Behavior-Based Price Discrimination under Endogenous Privacy

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Discussion Paper No. 228

January 20, 2020

Collaborative Research Center Transregio 190 | www.rationality-and-competition.de
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Behavior-based price discrimination under endogenous privacy

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January 14, 2020

Abstract

This paper analyzes consumers' privacy choice concerning their private data and firms' ensuing pricing strategy. The General Data Protection Regulation passed by the European Union in May 2018 allows consumers to decide whether to reveal private information in the form of cookies to an online seller. By incorporating this endogenous decision into a duopoly model with behavior-based pricing, we find two contrasting equilibria. Under revelation to both firms, consumers disclose their information. Under revelation to only one firm, consumers hide their information. Based on the model, we design a laboratory experiment. We find that there is a large share of consumers who reveal their private data. Particularly, less privacy-concerned subjects and subjects in the setting where only one firm receives information are more likely to reveal information.

Keywords: Behavior-based pricing, privacy, laboratory experiment

JEL Codes: C91, D11, D43, L13

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1 Introduction

Behavior-based price discrimination is a topic that has been widely discussed. As an example for behavior-based pricing, take an experiment Amazon ran in 2000. The online retailer tested its DVD pricing strategy: they set different prices for new customers, regular customers and product-loyal customers (i.e., customers who had already bought the very same DVD). Amazon used information on buyers' past purchases to discriminate between old and new customers. This was the first major web test of behavior-based pricing. The web test was followed by outrage due to the perceived violation of privacy (Streitfeld, 2000). More recent examples of discrimination between registered and new customers are Netflix's and Amazon Prime's offer of trial months to new customers. Odlyzko (2003) and Tucker (2012) show that the strategy of behavior-based pricing and personalized advertizing has spread across internet retailers.

Since Amazon's experiment a lot has changed in the field of data protection and privacy. Particularly, the passing of EU's General Data Protection Regulation (GDPR) in May of 2018 was a major break-through for privacy protection. In accordance with the regulation, consumers can now decide whether to allow websites to access their personal information contained in cookies. The information included are past purchases, search history, personal data and more. Online retailers use the data to make personalized offers in line with behavior-based pricing. Thus, with the GDPR, consumers have the power to act strategically in their cookie choice. [1] By electing to deny cookies, consumers stay anonymous to firms and cannot be identified as old customers. Conversely, when consumers allow a firm to access their cookies, they can be identified and targeted with customized prices.

In this paper we extend a standard model of behavior-based pricing (Fudenberg and Tirole, 2000) by including consumers' choices whether to allow cookies based on the concept of the GDPR. Within our novel model, we focus on how consumers react strategically to behavior-based pricing when privacy is endogenized, and how sellers' pricing strategy changes accordingly. We explore the research questions from two different angles: firstly, we solve our model theoretically and secondly, we test the resulting equilibria in a laboratory experiment.

In both our analyses, we build on the Hotelling (1929) model with two competitive firms and a continuum of consumers distributed along a straight line. We consider a two-period game, where a consumer buys one unit of a product in each period from one of the firms. In the first stage of the theoretical model, firms set identical prices for all consumers with no information about consumers' preferences. At this point, consumers decide from which firm to buy and whether to reveal their cookies. In the second stage, based on consumers'

[1] Throughout this paper we use the term "cookie" to refer to information about past purchases.

privacy strategy, firms set different prices and consumers, again, decide where to buy. The GDPR provides a good frame for analyzing consumers' endogenous choice.

In the theoretical analysis, we find that the optimal pricing strategy is a mixture of uniform pricing and standard behavior-based pricing (Fudenberg and Tirole, 2000). Depending on the firms' targetability of the competitor's consumers, we define different information settings and find opposing equilibria for consumer strategies. In the complete information case, when consumers' data is available to both competitors, consumers are best-off by giving up their privacy, in order to increase competition between sellers. In the incomplete information case, when consumers' data is only available to the respective firm they bought from, consumers are best-off by maintaining their privacy. Both equilibria are obtained under a pooling assumption. The more general case lies between the two extreme cases of complete and incomplete information. Here, sellers can target a random share of their competitor's consumers. In the general case, no pooling equilibrium exists.

To test the theoretical predictions, we design a controlled laboratory experiment. We relate measures of iterative reasoning and privacy concerns with behavior in a stylized market environment that closely resembles our theoretical model. With this approach, we investigate whether subjects act according to our predictions of full information disclosure in the complete information treatment and full information concealment in the incomplete information treatment.

In the experiment, we find that a lot of the consumers allow tracking of their past purchase, however, they are less likely to do so over time as well as when they are more concerned about privacy. Also, given only the firm consumers have bought from has access to consumer's information, subjects are initially more willing to reveal their data.

The literature on behavior-based pricing considers different aspects of consumer's decision about their privacy. The paper that is closest to ours analyzes consumers who can be tracked based on their past purchases in a monopoly (Conitzer et al., 2012). Other papers are concerned with a secondary market for consumer data (Casadesus-Masanell and Hervas-Drane, 2015; Taylor, 2004). Colombo (2016) and Esteves (2014) each take a look at an exogenous share of anonymous consumers, but do not consider an endogenous consumer decision.

Literature combining a theoretical analysis of behavior-based pricing with experimental evidence is scarce. Brokesova et al. (2014) experimentally test theoretical predictions of Chen and Pearcy (2010) concerning the role of price commitment and stochastic preferences for BBPD in an experiment with computerized buyers. Mahmood (2014) implements a model by Shin and Sudhir (2010) to analyze the impact of heterogeneous buyers, though the experimental approach is more akin to a differentiated products Bertrand competition than to the spatial competition of the underlying theory.

We contribute to the literature by focusing on consumers' endogenous privacy decisions in competitive markets under a set of different information schemes. Combining a theoretical model with an experiment to answer the research questions is a novel approach to such a problem.

2 Literature Review

In the theoretical literature, the paper closest to our work is Conitzer et al. (2012). They study a monopoly with an outside option and consumers who can choose to let the monopolist track their purchases. As in our paper, consumers have an endogenous privacy choice. However, Conitzer et al. (2012) do not study a competitive situation of behavior-based pricing, where the strategic action of consumers has different implications for pricing. Our focus is on consumers' privacy choice for different information settings, in which we diverge from the theoretical analysis of Conitzer et al. (2012). Acquisti and Varian (2005) also look at a monopoly with endogenous privacy choice and analyze the situation from a mechanism design perspective. In an extension they look at a competitive setting with a large number of firms under incomplete information between firms. Montes et al. (2018) consider a duopoly with a costly privacy choice for consumers. They focus on a data broker who sells consumers' data to competing firms. One of their main results is that information is usually only sold to one of the firms.

Another important paper is by Colombo (2016). He considers a set-up of incomplete information sharing in a duopoly case similar to our incomplete information case (in Section 4.2). Colombo uses a fixed parameter as share of anonymous consumers and does not consider consumers' endogenous privacy choice. The main point of our study, however, is to analyze the strategic decision of consumers.

There is a literature that connects firms to a secondary market of consumer information. In Casadesus-Masanell and Hervas-Drane (2015) sellers derive profit from buyers' purchases as well as from a secondary market where consumers' information can be disclosed. The decision of consumers to reveal information plays a twofold role here. The authors find that the profit maximizing strategy of firms is to focus on the consumer market. Taylor (2004) studies a model with two monopolists and horizontal product differentiation. Consumers' demands for the goods are positively correlated, therefore, each purchase contains valuable information for both monopolists. Taylor compares a non-disclosure to a full disclosure regime where firms can exchange information about consumers.

Other papers have looked at the quality of information in a spatial competition setting

(Esteves, 2014; Liu and Serfes, 2004) but do not look at consumers' privacy decision instead they use an exogenous parameter.

Extensive reviews of the literature on behavior-based price discrimination in general can be found in Armstrong (2006); Esteves et al. (2009); Fudenberg and Villas-Boas (2006).

The analysis of behavior-based pricing under endogenous privacy in the experiment relates to two branches of experimental literature. Firstly, the basic structure and procedure is related to spatial competition experiments. We extend the existing literature on BBPD and spatial competition with location choice experiments. BBPD experiments have been conducted by Brokesova et al. (2014) and Mahmood (2014). Brokesova et al. (2014) computerize the buyers side, which we do not. Mahmood (2014) only considers two fixed locations for buyers, whereby the experimental market rather resembles a Bertrand market with differentiated products than a spatial competition. We employ a BBPD experiment similar to those two but introduce features from spatial competition with location choice experiments by Camacho-Cuena et al. (2005) and Barreda-Tarrazona et al. (2011).

Secondly, we introduce privacy and data sharing elements. Similar issues have been studied before, but to our knowledge not in context of an explicit market experiment. Acquisti et al. (2013) identify a considerable gap between willingness to accept disclosure of private information and willingness to pay for the protection of private information. To alleviate this issue we renounce enforcing a default option on privacy, assuming disclosure and protection are both costless. Beresford et al. (2012); Preibusch et al. (2013) find that subjects have a remarkably low willingness-to-accept for giving up their privacy and are not acting on their stated privacy decisions when protection of privacy is costless. However, this finding contrasts Tsai et al. (2011) who find that subjects act on websites' certified privacy protection qualities when shopping online. They suggest that subjects might in fact be willing to pay premiums for privacy protection. Schudy and Utikal (2017) find that subjects' willingness to share personal information decreases when the number of recipients of said information increases. Feri et al. (2016) explore in a lab setting how privacy disclosure is affected by risks of privacy shock in the form of data breaches. They find that only those consumers, who regard their information as sensitive, demonstrate an effect on information disclosure under different likelihoods of data breaches.

3 Model

We consider a set-up following Hotelling (1929), where a line segment of length $\bar{\theta}$ spans a product characteristic space. Along the line, consumers are uniformly distributed with a density of $\bar{\theta}^{-1}$, i.e., we assume a consumer mass of 1. The location of a consumer is private knowledge to them and denoted by $\theta \in [0, \bar{\theta}]$, such that θ serves as a consumer's preferred variety of a good. The further away from the produced variety a consumer is located, the lower is their utility. Consumers' locations can also be interpreted as their type.

There are two firms each producing a variant of the same good at constant marginal costs k, which are normalized to zero; fixed costs are neglected. Firm A is located at the left end of the line segment, while firm B is placed at the right end. The firms compete for two periods, $t = 1, 2$, which we also refer to as stages.

In each period, consumers buy one unit of the good either from firm A or B, i.e., we assume that the valuation of the product is large enough to make sure each consumer buys one unit in each stage and no outside option is available. Considering a consumer located at $\hat{\theta}$, their utility is given by $U_A = v - p_a - \hat{\theta}$ or $U_B = v - p_b - (\bar{\theta} - \hat{\theta})$, depending on their purchasing decision. We assume consumers' unit transportation cost to be normalized to 1. Consumers' valuations, v, are the same over time for all consumers.

On top of the purchasing decisions, consumers also decide whether to accept the use of cookies, $q \in \{0, 1\}$, in the first period. We use cookies as proxy for a consumer's purchasing history, which is revealed to a company if $q = 1$. In that case, a firm is able to identify a buyer from period $t = 1$ and can thus set a different price in the upcoming period. Consumers have the option to act strategically with regards to revealing information. In the literature it is often assumed that such a privacy choice involves some costs (Conitzer et al., 2012; Montes et al., 2018). We refrain from such an assumption to keep the predictions for the experiment clean from any cost effects and not impose an implicit privacy concern on subjects in the experiment. Consumer's rationale is to maximize their utility. We do not take discounting into account.

In $t = 1$ competing firms set prices $\mathbf{p_1} = (p_1^A, p_1^B)$. In the second period pricing is more involved. Depending on the preceding cookie choice of consumers there is a share λ of anonymous customers who forbade the use of their cookies and a share $1 - \lambda$ of identifiable customers. These shares are essentially derived from consumers' choice regarding their cookies.

Given the cookie choice of a consumer, we differentiate between a continuum of information settings. The information settings differ according to the value of a parameter $\beta \in [0, 1]$. Simply speaking, β is a firms' targetability [2] of their competitor's turf in the second stage. That means, in the second stage each firm can randomly target a β share of its competitor's consumers who chose to reveal information in the first stage. To clarify β, consider the two extreme cases $\beta = 0$ and $\beta = 1$. When $\beta = 0$, firms cannot target their competitors' consumers. In this incomplete information setting, accepting the use of cookies, means that

[2] Chen et al. (2001) provide an extensive analysis of imperfect targetability in marketing.

only the firm a consumer has bought from can access information about a consumer's past purchase (contained in the cookie). When $\beta = 1$, firms can target all their competitor's consumers who chose to reveal their cookies. In this complete information setting, accepting the use of cookies, means that both firms can access the information about a consumer's past purchase (contained in the cookie). For any $\beta \in (0, 1)$ we formulate a general case where only a share β can be targeted by the competitor.

In the complete information setting, where both firms can target the competitors' consumers, each distinguishes three prices in the second stage: $p^i_{2,i}$, is a loyalty price for consumers who bought from firm i in the first stage and decide to buy from the same firm in the second stage; $p^j_{2,i}$, is a poaching price for identifiable consumers who bought from i in the first period and j in the second period; and p^i_2, is an anonymous price for consumers who belong to the share λ, where $i, j = A, B$ and $i \neq j$. The idea of poaching consumers was first explored in Fudenberg and Tirole (2000). In Section 4.2, we diverge from the complete information setting and assume that only firms that consumers have bought from in the first period can learn about the purchasing history. This alters the pricing strategy since firms can no longer set a poaching price $p^j_{2,i}$, because the information needed is not available to them. The case for $\beta \in (0, 1)$ is a mixture of the two extreme cases. Depending on consumer's location, consumers who revealed information, face a poaching price $p^j_{2,i}$ with probability β and with probability $1 - \beta$ the anonymous price p^i_2 from the competitor. Therefore, firms cannot commit to not use the information they obtain about consumers' first-period purchases.

At the beginning of the game β is randomly drawn and common knowledge. Each consumer privately learns their type θ. Then in the first period, firms set prices $\mathbf{p_1}$. Afterward, consumers simultaneously make their purchasing decision, $b_1 \in \{A, B\}$ and their cookie choice, $q \in \{0, 1\}$. In the second period, firms set prices $\mathbf{p_2} = (p^i_{2,i}, p^i_2, p^j_{2,i})$, and then β is realized. At the end of the second period consumers again choose to buy from A or B. Finally, consumers receive their utilities and firms earn profits.

