Online search tracking and consumer privacy*

Marcel Preuss†

March 2017

Abstract

Tracking technologies enable sellers to observe a consumer's browsing history on the internet. Consumers are heterogeneous regarding how selective their taste is. In a framework in which consumers search sequentially for prices and match utilities, tracking enables sellers to learn about a consumer's conditional willingness to pay. I find a unique equilibrium exhibiting an increasing price path. Moreover, I endogenize the consumer's choice to disable tracking. Interestingly, the entire browsing history is disclosed in equilibrium despite sellers engaging in price discrimination. While consumers are always made better off compared to no tracking, the effect on profits depends on search costs.

Keywords: consumer search, privacy, dynamic price discrimination.

JEL Classification: : D11, D18, D83, L13, L86

*I am extremely grateful to Martin Peitz for his support and guidance. I thank Chengsi Wang, Thomas Troeger, Nikita Roketskiy and conference participants from Enter Jamboree 2017 for valuable comments.

†Graduate School of Economic and Social Sciences at the University of Mannheim, Germany. E-mail: mpreuss@mail.uni-mannheim.de

Extended Abstract:

On march 28, 2017, US congress gave internet service providers (IPSs) green light to sell their customers' browsing histories to third parties. While this policy may be contested as violating individual privacy, its evaluation remains an open question from an economic viewpoint. In general, improved consumer information on the internet leads to targeting and price discrimination. In the present project, I focus on the issue of browsing history based price discrimination. Browsing data can be made available to online sellers in several ways. It can be obtained from advertising networks such as *Doubleclick* by Google which collect browsing information through cookie placements whenever consumers visit a website. Alternatively, these data are available at a consumer's ISP who can observe a consumer's entire browsing traffic. To focus on price discrimination, I abstain from modeling the upstream market in which these information are sold. Rather, I study what firms learn from observing a consumer's previous search history, whether consumers would allow this discrimination, and how price discrimination based on dynamically updated consumer information affects surplus.

The search model. There is a continuum of consumers $i \in [0, 1]$ and a large number of firms N. Consumers sample sellers sequentially in a random order. Consumers search for both prices and product fitness and pay a sampling cost $s > 0$ for each seller. Product fit is determined by the match utility v, which is assumed to be a random draw from the set $\{0, x\},\ x \in (\underline{v}, 1]$. Match utilities for sellers' products $(v_1, v_2, ..., v_N)$ are independently and identically distributed for each consumer. Consumers differ with respect to their x_i and are thus heterogeneous. Let x_i be distributed according to $F[\underline{v}, 1]$. Denote by $g(x_i) = Prob(v = x)$ the probability that a consumer i with a potential match value x_i receives her positive match value instead of $v_k = 0$ at any seller k. The relationship between x and $g(x)$ is supposed to capture the following relationship: Let x_i to refer to consumer i's taste exceptionality. The underlying idea is that a consumer with niche taste finds few products suitable but obtains a high match utility conditional on a match. The opposite is assumed to hold for consumers with low x_i, who can be referred to as mainstream consumers (Johnson and Myatt, 2006). Based on this interpretation, I assume that the matching probability function $g(x_i) \geq 0$ is weakly decreasing in x_i. Further, assume that both the PDF of the distribution $F()$: $f(x)$ and $g(x_i)$ are log-concave to ensure uniqueness. To prevent the Diamond paradox where consumers do not search, they cannot have perfect information about their taste x_i ex ante. Hence, I assume that both consumers and sellers know only the common CDF of types $F(\cdot)$.

While a consumer's browsing history might in principle contain information about both the number of previous sellers visited and a set of characteristics associated with those sellers, I only focus on the latter, i.e. the number of sellers. The reason is that learning about the exact features of products a consumer has turned down can be informative to sellers only if it is common knowledge how tastes are correlated across products. I assume that this information is not available to sellers.

