

Matching Ads to Users: Performance analysis of an Advertising Search Engine

Miguel Alcobendas, Naji Shajarisales

Yahoo! Research - Carnegie Mellon University

April 27, 2019

Introduction:

- Sponsored Search Ads



Web Images Video News More ▾ Anytime ▾

Also try: [flowers delivery](#), [spring flowers](#), [pictures of flowers](#)

Ads related to: flowers

1-800-FLOWERS - Same Day Delivery Available

www.1800flowers.com

1-800-Flowers.com Is The Best Place For **Flowers** & Gifts For Any Occasion!
Satisfaction Guarantee · Truly Original Gifts · Same Day Delivery
Types: Roses, Lilies, Orchids, Carnations, Gift Baskets

Birthday Flowers & Gifts

Bouquets & Gifts at 1-800 Flowers!
Send Your Best Birthday Wishes.

Get Well Flowers & Gifts

Send Flowers Directly to
Home or Hospital.

1

FTD® Fresh Flowers & Gifts - Up To 33% Off Flower Delivery

www.ftd.com/FreshFlower/FlowerDelivery

Shop FTD® Today & Send Fresh **Flowers** & Gifts. Get Up To 33% Off Your Order!
Same Day Delivery · Local Florist Delivery · Farm Fresh Flowers
Types: Roses, Lilies, Orchids, Tulips, Sunflowers, Irises

2

Teleflora® Flowers - \$10 Off Same Day Delivery

www.teleflora.com/Flowers/Delivery

Our Flower Arrangements Are Hand-Designed & Delivered by Florists. Order Now!
Same-Day Delivery · Satisfaction Guaranteed · Fresh Flowers in a Vase
Types: Roses, Lilies, Orchids, Daisies, Carnations, Sunflowers

Get Well Flowers - Send a Funeral Bouquet - Shop Birthday Flowers

3

\$19.99 - Flowers Same Day - Express Same Day Delivery

www.fromyouflowers.com

fromyouflowers.com has been visited by 10K+ users in the past month
Hand Delivery in 4 Hours - 20% Off All Items - "Best Value **Flowers**" - CBS News!
20% Off All Items - Same Day Delivery · From \$19.99
Types: Birthday, Love and Romance, Sympathy, Get Well, Congratulations

\$19.99 Flowers - Birthday Flowers & Gifts - Sympathy & Funeral - Get Well Wishes

4

Ads



Flowers: Pink
Roses -

From You Flow..
\$31.99



Smiles &
Sunshine With

ProFlowers
\$19.99



Flower Delivery:
Loving Lily &...

From You Flow..
\$27.99



Flowers -
Stunning

From You Flow..
\$35.99



Smiles And
Sunshine -...

ProFlowers
\$29.99



All The Frills
With Glass...

ProFlowers
\$39.98



Introduction:



- Sponsored Search Ads

Web Images Video News More ▾ Anytime ▾

Also try: [flowers delivery](#), [spring flowers](#), [pictures of flowers](#)

Ads related to: flowers

1-800-FLOWERS - Same Day Delivery Available

www.1800flowers.com

1-800-Flowers.com Is The Best Place For **Flowers** & Gifts For Any Occasion!
Satisfaction Guarantee · Truly Original Gifts · Same Day Delivery
Types: Roses, Lilies, Orchids, Carnations, Gift Baskets

Birthday Flowers & Gifts

Bouquets & Gifts at 1-800 Flowers!
Send Your Best Birthday Wishes.

Get Well Flowers & Gifts

Send Flowers Directly to
Home or Hospital.

1

FTD® Fresh Flowers & Gifts - Up To 33% Off Flower Delivery

www.ftd.com/FreshFlower/FlowerDelivery

Shop FTD® Today & Send Fresh **Flowers** & Gifts. Get Up To 33% Off Your Order!
Same Day Delivery · Local Florist Delivery · Farm Fresh Flowers
Types: Roses, Lilies, Orchids, Tulips, Sunflowers, Irises

2

Teleflora® Flowers - \$10 Off Same Day Delivery

www.teleflora.com/Flowers/Delivery

Our Flower Arrangements Are Hand-Designed & Delivered by Florists. Order Now!
Same-Day Delivery · Satisfaction Guaranteed · Fresh Flowers in a Vase
Types: Roses, Lilies, Orchids, Daisies, Carnations, Sunflowers

Get Well Flowers - Send a Funeral Bouquet - Shop Birthday Flowers

3

\$19.99 - Flowers Same Day - Express Same Day Delivery

www.fromyouflowers.com

fromyouflowers.com has been visited by 10K+ users in the past month
Hand Delivery in 4 Hours - 20% Off All Items - "Best Value **Flowers**" - CBS News!
20% Off All Items - Same Day Delivery · From \$19.99
Types: Birthday, Love and Romance, Sympathy, Get Well, Congratulations

\$19.99 Flowers - Birthday Flowers & Gifts - Sympathy & Funeral - Get Well Wishes

4

Ads



Flowers: Pink
Roses -
From You Flow..
\$31.99



Smiles &
Sunshine With
ProFlowers
\$19.99



Flower Delivery:
Loving Lily &...
From You Flow..
\$27.99



Flowers -
Stunning
From You Flow..
\$35.99



Smiles And
Sunshine -...
ProFlowers
\$29.99



All The Frills
With Glass...
ProFlowers
\$39.98

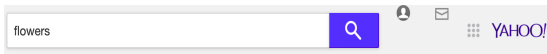


- Allocation Rule (GSP)

- Users

- Advertisers

Introduction:



- Sponsored Search Ads

Also try: [flowers delivery](#), [spring flowers](#), [pictures of flowers](#)

Ads related to: flowers

1-800-FLOWERS - Same Day Delivery Available

www.1800flowers.com

1-800-Flowers.com Is The Best Place For **Flowers** & Gifts For Any Occasion!
Satisfaction Guarantee · Truly Original Gifts · Same Day Delivery
Types: Roses, Lilies, Orchids, Carnations, Gift Baskets

Birthday Flowers & Gifts

Bouquets & Gifts at 1-800 Flowers!
Send Your Best Birthday Wishes.

Get Well Flowers & Gifts

Send Flowers Directly to
Home or Hospital.

1

FTD® Fresh Flowers & Gifts - Up To 33% Off Flower Delivery

www.ftd.com/FreshFlower/FlowerDelivery

Shop FTD® Today & Send Fresh **Flowers** & Gifts. Get Up To 33% Off Your Order!
Same Day Delivery · Local Florist Delivery · Farm Fresh Flowers
Types: Roses, Lilies, Orchids, Tulips, Sunflowers, Irises

2

Teleflora® Flowers - \$10 Off Same Day Delivery

www.teleflora.com/Flowers/Delivery

Our Flower Arrangements Are Hand-Designed & Delivered by Florists. Order Now!
Same-Day Delivery · Satisfaction Guaranteed · Fresh Flowers in a Vase
Types: Roses, Lilies, Orchids, Daisies, Carnations, Sunflowers

Get Well Flowers - Send a Funeral Bouquet - Shop Birthday Flowers

3

\$19.99 - Flowers Same Day - Express Same Day Delivery

www.fromyouflowers.com

fromyouflowers.com has been visited by 10K+ users in the past month
Hand Delivery in 4 Hours - 20% Off All Items - "Best Value **Flowers**" - CBS News!
20% Off All Items - Same Day Delivery · From \$19.99
Types: Birthday, Love and Romance, Sympathy, Get Well, Congratulations

