The Impact of Privacy Protection Measures on Online Advertising Markets

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Motivation: privacy, cookies, ads, antitrust

- **Privacy concerns in online advertising: Third-party Cookies** (3PCs)
  - Legislation: GDPR (EU, 2018), CCPA (California, 2020), etc.
  - Private initiative: Safari (2017) & Mozilla Firefox (2019)
- Google plans to **end Third-Party Cookie support on Chrome**
- **Industry-wide outcry**: undermine advertisers' ability to track and target consumers and reduce publishers' and seller' profits (**Expected 2024**)
- **Antitrust concerns**: consolidation of the ad supply chain by big players with alternatives to 3PCs

Our Paper

Evaluate the effects of removing 3PCs from Chrome in the online ad market

- Analyze a large sample of banner ad auctions from **Yahoo Ad Exchange**
- **Structurally model the auctions**: Welfare effects and Counterfactuals
- **Counterfactuals:** Simulate how online ad markets will be affected by
  - Chrome blocking 3PCs
  - Information advantage of big players
  - Alternative targeting technologies: “Privacy Sandbox”

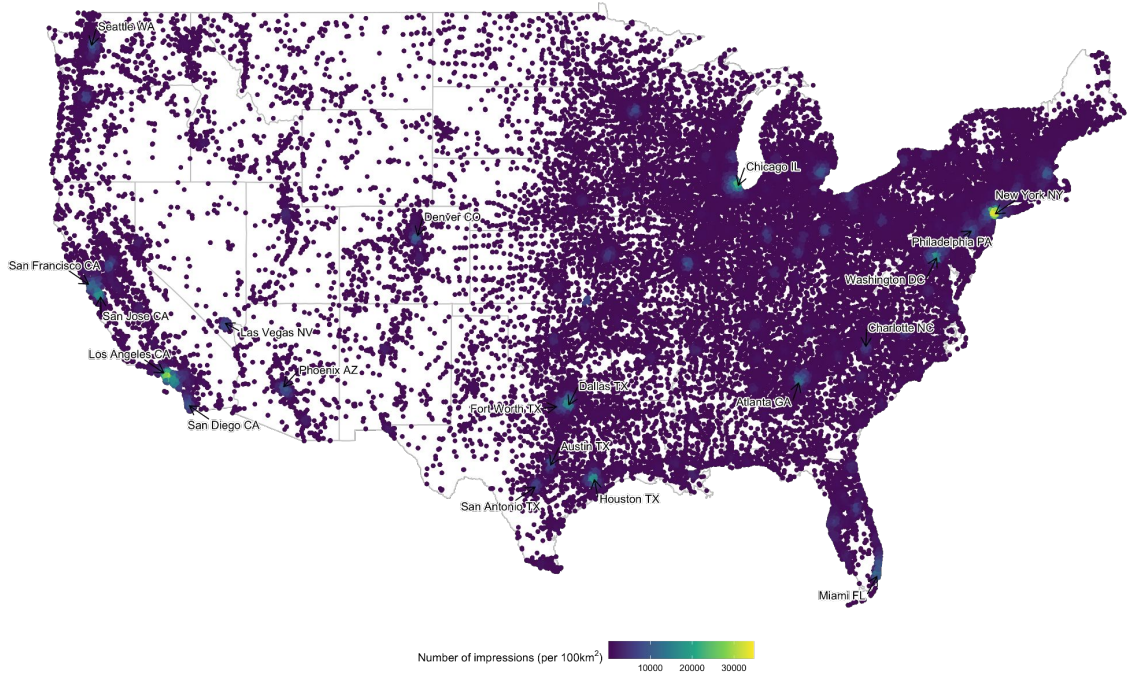
Ad Auction Data

Detailed **bid-level data** on ad auctions hosted on **Yahoo Ad Exchange**

- Banner display ads (Impressions)
- First price auction mechanism
- Participants include major **demand-side platforms (DSPs)** (e.g. Trade Desk, Google DBM, Amazon DSP, etc.), who are agents bidding on behalf of advertisers.
- One week from the second quarter of 2022, from the United States
- 16 **Yahoo** websites: Homepage, Finance, Mail, News, etc.

