Commercial Software, Adware, and Consumer Privacy*

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Abstract

I study the choice between selling new software commercially and bundling it with ads and distributing it for free as adware. Adware allows advertisers to send targeted information to consumers which improves their purchasing decisions, but also entails a loss of privacy. I show that adware is more profitable when the perceived quality of the software is relatively low, when tracking technology improves, when consumers benefit more from information on consumer products and are less likely to receive it from external sources. I also show that improvements in the technology of display ads will lead to less violation of privacy and will benefit consumers, that depending on the software's quality, there are either too many or too few display ads in equilibrium, and that from a social perspective, adware dominates commercial software.

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1 Introduction

Until the end of the 1990's, most commercial software was sold to users in retail stores. By the end of the 1990's, software providers began to distribute their software online. While many software providers require users to pay for the software after a trial period, others distribute their software for free as an adware and collect fees from advertisers, who use the software to track the behavior of the users and send them targeted ads about their products.[1] This paper studies the choice between selling the software commercially and distributing it as an adware in the context of a model that explicitly accounts for the strategic interaction between software providers, firms that sell consumer products and may advertise them online, and consumers who buy software and products.

The model considers a software provider who has developed a new software and needs to decide how to distribute it. The software provider faces consumers who differ in their preferences over products, but do not necessarily know at the outset which firm sells which product. Display ads (e.g., banner ads, pop-up ads, floating ads, flash ads, etc) allow firms to send consumers targeted information about products that match their tastes. At the same time, adware raises privacy concerns among consumers, privacy advocates, government protection agencies, and media and marketing associations (see FTC, 2012, and Department of Commerce Internet Policy Task Force, 2010). Definitions of privacy vary widely according to context and environment. Posner (1981) discusses several possible definitions, including the "concealment of information," "peace and quiet," and "freedom and autonomy." In this paper I consider the second definition, namely privacy as the right for "peace and quiet." This right is a main reason behind the "do-not-call list" that is enforced in the U.S. by the FTC and FCC, and is intended

[1]This paper considers only "legitimate" ad-supported software which is installed with the end-user consent. I do not consider "spyware" which is often installed without the end-user consent and tracks and collects personal information without consent. For a discussion on the early history of adware, see for example Stern (2004).

to prevent telemarketers from violating consumers' privacy at home.[2] The desire of consumers for "peace and quiet" is captured in my model by assuming that, in addition to potentially useful information about consumer products, adware users also get a disutility from display ads. Adware users then face a trade-off between the utility from using the software and the beneficial information they get about consumer products and the disutility from privacy loss. In equilibrium, consumers with large privacy concerns do not adopt the adware, while those with relatively small privacy concerns do. The number of adopters in turn determines the willingness of firms to pay for display ads and hence the profit from distributing the software as an adware.

I show that in equilibrium, the software will be distributed as an adware provided that its perceived quality is relatively low. When the perceived quality of the software is relatively high, it is more profitable to sell it commercially. This pattern is consistent with the experience of several popular software that were first distributed as adware, but then, newer and improved versions were distributed commercially.[3]

The fast technological improvements in context-based advertising have raised concerns

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[2]In a decision from February, 17, 2004, the U.S. Court of Appeals for the Tenth Circuit held that "the do-not-call registry" targets speech that invades the privacy of the home, a personal sanctuary that enjoys a unique status in our constitutional jurisprudence" (*Mainstream Marketing Services, Inc., TMG Marketing Inc., and American Teleservices Association v. Federal Trade Commission, et al.*, U.S. Court of Appeals for the 10th Circuit, No. 03-1429, and consolidated cases). Likwise, in *Frisby v. Schultz*, 487 U.S. 474, 484 (1988), the Supreme Court of the U.S. held that "One important aspect of residential privacy is protection of the unwilling listener. ... [A] special benefit of the privacy all citizens enjoy within their own walls, which the State may legislate to protect, is an ability to avoid intrusions. Thus, we have repeatedly held that individuals are not required to welcome unwanted speech into their own homes and that the government may protect this freedom." And, in *FCC v. Pacifica Found.*, 438 U.S. 726, 748 (1978) the Supreme Court of the U.S. held that "[I]n the privacy of the home ... the individuals right to be left alone plainly outweighs the First Amendment rights of an intruder."

[3]Cases in point are Gozilla and GetRight which are two of the most popular download managers. For instance, on http://www.gozilla.com/ (visited on March 1, 2012), they write "Under previous owners, Go!Zilla had included AdWare and bundled various other software programs in its installer. That is all gone now. We will do better. As of version 5.0, Go!Zilla will contain no bundled advertising software and "extras" in its installer." Likewise, the "A History of GetRight®" page (http://www.getright.com/getright_history.html, visited on March 1, 2012) says: "For awhile there, before the technology bubble burst, the Advertising in software really looked like the way to go. ...But the whole concept of ads in a program–no matter how it was done–was deemed spyware, and we pulled the ads in the later 4.x versions."

about the increasing loss of privacy on the Internet.[4] In my model, such improvements affect both consumers' privacy, as well as their information on consumers' products. I show that such improvements induce the software provider to distribute the software as adware for a wider set of parameters. Hence, consumers with large privacy concerns may be worse off since in order to obtain the software, they are also forced to receive display ads which lower their utility. Yet, the analysis shows that on aggregate, the benefit to consumers from improved information on consumer goods outweighs the associated loss of privacy.

I also show that the software provider chooses to distribute the software as adware for a larger set of parameters when consumers benefit more from information on consumer products that they receive via display ads and when there is a smaller probability of learning about such products from external sources. In addition, I show that the price of display ads can be too high or too low relative to the social optimum, depending on the software's quality, and that from a social perspective, adware dominates commercial software. Not surprisingly then, the paper implies that a ban on ad-supported software or mandatory "Do Not Track" mechanisms that allow consumers to opt out of tracking by advertisers may harm consumers by inducing the software provider to switch from adware to commercial software.

This paper contributes to the small but growing literature on the economics of privacy (see Hui and Png, 2006, for a literature survey). Several papers in this literature equate the loss of privacy with the disclosure of information on the consumers' preferences. Such information allows firms to use personalized prices that extract more consumer surplus when firms have market power (e.g., Acquisti and Varian (2004; Calzolari and Pavan, 2006; Conitzer, Taylor, and Wagman, 2012; Taylor 2004; and Wathieu, 2002), or it can serve as a screening device to ration

[4] See for instance, McDonald and Cranor (2012) and White House (2012). See also "Consumers turn to do-not-track software to maintain privacy" by Byron Acohido, USA Today, December 29, 2011, http://usatoday30.usatoday.com/tech/news/story/2011-12-29/internet-privacy/52274608/1 for a recent news report on online tracking and anti tracking technologies.

consumers when firms operate in a competitive market (Burke, Taylor, and Wagman, 2012).[5] But as Varian (1996) points out, when firms learn information about consumers' preferences, they can also offer them products that better meet their needs and thereby lower their search costs. Hence, disclosure of information on consumers' preferences involves a trade-off between a reduction of search costs and extraction of consumers' surplus. A different approach to consumers' loss of privacy is taken by Hann et al. (2008) and by Anderson and Gans (2012). Both papers consider a game in which firms send costly ads (or solicitations) to consumers who differ in their willingness to pay (WTP) for products, while consumers invest in ad avoidance.[6] They show since low WTP consumers will avoid ads, ads become more cost effective and hence encourage firms to send more of them. They also show that ad voidance can be welfare decreasing. My paper differs from the papers mentioned here since I abstract from the effect of information on consumer preferences on the prices of consumer products, and focus instead on the software provider's choice between commercial software and adware, and the resulting implications for consumers due to the effect on their purchasing decisions and on their loss of privacy.

Hann et al. (2007) empirically examine individuals' trade-offs between the benefits and costs of providing personal information to websites. They find that the benefits in terms of monetary rewards and future convenience significantly affect individuals preferences over websites with differing privacy policies. Among U.S. subjects, protection against errors, improper access, and secondary use of personal information is worth $\$30.49 - \$44.62$, while among Singapore subjects, it is worth $S\$57.11$.

Although my model considers the market for software, it can also be applicable to media

[5] de Cornière and De Nijs (2012) study a related model in which firms choose prices before learning information on consumers. Once they are informed, firms participate in an auction for displaying ads. When firms condition their bids on consumers' characteristics, they expect their ads to reach only the consumers with a low price-elasticity of demand and hence they set higher prices ex ante.

[6] Johnson (2012) also studies the strategic interaction between ad targeting by firms and ad avoidance by consumers.

markets (though in the software market it is generally easier to track the behavior of individual users and send them targeted ads).[7] In this context, my model suggests that ad-supported distribution of content (pure advertising) is more profitable than selling content for a fee (ad-free pay-per-view) when the contents' quality is low, and ad-free pay-per-view is more profitable when quality is sufficiently high. Moreover, my model suggests that pure advertising yields higher social surplus than ad-free pay-per-view and that consumers are better-off under pure advertising when quality is low and vice versa when quality is high. The last result seems at odds with Hansen and Kyhl (2001), who find that consumers are always better-off under pure advertising than under pay-per-view. However, unlike in my model, pay-per-view in their model is not ad-free, and in addition, they do not consider the beneficial effect of ads on consumers' choice of products. In addition, unlike in my paper, they do not consider the content providers' endogenous choice between pay-per-view and pure advertising.[8] Peitz and Valletti (2008) consider competition between two media platforms and show that under pure advertising, content is less differentiated than under pay-TV (where media platforms earn both advertising revenues as well as revenues from viewers), and moreover there is a higher advertising intensity if viewers strongly dislike advertising.

The rest of the paper is organized as follows: Section 2 presents the model. Section 3 characterizes the equilibrium when there is a single software provider who needs to choose whether to sell the new software commercially or distribute it for free as an adware and then make money by selling ads. Section 4 offers some comparative statics and Section 5 considers the policy implications of the model. Concluding remarks are in Section 6.