\$19.99 Flowers - Birthday Flowers & Gifts - Sympathy & Funeral - Get Well Wishes

4

Ads



Flowers: Pink
Roses -
From You Flow..
\$31.99



Smiles &
Sunshine With
ProFlowers
\$19.99



Flower Delivery:
Loving Lily &...
From You Flow..
\$27.99



Flowers -
Stunning
From You Flow..
\$35.99



Smiles And
Sunshine -...
ProFlowers
\$29.99



All The Frills
With Glass...
ProFlowers
\$39.98



- Allocation Rule (GSP)
- Users
- Advertisers
- Different rules impact
- User engagement
- Short vs long-term revenue

Introduction

- Objectives & Contributions:
 - Study the bias of Yahoo's search engine towards (at scale):
 - Allocation maximizing users' welfare
 - Allocation maximizing value-per-click of advertisers
 - Relationship between users' perceived ad quality and value-per-click of advertisers

Introduction

- **Objectives & Contributions:**

- Study the bias of Yahoo's search engine towards (at scale):
 - Allocation maximizing users' welfare
 - Allocation maximizing value-per-click of advertisers
- Relationship between users' perceived ad quality and value-per-click of advertisers

- **Problem:** Marketplace researchers do not observe:

- Long-term impact of different allocation rules (tempting rules)
- Value-per-click of advertisers (allocation rule is not truthful)
- Perceived quality of ads by users (ad-quality and position effect)

Introduction

- **Objectives & Contributions:**

- Study the bias of Yahoo's search engine towards (at scale):
 - Allocation maximizing users' welfare
 - Allocation maximizing value-per-click of advertisers
- Relationship between users' perceived ad quality and value-per-click of advertisers

- **Problem:** Marketplace researchers do not observe:

- Long-term impact of different allocation rules (tempting rules)
- Value-per-click of advertisers (allocation rule is not truthful)
- Perceived quality of ads by users (ad-quality and position effect)

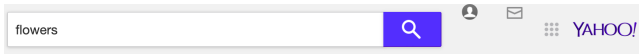
- **Data:**

- Yahoo's search engine (2017)
 - Production logs
 - Experiment (Identification)
- Displayed Queries: "cheap flight", "map", "game", "United Airlines", "100 Popular Keywords"

Rest of the Presentation

- **Allocation & Pricing Rule: Generalized Second Price Auction**
- Inference of Value-per-Click of Advertisers
- Inference of Perceived Ad-Quality by Users
- How to compare sequences of ads: Optimal Matching
- Results
- Conclusions

Generalized Second Price Auction



Web Images Video News More ▾ Anytime ▾

Also try: [flowers delivery](#), [spring flowers](#), [pictures of flowers](#)

Ads related to: flowers

1-800-FLOWERS - Same Day Delivery Available

www.1800flowers.com

1-800-Flowers.com Is The Best Place For **Flowers** & Gifts For Any Occasion!
Satisfaction Guarantee · Truly Original Gifts · Same Day Delivery
Types: Roses, Lilies, Orchids, Carnations, Gift Baskets

Birthday Flowers & Gifts

Bouquets & Gifts at 1-800 Flowers!
Send Your Best Birthday Wishes.

Get Well Flowers & Gifts

Send Flowers Directly to
Home or Hospital.

1

FTD® Fresh Flowers & Gifts - Up To 33% Off Flower Delivery

www.ftd.com/FreshFlower/FlowerDelivery

Shop FTD® Today & Send Fresh **Flowers** & Gifts. Get Up To 33% Off Your Order!
Same Day Delivery · Local Florist Delivery · Farm Fresh Flowers
Types: Roses, Lilies, Orchids, Tulips, Sunflowers, Irises

2

Teleflora® Flowers - \$10 Off Same Day Delivery

www.teleflora.com/Flowers/Delivery

Our Flower Arrangements Are Hand-Designed & Delivered by Florists. Order Now!
Same-Day Delivery · Satisfaction Guaranteed · Fresh Flowers in a Vase
Types: Roses, Lilies, Orchids, Daisies, Carnations, Sunflowers

3

\$19.99 - Flowers Same Day - Express Same Day Delivery

www.fromyouflowers.com

fromyouflowers.com has been visited by 10K+ users in the past month.
Hand Delivery in 4 Hours - 20% Off All Items - "Best Value **Flowers**" - CBS News!
20% Off All Items - Same Day Delivery - From \$19.99

Types: Birthday, Love and Romance, Sympathy, Get Well, Congratulations

\$19.99 Flowers - Birthday Flowers & Gifts - Sympathy & Funeral - Get Well Wishes

4

Ads



Flowers: Pink
Roses -
From You Flow..
\$31.99



Smiles &
Sunshine With
ProFlowers
\$19.99



Flower Delivery:
Loving Lily &...
From You Flow..
\$27.99



Flowers -
Stunning
From You Flow..
\$35.99



Smiles And
Sunshine -...
ProFlowers
\$29.99



All The Frills
With Glass...
ProFlowers
\$39.98



Generalized Second Price Auction

Allocation Mechanism

- \mathcal{J} advertising **slots** in the search results page (5 slots in desktop max)
- \mathcal{I} **advertisers** $>$ \mathcal{J}
- Each $i \in \mathcal{I}$ places a per **click bid** b_i on a single search **Keyword**
- Yahoo's search engine assigns a **scoring factor** to advertisers (s_i)
 - Click probability of ad i appearing in position 1 ($s_i = Pr_{i1}$)
 - Squashing factor ($s_i = Pr_{i1}^\theta$ where $\theta \geq 0$)
 - Coarsening - less accurate estimator for "clickability" (e.g. no gender)different scoring rule may impact revenue and/or ranking
- Advertisers are ranked by their **rank-score** q_i

$$q_i = \underbrace{b_i}_{\text{Advertiser}} \times \underbrace{s_i}_{f(\text{Clickability})}$$

Generalized Second Price Auction

Pricing Rule

- Advertiser i in position j only pays if user clicks
- **Payment:** Cost-per-click is the minimal bid i has to place to keep its position

$$c_{ij}(b) = \frac{s_{\pi(j+1)} \cdot b_{\pi(j+1)}}{s_i} \mathbb{1}[j \in \mathcal{J}]$$

where $\pi(j+1)$ denotes the advertiser that is located in position $j+1$

Generalized Second Price Auction

Example 1

$$q_i = s_i \times b_i$$

$$q_a = 0.07 \times 1$$

$$q_b = 0.05 \times 1$$

$$q_c = 0.025 \times 1$$

$$q_d = 0.01 \times 1$$

$$q_e = 0.001 \times 1$$

The screenshot shows a Yahoo! search results page for the query "flowers". The search bar at the top contains "flowers" and a magnifying glass icon. Below the search bar are navigation links for "Web", "Images", "Video", "News", "More", and "Anytime".

Below the navigation links, there is a section "Also try: flowers delivery, spring flowers, pictures of flowers".