Ad Auction Data

Figure: Geographical distribution of impressions



Ad Auction Data

Normalized Bids

Variable	Mean	Std
Bid	**1.000**	1.841
# Bidders (DSPs)	6.908	4.537
Winning Bid (Publisher Revenue)	2.164	3.630
No Cookie	0.399	0.490

Number of auctions: 1.23 million
Number of bids: 8.86 million

- Additional Features: site names, user characteristics (e.g. gender, age, location, monetization records, targeting segments), Device, Browser, Cookie Age, hour, DSP
- We assume bidders observe similar information as **Yahoo**

Ad Auction Data: Browser

	Bid		Winning Bid		Entry Probability	
Browser	**Cookie**	**Cookieless**	**Cookie**	**Cookieless**	**Cookie**	**Cookieless**
Chrome	**1.076**	**0.838**	**2.638**	**1.313**	**0.289**	**0.098**
Edge	0.882	0.609	1.992	0.902	0.179	0.073
Firefox	-	**0.717**	-	1.072	-	0.094
Safari	-	**0.794**	-	1.256	-	0.112
Other	0.981	0.559	1.958	0.785	0.182	0.065

- No evidence that **"cookieless by choice"** Chrome impressions are worse than **"cookieless by default"** Firefox/Safari impressions
- **Counterfactuals:** We assume all Chrome impressions become "cookieless" under 3PC-ban

Structural model and Estimation

Removing 3PCs from Chrome - Welfare Analysis and Counterfactuals

Model: Independent private value first-price auction model with entry

- Fixed number of 36 potential bidders (DSPs)
- Auction characteristics X_t
- Valuation $v_{it} \sim F_i(\cdot|X_t)$
- Two Stage Problem
  - Equilibrium entry probability $p_i(X_t)$
  - Bayes-Nash equilibrium bidding strategies $B_i : v_{it} \rightarrow b_{it}$

Structural model and Estimation

Bidder i's expected profit

Bayes-Nash eq. Bidding Function

$$\Pi_{it}(b_{it}, v_{it}) = (v_{it} - b_{it}) \prod_{j \neq i} Pr(b_{it} \geq B_j(v_{jt}) \text{ or } j \text{ does not enter})$$

