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Monopoly price discrimination and privacy: The hidden cost of hiding[☆]

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HIGHLIGHTS

- A monopolist can identify a consumer's willingness to pay with some probability.
- Consumers can stay unidentified at some cost.
- Consumers may be collectively better off absent this possibility.

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ABSTRACT

A monopolist can use a 'tracking' technology to identify a consumer's willingness to pay with some probability. Consumers can counteract tracking by acquiring a 'hiding' technology. We show that consumers may be collectively better off absent this hiding technology.

1. Introduction

Recent developments in digital technologies (e-commerce, social media and networks, mobile computing, sensor technologies) have not only driven individuals to leave an increasingly long digital trace behind them, but have also made available the tools to assemble, harness and analyse large and complex datasets (so-called 'Big data'). As a consequence, firms are now able to target advertising, product offerings and prices to their customers with an unprecedented precision.

When it comes to prices, firms' enhanced ability to price discriminate implies a reduction in consumer surplus. Yet, the same technological developments have also enabled individuals to protect their privacy (e.g., by erasing their digital trace or by concealing their actions online). Although one would expect that such countermeasures would restore (at least part of) the lost consumer surplus, we show in this note that the opposite may actually happen. Adding insult to injury, the use of privacy-protecting technologies may decrease consumer surplus even further.

We establish this point in a monopoly setting where the firm has access to a 'tracking' technology that allows it to identify the

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willingness to pay of its consumers with some probability; the firm then charges personalized prices to the consumers it identifies and a common regular price to the consumers it does not identify. Consumers have the possibility to acquire a 'hiding' technology that makes the firm's tracking technology inoperative. Our main result is to show that consumer surplus is often larger when this hiding technology is *not* available. In fact, when the technology is available, the firm has an incentive to limit its use by raising the regular price of its product. As a result, what some consumers gain by protecting their privacy is often more than offset by what the other consumers lose by paying a higher price or by not purchasing any longer.

Compared to the existing literature on privacy (see Acquisti et al., 2016, for a comprehensive and recent survey), the simple setting adopted in this note leaves aside a number of important features: price competition (as, e.g., in Taylor and Wagman, 2014, or in Montes et al., 2015), repeat purchases (as, e.g., in Conitzer et al., 2012), or data intermediaries (as, e.g., in Bergemann and Bonatti, 2015). However, this setting is novel in that it considers a tracking technology whose degree of precision can range between no and full identification of the consumers (in contrast with the existing literature that only considers the two extreme cases).[3]

2. The model

A monopolist produces some product at a constant marginal cost, which is set to zero for simplicity. A unit mass of consumers have a unit demand for the monopolist's product. A consumer's valuation for the product is noted r. The distribution of valuations is given by the cumulative distribution function $F(r)$ with support $[0, \bar{r}]$, where $\bar{r} \in (0, \infty]$, and by a continuous and differentiable density $f(r) \equiv F'(r) \geq 0$.

The monopolist can have access to a 'tracking technology' that allows it to identify the valuation of a consumer with probability λ (with $0 \leq \lambda \leq 1$).[4] The parameter λ can be interpreted as the precision of the tracking technology. In terms of pricing, this means that with probability λ, the monopolist knows the valuation of consumer r and charges this consumer a personalized price $p(r) = r$ (which captures the consumer's entire surplus), whereas with probability $(1-\lambda)$, the monopolist does not know the consumer's valuation and charges then a 'regular' price p. Arbitrage is supposed to be impossible or prohibitively costly.

Consumers have access to some 'hiding technology' that allows them to prevent the monopolist from discovering their valuation. The technology is assumed to have the following simple form: by paying a cost c, any consumer can make sure that the monopolist cannot identify her valuation, whatever the precision of its tracking technology.

We analyse the following three-stage game. First, the monopolist decides whether or not to use the tracking technology. Second, the monopolist sets its prices (i.e., the regular price p and, possibly, a schedule of personalized prices $p(r)$), while consumers decide whether or not to acquire the hiding technology. Third, consumers observe the price that the monopolist charges them and decide whether or not to buy the product.[5] We solve the game for its perfect Bayesian Nash equilibria.

