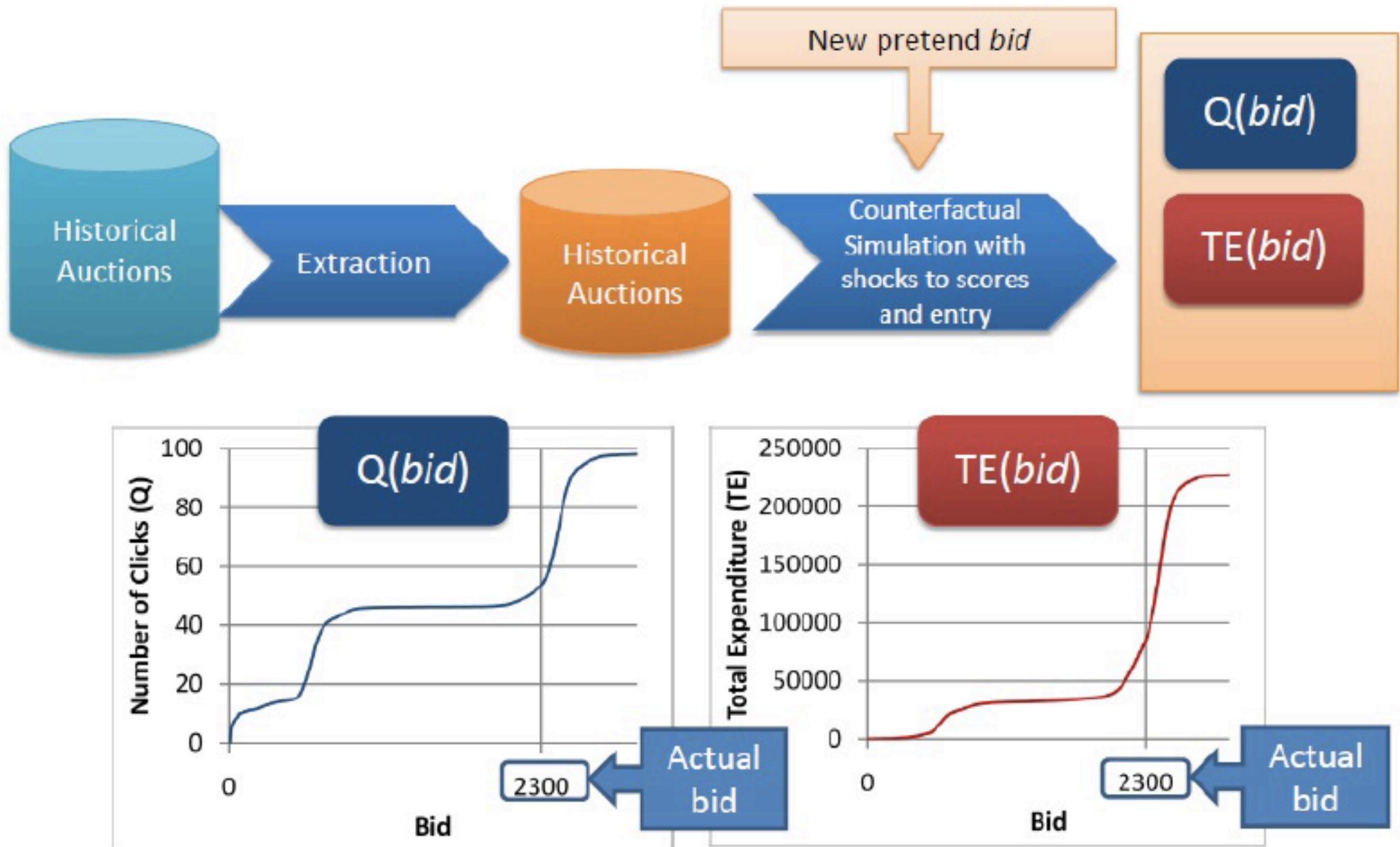
# Sponsored search auction

- Bidders do not observe realization of scores
  - In fact, scores are generated by proprietary prediction algorithm
- Can model bidders responding to expected outcome over many user queries
- Bidders characterized by values per click (VPC)
- Expected utility of bidder  $i$  is

$$\text{Utility}(\text{bid}_i; \text{VPC}_i) = \text{VPC}_i \text{Clicks}_i(\text{bid}_i) - \text{Payment}_i(\text{bid}_i)$$