Valuation CDF

$$= (v_{it} - b_{it}) \prod_{j \neq i} ((1 - p_j) + p_j F_j(B_j^{-1}(b_{it})))$$

$$= (v_{it} - b_{it}) \prod_{j \neq i} ((1 - p_j) + p_j G_j(b_{it}))$$

Valuation

Bid

Eq. Bids CDF

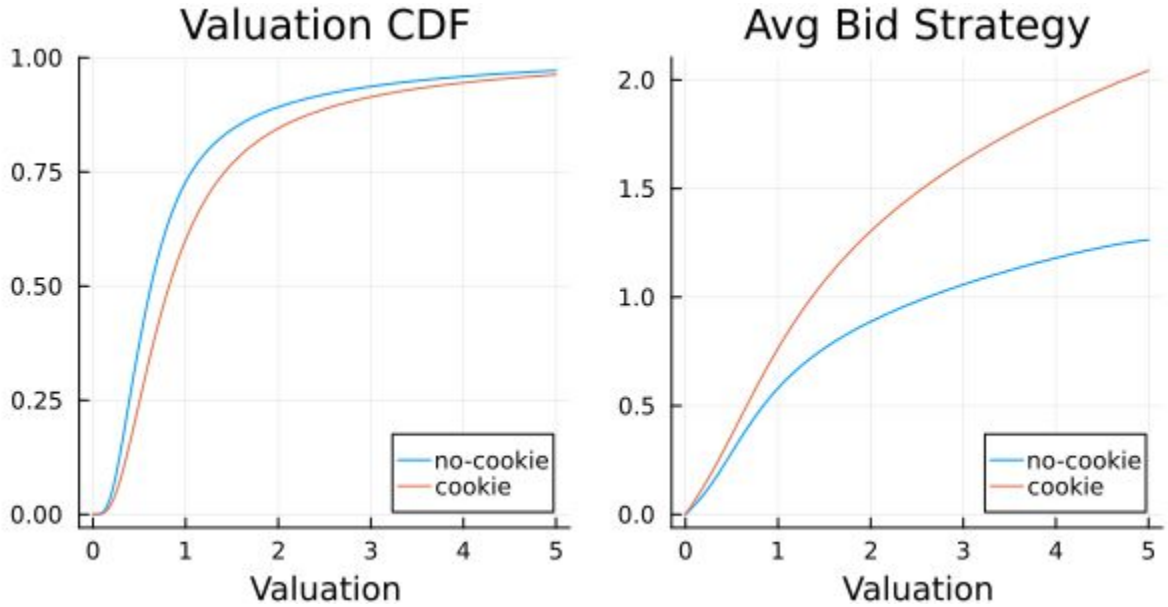
Eq. Entry Probability

Structural model and Estimation

Estimation approach

- Step 1: Estimate entry probability $p_i(X_t)$
- Step 2: Use FOC to recover valuations from observed bids (GPV 2000)
- Step 3: Estimate:
  - Valuation Distributions $F_i(\cdot|X_t)$
  - Bayes-Nash equilibrium bidding strategies B_i
- Bidder heterogeneity: Large (n=10), Medium (n=10), and small (n=16)

Estimated valuation and bidding strategy: Large DSPs



- $F_{cookie} \succeq_{FOSD} F_{cookieless}$: Valuations are higher for impressions with cookies
- Cookie auctions are more competitive, leading to higher equilibrium bids

Counterfactual: Chrome's cookie ban

Given estimated valuations, we simulate **counterfactual scenarios** of a cookie ban

- **Symmetric Ban**: 3PC ban affects all bidders, all Chrome impressions marked as cookieless for all DSPs
- **Asymmetric ban**: Emulate information monopolization and let one privileged DSP continue to observe impression characteristics

Implementation: Solving the first-price auction model under counterfactual valuation distributions

- Compute equilibrium bidding strategies for chrome impressions
- For simplicity, aggregate DSPs into three types: Small, Medium and Large
- A system of nonlinear ODE subject (Hubbard and Paarsch (2014))

Counterfactual: Cookie Ban hurt Publishers

	Status Quo	Symmetric Ban	%Δ	Asymmetric Ban	%Δ
Bid					
Mean	0.97	0.66	-31.5%	0.70	-27.2%
SD	1.00	0.69		0.74	
Number of Bidders					
Mean	8.95	3.56	-60.2%	3.82	-57.3%
SD	3.59	1.74		1.75	
Winning Bid (Publisher Revenue)					
Mean	1.99	1.07	**-46.5%**	1.16	**-41.9%**
SD	1.70	0.92		1.00	

- Symmetric and Asymmetric Bans have similar effects
- Publishers lose revenue (**fall > 40%**)

Counterfactual: Bidder Impact

		Advantaged Bidder	Avg Large Bidder	Avg Medium Bidder	Avg Small Bidder
Winning Frequency	**Status Quo**	**7.9%**	8.2%	1.6%	0.09%
	Sym-Ban	7.8%	8.1%	1.6%	0.10%
	Asym-Ban	**18.0%**	**7.2%**	1.5%	0.07%
Bidder Surplus $\Sigma(v_{ban} - b)$	**Status Quo**	**1,630**	1,782	172	7.4
	Sym-Ban	1,392	1,330	140	7.2
	Asym-Ban	**3,022**	**1,238**	137	6.9

- Information advantage appears in distributional effects
- DSP with information advantage wins **more auctions** and gains **more surplus**
- Other DSPs win **fewer auctions** and have **lower surplus** than the status quo

Counterfactual 2: Alternative Targeting Technology

Alternatives to third-party cookies (e.g. Google's Privacy Sandbox)

- Compiled user characteristics at aggregate level and label users with "topics" (e.g. automobile, pets, tennis)
- Still enables targeting but with coarser information

Counterfactual

- Use **16 Yahoo websites** as segments, replace 3PC-related impression characteristics with averages per website
- Consider symmetric impact and asymmetric impact with a bidder with informational advantage

