

# Who Benefits from Targeted Advertising?

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## Abstract

We investigate and compare the welfare and allocative effects of alternative consumer data-handling regimes in online targeted advertising. We develop a three-players model that includes firms, consumers, and an intermediary - the ad exchange - and analyze it under various scenarios that differ in the type and amount of consumer data available to the intermediary and to firms. Under general conditions, we find that the intermediary is the player that benefits the most from greater control over consumer data. We also find that, in general, the intermediary's incentives regarding the type of consumer information to be used for targeting are misaligned with the incentives of firms and consumers. Furthermore, we find that consumer surplus from targeting is higher when less personal information is made available to the intermediary during the

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targeting process. Our findings contribute to the ongoing debate over the economic and social implications of the evolution of online tracking and advertising systems.

## 1 Introduction

In both research and policy circles, a spirited debate has emerged over developments in Internet technologies that allow the collection and analysis of large amounts of consumer information. The aggregation of diverse databases of individuals data, and the application of increasingly sophisticated inferential techniques to those databases, can make services and transactions more efficient, and may help addressing complex societal problems (McAfee and Brynjolfsson, 2012). This so-called “data economy” (and the related notion of “big data”) may therefore become a source of innovation, growth, and welfare increases for firms and consumers alike. On the other hand, more data available to firms and decision makers may not always translate to more social progress, economic efficiency, or equality (Crawford et al., 2014). Economic imbalances between consumers and organizations may even increase due to the exacerbation of information asymmetries between data “subjects” and data “holders” (The White House Report, 2015). We contribute to this debate by investigating the extent to which the data economy can *increase* overall economic welfare, and the extent to which it can merely affect the *allocation* of welfare between different stakeholders. We focus on the case of online targeted advertising — one of the most common applications of the market for personal data (Tucker, 2012).

Much has been recently written, in both the academic and the trade literatures, regarding the potential benefits of increasingly widespread and precise collection and usage of consumer data for the targeting of online ads. Data analytics offer marketers and advertising firms the ability to create detailed profiles of consumers, predict their preferences, and serve them the right products or services. Industry representatives have emphasized the benefits that both advertisers and consumers can derive from these technologies: “targeting is not only

good for consumers [...] it's a rare win for everyone. [...] It ensures that ad placements display content that you might be interested in rather than ads that are irrelevant and uninteresting. [...] Advertisers [...] achieve higher brand awareness and a greater chance of selling the product. Publishers also win as being able to offer behavioral targeting increases the value of the ad placements and therefore their revenues" (Unanimis Consulting Limited, 2011). In an interview released by AdExchanger (2011)<sup>2</sup>, Chad Little, CEO of Fetchback, company part of Ebay Enterprise, said: "[...] behavioral tracking shouldnt be feared, but instead, embraced. Tracking can simplify and improve a consumer's online experience. By utilizing gathered behavioral data in a strategic manner, online retailers can put the power of the online tracking to work for their consumers." In turn, consumers may not like tracking, but seem to appreciate the importance of the ad-supported Internet. A poll commissioned by the Digital Advertising Alliance (DAA) in 2013 (Zogby Analytistics, 2013) shows that nearly 70 percent of U.S. respondents like at least some ads tailored directly to their interests, compared to only 16 percent who prefer to only see generic ads for products and services. In short, one of the claim put forward by industry representatives — and increasingly accepted by U.S. consumers as well — is that online targeted ads represent an economic win-win: they reduce search costs for consumers and advertising costs for firms. In this manuscript, we use economic modeling to test those claims. We investigate how the sharing of different types of consumer data can differentially affect the welfare of firms (advertisers), consumers (online users), and an intermediary (the ad exchange) that facilitates the matching between firms and consumers.

Our modeling approach advances current theoretical work in this area: unlike previous models of online advertising, our model 1) considers, simultaneously, three players (firms, consumers, and ad exchange); and 2) focuses on how the surplus produced by targeting is allocated to the different parties. The model focuses on Real-Time bidding, a technology recently introduced that allows the allocation of online display advertisement spaces at real-

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<sup>2</sup>If A Consumer Asked You, "Why Is Tracking Good?", What Would You Say? October 2011, <http://adexchanger.com/online-advertising/why-is-tracking-good/#valueclick>

time through online platforms called Ad Exchanges. Specifically, we focus on the interaction among three players: firms (the advertisers, who compete with each other for consumers' attention), consumers (the online users, who visit websites, are shown targeted ads, and purchase products online), and a monopoly intermediary (the ad exchange). We assume that consumers are characterized by two dimensions (or, analogously, two pieces of information): horizontal information, that captures consumers' preferences for specific products; and vertical information, that captures differences in consumers' purchase power. Advertisers are firms that produce products and want to advertise them to consumers. Firms buy advertisements by participating in real-time auctions run by the intermediary ad exchange. When a consumer arrives to a website, a signal containing information about that user is sent to the ad exchange; the ad exchange, in turns, sends the signal to the advertiser firms along with some or all pieces of consumers' information. Advertisers, on the basis of the information that they can receive about the user, decide how much to bid. The winner of the auction shows the advertisement to the consumer and pays the second-highest bid. We consider four possible scenarios that differ in the amount and/or type of information that is available to the Ad Exchange and (through the Ad Exchange) to the advertising firms during the bidding process. First, we consider the benchmark case in which no additional information about consumers is available. Second, we consider the case in which only the horizontal information, that is which product a consumer prefers, is available. Third, we consider the case in which only the vertical information (whether the consumer is high valuation or low valuation) is available. Finally, we consider the case in which both the horizontal and the vertical information about consumers can be observed. For each of the four scenarios we consider, we use Nash equilibrium strategies to first derive each advertisers' bidding strategy and pricing strategy; we then determine the winner of the auction and the final outcome of the game in terms of advertisers' profit, Ad Exchange's revenues and consumers' welfare. Our results can be summarized as follows. First, under general conditions, we find that the intermediary is the player that benefits the most from targeted advertising and greater control over