In our analysis we focus on determining equilibria where all consumers anonymize with the same probability independent of their location. We solve for perfect Bayesian Nash equilibria (PBE). In this context a PBE comprises a firm's strategy (first and second period prices given the information sets for each period [3]), consumers' strategy (first period purchase and cookie choice as functions of the location and p^i_1, as well as second period purchase as function of the location and second period prices) and the firms' beliefs about consumers' locations given their cookie choice. The firms' beliefs correspond to the consumer mass within segments of the Hotelling line. The segments are functions of the prices given consumers'

[3]The strategy should also contain second period prices if firms had set different prices in the first period. This is omitted here for simplicity.

privacy choices [4].

4 Equilibrium Analysis

In this section we determine the theoretical equilibria of the two-period game. We consider three distinct information settings: firstly, we assume that information about previous purchases is given to both firms, irrespective of the actual buying decision of consumers, i.e., $\beta = 1$. Secondly, we analyze the incomplete information case, where only the firm that a consumer has bought from in $t = 1$ can access consumers' cookies, i.e. $\beta = 0$. Lastly, we explore the general case for $\beta \in (0, 1)$, where consumers observe a poaching price p_i^j with probability β or put differently firms can target a random share of β consumers of their competitor.

We focus on pooling equilibria, where each buyer has an identical probability to reveal information independent of their location. In the extreme cases, we show that there is an optimal pooling equilibrium where consumers' cookie choices are in pure strategies. This means that all consumers, independent of their type, make the same decision regarding their cookies and $\lambda \in \{0, 1\}$. However, no pooling equilibrium exists in the general case.

4.1 Complete Information

In the complete information setting both firms receive information about a consumer's previous purchase given the consumer decides to share their cookies. This means $\beta = 1$. In a pooling equilibrium, we assume that with probability λ, a consumer decides to hide their cookies, and with probability $1 - \lambda$, to reveal their cookies.[5] Consumers who did not let firms access their cookies in the first stage, are anonymous to both firms and are treated as new customers. Therefore, they face prices p_2^A (p_2^B) from firm A (firm B) in the second stage. Consumers who reveal information about the purchase in the first period, can be recognized by firms and thus are offered different prices in the second stage, $p_{2,A}^A$ ($p_{2,A}^B$) as the prices offered by firm A (firm B) for those who bought from firm A in the first stage, and $p_{2,B}^B$ ($p_{2,B}^A$) as the prices provided by firm B (firm A) for those who bought from firm B in the first stage. Under the GDPR such a situation can arise, since firms can choose to share consumers' data with a partner firm or a competitor, as long as they inform consumers about the data transfer. In the literature there are several papers which consider a secondary

[4]The firms also have beliefs about the acions of anonymous consumers (whether they bought from A or B), however, they do not affect the analysis.

[5]Notice that under a pooling equilibrium the share of anonymous consumers λ can also be interpreted as probability.

market for consumer data or a data broker (Casadesus-Masanell and Hervas-Drane, 2015; Chen et al., 2001; Montes et al., 2018). In this literature a full revelation situation can also arise.

The firms' beliefs about consumers' locations are given by the segmentation of the Hotelling line. We divide consumers by their privacy choice into identifiable and anonymous consumers and can therefore consider two separated Hotelling lines. On the Hotelling line of consumers who did not share their purchase from the first period, there will be a mass of λ consumers. Firms segment this line by a marginal consumer θ_2 who is indifferent between buying from firm A and firm B. θ_2 is determined by $v - p_2^A - \theta_2 = v - p_2^B - (\bar{\theta} - \theta_2)$ as

$$\theta_2 = \frac{\bar{\theta}}{2} + \frac{p_2^B - p_2^A}{2}.$$

Therefore, firms believe that consumers with location $\theta \in [0, \theta_2)$ buy from firm A in the second period given they anonymized. Similarly, consumers with $\theta \in (\theta_2, \bar{\theta}]$ buy from firm B.

The maximization problem of the firms on this Hotelling line are given by:

$$\begin{aligned} &\underset{p_2^A}{max} \quad \lambda p_2^A \left[\frac{\bar{\theta}}{2} + \frac{p_2^B - p_2^A}{2}\right] \\ &\underset{p_2^B}{max} \quad \lambda p_2^B \left[\bar{\theta} - (\frac{\bar{\theta}}{2} + \frac{p_2^B - p_2^A}{2})\right]. \end{aligned}$$

We can derive the first-order conditions as

$$\frac{\bar{\theta}}{2} + \frac{p_2^B}{2} - p_2^A = 0 \qquad \frac{\bar{\theta}}{2} - p_2^B + \frac{p_2^A}{2} = 0$$

and we obtain the anonymous prices $p_2^A = p_2^B = \bar{\theta}$ and the marginal consumer, $\theta_2 = \frac{\bar{\theta}}{2}$.

The other Hotelling line has a mass of $1 - \lambda$ consumers who revealed their data in the first stage. They are confronted with behavior-based price discrimination. Among the mass of $1 - \lambda$ consumers, those who bought from firm A in the first stage are given two prices in the second period: $p_{2,A}^A$ as a loyal-customer price set by firm A and $p_{2,A}^B$ as a poaching price from firm B. Similarly, considering consumers who bought from firm B in the first stage also face two prices now, $p_{2,B}^B$ as a loyal-customer price from firm B, and $p_{2,B}^A$ as a poaching price from firm A.

Firms' beliefs lead to two segments on this Hotelling line. There is a marginal consumer characterized by $v - p_{2,A}^A - \theta_2^A = v - p_{2,A}^B - (\bar{\theta} - \theta_2^A)$, which is equivalent to

$$\theta_2^A = \frac{\bar{\theta}}{2} + \frac{p_{2,A}^B - p_{2,A}^A}{2}.$$

Accordingly, the marginal customer θ_2^B is determined by $v - p_{2,B}^A - \theta_2^B = v - p_{2,B}^B - (\bar{\theta} - \theta_2^B)$, which gives

$$\theta_2^B = \frac{\bar{\theta}}{2} + \frac{p_{2,B}^B - p_{2,B}^A}{2}.$$

This means, firms believe that identified consumers with $\theta \in [0, \theta_2^A)$ and $\theta \in (\theta_2^B, \bar{\theta}]$ are loyal to their first-period sellers. Whereas, consumers at $\theta \in (\theta_2^A, \theta_1)$ and $\theta \in (\theta_1, \theta_2^B)$ are poached by the competitor firm, where θ_1 denotes the first-period marginal consumer who is indifferent between buying from A and B.

Figure 1 depicts the beliefs/consumer shares and respective pricing by spanning a rectangle over both Hotelling lines connected vertically through the share λ.

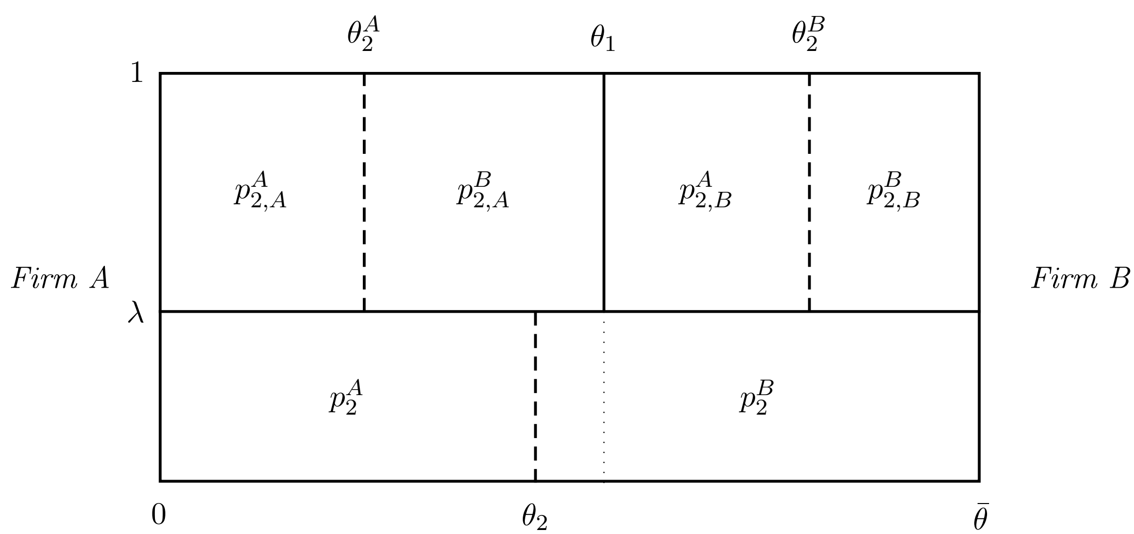


Figure 1: Customer segments under complete information

For the the Hotelling line with consumer mass $1-\lambda$, we have the following maximization problems:

$$\max_{p_{2,A}^A, p_{2,B}^A} \quad (1-\lambda)\left[p_{2,A}^A \theta_2^A + p_{2,B}^A(\theta_2^B - \theta_1)\right]$$

$$\max_{p_{2,B}^B, p_{2,A}^B} \quad (1-\lambda)\left[p_{2,B}^B(\bar{\theta} - \theta_2^B) + p_{2,A}^B(\theta_1 - \theta_2^A)\right]$$

By plugging θ_2^A and θ_2^B into these two equations, we can solve for the prices.

Lemma 1 *The set of prices in the second stage depend on* $\theta_1(\mathbf{p_1})$ *and the parameter* $\bar{\theta}$*. For firm A the anonymous, the loyalty and the poaching prices are:*

$$p_2^A = \bar{\theta} \qquad p_{2,A}^A = \frac{1}{3}(2\theta_1 + \bar{\theta})$$
$$p_{2,B}^A = \frac{1}{3}(3\bar{\theta} - 4\theta_1)$$

Accordingly, for firm B the prices are given by:

$$p_2^B = \bar{\theta} \qquad p_{2,B}^B = \frac{1}{3}(3\bar{\theta} - 2\theta_1)$$
$$p_{2,A}^B = \frac{1}{3}(4\theta_1 - \bar{\theta})$$

Proof. *See Appendix.* ■

Lemma 1 shows that if a customer chooses not to share their information in the first stage, they will face uniform pricing in the second stage. However, if they reveal information in the first stage, they will be confronted with behavior-based prices, including poaching prices offered by the competitive firm in the second stage. Lemma 1 demonstrates that prices are independent of λ.

When we move to the first stage, we need to think about the consumers' endogenous decisions about their cookies. By comparing the prices for anonymous consumers with the two prices for recognized buyers we can show that prices as anonymous customer are always higher, such that consumers can strategically choose to share their purchasing history, in order to receive lower prices in the second stage. This means the probability to hide cookies is zero and thus the mass λ of consumers on the anonymous Hotelling line is also zero.

Next we consider price setting of both firms in the first period. Similar to the second stage, there are two separated Hotelling lines in the first stage. For the line of consumers who did not share their cookies, there is a cut-off customer $\hat{\theta}_1$, who, in the first period, is indifferent between buying from firm A at p_1^A and buying from firm B at p_1^B [6], is determined by

$$v - p_1^A - \hat{\theta}_1 = v - p_1^B - (\bar{\theta} - \hat{\theta}_1)$$

where we can easily get that $\hat{\theta}_1 = \frac{\bar{\theta}}{2} + \frac{1}{2}(p_1^B - p_1^A)$.

On the other hand, on the line of those who shared their cookies in the first stage, the

[6] $\hat{\theta}_1$ is not influenced by the prices in the second stage, since the share of those who did not disclose their information is λ, and the two firms will maximize their profits by choosing p_2^A and p_2^B which are independent of the first stage.

marginal customer, θ_1, is defined by the following equivalence,

$$v - p_1^A - \theta_1 + \left[v - p_{2,A}^B - (\bar{\theta} - \theta_1)\right] = v - p_1^B - (\bar{\theta} - \theta_1) + \left[v - p_{2,B}^A - \theta_1\right]$$

The equation represents consumers indifferent between buying from firm A at p_1^A in stage one and afterward from firm B at $p_{2,A}^B$ in stage two, and buying from firm B at p_1^B in stage one and then purchasing from firm A at $p_{2,B}^A$ in stage two. Hence, the marginal consumer is given by $\theta_1 = \frac{\bar{\theta}}{2} + \frac{3}{8}(p_1^B - p_1^A)$.

In the first stage firms maximize the overall profits, thus firm A's problem is to maximize the following term with respect to the first-period prices

$$\pi^A = \lambda p_1^A \hat{\theta}_1 + (1-\lambda) p_1^A \theta_1 + \lambda p_2^A \theta_2 + (1-\lambda)\left[p_{2,A}^A \theta_2^A + p_{2,B}^A(\theta_2^B - \theta_1)\right].$$

Similarly, firm B maximizes

$$\pi^B = \lambda p_1^B(\bar{\theta} - \hat{\theta}_1) + (1-\lambda) p_1^B(\bar{\theta} - \theta_1) + \lambda p_2^B(\bar{\theta} - \theta_2) + (1-\lambda)\left[p_{2,A}^B(\theta_1 - \theta_2^A) + p_{2,B}^B(\bar{\theta} - \theta_2^B)\right].$$

From the second-stage analysis, we obtained $p_2^A = p_2^B = \bar{\theta}$ and $\theta_2 = \frac{\bar{\theta}}{2}$. Therefore the respective third terms in the profit functions do not affect the maximization problem. Inserting $p_{2,A}^A$, $p_{2,A}^B$, $p_{2,B}^A$, $p_{2,B}^B$, and θ_1 into the two maximization problems above we can derive the two first-order conditions,

$$\frac{\bar{\theta}}{2} + \frac{3+\lambda}{8} p_1^B - \frac{3+\lambda}{4} p_1^A - \frac{5}{16}(1-\lambda)(p_1^B - p_1^A) = 0$$

$$\frac{\bar{\theta}}{2} + \frac{3+\lambda}{8} p_1^A - \frac{3+\lambda}{4} p_1^B + \frac{5}{16}(1-\lambda)(p_1^B - p_1^A) = 0$$

.

