Choice-Screen Auctions

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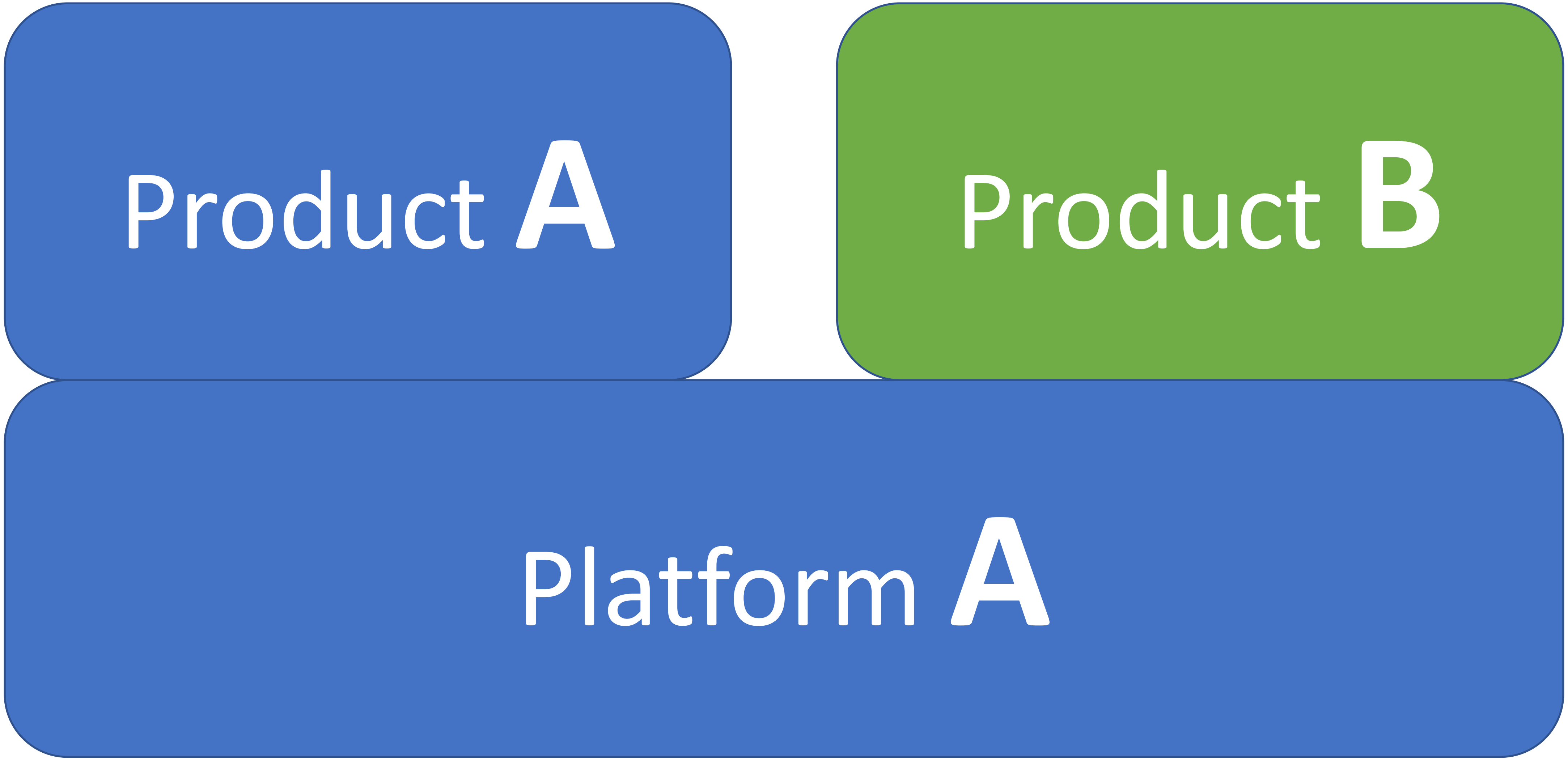
June 23, 2023