consumer data. Second, we find that consumers welfare is higher when only specific type of information are exchanged (horizontal information) and, generally, when less information is exchanged. Third, there exist situations in which the incentives of the Intermediary are misaligned with respect to consumers' interest; stated differently, the intermediary that acts as a profit-maximizing agent may decide to adopt strategies that lead to higher revenue for itself, while making consumers and/or advertisers worse off. Our findings have policy implications, because they highlight how the commerce in consumer data can differentially affect the welfare of data holders and data subjects. In particular, they contribute to the ongoing industry and regulatory debate over the economic and social implications of the adoption of increasingly sophisticated tracking and advertising technologies.

## 2 Related works

This paper is related to different strands of economic literature. First, it can be related to the early work on economics of advertising that look at the impact of advertising on product information and pricing. Butters (1977) proposes a model of informational advertisement, where the role of advertising is to provide information about the existence of the products. Grossman and Shapiro (1984) and Soberman (2004) extend the model to horizontally differentiated markets and analyze the impact of informative advertising on competition and on the availability of different varieties of the same product. Iyer et al. (2005) examines advertising strategy when companies can target advertising to different segments of consumers. What they argue is that the use of targeted advertising increases the market price and leads to higher profits in comparison to mass or random advertising. Similarly, Esteban and Hernandez (2007) argue that targeting may be seen as an implicit collusion device between firms producing differentiated goods since each firm will advertise only towards its consumers. This implies that, in equilibrium, the entire market will be divided into mutually exclusive captive segments where each firm acts as a pure local monopolist. Recently,

authors in the information system field have offered a more complete analysis of the targeted advertising ecosystem by taking into consideration the fact that the targeting process is an intermediated process (Zhang and Catona, 2012) or by considering the important role played by publishers in the targeting process (Chen et al., 2014). Zhang and Catona (2012) analyze how the existence of an independent, profit-maximizer intermediary that sells advertising space and implements the target technology impacts market's outcomes and targeting accuracy. They suggest that, when product market competition is low, the intermediary offers accurate targeting; when product market competition is high, the intermediary offers inaccurate target technology that decreases the ability of the advertisers to create informational differentiation. This leads to an increase in the price competition and gives firms the incentive to bid for the competitors' content topics.

Differently from those works, the focus of our model is on the welfare and allocative aspects of online targeted advertising. The competition among companies is mostly modeled as competition for advertisements' space and consumers allocation. Furthermore, we introduce the possibility that consumers differ along two dimensions: an horizontal one, that captures consumers' products preference; and a vertical one, that captures differences in consumers reservation prices, as some individuals may have higher purchase power than others. Typically, models focus on only one dimension at the time. In this paper, we bring those dimensions together to provide a more complete description of consumers' behavior.

Secondly, our work is related to the IS literature on online auctions and search-advertising (Bapna et al., 2003; Pinker et al., 2003; Katona and Sarvary, 2010; Liu et al., 2010; Chen and He, 2011). Those works study the features that characterizes online auctions and, some of those, have specifically focused on the equilibrium properties of the generalized second-price auction, commonly used to place search-advertisements. In this paper, we rely on existing results from auction theory (Vicrey, 1961; Ausubel and Milgrom, 2006) and focus on the Real-Time bidding technology that, introduced in 2007, has been growing really fast and it is expected to take over the market for the allocation of display advertising.

Finally, our work can be related to the literature on information congestion and consumers' privacy. Anderson-De Palma (2009) and Van Zandt (2004) develop models in which firms may send too many messages to consumers, which lowers social welfare because higher-value messages are crowded out by lower value messages. Hann et al. (2008) propose a model in which consumers try to avoid advertising to protect their privacy in two ways: through concealment or deflection. The authors show that while concealment efforts by low-type consumers may reduce total welfare, as more solicitations are shifted toward high-type consumers, deflection efforts reduce the direct privacy harm. Finally, Casadesus - Masanell and Hervás - Drane (2015) develop a model where firms compete for consumer information and derive revenues both from selling products as well as from disclosing consumer information. What they find is that, overall, competition in the market decreases the amount of consumer information that is disclosed; nevertheless, higher intensity of competition between firms can increase the stock of information disclosed and reduce consumer privacy.

Similarly to these works, we focus on the effects of targeted advertising on consumers' welfare. Differently, in the first version of the model, we assume that consumers do not use any blocking mechanism but they are always exposed to one advertisement.