[7] See Anderson and Gabszewicz (2006) for a survey of the literature on media and advertising and Anderson (2012) for a review and extention of the economics of advertising on the Internet.

[8] Prasad, Mahajan and Bronnenberg (2003) study the choice of content provider between different combinations of ads and subscription fees in order to screen among a population of viewers with heterogenous disutility from ads. They show that in general, the optimal strategy is to offer a menu with different combinations of subscription fee and ads.

2 The model

There are three types of agents in the model: a software provider, a continuum of consumers (or users), and $n \geq 2$ firms that sell consumer products. The software provider has developed a new software of a given quality and needs to decide whether to sell it commercially to consumers (through retail stores or online) or to bundle it with ads and distribute it for free. In the latter case, the software provider collects per impression prices from firms that use the software to send consumers targeted information about their products.[9]

2.1 The timing of the model

The model evolves in three stages. In stage 1, the software provider chooses whether to sell the software commercially, or distribute it for free as an adware.[10] Under the first option, the software provider sets a price, p, for the software. Under the second option, the software provider sets a per-impression advertising fee, r, that firms must pay in order to display ads using the adware. In stage 2, each consumer decides whether or not to adopt the software. In stage 3, which is reached only if the software provider chooses to distribute the software as an adware, the n firms choose how many ads to display. Finally, consumers buy products from firms.

2.2 Consumers

There is a mass one of potential consumers. Each consumer is interested in getting one software and one out of n consumer products, each of which is produced by a different firm. Consumers

[9] An "impression" is a single appearance of an ad on a web page.

[10] I do not consider the possibility that the software provider will offer both an adware and an ad-free commercial version. Obviously, if that was possible, the software provider would have liked to sell a commercial software to consumers with large privacy concerns and would have offered an adware to consumers with small privact concerns. Rather than focusing on "versioning," I examine in this paper the conditions under which each possibility is more profitable.

belong to n distinct and equally-sized groups: consumers in group i get a utility s if they buy product i and $s-t$ if they buy any other product, where s is the difference between the gross utility of buying the "right" product and the product's price. One can then think of t as the utility loss from mismatch between the product and the consumer's preferences. For simplicity, I will assume that t and s are the same for all products and treat them an exogenous parameters. Consumers, however, do not necessarily know about all firms at the outset: each consumer in group i learns about product i only with probability ρ. With probability $1-\rho$, the consumer does not know about product i, but may still end up buying it at random with probability $\frac{1}{n}$. The overall probability that a consumer in group i buys product i then is $\varphi = \rho + \frac{1-\rho}{n}$. The consumer's utility in this case is s. With probability $1-\varphi$, the consumer buys some other product and gets a utility $s-t$. The expected utility of a consumer who does not buy software is therefore

$$\overline{U} = \varphi s + (1-\varphi)(s-t). \tag{1}$$

Users of commercial software: Using q to denote the perceived quality of the software, the net utility of a consumer who buys commercial software is $\theta q - p$, where θ is the marginal willingness to pay for quality and is drawn from a uniform distribution on the unit interval. Given θ, the expected utility of each user of commercial software is

$$U^s(\theta) = \theta q - p + \overline{U}. \tag{2}$$

To ensure that the model attains an interior solution, I will make the following assumption:

Assumption 1: $\frac{q}{2} \leq (1-\varphi)t$

Assumption 1 implies that the "average" direct utility from the software, $\frac{q}{2}$, does not exceed the utility loss due to choosing the "wrong" consumer product. This assumption ensures that in equilibrium, firms will agree to pay for display ads.

Adware users: If a consumer adopts an adware, he gets in addition to the software, another piece of software that tracks his behavior and enables the software provider to send him targeted ads about products that match his preferences. In the current model, this means that the software provider likes to send adware users in group i ads about product i. I will assume however that the adware technology is imperfect: the probability that a targeted ad sent to a user in group i is indeed about product i is only $\phi < 1$. With probability $1 - \phi$, the adware fails to identify the user's true preferences and hence he receives an ad about a "wrong" product.

Let k_i be the number of impressions that firm i pays for (i.e., the number of times that firm i's ads are displayed on the user's screen) and let $m \in [0, 1]$ be the probability that an ad captures the user's attention. Assuming that the probability of noticing each impression is independent across impressions, and recalling that each ad is about a relevant product only with probability ϕ, the overall probability that a consumer in group i notices at least one relevant impression is

$$\mu_i = 1 - (1 - \phi m)^{k_i}. \tag{3}$$

With probability $1 - \mu_i = (1 - \phi m)^{k_i}$, the consumer either ignores all k_i impressions or pays attention only to irrelevant ads. In what follows, I will refer to μ_i as "consumers' attention."

It turns out that it is easier to express the model in terms of μ_i rather than k_i. To this end, note from equation (3) that

$$k_i = z \ln (1 - \mu_i), \qquad z \equiv \frac{1}{\ln(1 - \phi m)}. \tag{4}$$

Equation (4) represents the number of impressions that firm i needs to send in order to ensure attention level μ_i in group i (i.e., probability μ_i that its product is noticed by adware users in group i). Since $\ln(1-\mu_i) < 0$, k_i decreases with z, implying that as z (which is negative) increases towards 0, the ads technology improves, fewer impressions are needed to attract the same level of consumers' attention. Hence, z which increases with m, serves as a measure of how effective display ads are in attracting the attention of adware users.

Apart from ads, adware users in group i also learn about product i with probability φ (just like users of commercial software and those who do not buy software). Assuming that the probability of learning about products from an adware is independent of the probability of learning about it from other sources, the probability that an adware user in group i buys product i is $\mu_i + (1-\mu_i)\varphi$ (the probability that he learns about product i from the adware plus the probability that he does not learn about it from the adware but does learn about it from other sources); the probability that the adware user buys one of the $n-1$ "wrong" products is $(1-\mu_i)(1-\varphi)$.

While ads provide potentially useful information about consumer products, they also violate the privacy of adware users by intruding on their right "to be left alone." I assume that the resulting disutility of adware users is increasing with the number of impressions they receive and is given by βk_i, where β is independent of θ and is uniformly distributed in the population on the interval $[0, B]$. Hence, each consumer in my model is characterized by a pair of parameters: θ which is the marginal willingness to pay for the software, and β which is the marginal disutility from privacy loss. In what follows, I shall assume that B is sufficiently large:

Assumption 2: $B > \frac{\frac{3q}{2}+(1-\varphi)t}{2z\ln\left(\frac{\frac{q}{2}+(1-\varphi)t}{2(1-\varphi)t}\right)}$

This assumption implies that even among consumers with the highest willingness to pay for software (i.e., those with $\theta = 1$), there are some whose privacy concerns are so large that they will not adopt the adware even though it is distributed for free.

Assuming that the perceived quality of the adware is also q and using equation (1), the expected utility of an adware user in group i is given by

$$U_i^a(\theta,\beta,r) = \theta q - \beta z \ln(1-\mu_i) + (\mu_i + (1-\mu_i)\varphi)\, s + (1-\mu_i)(1-\varphi)(s-t) \qquad (5)$$
$$= \underbrace{\theta q}_{\text{Utility from software}} - \underbrace{\beta z \ln(1-\mu_i)}_{\text{Privacy loss}} + \underbrace{\mu_i (1-\varphi)\, t}_{\text{Better information}} + \underbrace{\overline{U}}_{\text{Outside option}}.$$

To understand the third term, notice that without an adware, the consumer would buy the "wrong" product with probability $\mu_i(1-\varphi)$ and would lose utility of t. Hence, $\mu_i(1-\varphi)\,t$ is the extra expected utility from the having better information on consumer products.

2.3 Firms

The demand for ads comes from firms that wish to bring their products to the consumers' attention. Hence the decisions of firms matter in my model only when the software provider offers an adware. Otherwise, each consumer (whether he owns a commercial software or not) either learns about the "right" product with probability φ or else picks one of the $n-1$ "wrong" products at random. By symmetry then, each firm serves a mass $\frac{1}{n}$ of consumers, each of whom is interested in buying one unit.

Now, suppose that the software provider offers an adware and suppose that a fraction α of all consumers adopt it. Of these consumers, $\frac{\alpha}{n}$ are in group i. The probability that each of these consumers will buy from firm i is $\mu_i + (1-\mu_i)\varphi$ (the probability that the consumer learns about product i from an ad, plus the probability the he does not learns about it from an ad, but still ends up buying it either because he learns about it from another sources or purely by chance). The probability that an adware user in group $j \neq i$ will buy from firm i is $\frac{(1-\mu_j)(1-\varphi)}{n-1}$ (the probability that the user fails to learn about product j times the probability he learns about product i, which is one of the $n-1$ "wrong" products). By the law of large numbers, firm i serves a total of $\frac{\alpha}{n}\left[\mu_i + (1-\mu_i)\varphi + \sum_{j\neq i}\frac{(1-\mu_j)(1-\varphi)}{n-1}\right]$ adware users. In addition, the firm serves $\frac{1-\alpha}{n}$ of consumers who do not own an adware and pick one of the n firms at random.