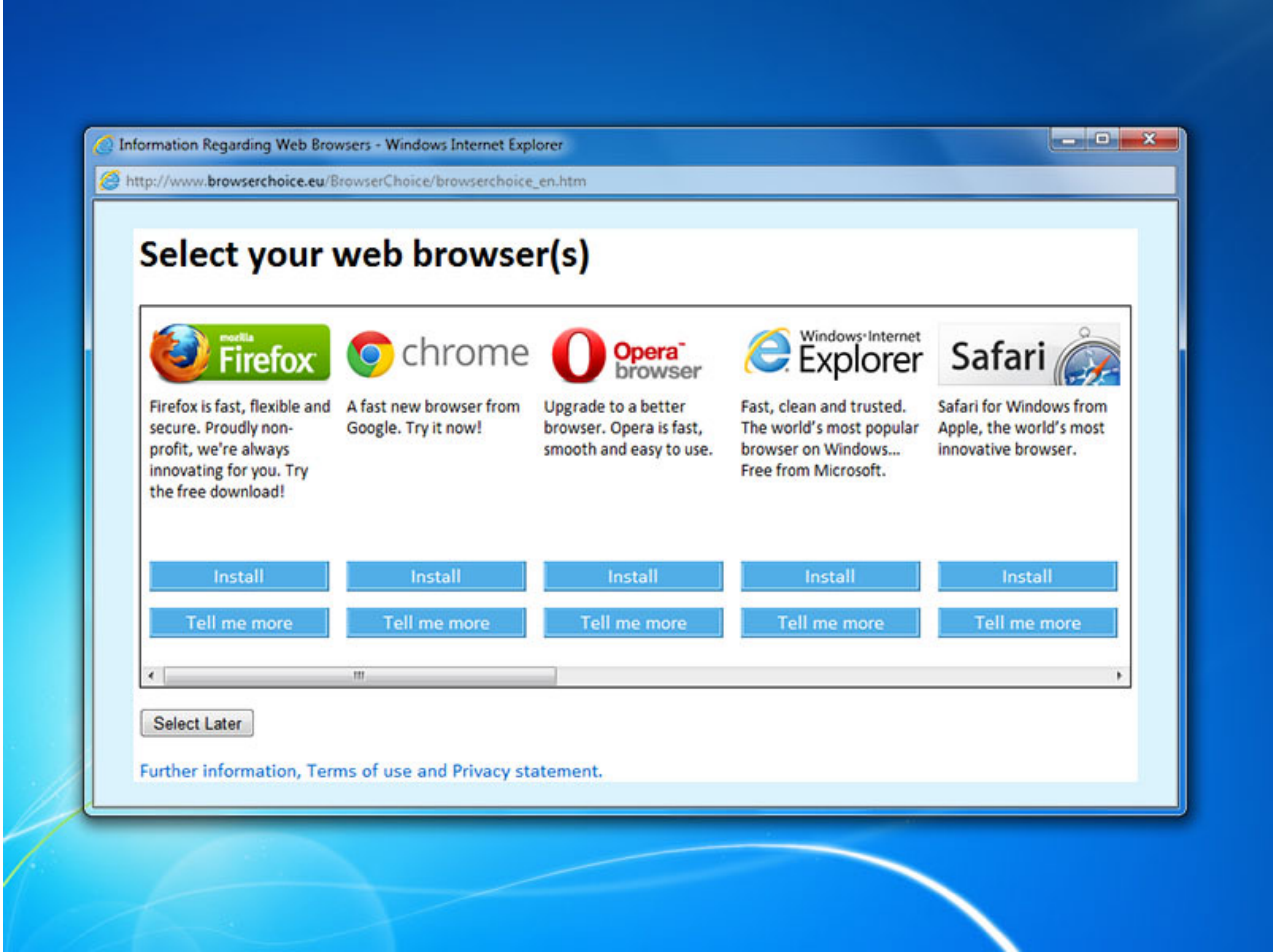

Product A
Product B
Platform A

Choice Screen – Microsoft Windows/browsers

- Initially proposed by Microsoft in 1999 as a potential remedy in the US, not adopted at the time

- Adopted in Europe 2010 – 2014 (agreement between MS and EC)

- Accidentally removed on one of the versions of Windows from May 2011 until July 2012, affecting ~15 million users. Microsoft admitted the error and paid a fine of €561 million.