## **3 The Model**

### **3.1 Real Time Bidding**

Real-time bidding (RTB) is a novel paradigm of serving ads with the aim of bringing more liquidity to the online advertising market. Specifically, RTB allows advertisers to buy online display advertisement spaces at real-time through Ad Exchanges. The mechanism works as follows: when a user visits a publisher's web site belonging to an Ad Exchange's network, a request is sent to the Ad Exchange which subsequently broadcasts it along with user data (user's IP address, geo-location, user's cookies, information about browsing behaviors and others) to ad buyers and holds an auction. Bidders analyze the impression and submit

their bid responses. As most of the Ad Exchange encourage truthful bidding through the use of second-price auctions, the best strategy for buyers is to bid in accordance with their true valuation for the consumer. The winning party is allowed to serve the advertisement to the user and pays the second-highest bid. The model developed in this paper focuses on three players: i) Advertisers. We assume that companies that wish to target specific consumers buy advertisements by participating to online auctions. For the rest of the paper we will use advertisers, companies and firms interchangeably. ii) Ad Exchange. We take into consideration the existence of one platform through which RTB and targeting can be implemented. For the rest of the paper, we will refer to this player as the Intermediary. iii) Consumers. They are the users of the website where the ad is displayed and they are the "object" of the auction. In other words, advertisers bid for a given consumer, represented by the collection of information that are exchanged and/or made available during the bidding process.

### **3.2 Basic Setting**

Our initial model consider the existence of two firms,  $i = 1,2$  that produce two different products at a constant marginal cost of production, assumed to be zero without loss of generality. The market consists of a unit mass of consumers. Each consumer has a demand for at most one unit of the product. Consumers differ along two dimensions. Each consumer can take one of two horizontal positions, capturing the consumer's natural preference for either one of the products. This means that each firm has a segment of consumers who have high preference for its product in the sense that, everything else equal, their willingness to pay is higher for that product. We denote by  $v$  a consumer's reservation price for his favorite product. Stated differently,  $v$  represents the maximum amount of money that the consumer is willing to pay for the product he likes the most. Similarly, we denote by  $w$  a consumer's reservation price for the other product. In other words,  $w$  represents the maximum amount of money that the consumer is willing to pay for a product that is not his favorite. We

assume that  $v \geq w$ . Put simply, the amount of money that a consumer is willing to pay for his favorite product is greater than the amount he is willing to pay for a different product. We assume that a proportion  $\alpha_1$  of consumers prefers Firm 1 and a proportion  $\alpha_2$  prefers Firm 2, with  $\alpha_1 + \alpha_2 = 1$  and  $0 \leq \alpha_i \leq 1$  with  $i = 1, 2$ . Those proportions are known to the firms. Differently, a firm does not know whether a specific consumer likes its product better than the other without any extra information. In other words, the only piece of information that a firm has is the probability of observing a consumer with a preference for its product; probability that is captured by the proportion  $\alpha_i$ . Consumers in this model do not differ only in their products preference. They also differ in their purchase power, as we allow them to take one of two different vertical positions: a consumer can be a low valuation consumer or a high valuation consumer. To better understand what we mean by vertical position, let us consider an example. Let us take two consumers, both with a preference for the product of Firm 1. According to our assumptions, this implies that both consumers are willing to spend more for product 1 than for product 2. Nevertheless, even though the two consumers have the same product's preference, they may have different purchase powers in the sense that one can afford to pay more than the other for the product he likes. For instance, the consumer with higher purchase power (that we call high valuation) can afford to pay a maximum of \$ 10; differently, the consumer with lower purchase power (that we call low valuation consumer) can only afford to pay a maximum of \$ 8. Note that this has consequences on the amount that the consumers are willing to pay for product 2. By definition, both consumers will be willing to spend less on product 2 because that is not their favorite product. Nevertheless, following the example, the high valuation consumer can pay a maximum of \$ 7 for product 2 while the low valuation consumer can pay a maximum of \$ 5 for product 2. From a notational point of view, we denote by  $v_h$  the amount that a high valuation consumer is willing to pay for his favorite product and we denote by  $w_h$  the amount he is willing to pay for the other product. Similarly, we denote by  $v_l$  the amount that a low valuation consumer is willing to pay for his favorite product and we denote by  $w_l$  the amount he is willing to

pay for the other product. We assume that a proportion  $\beta$  of consumers is a high valuation consumer and a proportion  $1 - \beta$  is a low valuation consumer, with  $0 \leq \beta \leq 1$ . As before, firms have information about  $\beta$ . Differently, without any extra information, a firm does not know whether a specific consumer is high valuation or low valuation. In other words, the only piece of information that a firm has, a priori, is the probability of observing a high valuation consumer; probability that is captured by the proportion  $\beta$ . In this model, consumers have preferences over products, but without advertising do not know which company sells which product and at what price. In this sense, advertising plays an informative role as it informs consumers of the existing firms and prices. Given the market's structure, the firm's objective is to target consumers that have a preference for its product and have a high reservation price. Nevertheless, as mentioned before, companies cannot target consumers directly as they cannot identify consumers without extra information; remember that the only pieces of information they have are the proportions  $\alpha$  and  $\beta$ . As a consequence, they have to rely on an intermediary (on-line platform) that possess the targeting technology and runs a second-price auction to allocate consumers between companies. Importantly, during the auction, the Ad Exchange may make available to the firms additional pieces of information about the consumers. Firms, after observing the set of information about the consumer, decide how much to bid for the advertisement and the pricing strategy for their product. The highest bidder wins and pay the bid of the second company. The fact that firms set their price along with the bidding strategy may seem a strong assumption; in fact, that assumption is equivalent to saying that firms can offer personalized discounts to consumers, that is realistic. Furthermore, our results do not change qualitatively even if we assume that prices are exogenous and set before the auction takes place.