The expected demand that firm i is facing, given the attention levels $\mu_1, ..., \mu_n$, is:

$$Q_i(\mu_1, \ldots, \mu_n) = \underbrace{\frac{1-\alpha}{n}}_{\text{Non-adware users}} + \underbrace{\frac{\alpha}{n}\left(\mu_i + (1-\mu_i)\varphi\right)}_{\text{Adware users in group i}} + \underbrace{\frac{\alpha}{n}\sum_{j \neq i} \frac{(1-\mu_j)(1-\varphi)}{n-1}}_{\text{Adware users in groups } j \neq i}. \quad (6)$$

Unlike some of the papers mentioned in the Introduction, where information on consumers' preferences is used to offer personalized prices, I assume that the profit per unit of consumer product is exogenous and equal to π.[11] Using r to denote the per-impression price that firms pay adware providers, and using equation (4), the expected profit of firm i is

$$\Pi_i(\mu_1, \ldots, \mu_n) = Q_i(\mu_1, \ldots, \mu_n)\pi - \frac{\alpha}{n} r \underbrace{z \ln(1-\mu_i)}_{k_i}. \quad (7)$$

Each firm i chooses the level of consumer attention μ_i it wishes to attract for its product in order to maximize its expected profit $\Pi_i(\mu_1, \ldots, \mu_n)$.

2.4 The software provider

The model starts after the software provider has already developed a new software whose quality is q and needs to decide how to distribute it.[12] If the software provider chooses to sell the software commercially at a price p, then only consumers with $\theta \geq \frac{p}{q}$ will buy it. Since θ is uniformly distributed on the unit interval, the provider's profit is

$$O^s(q,p) = p\left(1 - \frac{p}{q}\right).$$

[11] Since π is exogenous, my paper also abstracts from the effect of targeted ads on product market.

[12] One can endogenize the choice of q. This choice will depend on cost of investment in quality and hence the results will depend in such a model on the cost of investment rather than on q.

If the software provider distributes the software for free as an adware, he can collect money from advertisers. Specifically, the software provider sets a price r per impression in order to maximize his profit from selling ads; this profit is given by $r \sum_{i=1}^{n} k_i$, or using (4),

$$rz \sum_{i=1}^{n} \frac{\alpha}{n} \ln (1 - \mu_i) .$$

3 Equilibrium

This section characterizes the subgame perfect equilibrium of the model. Given $O^s(q,p)$ it is clear that if the software provider wishes to sell the software commercially, he will sell it at a price $p^* = \frac{q}{2}$ and will serve all consumers with $\theta \in \left[\frac{1}{2}, 1\right]$. The provider's profit in this case is $O^s(q, p^*) = \frac{q}{4}$.

The equilibrium if the software provider chooses the adware option is more involved: in Sections 3.1 and 3.2 I consider stages 2 and 3 of the adware subgame. In Section 3.3 I will consider the software provider's choice between commercial software and adware.

3.1 Stage 3: the choice of targeted ads

Suppose the software provider chooses to distribute the new software as an adware and sets a price r per impression. Each firm i then chooses μ_i by maximizing its expected profit $\Pi_i(\mu_1, \ldots, \mu_n)$. The first order condition for μ_i is:

$$\frac{\partial \Pi_i(\mu_1, \ldots, \mu_n)}{\partial \mu_i} = \frac{\alpha}{n} (1 - \varphi) \pi + \frac{\alpha}{n} \left(\frac{rz}{1 - \mu_i} \right) = 0.$$

The first term is the marginal benefit from displayed ads: ads increase the probability that each of the $\frac{\alpha}{n}(1-\varphi)$ adware users in group i, who is not already aware of product i from other sources, will learn about it. The profit from selling the product to such a consumer is π. The second term is the marginal cost of display ads (since $z < 0$, the second term is negative).

Solving the first order condition for μ_i, reveals that in equilibrium, the demand for consumers' attention in group i, as a function of the per-impression price r, is

$$\mu_i = \widehat{\mu}(r) \equiv 1 + \frac{rz}{(1-\varphi)\pi}, \qquad i = 1, 2, ..., n. \tag{8}$$

Notice that since $z < 0$, $\widehat{\mu}(r)$ is linearly decreasing with r (recall that $z < 0$) and has a choke price $\overline{r} \equiv -\frac{(1-\varphi)\pi}{z}$. Moreover, $\widehat{\mu}(r)$ is increasing with π and z, but is decreasing with φ. Intuitively, firms demand more display ads when the market is more profitable (π is larger) and when display ads attract consumers' attention more effectively (z increases towards 0), but demand fewer display ads when adware users are more likely to learn about the "right" products from other sources (φ is larger). It is interesting to note that each firm's demand for display ads is independent of α which is the fraction of consumers who choose to buy adware. The reason for this is that firms pay a price per impression, so if there is a smaller number of adware users, their payments to the adware provider decrease proportionally.

3.2 Stage 2: consumers' demand for adware

When the software provider chooses to distribute the software as an adware, each consumer needs to decide whether or not to adopt it. Substituting for $\widehat{\mu}(r)$ from (8) into (5), the utility from having an adware is

$$U^a(\theta, \beta, r) = \underbrace{\theta q}_{\text{Utility from software}} - \underbrace{\beta z \ln(1 - \widehat{\mu}(r))}_{\text{Privacy loss}} + \underbrace{\widehat{\mu}(r)(1-\varphi)t}_{\text{Better information}} + \underbrace{\overline{U}}_{\text{Outside option}}. \tag{9}$$

Consumers will adopt the adware if and only if $U^a(\theta, \beta, r) \geq \overline{U}$.

The decision to adopt adware is illustrated in Figure 1. As the figure shows, $U^a(\theta, \beta, r)$

is an inverse U-shaped function of r. Intuitively, an increase in r makes display ads more expensive and therefore lowers the demand of advertisers for consumers' attention. As a result, adware users enjoy more privacy, but at the same time, they also receive less potentially useful information about consumer products. As Figure 1 shows, the beneficial effect on privacy dominates when r is relatively small, while the decrease in information on consumer products may (but not necessarily) dominate when r is close to the choke price $\overline{r}$ at which $\widehat{\mu}(r) = 0$.[13]

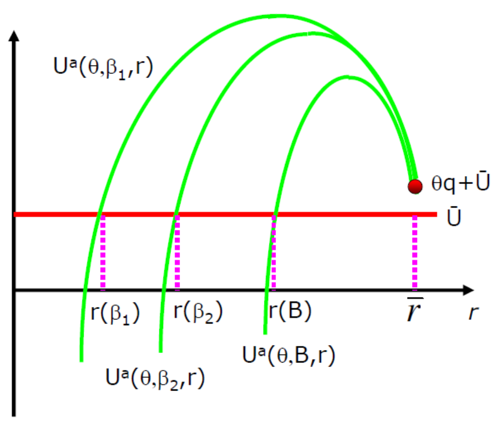

Figure 1: the decision to adopt adware

Since $\widehat{\mu}(\overline{r}) = 0$, then $U^a(\theta, \beta, \overline{r}) = \theta q + \overline{U} \geq \overline{U}$, so all consumers adopt the adware when r is sufficiently close to $\overline{r}$. By contrast, as $r \to 0$, $\widehat{\mu}(r) \to 1$, so $-\beta z \ln(1 - \widehat{\mu}(r)) \to -\infty$, and $U^a(\theta, \beta, r) < \overline{U}$, meaning that no consumer adopts the adware when r is sufficiently close to 0. As Figure 1 shows, the equation $U^a(\theta, \beta, r) = \overline{U}$ defines a unique value of r, denoted $r(\beta)$,

[13] In other words, when r is relatively small, in which case consumers receive many ads, an increase in r, which leads to fewer ads, has a bigger effect on increased privacy than it has on the reduction in information on consumer goods. By contrast, when r is close to $\overline{r}$, consumers receive few ads, so the negative effect on information may dominate the beneficial effect on privacy. Figure 1 shows $U^a(\theta, \beta, r)$ as an inverse U-shaped function even though it could also be strictly increasing for all $r \leq \overline{r}$. This possibility however does not affect any of the conclusions.

such that $U^a(\theta,\beta,r) > \overline{U}$ for all $r > r(\beta)$. Noting that $U^a(\theta,\beta,r)$ decreases with β, it follows that $r'(\beta) > 0$: the higher β is, the closer is $r(\beta)$ to $\overline{r}$. Figure 1 illustrates the situation for three values of β, with $\beta_1 < \beta_2 < B$. Recalling that $\beta \leq B$, it follows that when $r > r(B)$, $U^a(\theta,\beta,r) > \overline{U}$, so all consumers adopt the adware. But if $r < r(B)$, then $U^a(\theta,\beta,r) \leq \overline{U}$ for sufficiently large values of β.

Notice from Figure 1 that as r increases, there is a larger set of values of β for which consumers adopt an adware, i.e., $U^a(\theta,\beta,r) \geq \overline{U}$. Using equation (9), define $\widehat{\beta}(\theta,q,r)$ as the largest value of β for which $U^a(\theta,\beta,r) \geq \overline{U}$:

$$\widehat{\beta}(\theta,q,r) = \begin{cases} \frac{\theta q + \widehat{\mu}(r)(1-\varphi)t}{z\ln(1-\widehat{\mu}(r))} & r \leq r(B), \\ B & r > r(B). \end{cases} \tag{10}$$

That is, $\widehat{\beta}(\theta,q,r)$ is the critical marginal disutility of privacy loss, above which users do not adopt the adware. Notice that

$$\frac{\partial\widehat{\beta}(\theta,q,r)}{\partial r} = \frac{\theta q + (1-\varphi)t\left[\widehat{\mu}(r) + (1-\widehat{\mu}(r))\ln(1-\widehat{\mu}(r))\right]}{z(1-\widehat{\mu}(r))\left(\ln(1-\widehat{\mu}(r))\right)^2} \times \widehat{\mu}'(r) > 0,$$

where the inequality follows since $\widehat{\mu}'(r) < 0$ and $z < 0$, and since $\widehat{\mu}(r) + (1-\widehat{\mu}(r))\ln(1-\widehat{\mu}(r)) > 0$ for all $\widehat{\mu}(r) \in [0,1]$. Hence, when r increases (in which case firms send fewer ads), more consumers adopt an adware.