Information Regarding Web Browsers - Windows Internet Explorer
http://www.browserchoice.eu/BrowserChoice/browserchoice_en.htm
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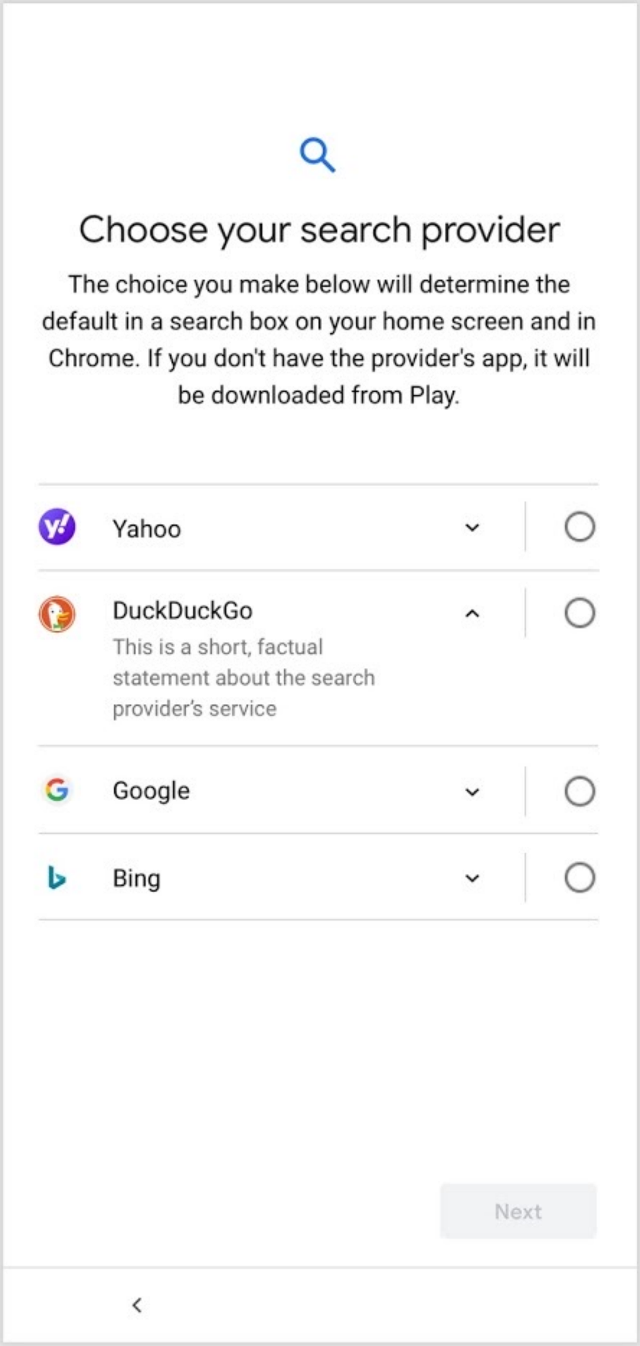
Choice Screens for search engines and browsers on Google's Android platform

- In 2017, Google paid a €4.3 billion fine to the EC for illegal tying of its Chrome browser and Google Search app and default search engine on the Android platform

- As part of the subsequent settlement, in 2018 Google agreed to display choice screens for alternative search engines and browsers to Android users in Europe, starting in 2019

Choice Screen Auctions

- Announced in August 2019
- Auctions are conducted quarterly, first auction for the period March 2020 – June 2020
- “The auction revenues help [Google] to continue to invest in developing and maintaining the Android platform.”



Why does Google use an auction to determine the search providers that appear in the choice screen?

An auction is a fair and objective method to determine which search providers are included in the choice screen. It allows search providers to decide what value they place on appearing in the choice screen and to bid accordingly.

The choice screen auction

Google will use a fourth-price auction to select the other general search providers that appear in the choice screen. Google will conduct auctions on a per-country basis. The search providers selected in the first auction cycle will be displayed during the 4 months following the launch of the choice screen on March 1, 2020. Future auction cycles will occur on a quarterly basis.