In the following sections, we consider and then compare four cases that differ in the amount and type of information that companies see about the consumer before submitting the bid:

i) No Information. Firms are not able to observe any extra information about the consumers.

ii) Only Horizontal Information. Firms are able to observe which product a consumer prefers but they do not observe the vertical position (purchase power). iiI) Only Vertical Information. Firms are able to observe whether the consumer is a high valuation or low valuation consumer but they do not observe his horizontal position (product's preference). iv) Both Horizontal and Vertical information. Firms obtain all the information about the consumer, that is his product's preference and purchase power. In the analysis that follows we consider those four different scenarios and we derive each firm's bidding strategy and pricing strategy and we analyze how the outcome of the game changes in terms of firms' profits, Ad Exchange profit and consumers' welfare. Before proceeding with the analysis, let us clarify those variables. Since we assume a marginal cost of production equal to zero, a firm's profits are simply given by revenues (if the consumer buys the product) minus the amount paid by the company if she wins the online auction for the advertisement (amount equal to the second-highest bid). As for the Ad Exchange, we do not consider any cost of running the auction. Hence, Ad Exchange's profits are simply equal to the amount paid by the firm that wins the online auction. Finally, we conservatively define consumer welfare as the difference between the maximum amount a consumer is willing to pay for a product and the price he actually pays for it.

### 3.3 Sequence of Events

The sequence of events in the model is as follows:

- 1) At any given point in time, a consumer arrives to a website. The consumer is characterized by two pieces of information: horizontal and vertical.
- 2) The Ad Exchange receives a signal that the specific consumer is online and turns the signal to advertisers that wish to show advertisements to that consumer.
- 3) The Ad Exchange runs a second-price auction to allocate the advertisement space. During the auction, it may make visible to the advertisers all or part of the information about the consumer (only the horizontal information, only the vertical information, or both).

- 4) On the bases of the information observed, advertisers decide how much to bid and set the price of the product.
- 5) The firm that submits the highest bid wins the auction, pays the second-highest bid and shows the ad to the consumer.
- 6) The consumer sees the ad and decide whether or not to buy the product. The consumer buys as long as the price is lower than his reservation price.

Figure 1 offers a visual representation of the sequence of the events.

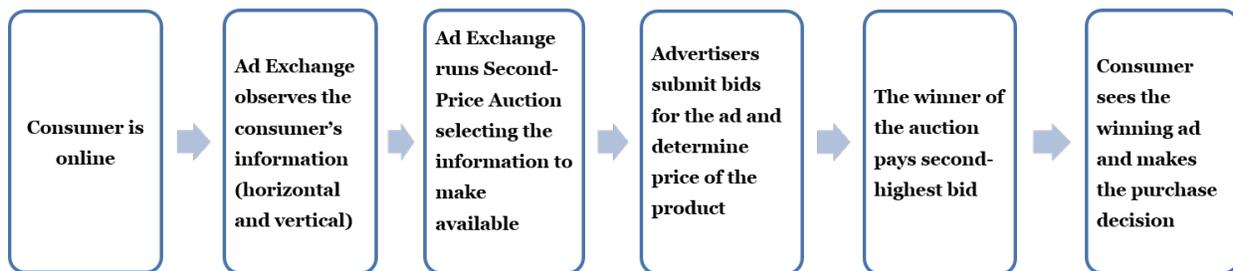


Figure 1: Sequence of Events

## 4 Analysis

We start considering the benchmark case where no additional information about consumers is available. In this scenario, companies have only the common information on the market's structure; therefore, their bidding and pricing strategies will be based on their expectation about the consumer's willingness to pay. Specifically, firms have four possible strategies they can adopt: i) a firm can try to capture the whole market by bidding  $b_i = w_l$  and setting  $P_i = w_l$ ; ii) a firm can decide to capture only his segment of consumers by bidding  $b_i = \alpha_i v_l$  and setting  $P_i = v_l$ ; iii) a firm can decide to capture only his segment of consumers and,

among those, the high valuation ones, by bidding  $b_i = \alpha_i \beta v_h$  and setting  $P_i = v_h$ ; iv) finally, if  $\beta$  is large enough, the company may try to capture all the high valuation consumers by bidding  $b_i = \beta w_h + (1 - \beta) \alpha_i w_h$  and setting  $P_i = w_h$ .

Among the four strategies, firms choose the one that yields the highest expected revenue. This depends on the value of the parameters  $\alpha$  and  $\beta$  that determine the market structure and on the consumers' valuations. When the market is symmetric, that is  $\alpha_i = \alpha_j$ , both firms will bid the same and profit will be zero in expectation.

LEMMA 1. *When firms do not observe extra information about consumers, firm  $i$  bids  $b_i = \max(w_l, \alpha_i v_l, \alpha_i \beta v_h, \beta w_h + (1 - \beta) \alpha_i w_h)$  and firm  $j$  bids  $b_j = \max(w_l, \alpha_j v_l, \alpha_j \beta v_h, \beta w_h + (1 - \beta) \alpha_j w_h)$ . When the market is symmetric.  $b_i = b_j$  and, in expectation, firm's profit will be zero. The intermediary revenue is  $\min(b_i, b_j)$ .*

The no information scenario can be related to a random advertising case: firms cannot target consumers. As a consequence, firms act in expectation but, by so doing, they may tend to bid more than what they should for a given advertisement and consumer. Since both firms have an incentive to bid, the intermediary's profit is positive and equal to the second higher bid.