The main content area displays "Ads related to: flowers". There are four ads highlighted with colored boxes and numbered 1 through 4:

- Ad 1 (Red box):** "1-800-FLOWERS - Same Day Delivery Available". URL: www.1800flowers.com. Description: "1-800-Flowers.com Is The Best Place For Flowers & Gifts For Any Occasion! Satisfaction Guarantee · Truly Original Gifts · Same Day Delivery". Types: "Roses, Lilies, Orchids, Carnations, Gift Baskets". It features two sub-sections: "Birthday Flowers & Gifts" (Bouquets & Gifts at 1-800 Flowers! Send Your Best Birthday Wishes.) and "Get Well Flowers & Gifts" (Send Flowers Directly to Home or Hospital.). Price: "\$31.99".
- Ad 2 (Blue box):** "FTD® Fresh Flowers & Gifts - Up To 33% Off Flower Delivery". URL: www.ftd.com/FreshFlower/FlowerDelivery. Description: "Shop FTD® Today & Send Fresh Flowers & Gifts. Get Up To 33% Off Your Order! Same Day Delivery · Local Florist Delivery · Farm Fresh Flowers". Types: "Roses, Lilies, Orchids, Tulips, Sunflowers, Irises". Price: "\$27.99".
- Ad 3 (Purple box):** "Teleflora® Flowers - \$10 Off Same Day Delivery". URL: www.teleflora.com/Flowers/Delivery. Description: "Our Flower Arrangements Are Hand-Designed & Delivered by Florists. Order Now! Same-Day Delivery · Satisfaction Guaranteed · Fresh Flowers in a Vase". Types: "Roses, Lilies, Orchids, Daisies, Carnations, Sunflowers". It features a sub-section: "Get Well Flowers - Send a Funeral Bouquet - Shop Birthday Flowers". Price: "\$27.99".
- Ad 4 (Orange box):** "\$19.99 - Flowers Same Day - Express Same Day Delivery". URL: www.fromyouflowers.com. Description: "fromyouflowers.com has been visited by 10K+ users in the past month. Hand Delivery in 4 Hours - 20% Off All Items - 'Best Value Flowers' - CBS News! 20% Off All Items - Same Day Delivery - From \$19.99". Types: "Birthday, Love and Romance, Sympathy, Get Well, Congratulations". Price: "\$19.99".

On the right side of the page, there is an "Ads" section with a grid of flower images and descriptions. The descriptions include "Flowers: Pink Roses - From You Flow.. \$31.99", "Smiles & Sunshine With ProFlowers \$19.99", "Flower Delivery: Loving Lily &... From You Flow.. \$27.99", "Flowers - Stunning From You Flow.. \$39.99", "Smiles And Sunshine - ... ProFlowers \$29.99", and "All The Frills With Glass... ProFlowers \$39.98".

Generalized Second Price Auction

Example 1

$$q_i = s_i \times b_i$$

$$q_a = 0.07 \times 1$$

$$c_{a,1} = \frac{0.05 \times 1}{0.07} = 0.7$$

$$q_b = 0.05 \times 1$$

$$c_{b,2} = \frac{0.025 \times 1}{0.05} = 0.5$$

$$q_c = 0.025 \times 1$$

$$c_{c,3} = \frac{0.01 \times 1}{0.025} = 0.4$$

$$q_d = 0.01 \times 1$$

$$c_{d,4} = \frac{0.001 \times 1}{0.01} = 0.1$$

$$q_e = 0.001 \times 1$$



Also try: [flowers delivery](#), [spring flowers](#), [pictures of flowers](#)

Ads related to: flowers

1-800-FLOWERS - Same Day Delivery Available

www.1800flowers.com

1-800-Flowers.com Is The Best Place For **Flowers** & Gifts For Any Occasion!
Satisfaction Guarantee · Truly Original Gifts · Same Day Delivery
Types: Roses, Lilies, Orchids, Carnations, Gift Baskets

1 Birthday Flowers & Gifts

Bouquets & Gifts at 1-800 Flowers!
Send Your Best Birthday Wishes.

1 Get Well Flowers & Gifts

Send Flowers Directly to
Home or Hospital.

FTD® Fresh Flowers & Gifts - Up To 33% Off Flower Delivery

www.ftd.com/FreshFlower/FlowerDelivery

Shop FTD® Today & Send Fresh **Flowers** & Gifts. Get Up To 33% Off Your Order!
Same Day Delivery · Local Florist Delivery · Farm Fresh Flowers
Types: Roses, Lilies, Orchids, Tulips, Sunflowers, Irises

Teleflora® Flowers - \$10 Off Same Day Delivery

www.teleflora.com/Flowers/Delivery

Our Flower Arrangements Are Hand-Designed & Delivered by Florists. Order Now!
Same-Day Delivery · Satisfaction Guaranteed · Fresh Flowers in a Vase
Types: Roses, Lilies, Orchids, Daisies, Carnations, Sunflowers

Get Well Flowers - Send a Funeral Bouquet - Shop Birthday Flowers

\$19.99 - Flowers Same Day - Express Same Day Delivery

www.fromyouflowers.com

fromyouflowers.com has been visited by 10K+ users in the past month
Hand Delivery in 4 Hours - 20% Off All Items - "Best Value **Flowers**" - CBS News!
20% Off All Items - Same Day Delivery - From \$19.99
Types: Birthday, Love and Romance, Sympathy, Get Well, Congratulations

[\\$19.99 Flowers - Birthday Flowers & Gifts](#) - [Sympathy & Funeral](#) - [Get Well Wishes](#)

Ads



Flowers: Pink
Roses -
From You Flow..
\$31.99



Smiles &
Sunshine With
ProFlowers
\$19.99



Flower Delivery:
Loving Lily &...
From You Flow..
\$27.99



Flowers -
Stunning
From You Flow..
\$39.99



Smiles And
Sunshine -...
ProFlowers
\$29.99



All The Frills
With Glass...
ProFlowers
\$39.98



Generalized Second Price Auction

Example 2

$$q_i = s_i \times b_i$$

$$q_a = 0.05 \times 2 = 0.10$$

$$q_b = 0.07 \times 1 = 0.07$$

flowers

Web Images Video News More Anytime

Also try: [flowers delivery](#), [spring flowers](#), [pictures of flowers](#)

Ads related to: flowers

1-800-FLOWERS - Same Day Delivery Available
www.1800flowers.com
1-800-Flowers.com Is The Best Place For **Flowers & Gifts** For Any Occasion!
Satisfaction Guarantee · Truly Original Gifts · Same Day Delivery
Types: Roses, Lilies, Orchids, Carnations, Gift Baskets

Birthday Flowers & Gifts Bouquets & Gifts at 1-800 Flowers! Send Your Best Birthday Wishes.	Get Well Flowers & Gifts Send Flowers Directly to Home or Hospital.
--	---

1

FTD® Fresh Flowers & Gifts - Up To 33% Off Flower Delivery
www.ftd.com/FreshFlower/FlowerDelivery
Shop FTD® Today & Send Fresh **Flowers & Gifts**. Get Up To 33% Off Your Order!
Same Day Delivery · Local Florist Delivery · Farm Fresh Flowers
Types: Roses, Lilies, Orchids, Tulips, Sunflowers, Irises

2

Teleflora® Flowers - \$10 Off Same Day Delivery
www.teleflora.com/Flowers/Delivery
Our Flower Arrangements Are Hand-Designed & Delivered by Florists. Order Now!
Same-Day Delivery · Satisfaction Guaranteed · Fresh Flowers in a Vase
Types: Roses, Lilies, Orchids, Daisies, Carnations, Sunflowers
Get Well Flowers - Send a Funeral Bouquet - Shop Birthday Flowers