We consider two benchmarks. First, *if the monopolist decides not to use the tracking technology* at the first stage of the game, then it charges the regular price to all consumers. Its problem is given by $\max_p p(1-F(p))$. The FOC for profit-maximization allows us to determine implicitly the optimal price p_0 by solving $1 - F(p_0) - p_0 f(p_0) = 0$. We assume that the distribution of valuations satisfies the monotone hazard rate condition: $(1-F(r))/f(r)$ is monotonically non-increasing for all r; this guarantees that the monopolist's objective function is quasi-concave and the SOC is satisfied. It follows that the monopolist sells a quantity $1 - F(p_0)$ at price p_0. The consumer surplus is then computed as

$$CS_0 = \int_{p_0}^{\bar{r}} (r - p_0) f(r)\, dr.$$

Second, *if no hiding technology were available*, the monopolist would charge p_0 to unidentified consumers and their valuation r to identified consumers. Hence the consumer surplus would be equal to:

$$CS_n(\lambda) = \lambda \times 0 + (1-\lambda) \int_{p_0}^{\bar{r}} (r - p_0) f(r)\, dr = (1-\lambda)\, CS_0. \tag{1}$$

Unsurprisingly, when consumers have no way to hide their identity, the consumer surplus decreases when the precision of the tracking technology (i.e., λ) increases.[6]

3. Equilibrium

Suppose that the monopolist uses the tracking technology and that consumers can counteract tracking by acquiring some hiding technology at a constant cost c. At stage 2, consumers anticipate that they will pay a price p^e if they are not identified or a personalized price equal to their valuation if they are. Given this expectation, which determines the mass of consumers who decide to hide, the monopolist chooses its optimal price p. It is then imposed that the expectations be fulfilled at equilibrium.

Hence, any consumer r with $r \geq p^e$ will have a surplus of $(1-\lambda)(r - p^e)$ if she does not acquire the hiding technology and a surplus of $r - p^e - c$ if she does. It is thus worth acquiring the hiding technology if and only if $c \leq \lambda(r - p^e)$, i.e., if the cost of hiding one's valuation (c) is inferior to the benefit of hiding it (i.e., to keep the surplus $r - p^e$ when the tracking technology would discover one's valuation if it is not hidden).[7] The latter inequality can be rewritten as $r \geq p^e + c/\lambda$. Consumers with such valuations will hide and will thus pay, with certainty, the regular price p^e; consumers with a lower valuation will pay their valuation with probability λ or will pay p^e with probability $(1-\lambda)$ if their

[3] An exception is Johnson (2013), who allows for gradations in information quality in his model of targeted advertising and advertising avoidance.

[4] Alternatively, we can assume that each valuation r is shared by a unit mass of consumers and that the technology allows the monopolist to identify a fraction λ of those consumers.

[5] This formulation implies, quite realistically, that (i) the firm is unable to observe a consumer's hiding decision before setting its prices, and (ii) consumers have to decide whether or not to hide before observing the price they are charged. We also considered an *alternative timing* in which the monopolist first sets and commits to its regular price, after which consumers observe this price and decide whether to hide or not. Then the tracking technology is applied and the monopolist sets personalized prices to the identified consumers. Finally, consumers observe the price they are charged (either personalized of regular) and decide to buy or not. Here, the monopolist is able to influence directly the consumers' hiding decision by committing to the regular price. This alternative timing yields, nevertheless, qualitatively equivalent results: the monopolist charges a larger regular price when both tracking and hiding are possible; the monopolist is better off with the tracking technology and consumers may be collectively better off by not having access to a hiding technology.

[6] When $\lambda = 1$, the monopolist captures the entire consumer surplus, which corresponds to the case of perfect price discrimination.

[7] Consumers with $r < p^e$ do not find it profitable to hide: if they do not hide, their surplus is zero, whereas if they hide, their surplus is $-c$ (as they do not buy the good).