In each country auction, search providers will state the price that they are willing to pay each time a user selects them from the choice screen in the given country. The three highest bidders will appear in the choice screen for that country. The provider that is selected by the user will pay the amount of the fourth-highest bid.

The auction winners, and Google, will be ordered randomly in the choice screen. In the event of a tie, Google will allocate the slots randomly among the tied bidders on a per device basis. In the event that fewer than three eligible search providers bid, Google will fill any remaining slots randomly from the pool of eligible search providers on a per device basis. The pool of eligible providers will include those that applied to participate in the choice screen but did not submit bids.

Example

Search Engine **X**	Search Engine **Y**
• Values each user at **$20**	• Values each user at **$10**
• **50** users will install it (if it is shown on the choice screen)	• **5000** users will install it (if it is shown on the choice screen)

Basic Model

- One slot (in addition to the platform's own search engine)
- n bidders (indexed by i)
- Bidder i has *popularity* (probability of being chosen|being shown) q_i
- Bidder i values each user at r_i
- Variables q_i, r_i are i.i.d uniform on $[0,1]$
- The platform values each user at $\pi > 1$
- "Per-appearance" auction: each bidder submits a bid. If wins, pays the second-highest bid. Optimal bid: $b_a^* = r_i q_i$
- "Per-install" auction: each bidder submits a bid. If wins *and subsequently chosen by the user*, pays the second-highest bid. $b_i^* = r_i$

Results ($n = 2$)

- The expected popularity q_i^w of the winner of the per-install auction is equal to $\frac{1}{2}$

- The expected payoff of the platform in the per-install auction is equal to $\frac{1}{6} + \frac{1}{2}\pi$

Outcomes of the "per appearance" auction:

For $x \in [0,1]$, the probability that $q_i r_i \le x$ is equal to $G(x) = x + \int_x^1 \frac{x}{q} dq = x - x \ln x$.

Thus, for a bidder with type (q, r), the probability of winning is $(qr) - (qr)\ln(qr)$.

Helpful facts: $\int x \ln(x) dx = \frac{1}{2}x^2 \ln(x) - \frac{x^2}{4}$ and $\int x^2 \ln(x) dx = \frac{1}{3}x^3 \ln(x) - \frac{x^3}{9}$.

For the population of bidders with type q and with types $r \sim U[0,1]$, the probability of winning is therefore $\int_0^1 \left((qr) - (qr)\ln(qr)\right) dr = q \int_0^1 \left(r - r \ln q - r \ln r\right) dr = q\left(\frac{1}{2} - \frac{1}{2}\ln q + \frac{1}{4}\right) = \frac{3}{4}q - \frac{1}{2}q \ln q$.

The expected popularity of the winner of the auction is equal to $2\int_0^1 q\left(\frac{3}{4}q - \frac{1}{2}q \ln q\right) dq = \int_0^1 \left(\frac{3}{2}q^2 - q^2 \ln q\right) dq = \frac{1}{2} + \frac{1}{9} = \frac{11}{18} > \frac{1}{2}$.

Outcomes from the point of view of the platform:

The expected payment made by the winner of the auction is equal to $E[\min\{q_1 r_1, q_2 r_2\}]$.

Given the distribution $G(\cdot)$ of each $q_i r_i$ derived above, the CDF of the distribution of $\min\{q_1 r_1, q_2 r_2\}$ is given by $G(x)^2 + 2G(x)(1 - G(x))$, with the corresponding density $2g(x) - 2g(x)G(x) = -2 \ln x(1 - x + x \ln x)$.

Thus, $E[\min\{q_1 r_1, q_2 r_2\}] = -2 \int_0^1 (x \ln x(1 - x + x \ln x))\, dx = \frac{7}{54}$, and the expected payoff of the platform is $7/54 + 7/18\pi < 1/6 + 1/2\pi$.