Given that θ is uniformly distributed in the population on the interval $[0,1]$, the mass of consumers who choose to adopt an adware, i.e., the demand for adware, is

$$\widehat{\alpha}(q,r) \equiv \int_0^1 \frac{\widehat{\beta}(\theta,q,r)}{B} d\theta. \tag{11}$$

Notice that since $\widehat{\beta}(\theta,q,r)$ is increasing with r, $\widehat{\alpha}(q,r)$, and hence the demand for adware is increasing with r. Moreover, the demand for adware is increasing with the software's quality, q, and is also increasing when z increases towards 0.

Figure 2 illustrates $\widehat{\alpha}(q,r)$. Since $\widehat{\beta}\left(\theta,q,r\right) < B$, in equilibrium, $\widehat{\alpha}(q,r) < 1$.

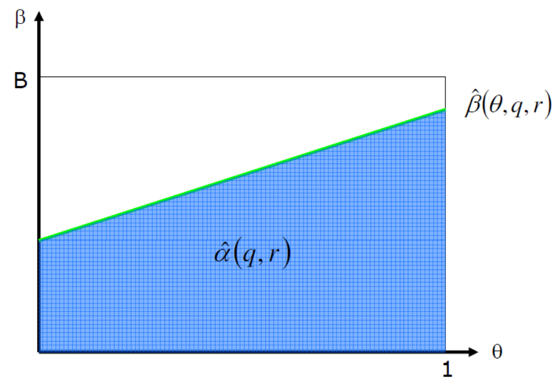

Figure 2: the mass of consumers who adopt adware

3.3 Stage 1: the software provider's problem

At this stage, the software provider needs to choose whether to commercially sell the new software or distribute it as an adware. Under the first option, the software provider sets a price of $p^* = \frac{q}{2}$ and earns a profit of $O^s\left(q,p^*\right) = \frac{q}{4}$.

To derive the software provider's profit under adware, let me assume that in equilibrium, $\widehat{\beta}\left(\theta,q,r\right) < B$ for all θ. Substituting from the first line in (10) into (11) and rearranging, the resulting demand for adware is given by

$$\widehat{\alpha}(q,r) = \frac{\frac{q}{2} + \widehat{\mu}\left(r\right)\left(1-\varphi\right)t}{Bz\ln\left(1-\widehat{\mu}(r)\right)}.$$

Recalling that the number of impressions sent to each adware user, $k_i = z\ln\left(1-\widehat{\mu}\left(r\right)\right)$, the aggregate demand of firms for display ads is given by

$$Q(q,r) = \widehat{\alpha}(q,r)\underbrace{z\ln\left(1-\widehat{\mu}\left(r\right)\right)}_{k_i} = \frac{\frac{q}{2}+\widehat{\mu}\left(r\right)\left(1-\varphi\right)t}{B}. \tag{12}$$

Recalling that $\widehat{\mu}'\left(r\right) < 0$, the aggregate demand for display ads is a downward sloping function of the per-impression price, r. This result is due to three effects. The first is a "price effect": an increase in r induces firms to pay for fewer ads per user, i.e., $z\ln\left(1-\widehat{\mu}\left(r\right)\right)$ decreases. Second, there is a "privacy loss effect": a decrease in the number of ads per user means smaller privacy loss and hence more users wish to adopt an adware. The third effect is an "information effect": a decrease in the number of ads also means that adware users obtain less information about consumer products and hence are less inclined to adopt the adware. However, the "price effect" and the "privacy loss" effects just cancel each other out, so the aggregate demand for ads, which is proportional to the number of adware users, falls with r.

Using (12), the software provider's profit from adware is

$$O^a(q,r) = r \times \underbrace{\frac{\left(\frac{q}{2}+\widehat{\mu}\left(r\right)\left(1-\varphi\right)t\right)}{B}}_{Q(q,r)}. \tag{13}$$

Since $\widehat{\mu}'\left(r\right) < 0$, $O^a(q,r)$ is strictly concave in r; the unique price per impression, r^*, which maximizes $O^a(q,r)$ is given by,

$$r^* = -\frac{\left(\frac{q}{2}+\left(1-\varphi\right)t\right)\pi}{2tz}. \tag{14}$$

Substituting for r^* into (8), consumer attention in equilibrium is

$$\widehat{\mu}\left(r^*\right) = \frac{\left(1-\varphi\right)t-\frac{q}{2}}{2\left(1-\varphi\right)t}. \tag{15}$$

Clearly, $\widehat{\mu}(r^*) < 1$. That is, the adware technology is imperfect in that some adware users end up buying the "wrong" product. Assumption 1 ensures that $r^* < \overline{r} \equiv -\frac{(1-\varphi)\pi}{z}$, where $\widehat{\mu}(\overline{r}) = 0$, so $\widehat{\mu}(r^*) > 0$. Moreover, it is straightforward to verify that Assumption 2 guarantees that $\widehat{\beta}(\theta, q, r^*) < B$, even when $\theta = 1$, as I have assumed.

Given r^*, the profit from adware is

$$O^a(q, r^*) = -\frac{\left(\frac{q}{2} + (1-\varphi)\,t\right)^2 \pi}{4tBz}. \tag{16}$$

Equation (16) shows that $O^a(q, r^*)$ is increasing with the software's perceived quality q, with the probability $1-\varphi$ that consumers will pick a "wrong" product when they do not have an adware, with the profit per-unit of consumer product, π, and with z that measures how effective ads are. Intuitively, the choice of r involves a trade-off between making money on each display ad and lowering the demand of firms for display ads. However, an increase in q and $1-\varphi$ induce some consumers who would otherwise not adopt adware due to privacy concerns to adopt it, and hence the adware provider ends up selling more display ads at each r; this allows the adware provider to raise r^* and hence boosts his profit. Likewise, an increase in π implies that firms are more eager to advertise, so the adware becomes more profitable. When z increases, firms need to display fewer ads to attract consumers' attention. This boosts the demand for ads and hence the software provider's profit.

Having found the profit from adware, I now compare it with the profit from commercial software in order to determine the most profitable way to distribute the new software.

Proposition 1: *The solution to the software provider's problem is as follows:*

(i) *If* $B < -\frac{2(1-\varphi)\pi}{z}$, *the software provider will offer adware for all values of* q.

(ii) *If* $B \geq -\frac{2(1-\varphi)\pi}{z}$, *the software provider will offer adware if* $q \leq q_1$ *and will offer commercial* *software if* $q > q_1$, *where*

$$q_1 \equiv \frac{2t\left(1+\frac{(1-\varphi)\pi}{Bz}-\sqrt{1+\frac{2(1-\varphi)\pi}{Bz}}\right)}{-\frac{\pi}{Bz}}.$$

Proof: Let

$$\Delta(q) \equiv O^a(q,r^*) - O^s(p^*) = -\frac{\left(\frac{q}{2}+(1-\varphi)\,t\right)^2\pi}{4tBz} - \frac{q}{4},$$

be the difference between the profit from adware, $O^a(q,r^*)$, and the profit from commercial software, $O^s(p^*)$. Note that $\Delta(q)$ is concave and attains a unique minimum at $q_{\min} = \frac{-2tBz}{\pi}\left[1+\frac{(1-\varphi)\pi}{Bz}\right]$. Evaluated at $q_{\min}$,

$$\Delta(q_{\min}) = \frac{tBz}{4\pi}\left[1+\frac{2\,(1-\varphi)\,\pi}{Bz}\right].$$

Part (i) of the proposition follows by noting that $\Delta(q_{\min}) > 0$ whenever $B < -\frac{2(1-\varphi)\pi}{z}$.

Next, suppose that $B \geq -\frac{2(1-\varphi)\pi}{z}$. Now $\Delta(q) = 0$ has two solutions:

$$q_1 \equiv \frac{2tBz}{-\pi}\left(1+\frac{(1-\varphi)\pi}{Bz}-\sqrt{1+\frac{2(1-\varphi)\pi}{Bz}}\right), \qquad q_2 \equiv \frac{2tBz}{-\pi}\left(1+\frac{(1-\varphi)\pi}{Bz}+\sqrt{1+\frac{2(1-\varphi)\pi}{Bz}}\right),$$

where $O^a(q,r^*) < O^s(q,p^*)$ if $q_1 \leq q \leq q_2$, and $O^a(q,r^*) > O^s(q,p^*)$ otherwise.

Recalling from Assumption 1 that $q \leq 2(1-\varphi)t$ and noting that $B \geq -\frac{2(1-\varphi)\pi}{z}$ implies that $0 \leq 1 + \frac{2(1-\varphi)t}{zB} \leq 1$, yields

$$q_2 - 2(1-\varphi)t = \frac{2tBz}{-\pi}\left(1+\frac{2(1-\varphi)\pi}{Bz}+\sqrt{1+\frac{2(1-\varphi)\pi}{Bz}}\right) \geq 0,$$

and

$$q_1 - 2(1-\varphi)t = \frac{2tBz}{-\pi}\left(1 + \frac{2(1-\varphi)\pi}{Bz} - \sqrt{1 + \frac{2(1-\varphi)\pi}{Bz}}\right) \leq 0.$$

Hence, the feasible solution is q_1. This completes part (ii) of the proposition. ■

Proposition 1 is illustrated in Figure 3. When the perceived quality of the software, q, is low, selling it commercially is not very profitable. On the other hand, the profit from adware is positive even when $q = 0$ since $O^a(0, r^*) > 0$. By continuity, the same is true for small values of q, so the software provider prefers to distribute the software for free as an adware when q is low, and make money by selling display ads. The reason that $O^a(q, r^*) > 0$ when q is low is that users with relatively small values of β, the benefit from learning about consumer products via display ads exceeds the associated disutility from privacy loss, so the software provider can still make money from adware even when $q = 0$. As Figure 3a shows, when $B \geq -\frac{2(1-\varphi)\pi}{z}$, the profit from commercial software eventually exceeds the profit from adware when q is sufficiently large, because consumers with high values of β will never adopt the adware, although the same consumers will buy commercial software if q is sufficiently large. Figure 3b shows that when $B < -\frac{2(1-\varphi)\pi}{z}$, the profit from adware exceeds the profit from commercial software for all feasible values of q.