3

\$19.99 - Flowers Same Day - Express Same Day Delivery
www.fromyouflowers.com
fromyouflowers.com has been visited by 10K+ users in the past month
Hand Delivery in 4 Hours - 20% Off All Items - "Best Value **Flowers**" - CBS News!
20% Off All Items - Same Day Delivery - From \$19.99
Types: Birthday, Love and Romance, Sympathy, Get Well, Congratulations
\$19.99 Flowers - **Birthday Flowers & Gifts** - **Sympathy & Funeral** - **Get Well Wishes**

4

Ads

Generalized Second Price Auction

- Truth-telling is **NOT** a dominant strategy for advertisers

Generalized Second Price Auction

- Truth-telling is **NOT** a dominant strategy for advertisers
- Expected profit of bidder i

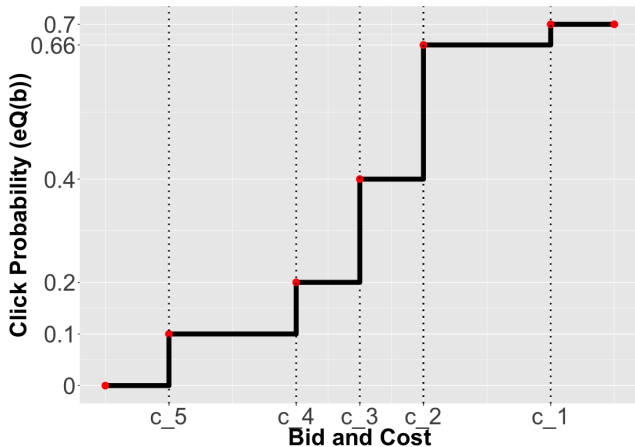
$$\pi_i(b; v_i) = (v_i - c_{i\sigma_i(b)}(b))eQ_i(b)$$

where

- v_i : Value-per-click of advertiser i (Unobserved)
- $c_{i\sigma_i(b)}(b)$: cost at position $\sigma_i(b)$
- $eQ_i(b)$: Allocation probability

Generalized Second Price Auction

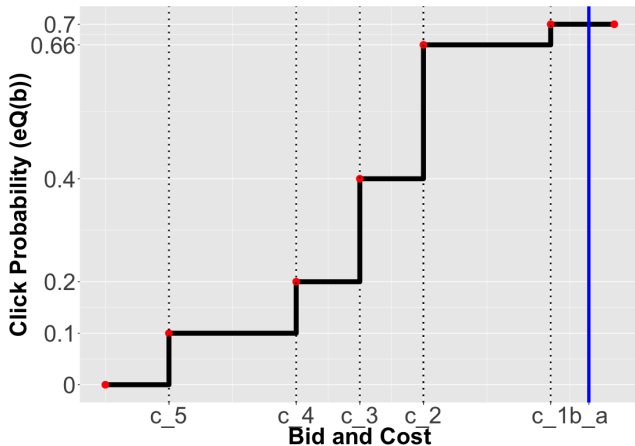
Truth-telling is NOT a dominant strategy



$$c_1 \gg c_2 \quad 0.7 \approx 0.66$$

Generalized Second Price Auction

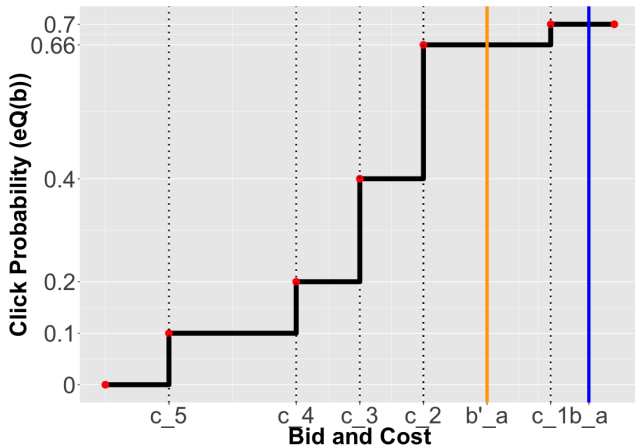
Truth-telling is NOT a dominant strategy



$$\pi_a(b_a; v_a) = (v_a - c_1(b))0.7$$

Generalized Second Price Auction

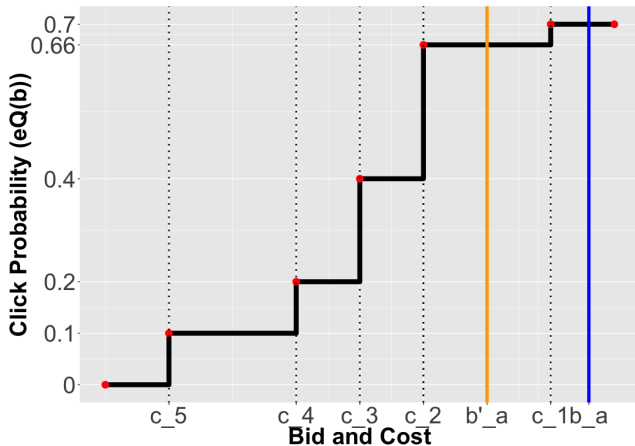
Truth-telling is NOT a dominant strategy



$$\pi_a(b'_a; v_a) = (v_a - c_2(b'_a))0.66$$

Generalized Second Price Auction

Truth-telling is NOT a dominant strategy



$$\pi_a(b'_a; v_a) = (v_a - c_2(b'_a))0.66 > \pi_a(b_a; v_a) = (v_a - c_1(b_a))0.7$$

- Allocation & Pricing Rule: Generalized Second Price Auction
- **Inference of Value-per-Click of Advertisers**
- Inference of Perceived Ad-Quality by Users
- How to compare sequences of ads: Optimal Matching
- Results
- Conclusions

Advertiser's Value-per-Click

- Truth-telling is **NOT** a dominant strategy \Rightarrow Infer Value-per-click
- Infer **advertisers' value-per-click** using the concept of no-regret learning (Nekipelov, Syrgkanis, and Tardos (2015))
 - Experimenting with bids as off-equilibrium (market exploration)
 - Weaker assumptions than Nash equilibrium
 - Assume that bidders are learning over time the strategy that maximizes their expected profits

Advertiser's Value-per-Click

- We can express the expected utility of bidder i at t as

$$\pi_{it}(b_{it}, v_i) = v_i \underbrace{eQ_{it}(b_{it})}_{\text{Click Probability}} - \underbrace{eC_{it}(b_{it})}_{\text{ExpectedCost}}$$

where at each time t bidder i bids b_{it}

Advertiser's Value-per-Click

- We can express the expected utility of bidder i at t as

$$\pi_{it}(b_{it}, v_i) = v_i \underbrace{eQ_{it}(b_{it})}_{\text{Click Probability}} - \underbrace{eC_{it}(b_{it})}_{\text{ExpectedCost}}$$

where at each time t bidder i bids b_{it}

- **Rationalizable Set:** A pair (ϵ_i, v_i) of value v_i and an error ϵ_i is a rationalizable pair for player i if it satisfies the below equation.

$$\forall b' \in \mathcal{B} : \frac{1}{T} \sum_{t=1}^T \pi_{it}(b_{it}, v_i) \geq \frac{1}{T} \sum_{t=1}^T \pi_{it}(b', v_i) - \epsilon_i$$