Next, we consider the case in which only the consumer' horizontal information is available to companies during the auction. Let us assume companies observe a consumer of type 1. Firm 1 can decide to adopt one of two strategies: it can choose to capture any consumer coming from its segment, by setting  $p_1 = v_l$ . In this case, the bid would be  $b_1 = v_l$ . Alternatively, if  $\beta$  is large enough, it can choose to capture, inside its segment, only the high valuation consumers by setting  $p_1 = v_h$ . In this case, the bidding strategy would be  $b_1 = \beta v_h$ . In summary, Firm 1 bidding strategy is  $b_1 = \max(\beta v_h, v_l)$ .

Note that also Firm 2 submits a positive bid. Indeed, since the consumer does have a positive valuation for its product too, it will follow a bidding strategy similar to company 1,

by bidding  $b_2 = \max(\beta w_h, w_l)$ . Those results are summarized in Lemma 2. The proof is contained in Appendix 1.

LEMMA 2. *When companies observe a consumer of type  $i$ , firm  $i$  bids  $b_i = \max(\beta v_h, v_l)$  and sets a price equal to  $p_i^* = v_h$  if  $\beta v_h \geq v_l$  and  $p_i^* = v_l$  otherwise. Firm  $j$  (with  $i, j = 1, 2$  and  $i \neq j$ ) bids  $b_j = \max(\beta w_h, w_l)$  and sets a price equal to  $p_j^* = w_h$  if  $\beta w_h \geq w_l$  and  $p_j^* = w_l$  otherwise. Since  $b_i = \max(\beta v_h, v_l)$  is always greater than  $b_j = \max(\beta w_h, w_l)$ , company  $i$  always wins the auction for consumer of type  $i$ . The Intermediary revenue is  $\max(\beta w_h, w_l)$ .*

When only the Horizontal Information is available, even though both companies submit a positive bid, company  $i$  that observes a consumer of type  $i$  always wins the auction. Consequently, consumers are always shown with the advertisement for their favorite product. Since in this case also the other company submits a positive bid, the Intermediary revenue is not zero.

The next scenario we consider is the case in which only the vertical information is available to companies during the auction, that is firms can distinguish between high valuation and low valuation consumers, but it does not know consumer's preferences.

Let us assume the consumer is high valuation. Firms know that the consumer will be willing to pay  $v_h$  for his favorite product and  $w_h$  for the other. They also know the respective probability of getting a consumer from a specific segment, that is  $\alpha$ . Hence, they can decide to adopt one of two strategies: i) company  $i$  can decide to capture any consumer that is high valuation by setting a price equal to  $w_h$ ; ii) or it can decide to capture any consumer coming from its segment and that is high valuation, by setting a price equal to  $v_h$ . The same reasoning can be applied to low valuation consumers. Lemma 2 summarizes the result. The proof is contained in Appendix 1.

LEMMA 3.a *When only consumers' vertical position is available, both companies submit a positive bid. If consumer is high valuation, company  $i$  sets  $p_i^* = v_h$  and bid  $b_i^* = \alpha_i v_h$  if  $\alpha_i v_h \geq w_h$ ; the company sets  $p_i^* = w_h$  and bid  $b_i^* = w_h$  otherwise. If consumer is low valuation, company  $i$  sets  $p_i^* = v_l$  and bid  $b_i^* = \alpha_i v_l$  if  $\alpha_i v_l \geq w_l$ ; the company sets  $p_i^* = w_l$  and bid  $b_i^* = w_l$  otherwise.*

In this case, it is not immediately clear which company is going to win the auction; the final outcome depends on the various parameters. Let us consider a high valuation consumer. If the market is asymmetric ( $\alpha > 0.5$ ) and the difference between  $v_h$  and  $w_h$  is large enough, company  $i$  with the largest segment of consumers bids  $\alpha_i v_h$  and wins the auction, with  $i = 1, 2$ . There are two main cases in which both companies submit the same bid and the consumer is randomly assigned: i) the market is symmetric and both submits  $\alpha v_h$ ; ii) the difference between  $v_h$  and  $w_h$  is not large enough and both submit  $w_h$ . The same reasoning is valid for a low valuation consumer.

LEMMA 3.b *If the market is asymmetric and  $v_h$  is sufficiently bigger than  $w_h$ , firm  $i$  that bids  $b = \alpha_i v_h$ , wins the auction and gets a consumer of type  $i$  with probability  $\alpha_i$ . Firm  $j$  bids  $\max\{\alpha_j v_h, w_h\}$  and the Intermediary revenue is  $\max\{\alpha_j v_h, w_h\}$ . If the market is symmetric, both companies submit  $\max\{\frac{1}{2}v_h, w_h\}$  and the consumer is randomly assigned. The Intermediary revenue is  $\max\{\frac{1}{2}v_h, w_h\}$ .*

In the last case we consider, both the horizontal and the vertical information about the consumer is available to companies during the auction. Let us assume firm observe a high valuation consumer of type 1. Then we have  $b_1 = v_h$  and  $p_1 = v_h$ , for firm 1. For firm 2, we have  $b_2 = w_h$  and  $p_2 = w_h$ . Similarly, if the consumer is low valuation we have that that  $b_1 = v_l$  and  $p_1 = v_l$ , for firm 1; for firm 2 we have  $b_2 = w_l$  and  $p_2 = w_l$ .