Proposition 1 *The optimal prices under complete information for the competing firms in both periods are*

$$\begin{aligned}
p_1^A = p_1^B &= \frac{4}{3+\lambda}\bar{\theta} \\
p_{2,A}^A = p_{2,B}^B &= \frac{2}{3}\bar{\theta} \\
p_{2,B}^A = p_{2,A}^B &= \frac{1}{3}\bar{\theta} \\
p_2^A = p_2^B &= \bar{\theta}
\end{aligned}$$

Therefore, the marginal consumer in the first stage is located at $\theta_1 = \frac{\bar{\theta}}{2}$, and we have thus *reached a symmetric PBE. The obtained PBE is characterized by a common consumer strategy where $\lambda = 0$.*

Proof. *See Appendix.* ■

From the results we can gather that given a consumer stays anonymous in the first period, they face uniform pricing in the second period. Otherwise, they are confronted with price discrimination, which leads to identical results as in standard behavior-based pricing (Fudenberg and Tirole, 2000) [7]. The limit cases of λ reveal an interesting insight. If $\lambda = 1$, which means that none of the consumers give their cookies in the first stage, this results in $p_1^A = p_1^B = \bar{\theta}$, the prices match a uniform pricing strategy. If $\lambda = 0$, which means that all consumers share their information in the first stage, we get that $p_1^A = p_1^B = \frac{4}{3}\bar{\theta}$, which is a standard behavior-based pricing strategy. Therefore, for all values of λ in between 0 and 1, p_1^A and p_1^B represent a mixture of uniform pricing and behavior-based pricing. Consumers are best off by giving their cookies, because they can benefit from the lower customized prices in the second stage. This means consumers act strategically [8]. By revealing their information they increase the competition between firms. Therefore, revealing cookies is a dominant strategy. In this case the pooling equilibrium is driven by consumers and not an optimal equilibrium from a firm's perspective.

4.2 Incomplete Information

In this section we analyze a setting where firms can only learn about cookies of customers who actually bought from them, i.e., $\beta = 0$. This implies that there is incomplete information in the market, as for example consumers of firm B, might reveal their purchasing history to B, such that B can identify them. However, firm A does not receive the information and therefore these consumers are anonymous to A. The pricing strategy in the second period is distinct from the complete information setting, where three different prices were set by each firm after consumers made a decision regarding their cookie choices. In comparison, in the incomplete information setting firms cannot distinguish between a competitor's customers and their own anonymous consumers. They are just one mass of non-identifiable consumers. This implies that firms can not set a poaching price to steal buyers from each other. The pricing strategy for the second period only entails a loyalty price, $p_{2,i}^i$ and an anonymous customer price, p_2^i for $i = A, B$. The first-period pricing is similar to the complete information case and not affected by the difference in the information setting. As before, there is a

[7] The results also hold if transportation costs are quadratic. See Appendix.

[8] The result extends to the case where consumers are myopic. As a robustness check, we show that being strategic or myopic does not affect the consumers' decisions. See Appendix.

marginal consumer in the first stage, $\theta_1(\mathbf{p_1})$ who is indifferent between buying from A and B. The analysis is similar to Colombo (2016). However, the essential difference is that he treats λ as a parameter, while we use it as proxy for consumers' endogenous decisions regarding their cookies.

In the incomplete information setting the Hotelling lines cannot be separated as in the complete information setting. The reason is that the anonymous price serves two functions. Firstly, it is the price for the own consumers who are not identifiable and secondly, it serves as a "poaching price" for competitors' consumers. The graph below depicts this clearly, since p_2^i appears on both Hotelling lines. Firms want to maximize their profits by choosing prices $p_{2,i}^i$ and p_2^i for $i = A, B$ in the second stage. As before, there is a share $1 - \lambda$ of consumers who choose to give their cookies and a share λ of consumers who hide their cookies. Firms' beliefs about the location of the anonymous and identifiable consumers are again given by the marginal consumers. For the share λ of consumers who are anonymous there is an indifferent customer located at θ_2, impartial between buying from A at price p_2^A and B at price p_2^B. For the identifiable consumers, there is a marginal consumer in each of the companies' turfs: $\theta_2^{A'}$ is indifferent between buying from A as identifiable consumer and buying from B as anonymous customer, whereas $\theta_2^{B'}$ is the respective cut-off value on B's turf.

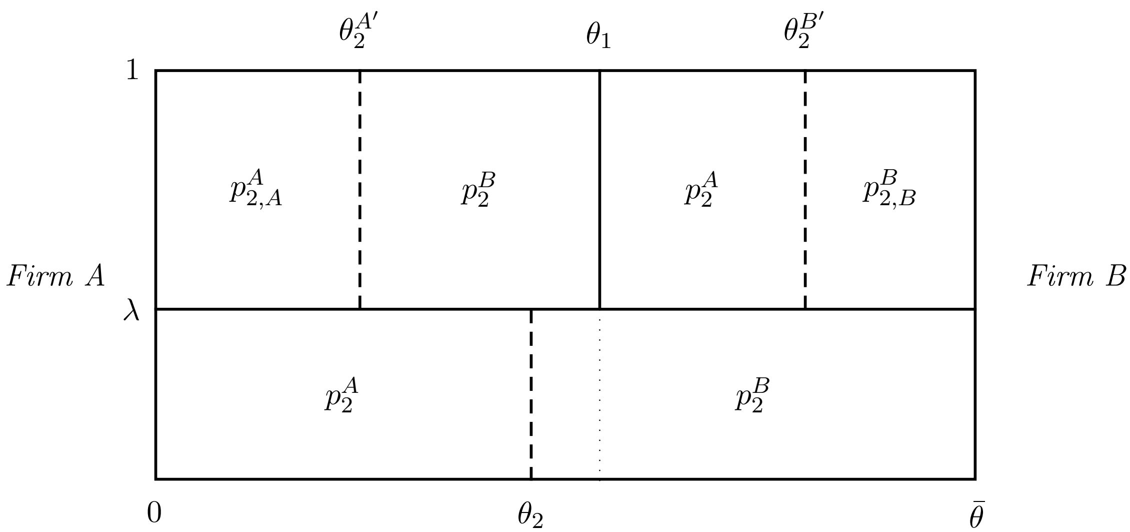


Figure 2: Customer segments under incomplete information

Figure 2 shows customer segmentation and price setting in a rectangle of Hotelling lines, where the two lines are again connected by λ. Firm's beliefs are again that anonymous consumers to the left of θ_2 buy from firm A and to the right buy from B. Given the consumers choose to identify, firms believe that to the left of $\theta_2^{A'}$ and to the right of $\theta_2^{B'}$ consumers are loyal. While consumers with $\theta \in (\theta_2^{A'}, \theta_1)$ and $\theta \in (\theta_1, \theta_2^{B'})$ are "poached" by the competitive firm with the anonymous price.

From Figure 2 we derive the maximization problems of the companies:

$$\max_{p_2^A, p_{2,A}^A} \pi_2^A = \max_{p_2^A, p_{2,A}^A} \lambda p_2^A \theta_2 + (1-\lambda) p_{2,A}^A \theta_A + (1-\lambda) p_2^A (\theta_B - \theta_1)$$
$$\max_{p_2^B, p_{2,B}^B} \pi_2^B = \max_{p_2^B, p_{2,B}^B} \lambda p_2^B (\bar{\theta} - \theta_2) + (1-\lambda) p_{2,B}^B (\bar{\theta} - \theta_B) + (1-\lambda) p_2^B (\theta_1 - \theta_A)$$

Lemma 2 *Solving the maximization problems, we can derive the following prices for the second stage. For firm A:*

$$p_2^A(\lambda, \mathbf{p_1}) = \frac{(9 - 2\lambda + 5\lambda^2)\bar{\theta} - 4(3-\lambda)(1-\lambda)\theta_1}{3\left[4 - (1-\lambda)^2\right]}$$
$$p_{2,A}^A(\lambda, \mathbf{p_1}) = \frac{(3 + 10\lambda - \lambda^2)\bar{\theta} + 2(3-\lambda)(1-\lambda)\theta_1}{3\left[4 - (1-\lambda)^2\right]}$$

For firm B:

$$p_2^B(\lambda, \mathbf{p_1}) = \frac{(-3 + 14\lambda + \lambda^2)\bar{\theta} - 4(3-\lambda)(1-\lambda)\theta_1}{3\left[4 - (1-\lambda)^2\right]}$$
$$p_{2,B}^B(\lambda, \mathbf{p_1}) = \frac{(9 + 2\lambda + \lambda^2)\bar{\theta} - 2(3-\lambda)(1-\lambda)\theta_1}{3\left[4 - (1-\lambda)^2\right]}$$

Proof. *See Appendix.* ■

The second-period prices in this case are not only dependent on the first-period prices, as is the case in the analysis of the complete information setting, but they also depend on λ as the share of buyers who choose to be anonymous.

All prices increase with λ, i.e., the more likely consumers are to hide their cookies, the higher are not only the anonymous prices but also the loyalty prices of both firms. This always holds for $\bar{\theta} = 1$ and $\theta_1 = \frac{1}{2}$ [9], two assumptions used in the literature (Colombo, 2016). The first is a simple standardization of the length of the Hotelling line, while the second uses the assumption that the line is separated symmetrically between the firms. Since firms are symmetric, the assumption is not restrictive. In the following analysis of the second-period prices we apply these assumptions. The Appendix contains more general results.

When studying the limit cases of $\lambda = 0$ and $\lambda \to 1$ [10], we can observe that under $\lambda = 0$ the loyalty prices for both firms are $\frac{2}{3}$ and the anonymous prices are $\frac{1}{3}$. These results correspond to the loyalty prices in the complete information case and the poaching prices, respectively. Given $\lambda \to 1$ all prices converge to $\bar{\theta} = 1$, the uniform pricing strategy.

[9] When solving for the first period we can show that this is the case. See Proposition 2.

[10] Notice that for $\lambda = 1$, the loyalty prices are no longer contained in the maximization problems.

We can also show that within the range of $\lambda \in [0, 1]$ the loyalty and anonymous prices do not cross which can be seen in Figure 3. [11] Therefore, even though the anonymous prices increase with λ, they are always below the loyalty prices. In Figure 3, we observe a situation that is similar to the prisoner's dilemma. Consumers face higher prices when they have probability of $\lambda \to 1$ for anonymizing. Pricing will correspond to uniform prices. On the other hand, if consumers were to decide to hide their information with probability 0, this would lead them to a price of $\frac{2}{3}$ which is below 1. This means if consumers can coordinate on putting zero probability on anonymizing, such that $\lambda = 0$, they would all gain. However, consumers have an incentive to deviate to stay anonymous with a positive probability, since they face an even lower anonymous price for any $\lambda > 0$. This incentive leads all consumers to anonymize.

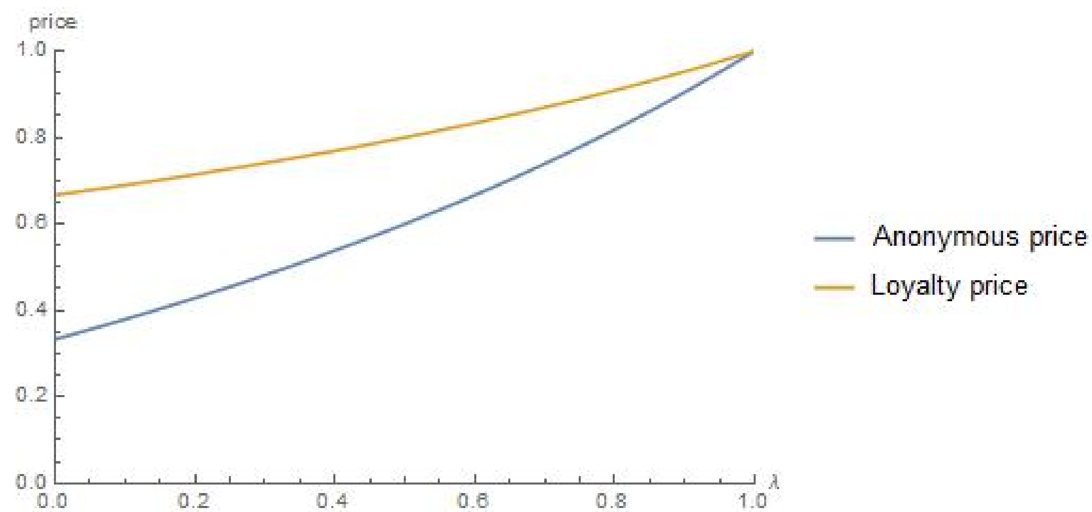


Figure 3: Prices of Firm A under restrictions

Since the prices of firm A and B are identical under these restrictions, we are only looking at the graph of prices for firm A as an example. The spread of the two price curves is getting smaller the larger λ is such that the incentive to deviate to a higher anonymous probability also decreases, since the price gap narrows with λ.

Because consumers' best strategy is to hide their cookies with probability $\lambda \to 1$, the two periods in this game are independent of each other. Therefore, in the first stage the firms solve the following maximization problems:

[11]For the formal analysis see Appendix.

$$\pi^A = p_1^A \theta_1 + \pi_2^A \rightarrow \max_{p_1^A}$$

$$\pi^B = p_1^A(\bar{\theta} - \theta_1) + \pi_2^B \rightarrow \max_{p_1^B}$$

where $\theta_1 = \frac{p_1^B - p_1^A + \bar{\theta}}{2}$ for $\lambda = 1$.

Proposition 2 *In the incomplete information case, final prices all coincide with the uniform pricing strategy, such that prices on the first and second stage are $\bar{\theta}$. Therefore, the PBE is an equilibrium in pure strategies with $\lambda = 1$.*
Proof. *See Appendix.* ■

Consumers have an incentive to choose to anonymize with highest probability, i.e. $\lambda = 1$. The results stands in contrast to the implication derived in the complete information case where all consumers give their cookies (i.e. $\lambda = 0$). In the incomplete information case companies obtain larger profits because they do not receive information about their consumers. Therefore, the firms cannot set customized prices but have to conform to a uniform pricing strategy.

4.3 General Case

In the previous sections, we have discussed the complete information ($\beta = 1$) and incomplete information ($\beta = 0$) cases. Now we focus on the general scenario, to analyze the case where each firm can randomly target part of their competitor's turf in the second stage.