Results ($n = 2$)

- The expected popularity q_i^w of the winner of the per-install auction is equal to $\frac{1}{2}$
- The expected popularity $q_a^w = \frac{11}{18}$ of the winner of the per-appearance auction is strictly greater than $q_i^w = \frac{1}{2}$

- The expected payoff of the platform in the per-install auction is equal to $\frac{1}{6} + \frac{1}{2}\pi$
- The expected payoff of the platform in the per-appearance auction, $\frac{7}{54} + \frac{7}{18}\pi$, is strictly lower than $\frac{1}{6} + \frac{1}{2}\pi$

Results ($n \to \infty$)

- The expected popularity q_i^w of the winner of the per-install auction is equal to $\frac{1}{2}$
- The expected popularity q_a^w of the winner of the per-appearance auction is equal to $1 > \frac{1}{2}$

- The expected payoff of the platform in the per-install auction is equal to $\frac{1}{2} + \frac{1}{2}\pi$
- The expected payoff of the platform in the per-appearance auction is equal to $1 < \frac{1}{2} + \frac{1}{2}\pi$

Extension: endogenous q_i and r_i

- One slot, n bidders (indexed by i)
- Bidder i has *technological type* t_i drawn i.i.d. from U[0,1]
- Prior to the auction, picks $r_i \geq 0$ and $q_i \geq 0$ s.t. $q_i + r_i = t_i$.

- "Per-appearance" auction: each bidder submits a bid. If wins, pays the second-highest bid. Optimal bid: $b_a^* = r_i q_i$
- "Per-install" auction: each bidder submits a bid. If wins *and subsequently chosen by the user*, pays the second-highest bid. $b_i^* = r_i$

Equilibrium in the per-appearance auction

Consider an auction with n bidders, and suppose bidder i has type $t_i \in [0, 1]$.

Fix other bidders' strategies, let $G(x)$ denote the distribution of the first-order statistic of those bidders' bids, and let $P(x)$ denote the expected payment that bidder i would make, conditional on winning the auction, if it submitted bid x.

Bidder i has two decisions to make: popularity q_i and bid b_i. Its payoff, as a function of these two decisions, is given by

$$\Pi(q_i, b_i) = G(b_i) \times (q_i(t_i - q_i) - P(b_i)) \, .$$

It is immediate that bidder i's optimal choice of popularity is to set

$$q_i = \frac{t_i}{2}. \tag{1}$$

This is the optimal strategy *regardless* of what other bidders' strategies are (or how many of those bidders there are), and thus the strategy profile in which each bidder sets $q_i = t_i/2$ and then bids $(t_i/2)^2$ per appearance constitutes an equilibrium.

Equilibrium in the per-install auction

Consider a symmetric equilibrium of the per-install auction with n bidders, and suppose equilibrium strategies are given by functions $q(t)$ and $b(t)$, with the first one denoting the popularity chosen by a bidder with type t and the second one denoting its bid.

Take a bidder of type t_i. Let $\Pi(q; t_i)$ denote the expected payoff of bidder i whose type is t_i *if it bids according to equilibrium strategy* $b(t_i)$, *but chooses an arbitrary popularity* $\tilde{q}$. We then have

$$\Pi(q; t_i) = F^{n-1}(t_i) \times \tilde{q} \times \left(t_i - \tilde{q} - E\left[b(\max_{j \neq i}\{t_j\} | \max_{j \neq i}\{t_j\} \leq t_i) \right] \right),$$

where $F(\cdot)$ is the CDF of the distribution of types t.

In equilibrium,

$$q(t_i) = \frac{t_i - E\left[b(\max_{j \neq i}\{t_j\}) | \max_{j \neq i}\{t_j\} \leq t_i \right]}{2}. \tag{2}$$

Next, recall that by incentive compatibility, we have $b(t_j) = t_j - q(t_j)$. We can then rewrite the expectation in equation (2) as

$$\begin{aligned} E\left[b(\max_{j\neq i}\{t_j\})|\max_{j\neq i}\{t_j\}\leq t_i\right] &= \frac{\int_0^{t_i}(s-q(s))dF^{n-1}(s)}{F^{n-1}(t_i)} \\ &= \frac{(n-1)\int_0^{t_i}(s-q(s))f(s)F^{n-2}(s)ds}{F^{n-1}(t_i)}, \end{aligned}$$

and subsequently rewrite equation (2) as

$$2q(t_i)F^{n-1}(t_i) = t_iF^{n-1}(t_i) - (n-1)\int_0^{t_i}(s-q(s))f(s)F^{n-2}(s)ds. \tag{3}$$