LEMMA 4. *When companies can observe both horizontal and vertical information, firm  $i$  always wins the auction for consumer  $i$ . The Intermediary revenue is  $w_h$  if the consumer is high valuation and  $w_l$  if the consumer is low valuation.*

In this last scenario, companies are able to observe both a consumer's product preference and purchase power. Consequently, firm 1 that observe, for instance, a high valuation consumer of type 1 can set the product's price to be exactly equal the consumer's reservation price,  $v_h$ , and it also submits a bid equal to  $v_h$  as he knows that the consumer will buy its product for sure at that price. Similarly, firm 2 knows that the consumer is only willing to pay  $w_h$  for its product; hence, it sets the price of product and the bid for the advertisement accordingly. Since by assumption we have that  $v_h > w_h$ , firm 1 that bids  $v_h$  always wins the auction for the consumer. The same reasoning applies to a consumer that is low valuation.

## 5 Welfare Analysis

In this section, we analyze how the size and allocation of the players benefits (defined as firms profits, intermediary's profit and consumer's welfare) changes across three different scenarios. In other words, we examine how differential access to consumers data may differentially affect the welfare of various stakeholders. To exemplify our reasoning, we consider the case of a consumer which is high valuation of type  $i$  and we examine how his surplus changes when different pieces of information about him are made available. When only the horizontal information is available, we found before that company  $i$  is always going to win the auction for consumer  $i$ . In other words, the consumer sees the advertisement for his favorite product and, consequently, he always buys his favorite product. If company  $i$  sets a price equal to  $v_h$ , the consumer surplus is 0; if company  $i$  sets a price equal to  $v_l$ , the consumer surplus is positive and equal to  $v_h - v_l$ . Company  $i$  is always left with a positive profit. If it sets a price equal to  $v_h$ , its profit is going to be  $v_h - \max(\beta w_h, w_l)$ ; analogously,

if it sets a price equal to  $v_l$ , its profit is going to be  $v_l - \max(\beta w_h, w_l)$ . The Intermediary profit is always going to be  $\max(\beta w_h, w_l)$ . When only the Vertical information is available, which company is going to win the auction mostly depends on the value of the parameters. In the previous section, we derived that if the market is asymmetric and the difference between  $v_h$  and  $w_h$  is large enough, the company with the largest segment of consumer wins the auction. Let us assume  $\alpha_i > \alpha_j$ . Then company  $i$  wins the auction, the consumer sees an advertisement for its favorite product and pays  $v_h$ . Consumer's surplus is going to be zero while company  $i$  makes positive profit equal to  $v_h \max(\alpha_j v_h, w_h)$ . Nevertheless, when  $\alpha_j \geq \alpha_i$ , company  $j$  wins the auction and the consumer (that we assumed at the beginning is of type  $i$ ) does not buy the product. Consequently, there is a company-consumer mismatch, and the company makes negative profit as it still has to pay the bid equal to  $\max \alpha_i v_h, w_h$ . Similarly, when the market tends to be symmetric and companies submit the same bid, the consumer is randomly assigned. This implies that there will be situations in which the consumer sees the advertisement for its favorite product, pays  $v_h$  and he gets zero surplus (or he pays  $w_h$  and gets a positive surplus equal to  $v_h - w_h$ ); company  $i$  will make a positive profit when it sets  $v_h$  and zero profit when it sets  $w_h$ . Similarly, there will be situations in which the consumer sees the advertisement for the other product and does not buy it, when price is  $v_h$ ; or he does buy it when price is  $w_h$ ; company  $j$  either ends up with a negative profit (when it wins the auction but consumer does not buy) or with a zero profit. The Intermediary profit will always be positive and equal to  $\max(\alpha v_h, w_h)$ , where  $\alpha$  is equal to smallest segment of consumers. When complete information about consumers is available, consumer of type  $i$  is always going to see the advertisement for its favorite product and it always ends up with zero surplus. Company  $i$  that wins the auction for consumer  $i$  is always going to make positive profit. In the example we are considering, it will set a price equal to  $v_h$ , pay a bid equal to  $w_h$  and make a profit equal to  $v_h - w_h$ . The Intermediary revenue is also going to be always positive; in this particular case, it will be equal to  $w_h$ .

To understand how the welfare and allocation of benefits change under the different scenarios, we run computational simulations of the model. For a given value of  $\beta$  and  $\alpha$ , that is, for a given market structure, we let consumers valuations,  $v_h, v_l, w_l$  and  $w_h$ , vary. This allows us to analyze how the results change depending on whether consumers are homogeneous (that is, they have very similar tastes, do not have a specific brand preference or differences in purchase power are negligible) or heterogeneous (tastes or purchase power are very different). More specifically, the ratio  $w_h/v_h$  represents the degree of horizontal differentiation: when the ratio is close to zero, consumers have well defined and different products' preference; their willingness to pay for their favorite product is substantially higher than their willingness to pay for any other product. When the ratio is close to one, consumers are more homogeneous and they are willing to pay a similar amount for the different products available in the market. The ratio between  $v_l/v_h$  represents the degree of vertical differentiation: when the ratio is close to zero, there is a great difference in purchase power between high valuation consumers and low valuation consumers. On the other hand, when the ratio is close to one, the difference between high valuation and low valuation consumers shrinks. Figure 2 shows the results from the model's simulation. The first graph focuses on consumers: the x-axis captures the degree of horizontal differentiation,  $w_h/v_h$  while the y-axis captures the degree of vertical differentiation,  $v_l/v_h$ . For a given degree of consumers' horizontal and vertical differentiation, the graph shows, in different colors, which scenario (No Information, Horizontal Information, Vertical Information or Complete Information) maximizes consumers' welfare. The results are very interesting and not obvious. For high degrees of horizontal information (low values of x), consumers' welfare is maximized when the horizontal information (green color) is available: indeed, when consumers's tastes are very different and, therefore, brands are very important, revealing the horizontal information ensures that each consumer sees the advertisement for the product he likes the most. Differently, for low degrees of horizontal differentiation (high values of x), consumers' welfare is maximized when no information (yellow color) is revealed. Indeed, since in that parameters'