We use β to represent a firm's targetability of their competitor's turf in the second stage. In the general case we look at $\beta \in (0, 1)$. In other words, a β share of the opponent's consumers can be targeted. [12] The time line of the general case is as follows: in $t = 1$ competing firms set prices $\mathbf{p_1} = (p_1^A, p_1^B)$ and consumers make their purchase decisions and cookie choices simultaneously. In the second period, firms set different customized prices $\mathbf{p_2} = (p_{2,i}^i, p_2^i, p_{2,i}^j)$. Then β is revealed, and consumers decide again where to buy depending on the prices they are facing. Above the beliefs about the consumers' locations were based on their privacy choices, now firms form beliefs given the privacy choice and targetability of consumers.

In the two extreme cases before we distinguished two Hotelling lines based on the privacy choice of consumers. Here, we obtain three Hotelling lines: for consumers who are anony-

[12] β is public information. The realization of β is random.

mous, for consumers who are identifiable but can not be targeted, and for consumers who are identifiable and can be targeted. [13]

Firms' beliefs about consumers' locations are determinded in the same way as in the extreme cases above. The weighting of each Hotelling line is different. This is depicted in Figure 4.

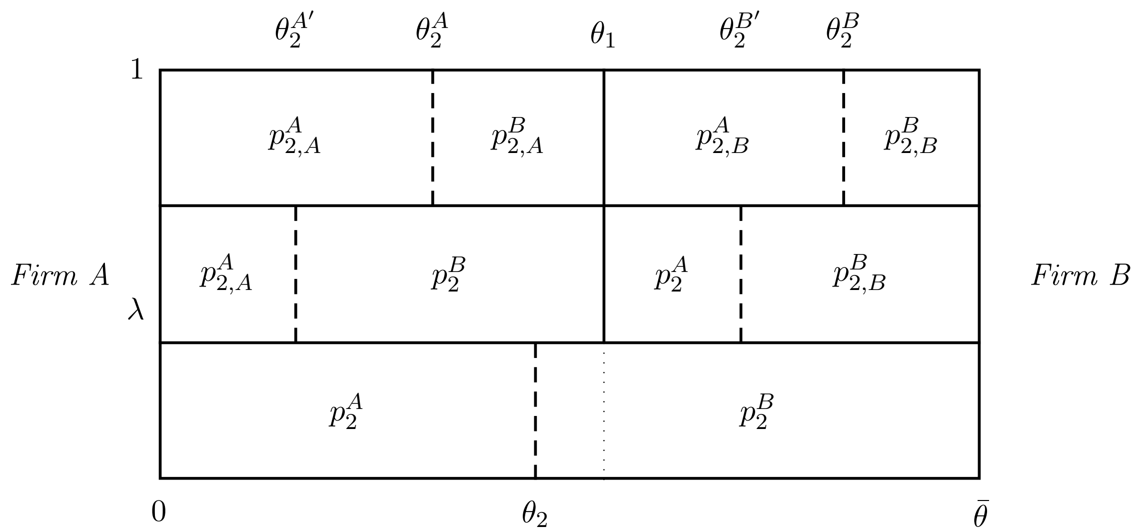


Figure 4: Customer segments with pooling equilibrium

Anonymous consumers face p_2^A and p_2^B in the second stage. Firms believe that to the left of θ_2 consumers buy from firm A and to the right of θ_2 they buy from B. Given consumers can be identified but not targeted, firms segment the line as in the incomplete case where $\beta = 0$. So that consumers with $\theta \in [0, \theta_2^{A'})$ and $\theta \in (\theta_2^{B'}, \bar{\theta}]$ are loyal to their firm. While consumers to the left and right of θ_1 are faced with the anonymous prices from the competitive firms. Given consumers can be identified and targeted, firms segment the line as in the complete case ($\beta = 1$) with θ_2^A and θ_2^B. Compared to the incomplete case, the only difference is that consumers to the left and right of θ_1 are poached with $p_{2,i}^j$ from the competitive firms. The maximization problems for the firms in the second stage are given by

[13] The reason why we treat those who can be targeted and who can not be targeted as separated Hotelling lines is that β is revealed after firms set prices in the second stage. Hence, everyone has the same probability β to be targeted by the competitor's firm if they have decided to reveal their information.

$$\max_{p_2^A, p_{2,A}^A, p_{2,B}^A} \quad \lambda p_2^A \theta_2 + \beta(1-\lambda)\left[p_{2,A}^A \theta_2^A + p_{2,B}^A(\theta_2^B - \theta_1)\right]$$
$$+ (1-\beta)(1-\lambda)\left[p_{2,A}^A \theta_2^{A'} + p_2^A(\theta_2^{B'} - \theta_1)\right]$$
$$\max_{p_2^B, p_{2,B}^B, p_{2,A}^B} \quad \lambda p_2^B(\bar{\theta} - \theta_2) + \beta(1-\lambda)\left[p_{2,A}^B(\theta_1 - \theta_2^A) + p_{2,B}^B(\bar{\theta} - \theta_2^B)\right]$$
$$+ (1-\beta)(1-\lambda)\left[p_2^B(\theta_1 - \theta_2^{A'}) + p_{2,B}^B(\bar{\theta} - \theta_2^{B'})\right].$$

We derive all prices in the second stage as functions of θ_1. The marginal consumers on the first stage are obtained given the consumers' privacy decisions. For anonymous consumers, $\hat{\theta}_1$ represents the marginal consumer who is indifferent between buying from firm A at p_1^A and buying from firm B at p_1^B, which is equivalent to

$$\hat{\theta}_1 = \frac{\bar{\theta}}{2} + \frac{1}{2}(p_1^B - p_1^A).$$

For identified consumers, θ_1 is the marginal consumer who is indifferent between buying from firm A at p_1^A in stage 1 and from firm B at $p_{2,A}^B$ with probability β or at p_2^B with probability $1-\beta$ in stage 2, and buying from firm B at p_1^B in stage 1 and afterward from firm A at $p_{2,B}^A$ with probability β or at p_2^A with probability $1-\beta$ in stage 2,

$$\begin{aligned} &v - p_1^A - \theta_1 + \beta\left[v - p_{2,A}^B - (\bar{\theta} - \theta_1)\right] + (1-\beta)\left[v - p_2^B - (\bar{\theta} - \theta_1)\right] \\ &= v - p_1^B - (\bar{\theta} - \theta_1) + \beta\left[v - p_{2,B}^A - \theta_1\right] + (1-\beta)\left[v - p_2^A - \theta_1\right] \end{aligned}$$

which results in

$$\theta_1 = \frac{4-\beta}{8\beta}(p_1^B - p_1^A) + \frac{\bar{\theta}}{2}.$$

The firms' overall profits are then given by

$$\max_{p_1^A} \quad \lambda p_1^A \hat{\theta}_1 + (1-\lambda)p_1^A \theta_1 + \lambda p_2^A \theta_2 + \beta(1-\lambda)\left[p_{2,A}^A \theta_2^A + p_{2,B}^A(\theta_2^B - \theta_1)\right]$$
$$+ (1-\beta)(1-\lambda)\left[p_{2,A}^A \theta_2^{A'} + p_2^A(\theta_2^{B'} - \theta_1)\right]$$

$$\max_{p_2^B} \quad \lambda p_1^B(\bar{\theta} - \hat{\theta}_1) + (1-\lambda)p_1^B(\bar{\theta} - \theta_1) + \lambda p_2^B(\bar{\theta} - \theta_2) + \beta(1-\lambda)\left[p_{2,A}^B(\theta_1 - \theta_2^A) + p_{2,B}^B(\bar{\theta} - \theta_2^B)\right]$$
$$+ (1-\beta)(1-\lambda)\left[p_2^B(\theta_1 - \theta_2^{A'}) + p_{2,B}^B(\bar{\theta} - \theta_2^{B'})\right].$$

Proposition 3 *No pooling equilibrium exists when $\beta \in (0,1)$. There are unique pooling equilibria when $\lambda = 1$ or $\lambda = 0$.*
Proof. *See Appendix.* ■

5 Experiment

Our experimental design consists of three components. The first and main part is a multi-stage market game, closely resembling our theoretical set-up. Second, we run a short and simple iterative thinking task. Lastly, we conduct a survey on privacy concerns following Malhotra et al. (2004) to collect the IUIPC score.[14] This privacy survey allows us to compare the abstract privacy decision of the market game with the general stance towards online privacy issues.

Market game

Our implemented market game closely follows the theoretical set-up and aims at testing our predictions concerning the buyers' privacy choices and the sellers' pricing choices under the two information set-ups. Subjects take the role of sellers or buyers, with roles remaining fixed for the duration of the experiment. Each market contains two sellers and six buyers and lasts for two periods. Two markets $m \in \{1, 2\}$ are simultaneously formed within one matching group, with matching groups consisting of four sellers $j \in \{A, B, C, D\}$ and six buyers $i \in \{1, 2, 3, 4, 5, 6\}$. The buyers are active in both markets, while sellers are only active in one market. This allows for a randomization of seller composition between market rounds, so that markets are independent between rounds and resemble one-shot interaction.[15]

An experimental market consists of eight adjacent locations, with the two sellers being located at either end and the six buyers in between on distinct locations as depicted in Figure 5.

Similar to Camacho-Cuena et al. (2005) and Barreda-Tarrazona et al. (2011) we allow sellers to choose integer prices from the interval $\in [0, 10]$. Buyers exert unit transport costs per unit of distance traveled.[16] Due to this discretization of prices and transport costs, equilibrium predictions are in pure strategies.

[14]The full questionnaire is listed in the appendix.

[15]In comparable seller-only experiments by Brokesova et al. (2014) matching groups of four were shown to be suitable, according to Mahmood (2014) buyer involvement increases when active in multiple markets.

[16]For example, a buyer at location five has to bear transport costs of five to buy from a seller at location zero.

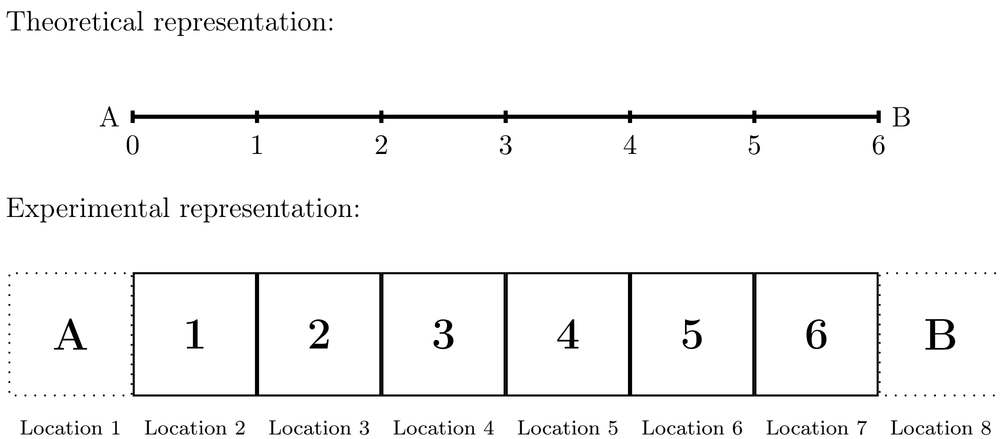


Figure 5: Conversion of theoretical into experimental market

Buyers have an induced reservation value of 15. The utility of a buyer for a purchase is

$$U_t^i = 15 - p_t^i - \theta$$

with p_t^i describing the price of the product that buyer i chose in period t. A seller j receives the profit

$$\Pi_j = p_1^j \cdot n_1^j + \mathbf{p_2^j} \cdot \mathbf{n_2^{j'}}$$

with p_1^j corresponding to the chosen first-period price under which n_1^j is the number of buyers who bought from j. Similar $\mathbf{p_2^j}$ is the vector of the second period prices and $\mathbf{n_2^j}$ the vector of second period buyers who bought from j. Our two main treatment variations are the *i*) complete information and *ii*) incomplete information set-up according to our theoretical model.

In an ensuing questionnaire we ask participants to express their stance towards privacy and whether they are concerned about privacy breaches. Beresford et al. (2012) found that subjects did not act according to their stated preferences in a comparable environment. However, the sensitive information in their case was exogenous and not related to the purchasing decision. In our experiment the relevant information emerges endogenously and is highly relevant for the purchasing decision in the second period.

Iterative thinking task

The iterative thinking task is a variation of the Game of 21 (Dufwenberg et al., 2010; Gneezy et al., 2010). In our version, players take turns increasing a counter that starts at 0 by increments of 1, 2 or 3. The game ends when either of two players reaches 22, where the player who picks 22 loses. Thereby, the game stays true to the original variation, where the player who picks 21 wins the game directly. Instead of using an interactive game between two subjects as intended in the original variation, we let each subject play against the computer. This is necessary in order to gather a measure on correct iterative reasoning for every subject. [17] Subjects learn that they play against the computer, without any detailed explanation on how the computer chooses. Thus, unknown to the players, the computer will avoid winning, while randomizing between the two or three available options.[18]

This task serves several purposes. We suspect that pricing decisions in this rather complex environment to be cognitively challenging for subjects. Heterogeneity of the subjects could lead to different observations of pricing behavior. We capture some of this heterogeneity in the capability of iterative reasoning. Likewise, buyers' privacy choices may be correlated with their ability to backward induct. A pragmatic purpose is that the task generates a "mental distance" between the market game and the privacy survey. We wish to capture the general stance on privacy of our subjects, which may be confounded due to the recent play of a market game which deals with privacy issues. While a confounding factor may not be an issue for within-treatment comparisons, it could affect between-treatment comparisons. We are mainly interested in the privacy concern measure for buyers and the iterative reasoning ability for sellers. But due to the stated reasons we collect both measures for both sides of the market.

Predictions

We present hypotheses which are fully based on our theoretical model and suggest explicit pricing, privacy and switching patterns. The predictions are confronted with behavioral conjectures based on prior experimental findings on privacy and behavior-based pricing. We incorporate our measures for iterative thinking and privacy concern to help approximate those suggestions to our experimental set-up.

Hypotheses

Table 1 summarizes pricing, privacy and switching predictions based on our model, given the experimental parameterization. We expect that all buyers reveal their information in the complete information set-up, while only exactly one buyer should reveal the information

[17] If two players interact and one plays the optimal strategy, no conclusions can be drawn concerning the other player.

[18] Whenever the player is on the winning path, the computer will randomize between all three options, while only randomizing between the two options which avoid the winning path, whenever the player is not on the winning path.

in the incomplete information set-up.[19] Note that the theoretically predicted prices in both treatments are the same for two extreme cases. When all buyers disclose their information, both set-ups correspond to BBPD. The opposite case, i.e. full anonymization, corresponds to the uniform pricing benchmark. While full disclosure is always better for the consumers, the incomplete information set-up yields a coordination problem for the buyers, since every buyer has an incentive to anonymize.