Traceable Search. Under traceable search, consumers still search randomly but expect sellers to observe their browsing history and to price discriminate. I seek to construct an equilibrium with an increasing price path. The equilibrium concept is *weak Perfect Bayesian Nash Equilibrium.* Off-path, both consumers and firms are assumed to hold passive beliefs. Suppose expectations satisfy: $p_1^e \leq p_2^e \leq ...p_N^e$. Given these expectations, a consumer has no incentive to continue searching after she encounters a match as she can neither obtain a better match utility nor find a lower price. Denote the continuation value from search by

$$V_{k+1} = \mathbb{E}\big[\max\big\{[v_{k+1} - p_{k+1}], 0, V_{k+2}\big\}|h = k\big] - s.$$

Then the consumer's optimal stopping rule is: *Buy* $v_k = x > p_k$*; continue search if* $v_k = 0$ *and* $V_{k+1} > 0$*; end search without buying otherwise.*

It follows that any searching consumer has not encountered a match previously. This allows to update beliefs about a consumer's type if search is traceable. The expected demand from a consumer with a history of $k-1$ sellers writes: $D_k(p) = \int_{p_k}^1 \frac{g(x)\big(1-g(x)\big)^{k-1}}{\int_{\underline{v}}^1 \big(1-g(t)\big)^{k-1} f(t)\mathrm{d}t} f(x)\mathrm{d}x$. I obtain that:

Proposition 1. *An equilibrium with a unique price path satisfying* $p_1 < p_2 < .... < p_N$ *exists.*

The consumer's stopping rule implies that firms can set prices monopolistically. As expected demand from a consumer is less elastic the more sellers larger her search history, prices rise along the search path.

Untraceable search. Without tracking search histories, sellers cannot price discriminate. The symmetric equilibrium must then exhibit a uniform price. Consumers expecting a constant price sequence follow the same stopping rule as described above. Consequently, sellers still set prices monopolistically. However, expected demand is composed of the expected demand for each possible search history, weighted by the respective probabilities. Denote by K^* the maximum number of searches a consumer is willing to make before leaving the market without a purchase (as $V_{K^*+1} < 0$). An equilibrium with a uniform price $p(K^*)$ exists and satisfies $p_{K^*} > p(K^*) > p_1$.

Consumer privacy choice. A consumer's search history can be considered as hard evidence on her willingness to pay. Suppose she could decide whether to disclose or hide this evidence prior to sampling another seller. As the decision to hide one's browsing history from a seller has no consequences when sampling additional sellers, the optimal decision is myopic and only depends on relative prices. Then the following result holds:

Proposition 2. *There exists a unique PBNE where firms charge discriminatory prices increasing with a consumer's traceable search history and a price p_{K^*} if history is hidden. Consumers always allow tracking.*

Existence follows from assuming sellers rationally adopt very pessimistic beliefs about consumers hiding their history. Uniqueness arises because consumers are always better off from disclosing their history to seller $k+1$ if others hide the history after sampling k sellers as the price conditional on hiding after seller k, denoted by $p(K^*, k)$, satisfies $p(K^*, k) > p_{k+1}$.

Comparative statics. How does the full disclosure outcome affect profits and consumer surplus compared to an environment without search-based price discrimination? Regarding consumer surplus, there are two opposing effects. Price discrimination reduces surplus from consumers who encounter a match only at later stages in the search process. However, each consumer has the chance to purchase the good at a lower price compared to no price discrimination if she encounters a match early. To analyze whether this *order effect* can dominate the *discrimination effect*, I make the following assumptions: $g(x)$ preserves the mean across types, i.e. $g(x) = \underline{v}/x$. Further, let $x \sim U[\underline{v}, 1]$ with $\underline{v} = 0.3$.

If search cost are below a certain threshold, it is always optimal for consumers to continue searching until they encounter a match if their history is untraceable. In contrast, the maximum number of sellers a consumer is willing to sample (K^*) is gradually decreasing in search costs if history is traceable. However, despite price discrimination and the potentially lower search intensity, it holds that:

Proposition 3. *Consumer surplus is larger under traceable search than under untraceable search.*

Surprisingly, profits are not always larger if search is traceable. If search costs are within an intermediate range, the reduced search intensity leads to lost profits due to not selling at high prices to niche consumers at later stages during their search process. This can lower profits overall.

Conclusion. The present paper studies search-based price discrimination and consumer privacy choices. Consumers search for both product fitness and prices and differ ex ante with respect to their match value distributions. I find that consumers always prefer to disclose their search history to sellers in order to benefit from the comparatively low price at the very next firm. Therefore, the entire search history is disclosed in equilibrium. In expectation, consumers always benefit from their myopic disclosure behavior. Interestingly, tracking can be detrimental to sellers' profits.