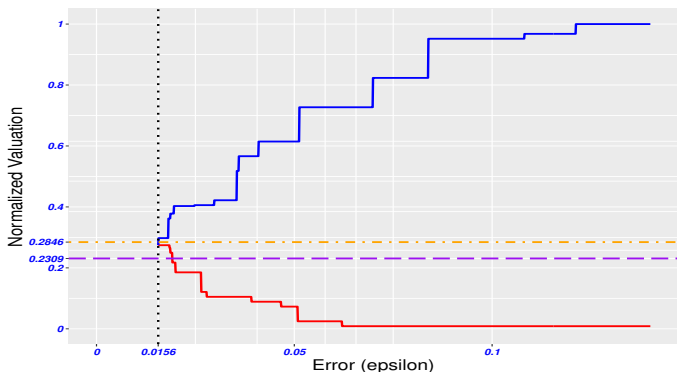
where b' corresponds to a fixed bid from the bid sequence $\{b_{it}\}_{t=1}^T$

Nash Equilibrium Condition $\rightarrow \epsilon_i = 0 \forall i$

Advertiser's Value-per-Click

- For any error ϵ , the set of values that belongs to the **rationalizable set** is

$$v_j \in \left[\max_{b': \Delta eQ(b'_j) < 0} \frac{eC_{it}(b'_j) - eC_{it}(b_{it}) + \epsilon}{eQ_{it}(b'_j) - eQ_{it}(b_{it})}, \min_{b': \Delta eQ(b'_j) > 0} \frac{eC_{it}(b'_j) - eC_{it}(b_{it}) + \epsilon}{eQ_{it}(b'_j) - eQ_{it}(b_{it})} \right]$$



- Value-per-click (v_j):** the smallest rationalizable error ϵ can be viewed as a point prediction for the value of the advertiser

- Allocation & Pricing Rule: Generalized Second Price Auction
- Inference of Value-per-Click of Advertisers
- **Inference of Perceived Ad-Quality by Users**
- How to compare sequences of ads: Optimal Matching
- Results
- Conclusions

Users' Perceived Ad-Quality

flowers

Web Images Video News More ▾ Anytime ▾

Also try: [flowers delivery](#), [spring flowers](#), [pictures of flowers](#)

Ads related to: flowers

1 **1-800-FLOWERS - Same Day Delivery Available**
[www.1800flowers.com](#)
1-800-Flowers.com Is The Best Place For **Flowers & Gifts** For Any Occasion!
Satisfaction Guarantee · Truly Original Gifts · Same Day Delivery
Types: Roses, Lilies, Orchids, Carnations, Gift Baskets

Birthday Flowers & Gifts Bouquets & Gifts at 1-800 Flowers! Send Your Best Birthday Wishes.	Get Well Flowers & Gifts Send Flowers Directly to Home or Hospital.
--	--

2 **FTD® Fresh Flowers & Gifts - Up To 33% Off Flower Delivery**
[www.ftd.com/FreshFlower/FlowerDelivery](#)
Shop FTD® Today & Send Fresh **Flowers & Gifts**. Get Up To 33% Off Your Order!
Same Day Delivery · Local Florist Delivery · Farm Fresh Flowers
Types: Roses, Lilies, Orchids, Tulips, Sunflowers, Irises

3 **Teleflora® Flowers - \$10 Off Same Day Delivery**
[www.teleflora.com/Flowers/Delivery](#)
Our Flower Arrangements Are Hand-Designed & Delivered by Florists. Order Now!
Same-Day Delivery · Satisfaction Guaranteed · Fresh Flowers in a Vase
Types: Roses, Lilies, Orchids, Daisies, Carnations, Sunflowers
Get Well Flowers - Send a Funeral Bouquet - Shop Birthday Flowers

4 **\$19.99 - Flowers Same Day - Express Same Day Delivery**
[www.fromyouflowers.com](#)
fromyouflowers.com has been visited by 10K+ users in the past month
Hand Delivery in 4 Hours - 20% Off All Items - "Best Value **Flowers**" - CBS News!
20% Off All Items · Same Day Delivery · From \$19.99
Types: Birthday, Love and Romance, Sympathy, Get Well, Congratulations
\$19.99 Flowers - Birthday Flowers & Gifts - Sympathy & Funeral - Get Well Wishes

Ads

- Disentangle ad effect from position effect
- The model accommodates multiple clicks and unobserved correlation across ads within the impression (Jiziorski and Segal (2015)).

Users' Perceived Ad-Quality

- **Utility-maximizing model** (allow counterfactuals)
- Assuming **no-unobserved correlation** among ads, the user's value of clicking on ad a located in position n

$$U_{ian} = u_a(x) - f_n + \epsilon_i$$

where

- $u_a(x)$: Perceived utility of ad a with features x
 - f_n : Cost of position n (e.g. scrolling effort, attention)
 - ϵ_i : idiosyncratic shock
-
- Objective: Infer $u_{a(n)}(x)$ and $f_n \forall n, a$
 - $\epsilon \sim$ EV Type 1 Distribution - Logistic Model (Maximum likelihood)
 - $\epsilon \sim$ Normal Distribution - OLS
-
- **Identification**: Randomization of displayed ads

Users' Perceived Ad-Quality

- Assuming **unobserved correlation** among ads, the user's value of engaging with an impression

$$U_i(\mathcal{C}) = \left(\sum_{n \in \mathcal{C}} (u_{a(n)}(x))^{1+R} \right)^{1/(1+R)} - \sum_{n \in \mathcal{C}} f_n + \tau_i$$

where

- \mathcal{C} : set of clicked positions in impression
 - $u_{a(n)}(x)$: Perceived utility of ad a displayed in n with features x
 - f_n : Cost of position n (e.g. scrolling effort, attention)
 - $R \in (-1, \infty)$ captures unobserved correlation among ads in a keyword
 - τ_i : idiosyncratic shock
-
- Objective: Estimate $u_{a(n)}(x)$, f_n and $R \forall n, a$
 - Formulate problem as a finite-horizon **Markov Decision Process**
 - State Variables: displayed ads in an impression
 - Actions: clicks on ads, click on organic links, or conclude search

- Allocation & Pricing Rule: Generalized Second Price Auction
- Inference of Value-per-Click of Advertisers
- Inference of Perceived Ad-Quality by Users
- **How to compare sequences of ads: Optimal Matching**
- Results
- Conclusions

Optimal Matching

- How to compare sequences of ads: sponsored, rankings maximizing users' welfare and advertisers' value-per-click (**Optimal Matching**)
- The **optimal matching distance** equals the smallest number of operations needed to turn one sequence into another
- **Operations**: insertion, deletion, and substitution (cost)
- The higher the distance, the more dissimilar the ad sequences
- **Challenge**: size asymmetry of sequences

Optimal Matching

- **Example:** Compare impressions with users' optimal sequence

Table: Impression Ads

Position 1	<i>avf.com</i>
Position 2	<i>isw.com</i>
Position 3	<i>pow.com</i>

Table: Users' Optimal Sequence

Position 1	<i>cnn.com</i>
Position 2	<i>avf.com</i>
Position 3	<i>pow.com</i>
Position 4	<i>fij.com</i>
Position 5	<i>isw.com</i>
Position 6	<i>kks.com</i>