Treatment	complete information	incomplete information
Introductory price	8	6
New customer price	6	6
Loyalty price	4	6
Switching price	2	(6)
Share of information disclosure	100%	0%
Share of inefficient switching	$33.\bar{3}\%$	0%

Table 1: Theoretical pricing, privacy and switching predictions

Behavioral conjectures

Beresford et al. (2012); Preibusch et al. (2013) find that subjects did not act on their stated privacy concerns. Following this we should not see differences in behavior between those subjects that we classify as privacy concerned compared to those that are unconcerned.

Brokesova et al. (2014) conducted BBPD experiments with subjects taking the role of sellers, while buyers were computerized. They find that point predictions do not hold, but comparative statics predictions do. In one treatment two second period prices were chosen and predicted to be equal to the first period price. However, they find that second period prices were lower than first period prices. We predict similar price patterns in the incomplete treatment, with two prices in the second period which are predicted to be equal to the first period price. Hence, behaviorally we would suspect subjects to decrease the second period prices compared to the first period prices.[20]

Schudy and Utikal (2017) have shown that subjects are less inclined to share information, the more parties are involved who receive the information. Subjects in our experiment face a similar situation, where there are two recipients in the complete information setup and only

[19] Acutally, our theory predicts full anonymization but rests on the fact that consumers are massless. Due to the discretization buyers bear a mass in the experiment. However, no matter what the number of buyers is, only exactly one should disclose the information.

[20] This might be caused by sellers trying to react and best respond to first period prices or due to the increased perceived risk, since the individual second period prices target less consumers compared to the first period price.

one in the incomplete information setup. Still, subjects benefit from sharing information in the former case. We expect that subjects disclose more information similar to the findings of Schudy and Utikal (2017) if they do not grasp the strategic interactions of the market game.

In total we invited 160 students in 8 sessions of 20 each as subjects in our experiment, with 96 taking the role of buyers and 64 taking the role of sellers. On average subjects earned about 20 EUR in the 90 minutes experiment. Most subjects are majors in economics, mathematics or industrial engineering and 36% of the subjects were female.Sessions were conducted in the laboratory of TU and WZB in July and September 2019...????

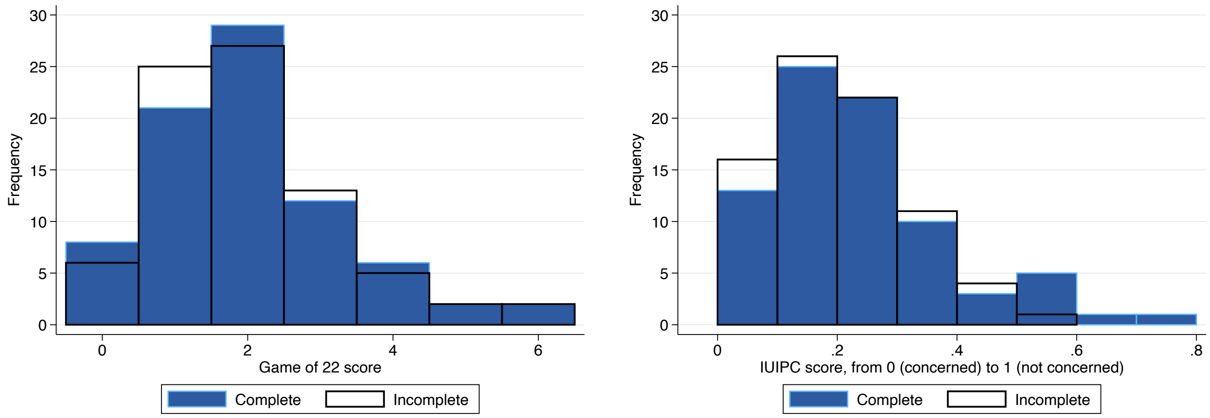
6 Results

Treatment	complete information	incomplete information
Introductory price		
Observed mean	5.68	5.48
Model prediction	8	6
New customer price		
Observed mean	4.19	4.02
Model prediction	6	6
Loyalty price		
Observed mean	4.12	3.97
Model prediction	4	6
Switching price		
Observed mean	3.28	(4.02)
Model prediction	2	(6)
Share of information disclosure		
Observed mean	67.19%	65.36%
Model prediction	100%	0%
Share of inefficient switching		
Observed mean	23.18%	15.73%
Model prediction	$33.\bar{3}$%	0%

Table 2: Summary statistics for pricing, privacy and switching behavior per treatment

Our main interest in the market game is the pricing strategies of sellers and the information disclosure by buyers. Table 2 shows the mean results and the associated predictions. At first glance introductory prices appear to be slightly higher in the complete information case compared to the incomplete information case, while both are below their predicted levels. In both treatments loyalty prices and new customer prices are very close, which we only predicted for the incomplet information case. The switching price in the complete information treatment is lower compared to the other second period prices. The share of consumers who disclose their information is nearly equal in both treatments with around $\frac{2}{3}$

of the consumers disclosing their information. Inefficient switching is higher in the complete information treatment compared to the incomplete information treatment.



(a) Game of 22 scores by Treatment

(b) IUIPC scores by Treatment

Figure 6: Histograms of side measures

In Figure 6 we show the distributions of our side measures concerning iterative thinking capabilities and privacy concern. Our findings in the Game of 22 (Figure 6a) are in line with Dufwenberg et al. (2010), with the majority of subjects being able to solve 2 steps of backward induction. In contrast to their results our subjects did not show an ability to immediately solve the game, with barely anyone solving the full 6 steps of induction. In total these results suggest that the game is suitable as a rough measure of iterative thinking capability and we can not detect any differences between our treatments. In the following we classify the subjects into three groups. The first group contains those subjects who score below average, with either 1 or 0 steps of induction and contains 37.50% of the subjects. The second group contains those subject who score the average of 2 steps and contains 35.00% of the subjects. The last group contains all the subjects who score above average that is 3 or higher and contains the remaining 27.50% of the subjects.

Our findings on privacy concern are depicted in Figure 6b. This distribution does not show remarkable treatment differences. However, there is an overall tendency towards privacy concern among our subjects. Going onwards we classify our subjects into two groups, using the median (0.2014) as a breaking point. All subjects who scored below the median are classified as "privacy concerned" and all who are above are classified as "privacy unconcerned".[21] We use these measures to get a deeper understanding on what is driving the information disclosure which seems to be unaffected by our treatment variation.

[21] All following results are consistent with a stricter classification of privacy concern, by using the 75th percentile as the breaking point opposed to the median.

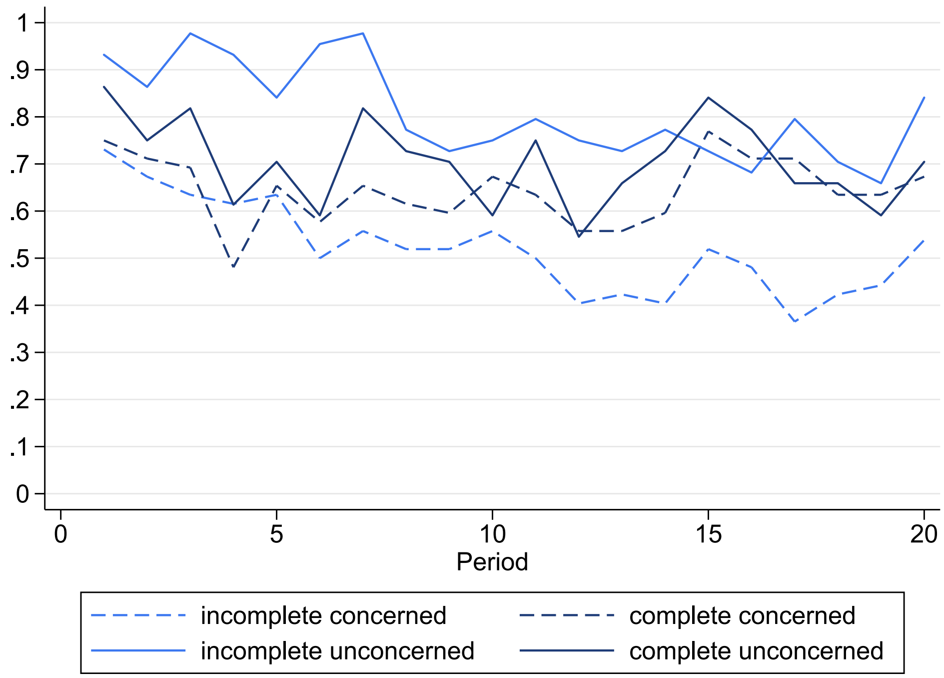


Figure 7: Average cookie choices by treatment and privacy concern of buyers

In Figure 7 we show the average rate of information disclosure over period by treatment and privacy concern classification. There are two major observations here. In the first ten rounds subjects have very similar information sharing rates apart from the privacy unconcerned consumers in the incomplete information treatment, who seem to be more willing to share their information. This might reflect the findings of Schudy and Utikal (2017) since in the incomplete information treatment there is one recipient compared to two recipients in the complete information treatment. However, for both privacy concerned and unconcered buyers we see a drop in information sharing over the periods, where especially concerned buyers in the incomplete treatment drop below the sharing rates of the remaining three groups in the last 10 rounds.

In Table 3 we explore these presumptions by employing a mixed effects logit model on the cookie choices of buyers, while controlling for demographics and experiment specific factors, as well as the iterative thinking capability. Specification (1) and (2) show that there is no blunt treatment effect visible. In specifications (3) and (4) we explore the role of learning, by including a dummy variable which indicates the second half of the experiment, corresponding to rounds 11 and after.[22] There is a significant drop of information disclosure in the incomplete information treatment, while there is no change after learning in the

[22]Results are similar when using a continuous variables indicating the round instead of the dummy for the second half.

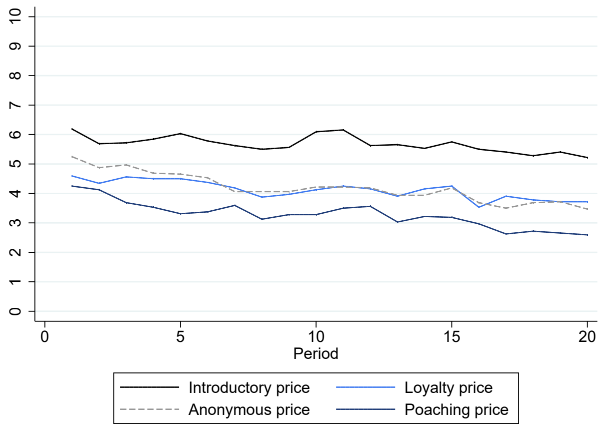
	Dependent variable: Cookie choice $\in \{0,1\}$							
	Treatment		Learning		Privacy concern		Learning + Privacy concern	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Incomplete	0.036	0.044	0.442	0.449	0.543	0.614*	0.965**	1.044***
	(0.278)	(0.260)	(0.295)	(0.278)	(0.382)	(0.359)	(0.399)	(0.375)
Second half			-0.046	-0.046			-0.046	-0.046
			(0.107)	(0.107)			(0.107)	(0.107)
Incomplete			-0.763***	-0.763***			-0.766***	-0.768***
× Second half			(0.156)	(0.156)			(0.156)	(0.156)
Concerned					0.029	-0.144	0.029	-0.145
					(0.375)	(0.353)	(0.382)	(0.359)
Incomplete					-1.008*	-1.180**	-1.038*	-1.223**
× Concerned					(0.533)	(0.495)	(0.543)	(0.504)
Market	No	Yes	No	Yes	No	Yes	No	Yes
Demographics	No	Yes	No	Yes	No	Yes	No	Yes
Cognitive ability	No	Yes	No	Yes	No	Yes	No	Yes
Observations	3840	3800	3840	3800	3840	3800	3840	3800

Standard errors in parentheses
* $p < .10$, ** $p < .05$, *** $p < .01$
Mixed effects logit with group and subject clustering.

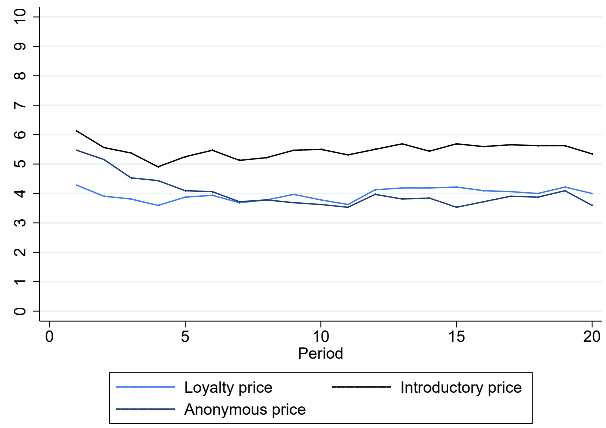
Table 3: Mixed effects logit results

complete information treatment. Similarly, we can find that concerned subjects are less likely to share information in the incomplete treatment, but not in the complete treatment, as depicted in specification (5) and (6). Lastly, specification (7) and (8) show that both effects are apparent simultaneously. The impact of the incomplete treatment is also strongly significant in specifications (7) and (8), since it captures the decisions of unconcerned subjects in the earlier rounds.

In Figure 8 we show the price paths per treatment. Similar to our descriptive summary we observe that introductory prices are larger than second period prices and only sellers in the complete information treatment seem to employ price discrimination by offering lower switching prices for consumers who share their information and bought from the competing seller in the introduction period. We find significant differences between all second period prices compared to first period prices. There are only significant differences between poaching prices compared to loyalty price and anonymous price in the complete information treatment among the second period prices. In line with the findings of Brokesova et al. (2014) we find evidence for comparative statics results but not for point predictions in terms of pricing strategies. Similar to their findings subjects tend to set lower second period prices compared to first period prices even when there is no strategic benefit to it. The relation of information disclosure and pricing strategies is more involved. Especially in the incomplete information



(a) Complete information treatment



(b) Incomplete information treatment

Figure 8: Average prices per period for both treatments

treatment the high rate of information sharing should have led sellers to increase their loyalty prices according to our theory. However, sellers seem reluctant to actually do this. Either sellers did not understand the strategic interaction, specifically that loyal customers tend to be closer to their location or sellers are driven by trust or reciprocity, such that they do not punish loyal customers with higher prices when those were the ones who shared their information with them. Note that poaching prices are lower compared to anonymous prices and represent a reward for sharing the information in the complete information treatment.