region brands do not matter as much, consumers are happy enough regardless of which advertisement they see. Finally, for low degrees of horizontal differentiation and high degrees of vertical differentiation, consumers's welfare is highest when the vertical information (red color) is revealed.

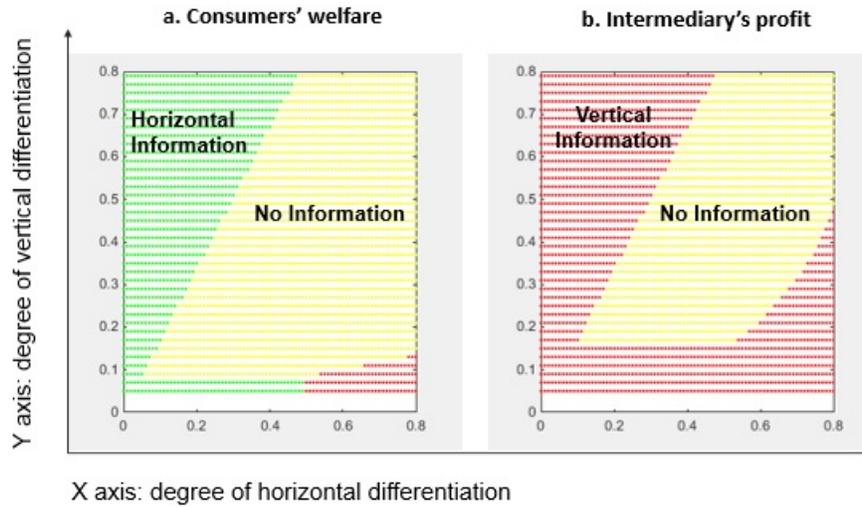


Figure 2: Consumers' welfare vs Intermediary's profit

The intuition is as follows: in that region, brands do not matter as much because consumers' tastes are very similar but the difference between high valuation and low valuation consumers is significant; if firms do not have information they may set a too high price for the product and low valuation consumers will be left out of the market. The second graph focuses on the intermediary: as before, the x-axis represents consumers' degree of horizontal differentiation while the y-axis represents consumers' degree of vertical differentiation. Similarly, for a given combination of the parameters, the graph shows which scenario maximizes the intermediary's profit. For high degree of horizontal differentiation (low values of x), the intermediary's profit is highest when the vertical information is revealed (red color). Indeed, revealing the vertical information about consumers intensifies the competition among firms that tend to bid more aggressively during the auction process. The same applies for low degrees of horizontal differentiation and high degrees of vertical differentiation. Differently, when consumers are more homogenous, the intermediary's profit is highest when no addi-

tional information is available. Indeed, in that case, firms tend to bid in expectation and they may end up bidding more than what they would have if additional information about consumers had been revealed. Finally, concerning advertisers' profit, the results are more straightforward and intuitive: for all the combination of parameters, advertisers' profit is maximized when both the horizontal and vertical information about consumers is revealed.<sup>3</sup> Figure 2 clearly draws attention to the existence of a tension between consumers' interest and intermediary's interest. Under specific circumstances, the interests of the two players are aligned. This corresponds to the yellow region in Figure 2.b: both consumers and intermediary are better off with a full privacy regime where no information about consumers is revealed. Nevertheless, there also exist situations in which the interests of the two players are misaligned. This happens in two cases: i) when consumers are better off with the horizontal information being revealed but the intermediary prefers to reveal the vertical information; ii) when the consumers are better off with no information being revealed but the intermediary prefers to reveal the vertical information.

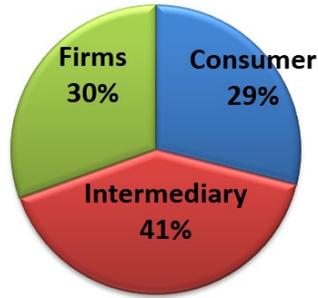
Additionally, we use the results from the simulation to compute the proportion of (expected) benefits that each player would obtain under the four different scenarios. This exercise is useful to understand how the allocation of benefits among consumers, intermediary and advertisers changes in the different scenarios. Figure 3, composed by four sub-figures, shows the results.