Take a derivative of both sides of equation (3) with respect to t_i:

$$\begin{aligned} 2q'(t_i)F^{n-1}(t_i) + 2(n-1)q(t_i)f(t_i)F^{n-2}(t_i) &= \\ F^{n-1}(t_i) + (n-1)t_if(t_i)F^{n-2}(t_i) - (n-1)t_if(t_i)F^{n-2}(t_i) &+ (n-1)q(t_i)f(t_i)F^{n-2}(t_i), \end{aligned}$$

which simplifies to

$$2q'(t_i) + (n-1)q(t_i)\frac{f(t_i)}{F(t_i)} = 1. \tag{4}$$

Equation (4) is a linear differential equation, with the initial condition $q(0) = 0$. In our case, $F(t_i) = t_i$ and $f(t_i) = 1$, and so the equation becomes

$$2q'(t_i) + (n-1)q(t_i)\frac{1}{t_i} = 1,$$

with the solution

$$q^{\mathsf{PIA}}(t_i) = \frac{t_i}{n+1}.$$

Recall that

$$q^{\mathsf{PAA}}(t_i) = \frac{t_i}{2}$$

regardless of n.

Results

- In the per-appearance auction, each bidder sets $q_i = \frac{t_i}{2}$, $r_i = \frac{t_i}{2}$
- In the per-install auction, each bidder sets $q_i = \frac{t_i}{n+1}$, $r_i = \frac{nt_i}{n+1}$

- The expected popularity of the winner is strictly higher in the per-appearance auction than in the per-install auction
- The expected payoff of the platform is strictly lower in the per-appearance auction than in the per-install auction

- As $n \to \infty$, $q_i^w \to 0$ **!!!**

Empirical Evidence from Android Choice Screen Auctions

- Four batches of auctions: January 2020 (for the period from March until June), June 2020 (for Q3), September 2020 (for Q4), and December 2020 (for Q1 of 2021).

- Each period, 31 independent auctions (one per country).

- Auctions on a per-install basis, with those submitting top three bids being shown on the choice screen and paying the fourth highest price every time a user chose one of them from the choice screen.