	Introductory price		New customer price		Loyalty price		Poaching price	
Incomplete	-0.205	-0.021	-0.173	0.167	-0.153	0.162	0.741*	0.920*
	(0.442)	(0.395)	(0.503)	(0.444)	(0.423)	(0.345)	(0.446)	(0.499)
Demographics	No	Yes	No	Yes	No	Yes	No	Yes
Cognitive ability	No	Yes	No	Yes	No	Yes	No	Yes
Observations	1280	1280	1280	1280	1280	1280	1280	1280

Standard errors in parentheses
* $p < .10$, ** $p < .05$, *** $p < .01$
Random-effects regression. Clustering on group level.

Table 4: Random-effects regression on treatment effects for prices

In Table 4 we show results from random-effects regression on the seller panel with clustering on group level. We find no effect on loyalty and new customer prices. The sign of the effect on introductory prices corresponds to our prediction but is insignificant. There is a significant effect on poaching prices, indicating that sellers poach more in the complete information treatment.

7 Welfare

In this section, we do not claim to make general statements about the regulation the European Union implemented. The reality of the GDPR is different from our framework. We are looking at a situation where two symmetric firms compete for consumers and each firm offers a clear choice on data privacy. This reflects a simplified version of reality. Nonetheless, we can show through which channels the GDPR works and how it affects consumers and firms. The following analysis is based on the two pooling equilibria we find for the extreme information settings. We compare these information settings for different measures of welfare to show the interests of consumers and firms.

Firms clearly prefer a setting where information is not shared with a competitor, since here their profits are larger:

$$\pi^*_{\beta=1} = \frac{17}{18}\bar{\theta}^2 < \pi^*_{\beta=0} = \bar{\theta}^2.$$

This is due to an increase in competition under full information and consumer's strategy to not share information under incomplete information. This is why prices are higher under incomplete information.

For consumers the case is not as simple, since they receive different utilities based on their type. The type-dependent utilities for the different information settings are given by the following terms:

$$U^*_{\beta=1}(A,\theta) = 2(v - \bar{\theta} - \theta) \textit{ for } \theta \in [0, \frac{\bar{\theta}}{3})$$

$$U^*_{\beta=1}(AB,\theta) = 2v - \frac{8}{3}\bar{\theta} \textit{ for } \theta \in (\frac{\bar{\theta}}{3}, \frac{2\bar{\theta}}{3})$$

$$U^*_{\beta=1}(B,\theta) = 2(v - 2\bar{\theta} + \theta) \textit{ for } \theta \in (\frac{2\bar{\theta}}{3}, \bar{\theta}]$$

$$U^*_{\beta=0}(A,\theta) = 2(v - \bar{\theta} - \theta) \textit{ for } \theta \in [0, \frac{\bar{\theta}}{2})$$

$$U^*_{\beta=0}(B,\theta) = 2(v - 2\bar{\theta} + \theta) \textit{ for } \theta \in (\frac{\bar{\theta}}{2}, \bar{\theta}]$$

When comparing the utility levels with different information settings, we find that consumers are indifferent between the information settings for $\theta \in [0, \frac{\bar{\theta}}{3})$ and $\theta \in (\frac{2\bar{\theta}}{3}, \bar{\theta}]$ but obtain a higher utility for $\theta \in (\frac{\bar{\theta}}{3}, \frac{2\bar{\theta}}{3})$ under the complete information setting. Consumers who are located further away from the firms can benefit from behavior-based pricing.

The consumer surplus shows that overall utility is larger under the complete information setting.

$$CS_{\beta=1} = 2v\bar{\theta} - \frac{22}{9}\bar{\theta}^2$$

$$CS_{\beta=0} = 2v\bar{\theta} - \frac{5}{2}\bar{\theta}^2$$

$$CS_{\beta=1} > CS_{\beta=0}$$

Consumers and firms prefer opposing information settings. Consumers' interest is to share their data with all firms on the market because firms cannot commit to not using the data. On the other hand, firms benefit from a situation where each competitor keeps the data of their consumers to themselves. Therefore, the level of data available to firms drive the results.

The overall welfare level is higher under the firm-preferred information setting. The efficiency loss incurred by firms under complete information is larger than the loss of consumers under incomplete information. Normally, a setting with complete information leads to an efficient outcome. Here, however, asymmetric information gives a larger welfare, which is due to the anonymization of consumers in that case.

$$W_{\beta=1} = 2v\bar{\theta} - \frac{5}{9}\bar{\theta}^2$$

$$W_{\beta=1} > 0 \Leftrightarrow \frac{5}{18}v > \bar{\theta}$$

$$W_{\beta=0} = 2v\bar{\theta} - \frac{1}{2}\bar{\theta}^2$$

$$W_{\beta=0} > 0 \Leftrightarrow 4v > \bar{\theta}$$

$$W_{\beta=0} > W_{\beta=1}$$

The welfare loss under the complete information setting is driven by inefficient switching of consumers that are poached by the other firm. While consumers gain from switching, as can be seen in the comparison of the utility levels, firms lose profits (compared to the incomplete information setting) because of the lower poaching prices they set.

In Figure 9 we observe that subjects in the experiment are more likely to switch in the complete information setting because sellers offer lower prices to poach consumers from their competitor. For all locations we observe higher switching rates in the complete treatment compared to the incomplete treatment. This is in line with the fact that we observe poaching efforts by sellers in the complete information treatment, but not in the incomplete information treatment as shown in Figure 8.

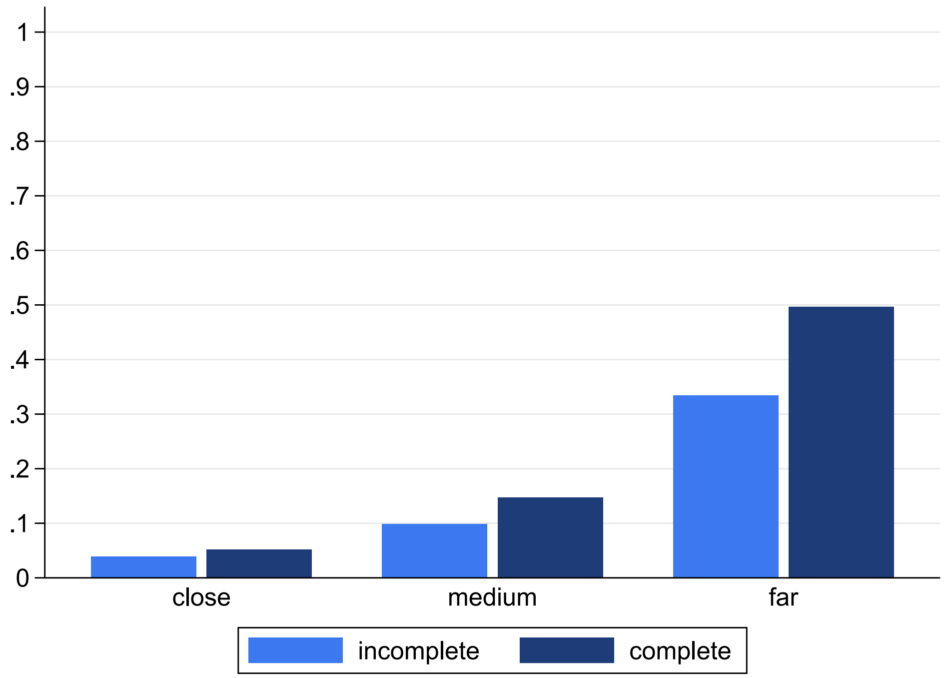


Figure 9: Switching by proximity to closest seller

8 Conclusion and Outlook

In this paper, we show that under the two distinct information settings two opposing optimal strategies for consumers regarding their information choice result. When both firms get the same information about buyers, it is best for consumers to reveal their cookies. This is the only equilibrium under pooling.

In the incomplete information setting where consumers' cookies are only passed on to the firm that they have bought from, it is an optimal strategy for all consumers to hide their purchasing history. When firms' targetability is between 0 and 1, we do not find an equilibrium under our pooling assumption.

In the experiment, we find a treatment effect for the concerned subjects. Concerned subjects share less information in the incomplete treatment. The effect is more pronounced for the second half of the experiment. In the first half, the privacy unconcerned buyers share more information when only one seller receives the information. We observe that sellers employ behavior-based pricing only in the complete treatment.

There are several directions to extend our research. The next steps include an analysis of potential separating equilibria in the different information settings. Opposed to a monopolistic market we can not exclude separating equilibria here. First results suggest that such equilibria might exist when sellers set equal loyalty and anonymous prices. This is in line with the pricing strategies that we observe in the experiment for both treatments. With new theoretical results on separating equilibria, we can check for corresponding patterns in our experimental data.

Another possible venture is to explore a setting where consumers choose different probabilities to share information with each seller. This implies extreme situations where consumers might select themselves into situations similar to the complete and incomplete setting, but also they might share information solely with their sellers competitor. Related to that is the case of imperfect information where one firm receives more or better information than the other.

Appendix

Quadratic transportation costs

In this model, the utility for a consumer with the location of θ is either $v - p^i - \theta^2$ if buying from Firm A, or $v - p^j - (\bar{\theta} - \theta)^2$ if buying from Firm B. As in the standard model, we employ backward induction and finally get that $p_1^A = p_1^B = \frac{4}{3+\lambda}\bar{\theta}^2$, and $\theta_1 = \frac{1}{2}\bar{\theta}$, $p_A^A = p_B^B = \frac{2}{3}\bar{\theta}^2$, $p_B^A = p_A^B = \frac{1}{3}\bar{\theta}^2$. If the cost is quadratic in the standard behavior-based pricing model, prices in the first stage are $p_1^A = p_1^B = \frac{4}{3}\bar{\theta}^2$, and uniform pricing strategy is $p_1^A = p_1^B = \bar{\theta}^2$. Thus, each buyer gives their cookies, in order to get the lower price in the second stage. λ is 0, and all the results in the complete case hold with quadratic costs.

Proof of Lemma 1

By plugging $\theta_2^A = \frac{\bar{\theta}}{2} + \frac{p_{2,A}^B - p_{2,A}^A}{2}$ and $\theta_2^B = \frac{\bar{\theta}}{2} + \frac{p_{2,B}^B - p_{2,B}^A}{2}$ into the maximization problems, we have

$$\max_{p_{2,A}^A, p_{2,B}^A} \quad (1-\lambda)\big[p_{2,A}^A(\frac{\bar{\theta}}{2} + \frac{p_{2,A}^B - p_{2,A}^A}{2}) + p_{2,B}^A(\frac{\bar{\theta}}{2} + \frac{p_{2,B}^B - p_{2,B}^A}{2} - \theta_1)\big]$$

$$\max_{p_{2,B}^B, p_{2,A}^B} \quad (1-\lambda)\big[p_{2,B}^B(\bar{\theta} - \frac{\bar{\theta}}{2} - \frac{p_{2,B}^B - p_{2,B}^A}{2}) + p_{2,A}^B(\theta_1 - \frac{\bar{\theta}}{2} - \frac{p_{2,A}^B - p_{2,A}^A}{2})\big]$$

First-order conditions solve

$$\begin{aligned}
&(1-\lambda)\big[\frac{\bar{\theta}}{2} + \frac{p_{2,A}^B}{2} - p_{2,A}^A\big] = 0 \\
&(1-\lambda)\big[\frac{\bar{\theta}}{2} + \frac{p_{2,B}^B}{2} - p_{2,B}^A - \theta_1\big] = 0 \\
&(1-\lambda)\big[\frac{\bar{\theta}}{2} - p_{2,B}^B + \frac{p_{2,B}^A}{2}\big] = 0 \\
&(1-\lambda)\big[\theta_1 - \frac{\bar{\theta}}{2} - p_{2,A}^B + \frac{p_{2,A}^A}{2}\big] = 0
\end{aligned}$$

where we can derive the results in Lemma 1 easily.

Proof of Proposition 1

In the case where all consumers reveal their information, beliefs about anonymous consumers are off-equilibrium. Consistent off-equilibrium beliefs are that no consumer is located on the Hotelling with mass λ, so that setting $p_2^A \geq p_{2,i}^i, p_{2,j}^i$ is a best response. Then no consumer anonymizes because prices are higher than under revealing information. The price comparison shows that this best response holds. Assume towards a contradiction that there is a PBE where consumers place a positive probability on anonymizing. Any consumer type only has an incentive to deviate if they are offered a price that is lower or at least equal to the price they are paying now. Given firms' profit-maximizing prices in the second stage (derived in Lemma 1), anonymous prices are always higher than loyal or poaching prices independent of λ. Therefore, consumers do not have an incentive to put a positive probability on anonymizing.

Comparing loyalty prices to anonymous prices, exemplary for firm A

$$p_2^A > p_{2,A}^A \Leftrightarrow \bar{\theta} > \frac{1}{3}(2\theta_1 + \bar{\theta})$$
$$\bar{\theta} > \theta_1$$

This is always the case, since the marginal consumer in the first period is always smaller than the length of the product space. Therefore, $p_2^A > p_{2,A}^A$.

Comparing poaching price to anonymous price:

$$p_{2,B}^A < p_2^A \Leftrightarrow \frac{1}{3}(3\theta_1 - 4\bar{\theta}) < \bar{\theta}$$
$$\theta_1 < \frac{7\bar{\theta}}{3}$$

This is always the case, since the marginal consumer is in-between the two firms and cannot be larger than the line segment itself. Therefore $p_2^A > p_{2,B}^A$.

Comparing competitors poaching price with loyalty price:

$$p_2^A > p_{2,A}^B \Leftrightarrow \bar{\theta} > \frac{4\theta_1 - \bar{\theta}}{3}$$
$$\frac{4\bar{\theta}}{3} > \frac{4\theta_1}{3}$$
$$\bar{\theta} > \theta_1$$

This always holds. Therefore $p_2^A > p_{2,A}^B$.