- $\text{Clicks}_i(\text{bid}_i)$  and  $\text{Payment}_i(\text{bid}_i)$  are expected allocation and payment rule (with score uncertainty)

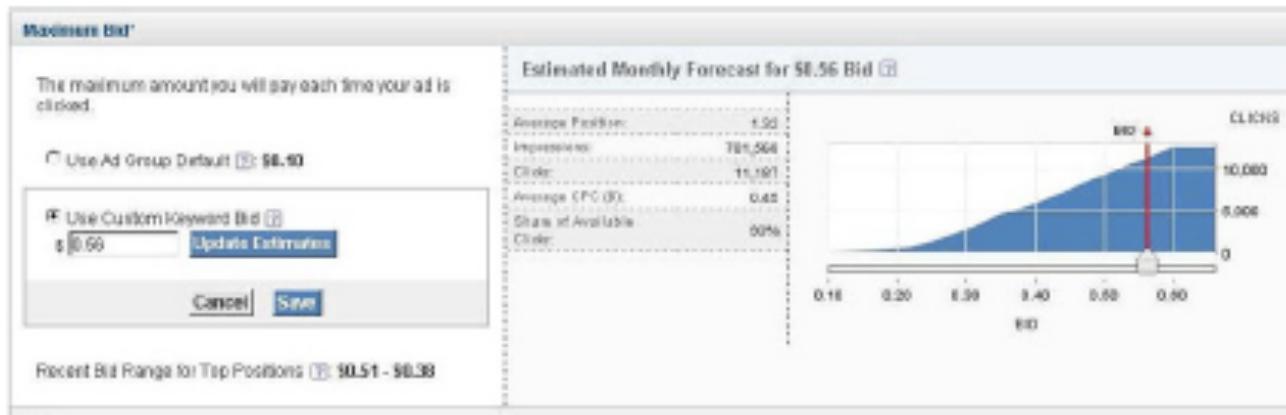
# Modeling the bidders



# Bid optimization

- Keep increasing the bid until marginal cost exceeds value

$$\text{Utility}(\text{bid}_i; \text{VPC}_i) = \text{VPC}_i \text{Clicks}_i(\text{bid}_i) - \text{Payment}_i(\text{bid}_i)$$



$$\text{VPC}_i = (\partial \text{Payment}_i(\text{bid}_i) / \partial \text{bid}_i) / (\partial \text{Click}_i(\text{bid}_i) / \partial \text{bid}_i)$$

- Note: can use similar approach if there are other objectives or there are budget constraints

# Bid optimization

The Kenshoo website features a dark header with the company logo and navigation links for 'Menu' and 'Contact Us'. Below the header, there's a large 'SEARCH' section with a stylized yellow 'X' icon. The text describes it as a premium solution for managing, automating, and optimizing search engine marketing campaigns at scale. It also mentions best-in-class portfolio bid management for various business goals like ROI, lead generation, or branding.

Kenshoo

PRODUCTS & SOLUTIONS CHANNELS

SEARCH

Premium solution for managing, automating, and optimizing search engine marketing campaigns at scale

Best-in-class portfolio bid management to optimize for almost any business goal - including ROI, lead generation, or branding

The Adobe Media Optimizer page is part of the Adobe Marketing Cloud. It features a green header with the 'AMC' logo and the text 'ADOBE MARKETING CLOUD / Adobe Media Optimizer'. Below the header, there's a large graphic of a piano keyboard with a play button icon. The text 'Find the audience i' is visible, followed by a blue banner with the text 'We've added dynamic creative optimization capabilities w'.

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