Counterfactual 2: Alternative Targeting Technology

		Advantaged Bidder	Avg Large Bidder	Avg Medium Bidder	Avg Small Bidder
Winning Frequency	**Status Quo**	**7.9%**	8.2%	1.6%	0.09%
	Sym-Ban	7.9%	8.0%	1.8%	0.10%
	Asym-Ban	**12.0%**	7.6%	1.8%	0.07%
Bidder Surplus $\Sigma(v_{ban} - b)$	**Status Quo**	**1,630**	1,782	172	7.4
	Sym-Ban	1,503	1,480	162	7.9
	Asym-Ban	**2,244**	**1,413**	165	7.1

The welfare loss is partially alleviated compared to the ban without targeting alternative counterfactual

- DSP with informational advantage: **18% (No Alternative)** → **12%**, **$3,022 (No Alternative)** → **$2,244**
- Surplus of Large DSPs: **$1,238 (No Alternative)** → **$1,413**

Conclusion

- Privacy policies have **sizeable impact** on online ad markets
- Chrome's ban of 3PCs can have substantial impact (**40% reduction in publisher's revenue**)
- **Alternative targeting technologies** can partially alleviate the unequal distributional effects
- **Informationally advantaged bidders** stand to gain at the expense of other bidders

Q&A

3rd Party vs 1st Party Cookies

- **What is a cookie?** It is a text file stored in users' device that contains data.
- **First-Party Cookies** are created and stored by the website that the user is visiting. Used to optimize user website experience (e.g. preferred language, information about user's login, preferred topics, etc.)
- **Third-Party Cookies** are not created by the website the user is visiting. It can be used to track users across different domains (**Targeted Ads**)

Structural model and Estimation

Caveats

- Competition between DSPs rather than individual advertisers
- Do not consider dynamics (e.g. budget allocation and sequential auctions)

Ad Auction Data: cookie vs no-cookie

	Cookie		No Cookie	
Variable	**Mean**	**Std**	**Mean**	**Std**
Bid	**1.071**	1.921	**0.758**	1.513
Winning Bid (Publisher Revenue)	**2.759**	4.121	**1.267**	2.477
# Bidders (DSPs)	**8.887**	4.148	**3.924**	3.295
Entry Probability	0.265	0.441	0.099	0.302

No Cookie users generate:

- Lower bids
- Lower Revenue (winning bid)
- Lower Entry

Counterfactual 2: Alternative Targeting Technology

	Status Quo	Symmetric Ban	%Δ	Asymmetric Ban	%Δ
Bid					
Mean	0.97	0.82	**-15.1%**	0.83	**-13.8%**
SD	1.00	0.84		0.85	
Number of Bidders					
Mean	8.95	6.07	**-32.2%**	6.17	**-31.1%**
SD	3.59	2.19		2.20	
Winning Bid (Publisher Revenue)					
Mean	1.99	1.55	**-21.9%**	1.58	**-20.9%**
SD	1.70	1.26		1.29	

Loss in publisher's revenue is **halved at ~20%** compared to **~40%** obtained in the cookie ban without alternative targeting

Impact of third party cookies on Bids: Reduced Form

$$y_i = \beta_c Cookie_i + x_i'\beta + \alpha_i + \epsilon_i$$

Dependent Variables	log(Bid)			log(Winning Bid)	
	(1)	(2)	(3)	(4)	(5)
Cookie Available	0.335*** (0.028)	0.318*** (0.046)	0.314*** (0.031)	0.887*** (0.018)	0.783*** (0.042)
User/Cookie Characteristics	No	Yes	Yes	No	Yes
Fixed Effects: Browser,Website,Time,City	Yes	Yes	Yes	Yes	Yes
DSP Fixed Effect	No	No	Yes	No	No

Cookie impressions generate **more revenue** and **higher bids**

Impact of third party cookies on Entry: Reduced Form

Dependent Variables	Number Bidders		Entry		
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) Logit
Cookie Available	5.715*** (0.295)	5.053*** (0.304)	0.144*** (0.009)	0.144*** (0.009)	1.127*** (0.072)
User/Cookie Characteristics	No	Yes	Yes	Yes	Yes
Fixed Effects: Browser,Website,Time,City	Yes	Yes	Yes	Yes	Yes
DSP Fixed Effect	No	No	Yes	Yes	No

Cookie impressions generate **more entry**