Complete Information with Myopic Consumers

In the main analysis we consider consumers to be strategic. Now we want to extend our analysis to the case in which some consumers are myopic in the first stage with regard to their purchasing decision (Baye and Sapi, 2014; Carroni et al., 2015). We assume that there is a share α of myopic consumers and a share $1-\alpha$ of strategic consumers. For myopic consumers, their rationale is to choose the cheaper good in the first stage, however, they are strategic afterwards, including the cookie choice and the purchasing decision in the second stage. To the contrary, strategic consumers are always forward-looking in both stages. Therefore, the difference in this setting lies in the first stage, where, among myopic consumers, marginal consumer θ_1' is just indifferent between buying from firm A at p_1^A in stage 1 and buying from firm B at p_1^B in stage 1, that is, $v-p_1^A-\theta_1' = v-p_1^B-(\bar{\theta}-\theta_1')$, leading to $\theta_1' = \frac{\bar{\theta}}{2}+\frac{p_1^B-p_1^A}{2}$. On the other hand, among strategic consumers[23], the cut-off consumer θ_1 is indifferent between buying from firm A at p_1^A in stage 1 and then buys from firm B at $p_{2,A}^B$ in stage 2, and buying from firm B at p_1^B in stage 1 and then buys from firm A at $p_{2,B}^A$ in stage 2 [24], therefore,

$$v - p_1^A - \theta_1 + \left[v - p_{2,A}^B - (\bar{\theta} - \theta_1)\right] = v - p_1^B - (\bar{\theta} - \theta_1) + \left[v - p_{2,B}^A - \theta_1\right]$$

In order to solve this two-stage problem we apply backward induction. Starting from the second stage, again there are two separated Hotelling lines, respectively for consumers who did and who did not give their cookies. No matter whether they belong to the group of myopic consumers or the group of strategic consumers, the cut-offs are the same, since even myopic consumers are also strategic in the second stage. Among those who gave their cookies in the first stage, the two cut-offs, θ_2^A and θ_2^B, are equivalent to $\frac{\bar{\theta}}{2}+\frac{p_{2,A}^B-p_{2,A}^A}{2}$ and $\frac{\bar{\theta}}{2}+\frac{p_{2,B}^B-p_{2,B}^A}{2}$, respectively[25]. Moreover, for those who did not give their cookies in the first stage, as we discussed before, they will face uniform pricing in the second stage, with $p_2^A = p_2^B = \bar{\theta}$ and $\theta_2 = \frac{\bar{\theta}}{2}$.

Therefore, the competitors maximize their profits from the Hotelling line with mass $1-\lambda$ as follows

$$\max_{p_{2,A}^A, p_{2,B}^A} \quad \alpha(1-\lambda)\left[p_{2,A}^A\theta_2^A + p_{2,B}^A(\theta_2^B - \theta_1')\right] + (1-\alpha)(1-\lambda)\left[p_{2,A}^A\theta_2^A + p_{2,B}^A(\theta_2^B - \theta_1)\right]$$

$$\max_{p_{2,B}^B, p_{2,A}^B} \quad \alpha(1-\lambda)\left[p_{2,B}^B(\bar{\theta} - \theta_2^B) + p_{2,A}^B(\theta_1' - \theta_2^A)\right] + (1-\alpha)(1-\lambda)\left[p_{2,B}^B(\bar{\theta} - \theta_2^B) + p_{2,A}^B(\theta_1 - \theta_2^A)\right]$$

Lemma 3 *Combining these two optimization problems and deriving the first order condi-*

[23]To make it more precise, strategic consumers mean those who are forward-looking and give their cookies in the first stage.

[24]This indifferent condition is the same as in the complete information case without myopic consumers.

[25]The method to derive these cut-offs are identical to the complete information case.

tions, we obtain the following prices in the second stage

$$p_{2,A}^{A} = \frac{\bar{\theta}}{3} + \frac{2}{3}\theta_1 + \frac{2}{3}\alpha(\theta_1' - \theta_1) \qquad p_{2,B}^{A} = \bar{\theta} - \frac{4}{3}\theta_1 + \frac{4}{3}\alpha(\theta_1 - \theta_1')$$
$$p_{2,B}^{B} = \bar{\theta} - \frac{2}{3}\theta_1 + \frac{2}{3}\alpha(\theta_1 - \theta_1') \qquad p_{2,A}^{B} = -\frac{\bar{\theta}}{3} + \frac{4}{3}\theta_1 + \frac{4}{3}\alpha(\theta_1' - \theta_1)$$

Note that on the Hotelling line with consumer mass λ nothing changes and therefore the prices correspond to uniform pricing.

On the first stage, the cut-offs are different among the myopic consumers and strategic consumers, and also depend on whether they give the cookies or not. Therefore, there are four groups of different consumers. Among the mass of λ consumers who do not give the cookies, a mass of $\alpha\lambda$ are myopic and a mass of $(1-\alpha)\lambda$ are strategic. However, no matter whether they are myopic or strategic, the cut-offs they face are the same, that is $\theta_1' = \frac{\bar{\theta}}{2} + \frac{p_1^B - p_1^A}{2}$ [26]. Similarly, among the mass of $1-\lambda$ consumers who give the cookies, there are $\alpha(1-\lambda)$ myopic consumers facing the cut-off of θ_1', while a mass of $(1-\alpha)(1-\lambda)$ are strategic consumers with the cut-off of θ_1.

Combining these indifferent conditions and the results from Lemma 3, we get that $\theta_1' = \frac{\bar{\theta}}{2} + \frac{p_1^B - p_1^A}{2}$ and $\theta_1 = \frac{\bar{\theta}}{2} - \frac{4\alpha-3}{8(1-\alpha)}(p_1^B - p_1^A)$. Maximizing the overall profits in the first period with respect to the first-stage prices, the two firms have the resulting objective functions

$$\begin{aligned}
\pi^A &= \alpha\big[\lambda p_1^A\theta_1' + (1-\lambda)p_1^A\theta_1' + \lambda p_2^A\theta_2 + (1-\lambda)p_{2,A}^A\theta_2^A + (1-\lambda)p_{2,B}^A(\theta_2^B - \theta_1')\big] \\
&\quad + (1-\alpha)\big[\lambda p_1^A\theta_1' + (1-\lambda)p_1^A\theta_1 + \lambda p_2^A\theta_2 + (1-\lambda)p_{2,A}^A\theta_2^A + (1-\lambda)p_{2,B}^A(\theta_2^B - \theta_1)\big] \\
\pi^B &= \alpha\big[\lambda p_1^B(\bar{\theta} - \theta_1') + (1-\lambda)p_1^B(\bar{\theta} - \theta_1') + \lambda p_2^B(\bar{\theta} - \theta_2) + (1-\lambda)p_{2,B}^B(\bar{\theta} - \theta_2^B) + (1-\lambda)p_{2,A}^B(\theta_1' - \theta_2^A)\big] \\
&\quad + (1-\alpha)\big[\lambda p_1^B(\bar{\theta} - \theta_1') + (1-\lambda)p_1^B(\bar{\theta} - \theta_1) + \lambda p_2^B(\bar{\theta} - \theta_2) \\
&\quad + (1-\lambda)p_{2,B}^B(\bar{\theta} - \theta_2^B) + (1-\lambda)p_{2,A}^B(\theta_1 - \theta_2^A)\big]
\end{aligned}$$

[26] θ_1' will not be influenced by the prices in the second stage, which is similar to the complete information case.

Lemma 4 *Substituting the respective prices into the system of equations given by the first-order conditions, we derive the final results for the first- and second-stage prices:*

$$
\begin{aligned}
p_1^A = p_1^B &= \frac{4}{3+\lambda}\bar{\theta} \\
p_{2,A}^A = p_{2,B}^B &= \frac{2}{3}\bar{\theta} \\
p_{2,B}^A = p_{2,A}^B &= \frac{1}{3}\bar{\theta} \\
p_2^A = p_2^B &= \bar{\theta}
\end{aligned}
$$

Everyone chooses to give cookies, therefore the optimal λ is 1 and the resulting prices are identical to the complete information case.

The result above is a robustness check, showing that being strategic or myopic does not affect any decisions. Buyers always choose to give their cookies, in order to benefit from the competition; while firms use standard behavior-based price discrimination to maximize their profits.

Proof of Lemma 2

When maximizing the profit functions of the second stage, we get the following expressions for the first-order conditions:

$$
\begin{aligned}
\frac{\partial \pi_2^A}{\partial p_2^A} &= \frac{\lambda}{2}(p_2^B - 2p_2^A + \bar{\theta}) + \frac{(1-\lambda)}{2}(p_{2,B}^B - 2p_2^A + \bar{\theta}) - (1-\lambda)\bar{\theta} = 0 \\
\frac{\partial \pi_2^A}{\partial p_{2,A}^A} &= \frac{(1-\lambda)}{2}(p_2^B - 2p_{2,A}^A + \bar{\theta}) = 0 \\
\frac{\partial \pi_2^B}{\partial p_2^B} &= \frac{\lambda}{2}(-2p_2^B + p_2^A + \bar{\theta}) + \frac{(1-\lambda)}{2}(-2p_2^B + p_{2,A}^A - \bar{\theta} + 2\theta_1) = 0 \\
\frac{\partial \pi_2^B}{\partial p_{2,B}^B} &= \frac{(1-\lambda)}{2}(-2p_{2,B}^B + p_2^A + \bar{\theta}) = 0
\end{aligned}
$$

This gives a system of equations, where prices are dependent on each other and need to be substituted into each other in order to receive the final set of prices of the second period that are only depending on λ and $\mathbf{p_1}$.

$$\begin{aligned}
p^A_{2,A}(p^B_2) &= \frac{\bar{\theta} + p^B_2}{2} \\
p^A_2(p^B_2) &= \frac{(3-\lambda)\bar{\theta} + 2\lambda \cdot p^B_2 - 4(1-\lambda)\theta_1}{3+\lambda} \\
p^B_{2,B}(p^A_2) &= \frac{\bar{\theta} + p^A_2}{2} \\
p^B_2(p^A_2) &= \frac{-(1-3\lambda)\bar{\theta} + 2\lambda \cdot p^A_2 + 4(1-\lambda)\theta_1}{3+\lambda}
\end{aligned}$$

Analysis of second-period prices of section 4.2

The comparative static analysis of the prices in the second period of the incomplete information case reveal that all prices increase with λ under the restriction that θ_1 is symmetric and $\bar{\theta} = 1$. The general analysis gives certain conditions for which the property is fulfilled, as well.

$$\begin{aligned}
\frac{\partial p^A_2}{\partial \lambda} &= \frac{8\{(-3+\lambda)^2\theta_1 + [-3+\lambda(6+\lambda)]\,\bar{\theta}\}}{3(-3+\lambda)^2(1+\lambda)^2} \\
\frac{\partial p^A_2}{\partial \lambda} &> 0 \Leftrightarrow 8\{(-3+\lambda)^2\theta_1 + [-3+\lambda(6+\lambda)]\,\bar{\theta}\} > 0
\end{aligned}$$

The partial derivative simplifies to $\frac{4}{(-3+\lambda)^2}$ under the restriction that $\bar{\theta} = 1$ and $\theta_1 = 0.5$ which is always larger than zero.

$$\frac{\partial p^A_{2,A}}{\partial \lambda} = \frac{8\,(\lambda^2+3)\,\bar{\theta} - 4(\lambda-3)^2\theta_1}{3(\lambda-3)^2(\lambda+1)^2}$$

which is larger than zero if the nominator is larger than zero and can be simplified to $\frac{2}{(\lambda-3)^2}$ under the common restrictions. This term is always larger than zero. For firm B the same applies:

$$\begin{aligned}
\frac{\partial p^B_2}{\partial \lambda} &= \frac{16\,(\lambda^2+3)\,\bar{\theta} - 8(\lambda-3)^2\theta_1}{3(\lambda-3)^2(\lambda+1)^2} \\
\frac{\partial p^B_{2,B}}{\partial \lambda} &= \frac{4\{(\lambda-3)^2\theta_1 + [\lambda(\lambda+6)-3]\,\bar{\theta}\}}{3(\lambda-3)^2(\lambda+1)^2}
\end{aligned}$$

which are both larger than zero if the respective nominator is larger than zero. Applying the usual restrictions on the line segment and the symmetric equilibrium, the former term simplifies to $\frac{4}{(-3+\lambda)^2}$, while the latter is given by $\frac{2}{(\lambda-3)^2}$.

Evaluating the limits of the prices for values of λ reveals information about the highest and lowest possible prices within the range of λ, which can be easily seen in the graph of the price curves (see Figure 3)

$$\lim_{\lambda\to 0} p^A_{2,A} = \frac{3\bar{\theta}+6\theta_1}{9}$$
$$\lim_{\lambda\to 0} p^A_2 = \frac{9\bar{\theta}+-12\theta_1}{9}$$

which, evaluated at $\bar{\theta}=1$ and $\theta_1=0.5$, are $\frac{2}{3}$ and $\frac{1}{3}$. These give the lowest possible loyalty and anonymous prices for firm A. Whatsoever, the same holds for firm B, as well.

When studying the other end of the range, we have to consider that the loyalty prices are not defined for a $\lambda=1$, therefore we are observing the left-sided limit of $\lambda\to 1$.

$$\lim_{\lambda\to 1^-} p^A_{2,A} = \lim_{n\to\infty} \frac{\left[9-2(1-\frac{1}{n})+5(1-\frac{1}{n})^2\right]\bar{\theta}-4\left[3-(1-\frac{1}{n})\right]\left[1-(1-\frac{1}{n})\right]\theta_1}{3\{4-\left[1-(1-\frac{1}{n})\right]^2\}} = \frac{12\bar{\theta}}{12} = \bar{\theta}$$

This holds true for all prices.