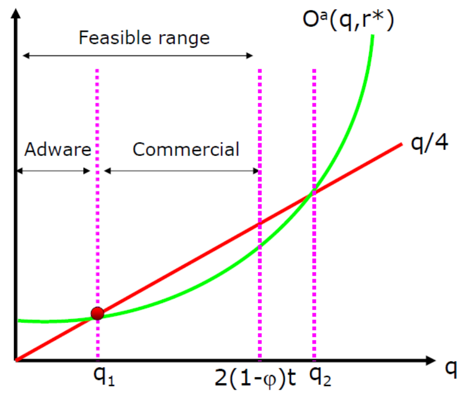

Figure 3a: commercial software is more profitable when q is high

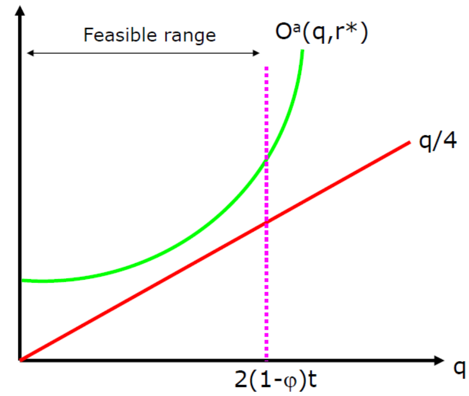

Figure 3b: adware is more profitable for all values of q

Casual observation suggests that many popular software programs are first distributed as adware, but then, newer and improved versions are sold commercially. Examples for this pattern include Gozilla and GetRight which are popular download managers. Proposition 1 provides a possible explanation for this pattern. It should be noted that q need not represent the "true" quality of the software but rather its perceived quality by potential users. If potential users believe that q is lower than it really is and the software provider has no way of credibly convincing them otherwise, then it pays to first distribute the software as an adware. As more consumers use the software and learn about its true quality, the perceived quality of the software increases and the software provider benefits from selling newer versions commercially.

4 Comparative statics

As mentioned in the Introduction, the technology of sending context-based targeted ads to specific online users is expected to improve further in the near future.[14] Naturally, such improvements raise concerns about the increasing loss of privacy on the Internet. It is therefore interesting to find out how improvements in adware technology will affect consumers in the context of the current model, where both privacy loss, as well as the benefits from improved information on consumers' products, are explicitly taken into account.

To address this issue, notice that the adware technology can become better either because it is able to identify consumers' preferences with greater accuracy (i.e., ϕ is higher), or because ads capture the attention of users more often (i.e., m is higher). Either way, $z = \frac{1}{\ln(1-\phi m)}$ increases towards 0; hence, I can simply study the effect of improvements in the adware technology by studying how the equilibrium responds to increases in z.

Note from (14) and (16) that both r^* and $O^a(q, r^*)$ increase when z increases towards 0. The reason for this is that an increase in z towards 0 boosts the demand of firms for display ads and this enables the adware provider to raise the price per impression. Consequently, adware is more profitable than commercial software for a wider set of parameters.

Does an increase in z benefit consumers as well? To address this question, recall that consumers adopt an adware if and only if $\beta \leq \widehat{\beta}(\theta, q, r)$; the utility of each adware user is $U^a(\theta, \beta, r)$. Since the utility of each non user is $\overline{U}$, consumer surplus is given by

$$CS^a(q, r) = \int_0^1 \left[\int_0^{\widehat{\beta}(\theta,q,r)} \frac{U^a(\theta, \beta, r)}{B} d\beta + \int_{\widehat{\beta}(\theta,q,r)}^{B} \frac{\overline{U}}{B} d\beta \right] d\theta. \tag{17}$$

As we saw earlier, in equilibrium, $\widehat{\beta}(\theta, q, r^*) < B$ even when $\theta = 1$. Using equations (9),

[14] See for instance the concern regarding large platform providers (FTC, 2012), and third party web tracking and tracking on mobile apps (Mayer and Mitchell, 2012).

(10) and (15), the value of consumer surplus in equilibrium is

$$
\begin{aligned}
CS^{a}(q,r^{*}) &= \frac{3\left(\frac{q}{2}+\widehat{\mu}\left(r^{*}\right)\left(1-\varphi\right)t\right)^{2}+\left(\frac{q}{2}\right)^{2}}{6Bz\ln\left(1-\widehat{\mu}(r^{*})\right)}+\overline{U} \\
&= \frac{3\left(\frac{q}{2}+\left(1-\varphi\right)t\right)^{2}+4\left(\frac{q}{2}\right)^{2}}{24Bz\ln\left(\frac{\frac{q}{2}+(1-\varphi)t}{2(1-\varphi)t}\right)}+\overline{U}.
\end{aligned} \tag{18}
$$

By Assumption 1, $\ln\left(\frac{\frac{q}{2}+(1-\varphi)t}{2(1-\varphi)t}\right)\leq 0$, implying that $CS^{a}(q,r^{*})$ is increasing with z. Hence, technological improvements in adware technology benefit consumers. Intuitively, an increase in z affects consumers in two ways. First, holding consumer attention $\widehat{\mu}(r)$ fixed, an increase in z means that fewer impressions are needed to send relevant information to adware users. Hence, consumers experience less loss of privacy. Second, an increase in z affects $\widehat{\mu}(r)$ itself both directly, as well as indirectly through its effect on r^{*}. The direct effect of z on $\widehat{\mu}(r)$ is positive because an increase in z makes display ads a more effective marketing tool. At the same time, an increase in z induces the software provider to raise r^{*} and this depresses the demand for display ads. It turns out that the direct and indirect effects cancel each other out, so as (15) shows, $\widehat{\mu}(r^{*})$ is independent of z. Consequently, only the first positive effect is at work, implying that adware users benefit from an increase in z. Since consumers can always choose not to adopt the adware, their surplus must increase.

It should also be noted that since $\widehat{\mu}(r^{*})$ is independent of z, the number of impressions that each adware user receives in equilibrium, $z\ln\left(1-\widehat{\mu}\left(r^{*}\right)\right)$, falls with z. This implies in turn that improvement in adware technology leads to less violation of privacy rather than more as some technological experts argue. This discussion is now summarized as follows:

Proposition 2: *Following an improvement in the technology of display ads that increases z (either due to an increase in the accuracy of identifying the consumer's preferences or in the probability of attracting his attention):*

(i) *the software provider raises the price per impression, distributes the software as adware for a larger set of parameters, and is weakly better off*

(ii) *more consumers adopt the adware and, conditional on adware being offered even before the increase, consumers become better off,*

(iii) *fewer impression are sent in equilibrium, so adware users face smaller loss of privacy.*

Bergemann and Bonatti (2011) and Johnson (2012) also examine the effect of improvements in targeting technology on advertising prices and on welfare. Bergemann and Bonatti (2011) consider a model with many advertising channels, each of which is targeting a different audience. The price of advertising is determined in their model by a market clearing condition. They show that an increase in targeting improves the social value of advertising, but since it also increases the concentration of firms advertising in each market, the equilibrium price of advertisements is first increasing, then decreasing, in the targeting capacity. Johnson (2012) considers a model with exogenous price of advertising, in which consumers can decide to avoid ads. He shows that an improvement in the ability of firms to identify consumers benefits firms even though consumers adjust their ad avoidance decisions. Consumers gain by receiving more relevant ads (a positive mix effect), but at the same time, they also receive more ads, which they do not appreciate (a negative volume effect). Consequently, consumer's utility is a U-shaped function of targeting accuracy.

One may also wonder how things change when the adware can be used to advertise products that consumers care more about (i.e., t, which is the utility loss from buying the "wrong" product, is larger) and are less likely to know about from external sources (i.e., φ is smaller). The following proposition follows immediately from equations (14) and (16):

Proposition 3: *An increase in the loss of utility from buying a "wrong" product, t, induces the software provider to lower the price per impression, r^*, but since it raises the profit from adware,*

$O^a(q, r^*)$, it induces the software provider to distribute the software as adware for a larger set of parameters. An increase in the probability that consumers know about products from external sources, φ, induces the software provider to lower the price per impression, r^*, and since it lowers the profit from adware, $O^a(q, r^*)$, it induces the software provider to distribute the software as adware for a smaller set of parameters.

Intuitively, an increase in t implies that consumers attach more value to the information on consumer products that they receive from display ads, so the demand for adware increases. As a result, the software provider prefers adware over commercial software for a larger set of parameters. At the same time, recall that the software provider chooses r by trading off the increase in the revenue per display ad against the negative effect of r on the demand for display ads. The latter negative effect is stronger when t is larger (r lowers the firms' demand for display ads which consumers value), so the software provider does not raise r by as much as he does when t is lower.

An increase in φ implies that consumers attach less value to the information on consumer products that they receive from display ads. This lowers the demand for adawre, forces the software provider to lower the price per impression, and makes adware less profitable.

5 Policy implication

I now proceed to evaluate the policy implications of Proposition 1. I begin by asking the following question: suppose the software provider has decided to distribute the software as an adware. Is the resulting price per impression and number of impressions that each adware user receives socially optimal? The following examples show that the answer is "it depends": in equilibrium, the price per impression, r^*, could be excessive or it could be too small.