- Outcomes from https://www.android.com/choicescreen-winners/

Country	Population	Info.com	PrivacyWall	DuckDuckGo	Bing	GMX	Yandex	Qwant	Seznam	Givero	Ecosia
Germany	83,990,646	1, 2, 3, 4	2, 3, 4	1, 2	3, 4	1					
United Kingdom	67,999,326	1, 2, 3, 4	2, 3, 4	1, 2	1, 3, 4						
France	65,297,182	1, 2, 3, 4	2, 3, 4	1, 2	3, 4			1			
Italy	60,457,546	1, 2, 3, 4	2, 3, 4	1, 2	3, 4			1			
Spain	46,789,532	1, 2, 3, 4	2, 3, 4	1, 2	3, 4			1			
Poland	37,847,219	1, 2, 3, 4	3, 4	1, 2		2, 3, 4	1				
Romania	19,196,044	1, 2, 3, 4	1, 3, 4	1, 2		2, 3, 4	1, 3, 4				
Netherlands	17,142,323	1, 2, 3, 4	2, 3, 4	1, 2	3, 4	1					
Belgium	11,608,284	1, 2, 3, 4	2, 3, 4	1, 2, 4	3			1			
Czech Republic	10,717,516	1, 2, 3, 4	3, 4	1, 2					1, 2, 3, 4		
Greece	10,415,204	1, 2, 3, 4	1, 3, 4	1, 2		2, 3, 4	1, 3, 4	1			
Portugal	10,190,296	1, 2, 3, 4	1, 4	1, 2		2, 3, 4	1, 3	1			
Sweden	10,114,623	1, 2, 3, 4	1, 2, 3, 4	1, 2	3, 4						
Hungary	9,657,366	1, 2, 3, 4	1, 3, 4	1, 2		2, 3, 4	1, 3, 4				
Austria	9,032,162	1, 2, 3, 4	2, 3, 4	1, 2	3	1, 4					
Bulgaria	6,938,828	1, 2, 3, 4	1, 3, 4	1, 2, 3		2, 3, 4	1, 3, 4				
Denmark	5,795,666	1, 2, 3, 4	1, 2, 3, 4	1, 2	3, 4		1	1		1	
Finland	5,543,674	1, 2, 3, 4	2, 3, 4	1, 2	3, 4		1				
Slovakia	5,461,816	1, 2, 3, 4	4	1, 2		3			1, 2, 3, 4		
Norway	5,428,345	1, 2, 3, 4	1, 2, 3, 4	1, 2	3, 4						
Ireland	4,960,177	1, 2, 3, 4	1, 2, 3, 4	1, 2	3, 4						
Croatia	4,099,199	1, 2, 3, 4	1, 4	1, 2, 3		2, 3, 4	1, 4				
Lithuania	2,710,479	1, 2, 3, 4	3, 4	1, 2		2, 3, 4	1				
Slovenia	2,079,635	1, 2, 3, 4	1	1, 2		2, 3, 4	1				3, 4
Latvia	1,881,006	1, 2, 3, 4	3, 4	1, 2		2, 4	1, 3, 4				
Estonia	1,328,929	1, 2, 3, 4		1, 2		2, 3, 4	1, 3, 4				
Republic of Cyprus	1,190,962	1, 2, 3, 4	1	1, 2		2, 3, 4	1, 3, 4				
Luxembourg	629,798	1, 2, 3, 4		1, 2		3, 4		1, 2, 3, 4			
Malta	514,564	1, 2, 3, 4	1, 3, 4	1, 2		2, 3, 4	1				
Iceland	341,834	1, 2, 3, 4	1, 4	1, 2, 3		2, 3, 4	1				
Liechtenstein	38,150	1, 2, 3, 4	4	1, 2, 3		2, 3, 4		1			
Average pop. (M)	519.4	519.4	373.3	265.5	208.9	112.3	58.8	53.3	16.2	1.4	1.0

Popularity and Ratings of Search Engine Apps

Search Engine	Av. Pop.	# Installs	Rating	# Reviews
info.com	519.4	50,000+	4.1	63
PrivacyWall	373.3	100,000+	4.1	269
DuckDuckGo	265.5	10,000,000+	4.8	981,088
Bing	208.9	10,000,000+	4.4	184,988
GMX	112.3	10,000+	4.4	17
Yandex	58.8	100,000,000+	4.5	1,020,289
Qwant	53.3	1,000,000+	3.9	10,817
Seznam	16.2	1,000,000+	4.2	66,767
Givero	1.4	100+	n/a	n/a
Ecosia	1.0	5,000,000+	4.6	123,794

Incentives: quotes from search engines

- DuckDuckGo (the most highly rated search engine app, 10M+ installs): “Despite DuckDuckGo being robustly profitable since 2014, we have been priced out of this auction because we choose to not maximize our profits by exploiting our users. In practical terms, this means our commitment to privacy and a cleaner search experience translates into less money per search. This means we must bid less relative to other, profit-maximizing companies.”
- Ecosia (the second most highly rated search engine app, uses its profits to plant trees around the world, 5M+ installs): “Ecosia is a not-for-profit search engine. Taking part in Google’s auction would force us to spend our income on an unnecessary bidding war with other (profit-oriented) search engines. We’d rather use it to plant trees on our endangered planet.”

A few months later …

“Following further feedback from the [European Commission], we are now making some final changes to the Choice Screen including making participation free for eligible search providers. We will also be increasing the number of search providers shown on the screen. These changes will come into effect from September this year on Android devices.”

Official Google announcement (June 8, 2021)

Conclusions

- New regulatory tool (kudos to Google and EC for trying new solutions)
- ... that is potentially applicable in other important settings
- … but needs to be fixed
- Details matter!

Thank you!