The general results for the convexity of the prices is given by the following equations:

$$\frac{\partial^2 p^A_2}{\partial\lambda^2} = -\frac{16\left((\lambda-3)^3\theta_1+(\lambda(\lambda(\lambda+9)-9)+15)\bar{\theta}\right)}{3(\lambda-3)^3(\lambda+1)^3}$$
$$\frac{\partial^2 p^A_{2,A}}{\partial\lambda^2} = \frac{8\left((\lambda-3)^3\theta_1-2\left(\lambda^3+9\lambda-6\right)\bar{\theta}\right)}{3(\lambda-3)^3(\lambda+1)^3}$$
$$\frac{\partial^2 p^B_2}{\partial\lambda^2} = \frac{16\left((\lambda-3)^3\theta_1-2\left(\lambda^3+9\lambda-6\right)\bar{\theta}\right)}{3(\lambda-3)^3(\lambda+1)^3}$$
$$\frac{\partial^2 p^B_{2,B}}{\partial\lambda^2} = -\frac{8\left((\lambda-3)^3\theta_1+(\lambda(\lambda(\lambda+9)-9)+15)\bar{\theta}\right)}{3(\lambda-3)^3(\lambda+1)^3}$$

Under the standard assumptions of $\bar{\theta}=1$ and $\theta_1=0.5$ these expressions can be simplified and are all larger than zero, such that the price curves are convex.

$$\frac{\partial^2 p^A_2}{\partial\lambda^2} = -\frac{8}{(\lambda-3)^3} > 0$$
$$\frac{\partial^2 p^A_{2,A}}{\partial\lambda^2} = -\frac{4}{(\lambda-3)^3} > 0$$
$$\frac{\partial^2 p^B_2}{\partial\lambda^2} = -\frac{8}{(\lambda-3)^3} > 0$$

$$\frac{\partial^2 p_{2,B}^B}{\partial\lambda^2} = -\frac{4}{(\lambda-3)^3} > 0$$

Proof of Proposition 2

In the case where all consumers anonymize, beliefs about identified consumers are off-equilibrium. Consistent off-equilibrium beliefs for example are that there are no consumers on the upper Hotelling line in Figure 3, so that setting $p_{2,i}^i, p_{2,i}^j \geq p_2^i$ is a best response. If we assume that consumers put a positive probability on giving their cookies, we end up in a situation we analyzed in the main body based on Figure 3. Consumers still have an incentive to make sure to receive a lower price and therefore choose to anonymize with $\lambda \to 1$.

Since $\lambda = 1$, as was derived by the price comparison in the backward induction, the two periods of the game are no longer dependent on each other. Therefore we can directly calculate the prices for the second stage, by substituting $\lambda = 1$ into the set of prices derived in Lemma 2. As can be derived from the limit case analysis, only the anonymous prices of firms A and B are relevant now, since the loyalty prices are no longer contained in the maximization problem. p_2^A and p_2^B both take the value $\bar{\theta}$ which corresponds to a uniform pricing strategy. The profits for each firm in this period are $\frac{\bar{\theta}^2}{2}$.

When solving the maximization problem in the first period, where profits over both periods are maximized, period 2 profit is only an additive constant. The first-order conditions of the maximization problems give the following reaction functions:

$$p_1^A(p_1^B) = \frac{p_1^B + \bar{\theta}}{2}$$
$$p_1^B(p_1^A) = \frac{p_1^A + \bar{\theta}}{2}$$

which then give the final prices for period $t = 1$ of $\bar{\theta}$ for both firms. Substituting the derived prices into the marginal customer of period 1, we get $\theta_1 = \frac{\bar{\theta}}{2}$, which shows that the complete market is evenly split between the two firms.

Proof of Proposition 3

When solving the maximization of two firms' overall profits, we get that

$$p_2^A = p_2^B = \frac{2\lambda + \beta\lambda + 2 - 2\beta}{-2\lambda + 5\beta\lambda + 6 - 6\beta}\bar{\theta}$$

$$p_{2,B}^A = p_{2,A}^B = \left[\frac{1}{4-\beta} + \frac{1-\beta}{4-\beta} \cdot \frac{2\lambda + \beta\lambda + 2 - 2\beta}{-2\lambda + 5\beta\lambda + 6 - 6\beta}\right]\bar{\theta}$$
$$p_{2,A}^A = p_{2,B}^B = \left[\frac{2}{4-\beta} + \frac{2(1-\beta)}{4-\beta} \cdot \frac{2\lambda + \beta\lambda + 2 - 2\beta}{-2\lambda + 5\beta\lambda + 6 - 6\beta}\right]\bar{\theta}$$

which shows that $p_2^i > p_{2,i}^j$ and $p_{2,i}^i = 2p_{2,i}^j$. Moreover, $p_2^i \geq p_{2,i}^i$ is equivalent to $\lambda(2-\beta)(4-\beta) + 2\beta(5-\beta) \geq 8$. We look at the following three scenarios separately:

1. $\beta = 1$
Under such circumstance, $\lambda(2-\beta)(4-\beta)+2\beta(5-\beta) \geq 8$ holds for all λ, therefore $p_2^i \geq p_{2,i}^i$. Together with the fact that $p_2^i > p_{2,i}^j$, no one has an incentive to hide cookies, since the anonymous price is the highest among all customized prices. Thus, all consumers give their cookies and $\lambda = 0$. This matches with our complete information case, in which there is a unique pooling equilibrium.

2. $\beta = 0$
This is the incomplete information case, in which no poaching price exists. $\lambda(2-\beta)(4-\beta) + 2\beta(5-\beta) \geq 8$ holds if and only if $8\lambda \geq 8$, which means that if $\lambda \to 1$, $p_2^i \to p_{2,i}^i$ [27]. On the other hand, if $\lambda \neq 1$, then $p_2^i < p_{2,i}^i$, which shows that all consumers hide their cookies, in order to face the lower anonymous price in the second stage. In the end, all consumers hide cookies and $\lambda = 1$ is the unique pooling equilibrium in this scenario.

3. $\beta \in (0, 1)$
When β is in this range, we cannot directly compare the values between anonymous price p_2^i and loyalty price $p_{2,i}^i$. Therefore we discuss two cases as follow:

If $p_2^i \geq p_{2,i}^i$, then we have $\lambda(2-\beta)(4-\beta) + 2\beta(5-\beta) \geq 8$. In such a condition, everyone should give cookies in order to get a lower price in the second stage, that is, $\lambda = 0$. Therefore, $2\beta(5-\beta) \geq 8$ should hold in this case. However, the weak inequality only holds for $\beta = 1$. The contradiction proves that there is no pooling equilibrium in this case.

If $p_2^i < p_{2,i}^i$, we first look at the consumers who are close to the center. Without loss of generality, we focus on the consumer who is located an ε unit to the left of the center, where ε is very small but strictly positive. Denote this location as θ [28], so they bought from firm A in the first stage. If this consumer decides to reveal information, there is a probability β that they are targeted in the second stage and then choose the lower cost [29] between $p_{2,A}^A + \theta$ and $p_{2,A}^B + (\bar{\theta} - \theta)$; and there is a probability $1 - \beta$ that they are not targeted and determine

[27] Note that when $\lambda = 1$, $p_{2,i}^i$ doesn't exist. Under such circumstance all consumers hide their cookies, thus there will be no loyalty price.

[28] We can also write his location as $\frac{\bar{\theta}}{2} - \varepsilon$.

[29] The total costs include the price of the product plus the transportation costs.

the lower cost between $p_{2,A}^A + \theta$ and $p_2^B + (\bar{\theta} - \theta)$. On the other hand, if this consumer is anonymous, the cost they face in the second stage is $p_2^A + \theta$[30]. Moreover, in this case we have that $p_{2,A}^A > p_2^A = p_2^B > p_{2,A}^B$. Thus, since the differences between the transportation costs are infinitesimal, if this consumer reveals information, they always buy from firm B in the second stage, since both the poaching price and anonymous price offered by firm B are lower than the loyalty price from firm A. Similarly, we can show that if they reveal the information, the expected cost in the second stage is lower than that if the consumer is anonymous [31]. Therefore, this consumer chooses to give cookies in the first stage, in order to get a lower expected cost in the second stage.

Using a similar method, we now check the consumers who are near the endpoints. Again, without loss of generality, we take the consumer who is located just to the right of firm A as an example and denote the location as θ'. If the consumer reveals information, there is a probability β that they are targeted in the second stage and then choose the lower cost between $p_{2,A}^A + \theta'$ and $p_{2,A}^B + (\bar{\theta} - \theta')$; and there is a probability $1 - \beta$ that they are not targeted and choose the lower cost between $p_{2,A}^A + \theta'$ and $p_2^B + (\bar{\theta} - \theta')$. On the other hand, if this consumer keeps their privacy, the cost they face in the second stage is $p_2^A + \theta'$. Considering that this consumer is located just to the right of firm A, the difference of transportation costs between buying from firm A and firm B converges to $\bar{\theta}$. Then we can show that $p_{2,A}^A + \theta' < p_{2,A}^B + (\bar{\theta} - \theta')$ and $p_{2,A}^A + \theta' < p_2^B + (\bar{\theta} - \theta')$[32], which means that if the consumer at θ' reveals information, they always buy from firm A in the second stage, resulting in the expected cost of $p_{2,A}^A + \theta'$. However, if the consumer hides the cookies, the cost in the second period is $p_2^A + \theta'$, which is smaller than $p_{2,A}^A + \theta'$ given that $p_2^A < p_{2,A}^A$. Thus, this consumer chooses to hide cookies in the first stage. Comparing the two situations mentioned above, we show that the consumer close to the center would like to reveal cookies, while the one near the endpoint would like to hide cookies. This contradicts our pooling assumption, where all consumers have the same probability of choosing to anonymize. Therefore, there is no pooling equilibrium under $\beta \in (0, 1)$.

[30] Basically, the consumer should also compare the costs between $p_2^A + \theta$ and $p_2^B + (\bar{\theta} - \theta)$. However, considering that $p_2^A = p_2^B$, they choose to buy from firm A in the second stage.

[31] If this consumer gives cookies, the expected cost in the second stage is $\beta \left[p_{2,A}^B + (\bar{\theta} - \theta)\right] + (1 - \beta)\left[p_2^B + (\bar{\theta} - \theta)\right]$. Otherwise, if the consumer is anonymous, the cost are $p_2^A + \theta$. Again, since differences between the transportation costs are infinitesimal, if they give cookies, the expected cost is lower than if they hide cookies, due to the fact that $\beta p_{2,A}^B + (1 - \beta) p_2^B < p_2^A$.

[32] Since $p_{2,A}^A > p_2^A = p_2^B > p_{2,A}^B$ and $(\bar{\theta} - \theta') - \theta' \to \bar{\theta}$, we just need to show that $p_{2,A}^A - p_{2,A}^B < \bar{\theta}$. From the maximization problems, we get that $p_{2,A}^A = 2p_{2,A}^B$. Thus, we need to show that $p_{2,A}^B < \bar{\theta}$. Due to the fact that $(1 - \lambda)(1 - \beta) > 0$, we can easily prove that $p_2^A = p_2^B < \bar{\theta}$. Given that $p_2^A = p_2^B > p_{2,A}^B$, we complete the proof of $p_{2,A}^B < \bar{\theta}$.

Instructions for the experiment

Market game - Incomplete information [Complete information][33]

A market

Participants take the role of buyers or sellers and are active in a market with eight locations. Two sellers sell the same good and are located on either end of the market. Six buyers are located between the two sellers according to the following graphical depiction:

Seller	**Buyer**	**Buyer**	**Buyer**	**Buyer**	**Buyer**	**Buyer**	**Seller**
Location 1	Location 2	Location 3	Location 4	Location 5	Location 6	Location 7	Location 8

Buyers buy exactly one good in each of the two periods. Sellers choose prices p at the beginning of each period. Prices must be integers between 0 and 10. Buyers pay the price of a good and transport costs t according to their distance to the respective seller. Buyers pay transport costs of one unit per field and have to move to the sellers' location. Buyers receive earnings according to the following earnings function:

$$Earnings = 15 - p - t$$

At the beginning of the first period sellers choose an *introductory price*. Buyers choose one seller and decide whether to allow *cookies*. At the beginning of the second period sellers choose three prices: a *loyalty price*[, a *poaching price*] and a *new customer price*. The profit of sellers in a market corresponds to the sold number of goods multiplied with their respective price according to the following profit function:

$$Profit = p \cdot n$$

[33]Here you find translated short versions of the instrutions for the experiment. Original instructions are in German and can be made available upon request. Note that transportation costs in the instructions are denoted by t which corresponds to θ in the main body.

The following table depicts which buyer sees which price of the two sellers in the second period, according to their initial purchasing decision and cookie choice.

Chosen seller in first period	Allow use of cookies	Price of seller 1	Price of seller 2
Seller 1	allow	Loyalty price	New customer price
Seller 1	don't allow	New customer price	New customer price
Seller 2	allow	New customer price	Loyalty price
Seller 2	don't allow	New customer price	New customer price

[Differences in the complete information treatment.]

Chosen seller in first period	Allow use of cookies	Price of seller 1	Price of seller 2
Seller 1	allow	Loyalty price	**Poaching price**
Seller 1	don't allow	New customer price	New customer price
Seller 2	allow	**Poaching price**	Loyalty price
Seller 2	don't allow	New customer price	New customer price

Procedure

At the beginning of the experiment each participant is assigned a role, which remains fixed for the remainder of the experiment of 20 rounds in total. In each round there are two markets with two sellers each. Six buyers are active in **both** markets, while sellers are active in **one** of the markets. Within one round locations of buyers and sellers are fixed. Each round buyers are assigned random new locations in both markets. Sellers are randomly assigned to one market with a random location at either end of the market in each round.

Privacy concern survey - IUIPC score[34]

All statements are rated by the subjects on a seven-point scale from "strongly agree" to "strongly disagree". The first three statements relate to control issues, statements four to six relate to awareness and the remaining four statemtents relate to collection issues.

1) Consumer online privacy is really a matter of consumers' right to exercise control and autonomy over decisions about how their information is collected, used, and shared.
2) Consumer control of personal information lies at the heart of consumer privacy.
3) I believe that online privacy is invaded when control is lost or unwillingly reduced as a result of a marketing transaction.
4) Companies seeking information online should disclose the way the data are collected, processed, and used.
5) A good consumer online privacy policy should have a clear and conspicuous disclosure.
6) It is very important to me that I am aware and knowledgeable about how my personal information will be used.
7) It usually bothers me when online companies ask me for personal information.
8) When online companies ask me for personal information, I sometimes think twice before providing it.
9) It bothers me to give personal information to so many online companies.
10) I'm concerned that online companies are collecting too much personal information about me.

Iterative thinking task - The game of 22[35]

The rules of the game are as follows: This is a two-player game in which players increase a counter. This counter starts at 0 and ends at 22 and must be moved each turn by 1, 2 or 3 steps, with players acting sequentially. You will play this game against the computer and you are the first to move. The player who reaches 22 loses. If the computer loses the game, you will earn 2€ , while you will earn 0€ if you lose.

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**

Figure 10: Representation of the Game of 22

[34]Original questions of Malhotra et al. (2004) were translated to German.
[35]Instructions are originally in German and presented on screen.

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