Optimal Matching

- In users' sequence, discard non-displayed ads with ranking below the worse ad in the impression

Table: Impression Ads

Position 1	<i>avf.com</i>
Position 2	<i>isw.com</i>
Position 3	<i>pow.com</i>

Table: Users' Optimal Sequence

Position 1	<i>cnn.com</i>
Position 2	<i>avf.com</i>
Position 3	<i>pow.com</i>
Position 4	<i>fij.com</i>
Position 5	<i>isw.com</i>
Position 6	<i>kks.com</i>

Optimal Matching

- In users' sequence, discard non-displayed ads with ranking below the worse ad in the impression (we do not care about the tail)

Table: Impression Ads

Position 1	<i>avf.com</i>
Position 2	<i>isw.com</i>
Position 3	<i>pow.com</i>

Table: Users' Optimal Sequence

Position 1	<i>cnn.com</i>
Position 2	<i>avf.com</i>
Position 3	<i>pow.com</i>
Position 4	<i>fij.com</i>
Position 5	<i>isw.com</i>

Optimal Matching

- Transformation 1 - Deletion. Remove non-displayed ads
- Edit cost: $+1 +1 = 2$

Table: Impression Ads

Position 1	<i>avf.com</i>
Position 2	<i>isw.com</i>
Position 3	<i>pow.com</i>

Table: Users' Optimal Sequence

Position 1	<i>cnn.com</i>
Position 2	<i>avf.com</i>
Position 3	<i>pow.com</i>
Position 4	<i>fij.com</i>
Position 5	<i>isw.com</i>

Optimal Matching

- Transformation 1 - Deletion. Remove non-displayed ads
- Edit cost: $+1 +1 = 2$

Table: Impression Ads

Position 1	<i>avf.com</i>
Position 2	<i>isw.com</i>
Position 3	<i>pow.com</i>

Table: Users' Optimal Sequence

Position 1	<i>avf.com</i>
Position 2	<i>pow.com</i>
Position 3	<i>isw.com</i>

Optimal Matching

- Transformation 2 - Substitution. *isw.com* by *pow.com*
- Edit cost: $2 + 2 = 4$

Table: Impression Ads

Position 1	<i>avf.com</i>
Position 2	<i>isw.com</i>
Position 3	<i>pow.com</i>

Table: Users' Optimal Sequence

Position 1	<i>avf.com</i>
Position 2	<i>pow.com</i>
Position 3	<i>isw.com</i>

Optimal Matching

- Transformation 2 - Substitution. *isw.com* by *pow.com*
- Edit cost: $2 + 2 = 4$

Table: Impression Ads

Position 1	<i>avf.com</i>
Position 2	<i>isw.com</i>
Position 3	<i>pow.com</i>

Table: Users' Optimal Sequence

Position 1	<i>avf.com</i>
Position 2	<i>pow.com</i>
Position 3	<i>pow.com</i>

Optimal Matching

- Transformation 3 - Substitution. *pow.com* by *isw.com*
- Edit cost: $4 + 2 = 6$

Table: Impression Ads

Position 1	<i>avf.com</i>
Position 2	<i>isw.com</i>
Position 3	<i>pow.com</i>

Table: Users' Optimal Sequence

Position 1	<i>avf.com</i>
Position 2	<i>pow.com</i>
Position 3	<i>pow.com</i>

Optimal Matching

- Transformation 3 - Substitution. *pow.com* by *isw.com*
- Edit cost: $4 + 2 = 6$

Table: Impression Ads

Position 1	<i>avf.com</i>
Position 2	<i>isw.com</i>
Position 3	<i>pow.com</i>

Table: Users' Optimal Sequence

Position 1	<i>avf.com</i>
Position 2	<i>isw.com</i>
Position 3	<i>pow.com</i>

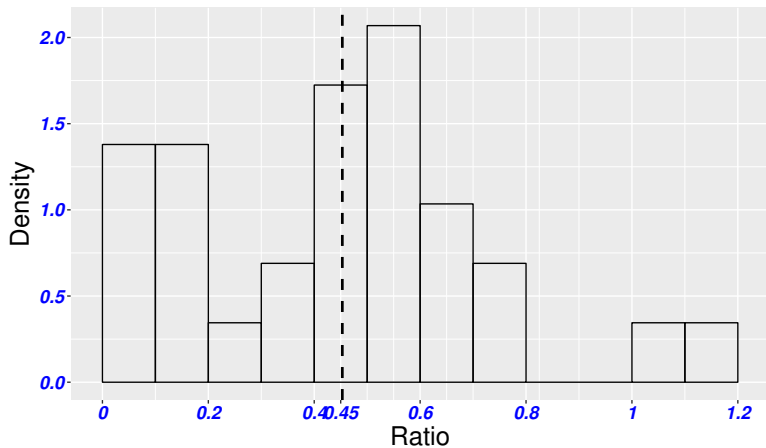
- Allocation & Pricing Rule: Generalized Second Price Auction
- Inference of Value-per-Click of Advertisers
- Inference of Perceived Ad-Quality by Users
- How to compare sequences of ads: Optimal Matching
- **Results**
- Conclusions

Data

- **Canonized Keywords:** "game", "cheap flight", "united airlines", "ups", "map", "100 keywords"
- **Individual impression logs** from Yahoo's desktop searches collected during the second semester of 2017
- Supplement Yahoo's data with traffic information of ad domains using information from "**Alexa.com**"
- **Users' utility function:** experiment where the order of ads is randomized (Identification - disentangle ad-quality from position effects)
- **Advertisers' value-per-click:** production logs (all traffic)