To develop the examples, note that since the amounts that firms pay the adware provider for display ads wash out, and since all consumers end up buying one unit of some good so that their aggregate demand is $\sum_{i=1}^{n} Q_i(\widehat{\mu}(r), \ldots, \widehat{\mu}(r)) = 1$, the aggregate profit of firms and the adware provider is π. Hence, given r, social welfare under adware is given by

$$W^a(q, r) = CS^a(q, r) + \pi, \tag{19}$$

where $CS^a(q, r)$ is given by (17). Since $W^a(q, r)$ differs from $CS^a(q, r)$ only by a constant, the socially optimal price per impression, denoted r^{**}, also maximizes consumers' surplus.

Example 1 (r^* is excessive): Suppose that $\pi = 10$, $B = 10$, $z = -5$, $t = 8$, and $\varphi = \frac{1}{2}$. Since in this example, $B \geq -\frac{2(1-\varphi)\pi}{z} = 2$, Proposition 1 implies that the software provider will offer adware when $q \leq q_1 \equiv \frac{2t\left(1+\frac{(1-\varphi)\pi}{Bz}-\sqrt{1+\frac{2(1-\varphi)\pi}{Bz}}\right)}{-\frac{\pi}{Bz}} = 0.4458$, and will offer commercial software when $q > 0.4458$. By (14), $r^* = \frac{8+q}{16}$, which is below the choke price of r, which is $\overline{r} \equiv -\frac{(1-\varphi)\pi}{z} = 1$, for values of q for which the software provider offers adware.

As for the socially optimal price per impression, r^{**}, (10) implies that

$$\widehat{\beta}(\theta, q, r) = \min\left\{\frac{\theta q + 4(1-r)}{5\ln(r)}, 10\right\}.$$

Assuming that r is such that $\widehat{\beta}(\theta, q, r) = \frac{\theta q + 4(1-r)}{5\ln(r)} < 10$, it follows from (17) that,

$$CS^a(q, r) = -\frac{\left(\frac{q}{2}\right)^2 + 6(1-r)\left(\frac{q}{2} + 2(1-r)\right)}{75\ln(r)} + \overline{U}.$$

If $q = 0$, then $\widehat{\beta}(\theta, q, r) = \frac{4(1-r)}{5\ln(r)} < \frac{4}{5}$, so by the above equation,

$$CS^a(0, r) = -\frac{4(1-r)^2}{25\ln(r)} + \overline{U}.$$

This expression is maximized at $r = 0.285$. Since $q = 0$, $r^* = 0.5$, so $r^* > r^{**}$, implying that in equilibrium, there are too few display ads relative to the socially optimal level.

Example 2 (r^* is excessive): Consider the same parameter values as in Example 1, but now let $q = 0.1$. Now, $\widehat{\beta}(\theta, q, r) = \frac{0.1\theta + 4(1-r)}{5\ln(r)} < 10$ only when $r < 0.997$. Assuming this is so,

$$CS^a(0.1, r) = -\frac{4\left(1.025 - 2.025r + r^2\right)}{25\ln(r)},$$

which is maximized at $r = 0.293$. At this value, $CS^a(0.1, 0.293) = 0.0675 + \overline{U}$. Alternatively, if $r = 1$, then firms will choose not to send any display ads, so $U^a(\theta, \beta, 1) = \theta q + \overline{U}$. Consequently, equation (17) implies that $CS^a(0.1, 1) = \frac{0.1}{2} + \overline{U} < CS^a(0.1, 0.293)$. Therefore, $r^{**} = 0.293$. Since $r^{**} < r^* = \frac{8+0.1}{16} = 0.506$, there are once again too few display ads in equilibrium.

Example 3 (r^* is too small): Consider again the same parameter values as in Example 1, but now let $q = 0.2$, so $\widehat{\beta}(\theta, q, r) = \frac{\theta q + 4(1-r)}{5\ln(r)} < 10$ only when $r < 0.9956$. At this range,

$$CS^a(0.2, r) = -\frac{4\left(1.0508 - 2.05r + r^2\right)}{25\ln(r)}.$$

This expression is maximized at $r = 0.302$ and attains a value of $CS^a(0.2, 0.302) = 0.0699 + \overline{U}$. But at $r = 1$, $CS^a(0.2, 1) = 0.1 + \overline{U} > 0.0699 + \overline{U}$, so $r^{**} = 1$. Since $r^* = \frac{8+0.2}{16} = 0.5125$, the equilibrium price per impression is now too low relative to the social optimum, and as a result, now there are too many display ads in equilibrium.

The three examples show that under adware, the equilibrium price per impression, r^*, could either be excessive or too small, depending on the software's quality. The reason is that when the software provider sets r, he only takes into account the effect of r on the mass of consumers who adopt the adware (which in turn increases the profit from selling display ads). The software provider, however, fails to take into account the effect of r on the utility of inframarginal adware users. Since an increase in r induces firms to buy fewer display ads, such an increase implies that adware users will receive less information on consumer goods (a negative externality), but will also experience less privacy loss (a positive externality). If the negative externality dominates, r^* will be excessive. If the positive externality dominates, r^* will be too small. The reason why the result depends on the software's quality q is that when q is higher, even consumers with high privacy concerns are willing to adopt the adware, so among the population of adware users there is a greater concern for privacy. Hence, from social perspective, r^* is more likely to be too small, with too many ads being display in equilibrium.

Having compared r^* with the social optimum under the assumption that the software provider offers the software as adware, I next compare the equilibrium choice between adware and commercial software with the socially optimal choice. Under adware, social welfare is given by equation (19). Under commercial software, only consumers with $\theta \geq \frac{p}{q}$ buy the software and their utility, $U^s(\theta)$, is given by equation (2). Consumers with $\theta < \frac{p}{q}$ do not buy the software and their utility is $\overline{U}$. Hence, social welfare under commercial software is given by

$$W^s(q,p) = \underbrace{\int_0^{\frac{p}{q}} \overline{U} d\theta + \int_{\frac{p}{q}}^1 U^s(\theta) d\theta}_{CS^s(q,p)} + \underbrace{p\left(1 - \frac{p}{q}\right)}_{O^s(q,p)} + \pi.$$

This expression is maximized at $p = 0$, and $W^s(q, 0) = \frac{q}{2} + \overline{U} + \pi$.

Proposition 4: *From social perspective, adware dominates commercial software.*

Proof: To prove the proposition, note that under commercial software social welfare is $W^s(q, p^*)$, where $p^* = \frac{q}{2}$, while under adware it is $W^a(q, r^*)$. Now notice that at $r = \overline{r}$, firms will choose not to send any display ads, so $U^a(\theta, \beta, 1) = \theta q + \overline{U}$. By equation (17), $CS^a(q, \overline{r}) = \frac{q}{2} + \overline{U}$, so social welfare under adware is given by

$$W^a(q, \overline{r}) = \frac{q}{2} + \overline{U} + \pi,$$

which is equal to $W^s(q,0)$. Hence,

$$W^a(q,r^*) > W^a(q,\overline{r}) = W^s(q,0) > W^s(q,p^*),$$

which proves the proposition. ■

The intuition for Proposition 4 is simple: by setting $r = \overline{r}$ (so that firms choose not to pay for display ads), it is possible to replicate with adware the outcome that obtains under commercial software when $p = 0$: all consumers end up using the software, no information is sent to consumers, and there is no privacy loss. If the social optimum involves $r < \overline{r}$, welfare under adware is even higher, so clearly adware dominates commercial software.

The rapid growth of "spyware" (or even "malware"), which is often installed without the end-user's knowledge and tracks and collects personal information without consent (see e.g., Urbach and Kibel, 2004), has prompted some U.S. legislators to consider legislation that would either ban or substantially restrict the use of ad-supported software.[15] Utah has already passed such legislation that, among other things, prohibits any party from installing software that monitors computer usage, uses context-based triggering mechanisms, and also prohibits the use of context-based pop-ups that obscure the underlying content.[16] Using the model, I now examine the effect of bans on adware.

Proposition 5: *A ban on adware hurts the software provider whenever* $q \leq q_1$ *and also hurts*

[15]For example, the 112th Congress considered the creation of Do Not Track mechanisms that allow consumers to control the collection and use of their online browsing data (Do-Not-Track Online Act of 2011, S. 913 in the U.S. Senate and the Do Not Track Me Online Act, H.R. 654, at the House of Representatives). Apart from violations of privacy, spyware also causes various technical problems. In a workshop on Spyware held at the FTC in April 2004, Bryson Gordon from McAfee Security, argued that spyware related problems are right now "the single largest issue that we are seeing," and Maureen Cushman from Dell argued that spyware become "a huge technical support issue for us," and that "Spyware related technical support calls have been as high as 12 percent of all technical support requests to the Dell technical support queue." See http://www.ftc.gov/bcp/workshops/spyware/transcript.pdf

[16]Similar legislation was introduced in California, the U.S. Senate (Spy Block Act, S.2145), the House of Representatives (Safeguard Against Privacy Invasions Act H.R. 2929), and in several other states.

consumers when q is sufficiently small.

Proof: When $q \leq q_1$, the software provider prefers to offer adware, so by revealed preferences, a ban on adware would hurt him (when $q > q_1$, the software provider offers commercial software anyway, so a ban on adware is irrelevant). As for consumers, recall that in the commercial software case $p^* = \frac{1}{2}$. Hence, in equilibrium, consumer surplus under commercial software is

$$\begin{aligned} CS^s(q, p^*) &= \int_0^{\frac{p^*}{q}} \overline{U} d\theta + \int_{\frac{p^*}{q}}^1 U^s(\theta)\, d\theta \\ &= \int_{\frac{p^*}{q}}^1 (\theta q - p^*)\, d\theta + \overline{U} = \frac{q}{8} + \overline{U}. \end{aligned}$$

Consumer surplus in the case of adware is given by equation (18). Now, a ban on adware surely hurts consumers if $q \leq q_1$ (an adware if offered in equilibrium) and if

$$CS^a(q, r^*) - CS^s(q, p^*) = \frac{3\left(\frac{q}{2} + (1-\varphi)\, t\right)^2 + 4\left(\frac{q}{2}\right)^2}{24Bz \ln\left(\frac{\frac{q}{2} + (1-\varphi)t}{2(1-\varphi)t}\right)} - \frac{q}{8} > 0.$$

Clearly the inequality holds when $q = 0$, and by continuity, it also holds for q sufficiently small. The example that appears below, shows that this is not always true: there are cases such that $q \leq q_1$ and yet $CS^a(q, r^*) \leq CS^s(q, p^*)$, meaning that a ban on adware may help consumes provided that q is sufficiently large (but still below q_1). ■

That a ban on adware hurts the software provider is obvious. Less obvious is why such a ban might hurt consumers. The reason for this is as follows: when the software provider offers adware, consumers with low privacy concerns get a positive surplus from the adware, while those with high privacy concerns do not adopt it. Hence, a ban on adware hurts consumers with low privacy concerns, but helps consumers with high privacy concerns as they can now buy a commercial software if their marginal benefit from quality is sufficiently high.[17] Since the surplus from commercial software is decreasing with q, it is not surprising that when q is low, a ban on adware hurts consumers. When q is high, the gain to consumers who will not adopt an adware due to privacy concerns may exceed the loss to consumers with low privacy concerns, who are now forced to buy the software instead of getting it for free. The following example demonstrates this point:

Example 4 (a ban on adware hurts consumers when q is small, but may benefit them when q is high): Consider the same parameter values as in Examples 1-3 above. For these parameter values, $CS^a(q, r^*) - CS^s(q, p^*) \geq 0$ for all $q \leq 0.599$ and $CS^a(q, r^*) - CS^s(q, p^*) < 0$ for $q > 0.599$. Since Example 1 shows that $q_1 = 0.4458$, it follows that whenever adware is offered, i.e., whenever $q_1 \leq 0.4458$, we have $CS^a(q, r^*) - CS^s(q, p^*) \geq 0$, so a ban on adware always hurts consumers.

Given the parameter values in this example, q_1 is increasing with π, and $q_1 > 0.599$ whenever $\pi > 12.97$. Since $CS^a(q, r^*) - CS^s(q, p^*)$ is independent of π, it follows that whenever $\pi > 12.97$, a ban on adware would hurt consumers for all $q < 0.599$ (the software provider wishes to offer adware and consumers prefer adware), but would benefit consumers for all $0.599 < q \leq q_1$ (the software provider wishes to offer adware but consumers prefer commercial software). Hence, the example shows that if π is sufficiently large, there exists a range of values such that a ban on adware is beneficial to consumers. Otherwise a ban on adware hurts consumers.

Finally, the 112th U.S. Congress has recently considered the creation of "Do Not Track" mechanisms that will allow consumers to control the collection and use of their online browsing data and in particular, opt out of tracking by advertisers (Do-Not-Track Online Act of 2011, S. 913 in the U.S. Senate and the Do Not Track Me Online Act, H.R. 654, at the House of

[17] A ban on adware may have another harm since it lowers the software provider's profit and hence may reduce the incentive to invest in quality. Hence, a ban on adware may result in software of lower quality.

Representatives). Using my model it is possible to consider the effect of this proposed legislation on consumers: when a Do-Not-Track (DNT) option is in place, adware users receive targeted ads only if the benefit from more information, $\widehat{\mu}(r)\,(1-\varphi)\,t$, exceeds the associated privacy loss, $-\beta z \ln(1-\widehat{\mu}(r))$, that is, whenever

$$\beta \leq \widehat{\beta}\,(r) \equiv \frac{\widehat{\mu}(r)\,(1-\varphi)\,t}{-z\ln(1-\widehat{\mu}(r))}.$$

When $\beta > \widehat{\beta}\,(r)$, adware users opt out of targeted ads. Since β is uniformly distributed in the population on the $[0, B]$ interval, the resulting share of adware users who receive ads is $\widehat{\alpha}(q,r) = \frac{\widehat{\beta}(r)}{B}$. Using this expression and repeating the same steps as in Section 3.3, the unique price per impression, r^*, which maximizes $O^a(q,r)$ under a DNT option is given by

$$r^* = -\frac{(1-\varphi)\,\pi}{2z},$$

and the associated profit from adware is

$$O^a(q,r^*) = -\frac{(1-\varphi)^2\,\pi}{4Bz}.$$

This profit is below the profit without a DNT option. Intuitively, when a DNT option is in place, some adware users who would otherwise receive ads, choose to opt out of ads and hence the income from selling ads to advertisers falls. Since the profit from commercial software is still $\frac{q}{4}$, the software provider will offer adware whenever $q \leq -\frac{(1-\varphi)^2\pi}{Bz}$, and will provide commercial software if $q > -\frac{(1-\varphi)^2\pi}{Bz}$, provided this is feasible by Assumption 1.[18] This result is similar to that in Proposition 1, though the fact that adware is now less profitable means that the software

[18] Since $q \leq 2(1-\varphi)\,t$ by Assumption 1, the software producer will offer adware for all values of q if $B \leq -\frac{(1-\varphi)\pi}{2zt}$. If $B > -\frac{(1-\varphi)\pi}{2zt}$, the software provider wiill provide adware if $q \leq -\frac{(1-\varphi)^2\pi}{zB}$ and will provide commercial sofware if $\frac{(1-\varphi)^2\pi}{zB} < q \leq 2(1-\varphi)\,t$.

provider will offer adware for a smaller set of parameters when a DNT option is in place.

To examine the implications of a mandatory DNT option for consumers, note that when a DNT option is in place, all consumers adopt an adware since they can always opt out of targeted ads if their privacy concerns are high. The utility of consumers then is $\theta q+\overline{U}$ if they opt out of ads and $\theta q+\overline{U}+[\mu_i(1-\varphi)t-\beta z\ln(1-\mu_i)]$ if the do not opt out, where the square bracketed term is positive (otherwise the consumer opts out). Under commercial software in turn, the utility of consumers is $\theta q-\frac{q}{2}+\overline{U}$, if the consumer adopts the software, and $\overline{U}$ otherwise. Clearly then, consumers are better off under adware, which means in turn that a DNT option hurts consumers if it induces the software provider to switch from adware to commercial software.

However, if the software provider offers adware even when a DNT option is place, then consumer surplus is given by

$$CS^{DNT}(q,r)=\int_0^1\left[\int_0^{\widehat{\beta}(r)}\frac{U^a(\theta,\beta,r)}{B}d\beta+\int_{\widehat{\beta}(r)}^{B}\frac{\theta q+\overline{U}}{B}d\beta\right]d\theta.$$

Since $\widehat{\beta}(r)<\widehat{\beta}(\theta,q,r)$ and since $\theta q+\overline{U}>U^a(\theta,\beta,r)$ for $\beta>\widehat{\beta}(r)$, it follows that

$$\begin{aligned}CS^{DNT}(q,r) &= \int_0^1\left[\int_0^{\widehat{\beta}(r)}\frac{U^a(\theta,\beta,r)}{B}d\beta+\int_{\widehat{\beta}(r)}^{\widehat{\beta}(\theta,q,r)}\frac{\theta q+\overline{U}}{B}d\beta+\int_{\widehat{\beta}(r)}^{B}\frac{\theta q+\overline{U}}{B}d\beta\right]d\theta\\ &> \int_0^1\left[\int_0^{\widehat{\beta}(r)}\frac{U^a(\theta,\beta,r)}{B}d\beta+\int_{\widehat{\beta}(r)}^{\widehat{\beta}(\theta,q,r)}\frac{U^a(\theta,\beta,r)}{B}d\beta+\int_{\widehat{\beta}(r)}^{B}\frac{\theta q+\overline{U}}{B}d\beta\right]d\theta\\ &= CS^a(q,r).\end{aligned}$$

That is, consumers are better-off if the software provider continues to offer adware even when a DNT option is in place.

I now summarize the discussion as follows:

Proposition 6: *A mandatory DNT option hurts the software provider and also hurts consumers* *if it induces the software provider to switch from adware to commercial software. However if the software provider continues to offer adware even when a DNT option is in place, then consumers are better off than they are without a DNT option.*

6 Conclusion

This paper presents a framework for studying the choice of software providers between selling their software commercially and distributing it for free as adware and making money by selling display ads. The model takes explicit account of the strategic interaction between the software provider, advertisers, and consumers and highlights the trade-off that adware users face between improved information on consumer products and the violation of their privacy. Given this trade-off, consumers choose to adopt adware only if their privacy concerns are small.

The model reveals that the software provider will prefer to sell the software commercially only when its perceived quality is sufficiently high. Otherwise, the profit from selling the software commercially is limited. At the same time, consumers who are not too sensitive to privacy loss will adopt an adware even when its perceived quality is small, so the software provider can still make money by distributing the software as adware and selling display ads to advertisers. The software provider is also more likely to distribute the software as adware when the technology to identify the preferences of adware users improves, when consumers benefit more from information on consumer products, and when there is a smaller probability receiving this information from external sources. The model also reveals that improvements in the technology of display ads will lead to less violation of privacy and will benefit consumers, that depending on the software's quality, there are either too many or too few display ads in equilibrium, and that from a social perspective, adware dominates commercial software. In addition, the model shows that restrictions on adware which are intended to protect the privacy of software users (e.g., mandatory "Do Not Track" mechanisms that allow consumers to opt out of tracking by advertisers or even a complete ban on adware) may hurt consumers by forcing them to pay for the software and by denying them potentially useful targeted information about consumer products.