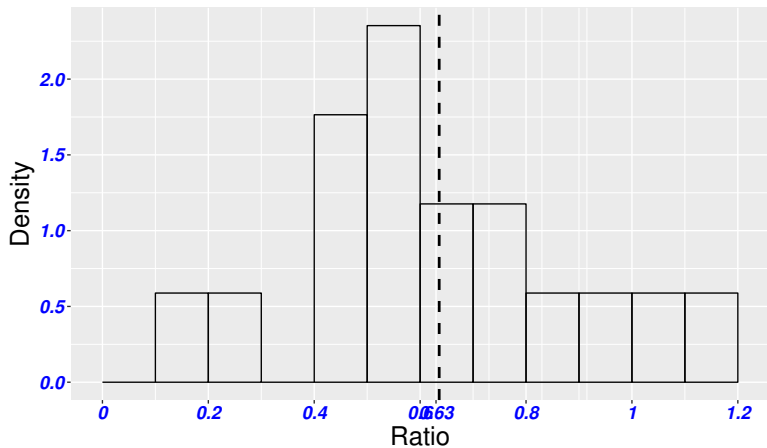
Results: Advertisers' Value-per-Click

Figure: Game: Average bid to predicted value ratio



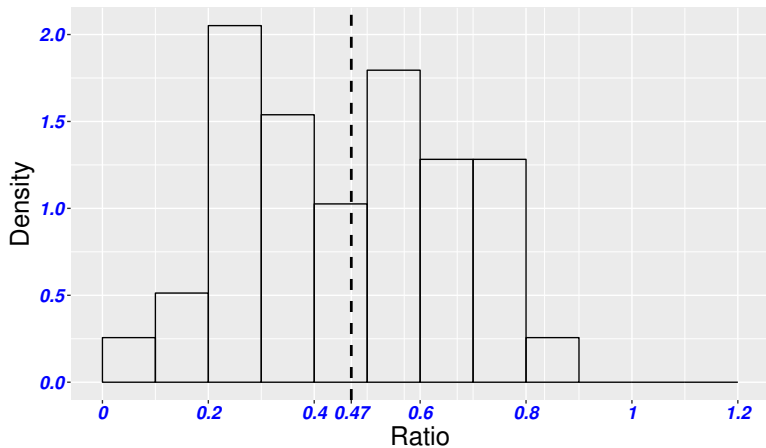
Results: Advertisers' Value-per-Click

Figure: Cheap flight: Average bid to predicted value ratio



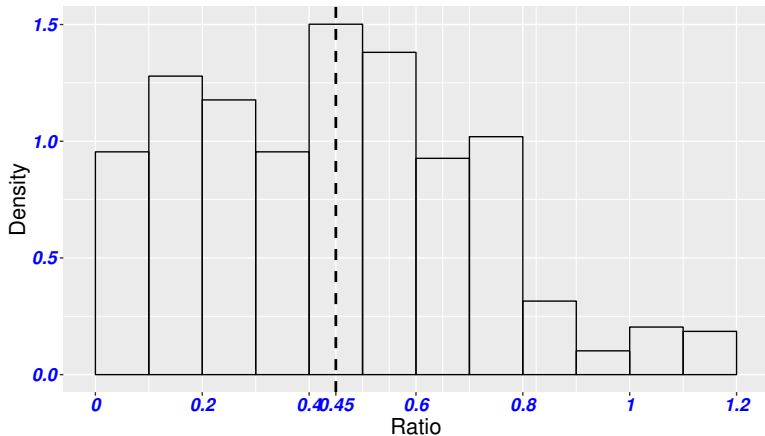
Results: Advertisers' Value-per-Click

Figure: United Airlines: Average bid to predicted value ratio



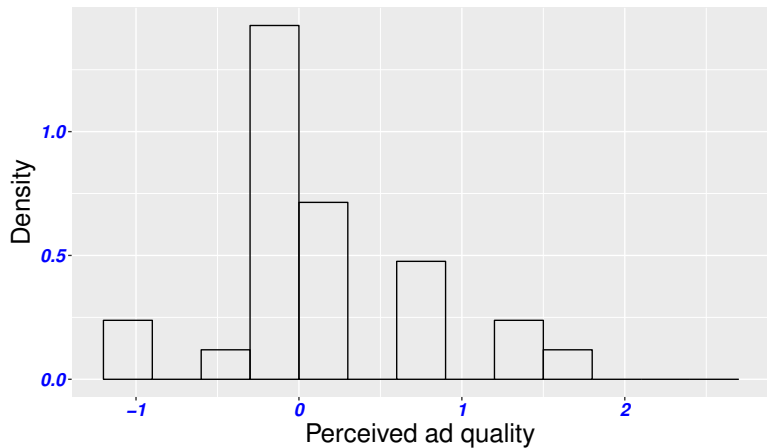
Results: Advertisers' Value-per-Click

Figure: 100 Keywords: Average bid to predicted value ratio



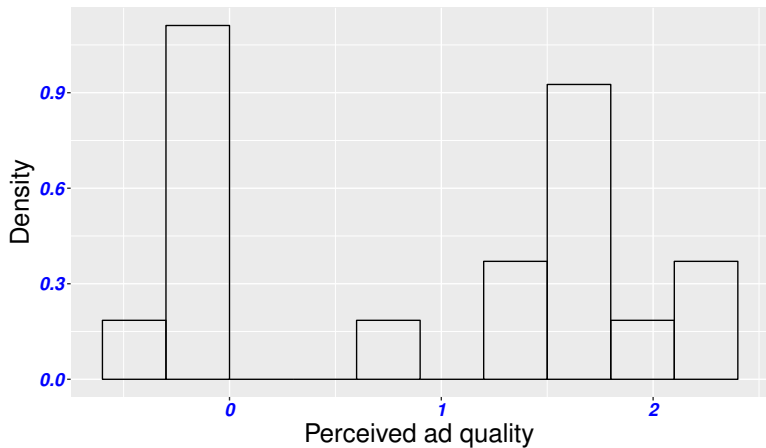
Results: Users' Ad-Quality

Figure: Game: Ads Utility Distribution



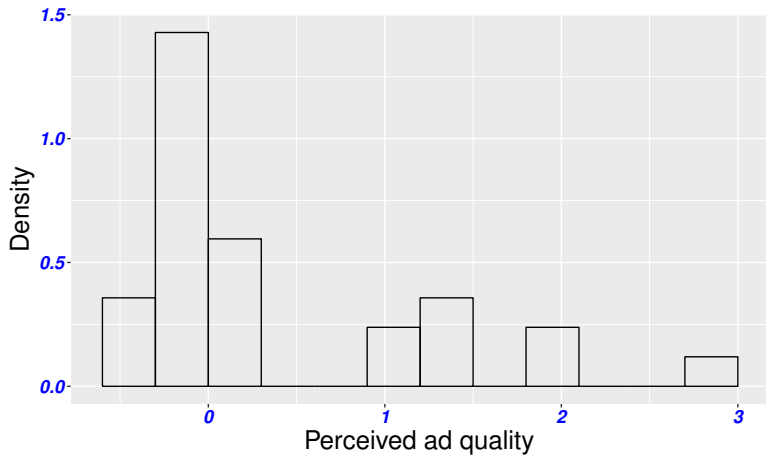
Results: Users' Ad-Quality

Figure: Cheap Flight: Ads Utility Distribution



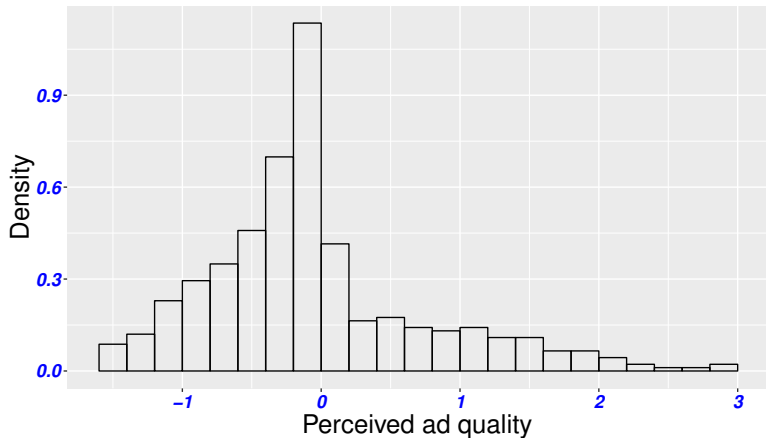
Results: Users' Ad-Quality

Figure: United Airlines: Ads Utility Distribution



Results: Users' Ad-Quality

Figure: 100 Keywords: Ads Utility Distribution



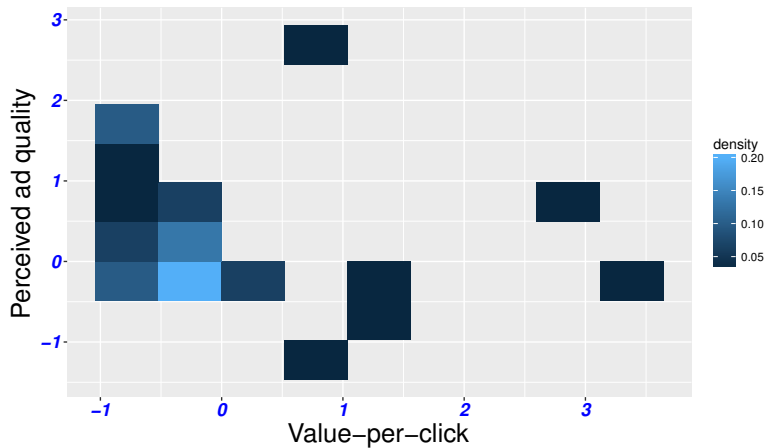
Results: Ad-Quality vs Value-per-Click

- **Question:** Is there any relationship between users' perceived quality and advertisers' value-per-click?