7 Appendix

In this appendix I consider the consequences of relaxing Assumption 1. Absent Assumption 1, it is no longer immediately obvious that $\widehat{\beta}(\theta, q, r^*) < B$ for all θ. There are now two possibilities: (i) $\widehat{\beta}(\theta, q, r^*) > B$ for all θ, and (ii) $\widehat{\beta}(\theta, q, r^*) < B$ for small values of θ and $\widehat{\beta}(\theta, q, r^*) > B$ for large values of θ close to 1. It turns out that case (ii) is very complex, due to the fact that $\widehat{\alpha}(q, r)$ is now given by $\frac{(B-\widehat{\beta}(0,q,r))\widehat{\theta}(q,r)}{2}$, where $\widehat{\theta}(q, r)$ is the value of θ at which $\widehat{\beta}(\theta, q, r) = B$. Hence, I will only analyze here case (i).

When $\widehat{\beta}(\theta, q, r^*) > B$ for all θ, it is obvious from Figure 2 that $\widehat{\alpha}(q, r) = 1$: all consumers adopt an adware. In this case, the aggregate demand of firms for display ads is $Q(q, r) = z \ln(1 - \widehat{\mu}(r))$, and, using (8), the software provider's profit from adware can be written as

$$O^a(q, r) = r \times z \ln(1 - \widehat{\mu}(r)) = r \times z \ln\left(\frac{-rz}{(1-\varphi)\pi}\right).$$

Since $\frac{\partial^2 O^a(q,r)}{\partial r^2} = \frac{z}{r} < 0$, $O^a(q, r)$ attains a unique maximum at

$$r^* = -\frac{(1-\varphi)\pi}{ez}.$$

This value is below the choke price of r which is $\overline{r} \equiv -\frac{(1-\varphi)\pi}{z}$. Substituting for r^* into (8), consumer attention in equilibrium is

$$\widehat{\mu}(r^*) = \frac{e-1}{e},$$

which is below 1. Substituting in (10), yields

$$\widehat{\beta}(\theta, q, r^*) = \frac{\theta q - \frac{e-1}{e}(1-\varphi) t}{z}.$$

This expression is indeed above B for all θ provided that

$$-\frac{(e-1)(1-\varphi) t}{ez} > B.$$

In what follows, I will maintain this assumption.

When this assumption hold, the profit from adware is

$$O^a(q, r^*) = r \times z \ln\left(\frac{-rz}{(1-\varphi)\pi}\right) = -\frac{(1-\varphi)\pi}{e}.$$

Since the profit from commercial software is $\frac{q}{4}$, it follows that the software provider will offer adware when q is small and commercial adware when q is large, exactly as in Proposition 1. Moreover, as in Proposition 2, an increase in z raises r^*, has no effect on $\widehat{\mu}(r^*)$, and raises the number of impression sent in equilibrium, $z \ln(1 - \widehat{\mu}(r^*))$. However, unlike in Proposition 2, an increase in z does not affect the software provider's profit.

As for consumers, noting that all consumers adopt adware when it is offered, consumer surplus under adware is given by

$$\begin{aligned} CS^a(q, r) &= \int_0^1 \left[\int_0^B \frac{U^a(\theta, \beta, r)}{B} d\beta\right] d\theta \\ &= \frac{q}{2} + (1-\varphi) t + \frac{rtz}{\pi} - \frac{Bz \ln\left(-\frac{rz}{(1-\varphi)\pi}\right)}{2} + \overline{U}. \end{aligned}$$

Evaluated at r^*, the value of consumer surplus is

$$CS^a(q, r^*) = \frac{q}{2} + \frac{(1-\varphi)\, t\,(e-1)}{e} + \frac{Bz}{2} + \overline{U}.$$

This expression is clearly increasing with z, so as in Proposition 2, an increase in z benefits consumers when adware is offered.

It is easy to check that $CS^a(q, r)$ is strictly concave. The unique value of r that maximizes it is given by

$$r^{**} = \frac{B\pi}{2t}.$$

Since social welfare is equal to consumer surplus plus π (the aggregate profits of firms and the adware provider), r^{**} is also the socially optimal price per impression. Notice that since I assume that $B < -\frac{(e-1)(1-\varphi)t}{ez}$,

$$r^{**} < -\frac{(e-1)\,(1-\varphi)\,\pi}{2ez} < -\frac{(1-\varphi)\,\pi}{ez} \equiv r^*.$$

Hence, from social perspective, the price per impression is excessively high, meaning that too few impressions are being sent in equilibrium.

8 References

Acquisti Alessandro and Varian Hal (2005), "Conditioning Prices on Purchase History," *Marketing Science*, **24(3)**, 1-15.

Anderson Simon (2012), "Advertising on the Internet," in Peitz Martin and Waldfogel Joel Eds., *The Oxford Handbook of the Digital Economy,* Oxford University Press.

Anderson Simon and Gabszewicz Jean (2006), "The Media and Advertising: A Tale of Two-

Sided Markets," in Ginsburgh V. and D. Throsby (Eds.), *Handbook of the Economics of Art and Culture*, Elsevier Science, Amsterdam.

Anderson Simon and Gans Joshua (2011), "Platform Siphoning: Ad-Avoidance and Media Content," *American Economic Journal: Microeconomics*, **3(4)**, 1-34.

Bergemann Dirk and Bonatti Alessandro (2011), "Targeting in Advertising Markets: Implications for Offline versus Online Media," *Rand Journal of Economics,* **42(3)**, 417–443.

Burke Jeremy, Taylor Curtis, and Wagman Liad (2012), "Information Acquisition in Competitive Markets: An Application to the US Mortgage Market," forthcoming in *American Economic Journal: Microeconomics*.

Calzolari Giacomo and Pavan Alessandro (2006), "On the Optimality of Privacy in Sequential Contracting," *Journal of Economic Theory*, **130(1)**, 168-204.

Conitzer Vincent, Taylor Curtis, and Wagman Liad (2012), "Hide and seek: Costly Consumer Privacy in a Market with Repeat Purchases," *Marketing Science*, **31(2)**, 277-292.

de Cornière Alexandre and De Nijs Romain (2012), "Online Advertising and Privacy," Mimeo.

Department of Commerce Internet Policy Task Force (2010), "Commercial Data Privacy and Innovation in the Internet Economy: A Dynamic Policy Framework," available at http://www.ntia.doc.gov/files/ntia/publications/iptf_privacy_greenpaper_12162010.pdf

FTC (2012), "Protecting Consumer Privacy in an Era of Rapid Change: Recommendations For Businesses and Policymakers," available at www.ftc.gov/os/2012/03/120326privacyreport.pdf

Hann Il-Horn, Hui Kai-Lung , Lee Tom S., and Png Ivan (2007), "Analyzing Online Information Privacy Concerns: An Information Processing Theory Approach," *Journal of Management Information Systems*, **24(2)**, 13-42.

Hann Il-Horn , Hui Kai-Lung , Lee Tom S., and Png Ivan (2008), "Consumer Privacy and Marketing Avoidance: A Static Model," *Management Science*, **54(6)**, 1094–1103.

Hansen Claus Thustrup and Kyhl Soren (2001), "Pay-per-view Broadcasting of Outstanding Events: Consequences of a Ban," *International Journal of Industrial Organization*, **19**, 589-609.

Hui Kai-Lung and Png Ivan (2006), "Economics of Privacy," in Terrence Hendershott, Ed., *Handbooks in Information Systems*, Vol. 1, Amsterdam: Elsevier.

Johnson Justin (2012), "Targeted Advertising and Advertising Avoidance," *Rand Journal of Economics*, forthcoming

Mayer, Jonathan R. and John C. Mitchell (2012), "Third-Party Web Tracking: Policy and Technology," http://cyberlaw.stanford.edu/publications/third-party-web-tracking-policy-and-technology

McDonald Aleecia M. and Lorrie Faith Cranor (2012), "Americans' Attitudes About Internet Behavioral Advertising Practices," WPES'10, October 4, 2010, Chicago, Illinois, USA, http://www.aleecia.com/authors-drafts/wpes-behav-AV.pdf

Peitz Martin and Valletti Tommaso (2008), "Content and Advertising in The Media: Pay-TV Versus Free-to-Air," *International Journal of Industrial Organization*, **26**, 949-956.

Posner Richard. (1981), "The Economics of Privacy," *American Economic Review, Papers and Proceedings*, **71**, 405-409.

Prasad Ashutosh, Mahajan Vijay, and Bronnenberg Bart (2003), "Advertising Versus Pay-Per-View in Electronic Media," *International Journal of Research in Marketing*, **20**, 13–30.

Smith H. Jeff, Milberg Sandra J. and Burke Sandra J. (1996) "Information Privacy: Measuring Individuals' Concerns About Organizational Practices," *MIS Quarterly*, **20**, 167-196.

Sonnac Nathalie (2000), "Readers' Attitudes Toward Press Advertising: Are They Ad-Lovers or Ad-Averse?," *Journal of Media Economics*, **13(4)**, 249-259.

Stern James (2004), "Spyware, Adware, Malware, Thief," Association of Shareware Professional, Inc. http://www.ftc.gov/os/comments/spyware/040318assocofsharewareproff.pdf

Taylor Curtis (2004), "Consumer Privacy and the Market for Customer Information", *Rand Journal of Economics*, **35**, 631–51.

Varian Hal (1996), "Economic Aspects of Personal Privacy," In U.S. Department. of Commerce, Privacy and Self-Regulation in the Information Age.

Urbach Ronald and Kibel Gary (2004), "Adware/Spyware: An Update Regarding Pending Litigation and Legislation," *Intellectual Proprty and Technology Law Journal*, **16(7)**, 12-16.

Wathieu Luc (2002), "Privacy, Exposure, and Price Discrimination," HBS Marketing Research Paper No. 02-03

White House (2012), "Consumer Data Privacy in a Networked World: A Framework for Protecting Privacy and Promoting Innovation in The Global Digital Economy," available at http://www.whitehouse.gov/sites/default/files/privacy-final.pdf