Answer: Hard to tell

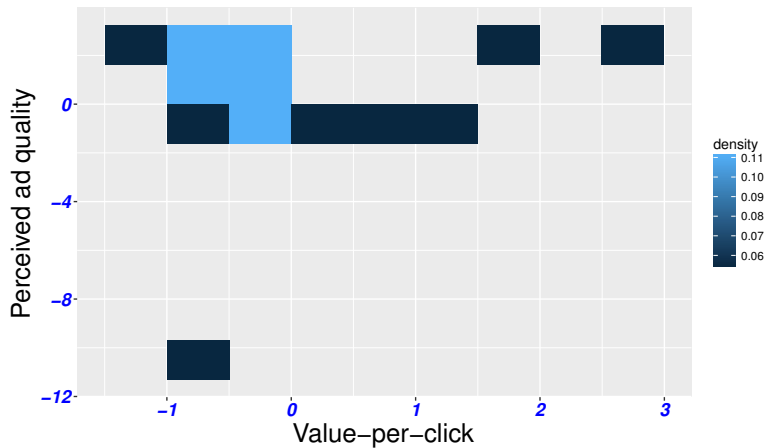
Results: Ad-Quality vs Value-per-Click

Figure: Game: Ad-quality vs Advertiser's value-per-click



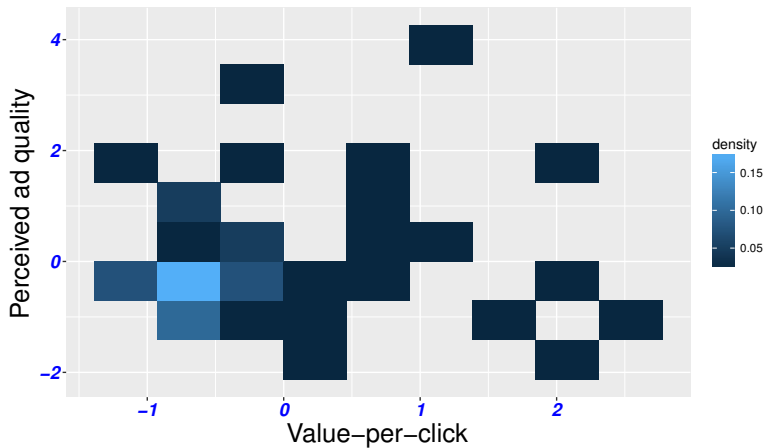
Results: Ad-Quality vs Value-per-Click

Figure: Cheap flight: Ad-quality vs Advertiser's value-per-click



Results: Ad-Quality vs Value-per-Click

Figure: United Airlines: Ad-quality vs Advertiser's value-per-click



Results: Optimal Matching

- **Question:** Quantify the bias of Yahoo's search engine

Results: Optimal Matching

- **Question:** Quantify the bias of Yahoo's search engine

Table: Optimal Matching Distance

	100 KW	Cheap Flight	Game	Map	United	Ups
Distance (User)	8.88 (4.65)	8.72 (4.11)	12.32 (8.37)	22.57 (5.37)	25.10 (8.27)	9.35 (6.50)
Distance (Value-per-click)	10.17 (4.90)	10.06 (4.78)	15.69 (8.83)	16.46 (3.88)	26.96 (7.38)	9.66 (4.49)
Distance Difference	-1.29** (6.76)	-1.34** (6.01)	-3.36 ** (9.06)	6.11** (7.01)	-1.86** (9.11)	-0.31 (5.71)
Distance Difference (%)	-12.7%	-13.3%	-27.3%	37.2%	-6.8%	-3.3%

** $p < 0.05$, * $p < 0.1$

Conclusions

- Hard to measure long time impact of score ranking rules
- Measure the bias of Yahoo's search engine towards advertisers and/or users at scale
- Analyze the relationship between users' and advertisers' preference
- Caveats:
 - Users' heterogeneity (Keyword shows clear intent)
 - Advertisers' targeting criteria (e.g. geo)
- We did not discuss:
 - Revenue implications
 - Simulate allocation mechanisms (e.g. VCG implementation - Facebook)

Thank You!

Users' Utility

- **Utility-maximizing model** (allow counterfactuals)
- The model accommodates multiple clicks and unobserved correlation across ads within the impression.
- $u_{a(n)}(x)$: Perceived utility of ad a in position n with features x
- f_n : Cost of position n
- Infer $u_{a(n)}(x)$ and $f_n \forall n, a$
- **Markov Decision Process** (alternative logistic model):
 - State: displayed ads in an impression
 - Actions: clicks on ads or conclude search

$$V(C_t, d_t) = \underbrace{\left(\sum_{n \in C(t) \cup d_t} u_{a(n)}(x)^{1+R} \right)^{1/(1+R)} - \sum_{n \in C(t) \cup d_t} f_n}_{\text{Present Reward}} + \underbrace{\beta \log \left[\sum_{d_{t+1} \in D(t+1)} \exp[V(C_{t+1}, d_{t+1})] \right]}_{\text{Expected Future Reward}}$$

Users' Utility: Estimation

- 1 For a given value of u , f , α and R compute the continuation value $V(\cdot)$ for all t . In finite-horizon problems the optimal decision rule $\delta^* = (\delta_0, \dots, \delta_T)$ is computed by backward induction starting at the terminal period T .
- 2 Given $V(\cdot)$ for all t and all d_t , compute the probability that users choose action d_t ,

$$P(d_t|C_t) = \frac{\exp[V(C_t, d_t)]}{\sum_{l_t \in D(C_t)} \exp[V(C_t, l_t)]}$$

- 3 Iterate in order to find u , f , α and R that maximizes the likelihood function

$$\{\hat{u}, \hat{f}, \hat{\alpha}, \hat{R}\} = \operatorname{argmax}_{\theta} \prod_{k=1}^K \prod_{t=1}^{T_k} P(d_t^k | C_t^k)$$

where K corresponds to the total number of impressions, and T_k is equal to the maximum number of sponsored ads in impression k .

Results: Counterfactual

Table: Counterfactual

	Cheap Flight	Game	Map
Counterfactual: Advertiser			
eCTR	25.32% **	45.21% **	-12% **
User Utility	18.16%*	20.67%	-1.53%
Advertiser Utility	26.35% **	77.29% **	4.42%
Counterfactual: User			
eCTR	43.81% **	73.34% **	6.39% *
User Utility	23.01%**	36.81%	3.26%
Advertiser Utility	13.56%	59.90% **	-8.67%

** $p < 0.05$, * $p < 0.1$