The results are consistent with the analysis above. Consumers obtain a substantial proportion of the benefits either in the horizontal information case (Figure 3.a) or in the no information case (Figure 3.c). Consumers obtain a positive surplus also in the vertical information case (Figure 3.b) and no surplus in the complete information case (Figure 3.d). Firms' proportion is highest in the complete information case while it is zero in both the vertical information and the no information case. Finally, the intermediary obtains a positive (and the greatest) proportion in all the cases with the best scenario being the vertical

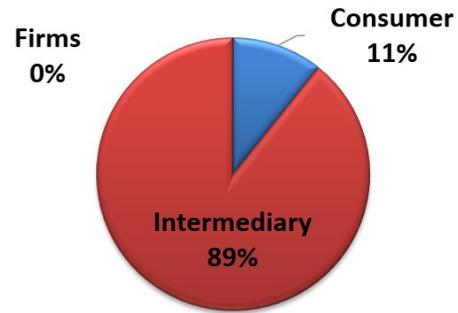
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<sup>3</sup>We omit to include the graph for the advertisers' profit as it simply is a monochromatic quadrant: for all the combinations of the parameters, the best scenario for the advertisers is the complete information case.

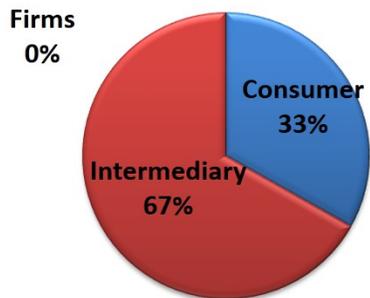
**a. Horizontal Information**



**b. Vertical Information**



**c. No Information**



**d. Complete Information**

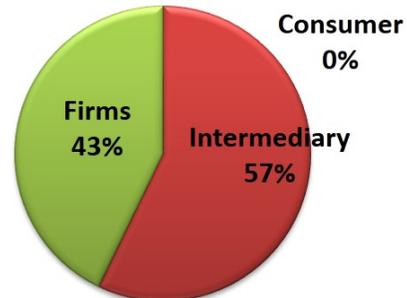


Figure 3: Allocation of Benefits (proportions) among Consumer, Advertiser and Intermediary under the four scenarios

information where the intermediary obtains the great majority of the benefits.

## 6 Limitations and Possible Extensions

The model we propose can be extended in various ways. First of all, some of the assumptions on consumers behavior may look simplistic and can be relaxed. We assume that consumers see only one advertisement at the time, either for firm 1 or for firm 2. We could extend the model by considering the existence of  $n$  competing firms and by allowing the possibility that a consumer is displayed with more than one advertisement at the time. Furthermore, in the proposed version of the model, a consumer buys as long as the price of the advertised product is no greater than the consumer's reservation price for that product. We could

relax this assumption by including consumers search behavior to account for the fact that consumers may decide to shop around before buying. In addition, consumers are not able to block or avoid advertisements; introducing consumers' ability to control the type and amount of information that is being collected online seems to be an interesting and relevant case, particularly nowadays that online users can rely to various privacy-enhancing technologies. Concerning the assumptions on the Ad Exchange, we currently consider the existence of a monopoly intermediary. We could allow some degree of competition also on the intermediary side and consider the possibility that companies decide to enter different Ad networks. Finally, the proposed model takes into consideration the interaction between three types of players: advertisers, intermediary and consumers. The online advertising ecosystem is more complex and includes additional subjects. For instance, companies that want to participate to auctions for online advertising usually rely on Demand Side Platform (DSP) that serves advertisers or ad agencies by bidding for their campaigns in multiple ad networks automatically. On the other side, Supply Side Platforms (SSP) serves publishers by registering their inventories (ads space) in different ad networks and accepting the most beneficial automatically. Taking into consideration the existence of those players may help offering a more complete analysis of the online advertising market.

## **7 Conclusion and Policy Implications**

In this paper, we analyzed the welfare and allocative impact of targeted advertising by developing an analytical model based on Real-Time Bidding. The model focuses on the interaction among three types of players: firms (the advertisers, who compete with each other for consumers' attention), consumers (the online users, who visit websites, are shown targeted ads, and purchase products online), and an intermediary (the ad exchange, which tracks consumers data and serves them the firms' ads). We assumed that consumers are characterized by two dimensions: horizontal information, that captures consumers' prefer-

ences for specific products; and vertical information, that captures differences in consumers' purchase power. Advertisers, firms that produce products and want to advertise them to consumers, buy advertisements by participating in real-time auctions run by the intermediary. We considered four scenarios that differed in the amount and/or type of information that is available on the market and that advertising firms have available during the bidding process: i) the case in which only the horizontal information, that is which product a consumer prefers, is available. ii) The case in which only the vertical information (whether the consumer is high valuation or low valuation) is available. iii) The case in which both the horizontal and the vertical information about consumers is available. iv) A case in which no information about consumers is available, corresponding to a benchmark case of full privacy protection. For each of the four scenarios, we derived each advertisers' bidding strategy and pricing strategy; we then determined the winner of the auction and the final outcome of the game in terms of advertisers' profit, Ad Exchange's revenues and consumers' welfare. We found that consumers welfare is higher when only specific type of information are exchanged (horizontal information) and, generally, when less information is exchanged. Furthermore, there exist situations in which the incentives of the Intermediary are misaligned with respect to consumers' interest; stated differently, the intermediary that acts as a profit-maximizing agent may decide to adopt strategies that lead to higher revenue for itself while making consumers and/or advertisers worse off. Finally, under certain conditions the intermediary obtains the highest proportion of benefits from the targeting process.

By illustrating how different degrees of consumer data tracking and sharing can differentially affect the welfare of data holders and data subjects, these findings can contribute to the ongoing industry and regulatory debate over the economic and social implications of the adoption of tracking and advertising systems. Interestingly, these results do not imply that the collection of consumer information should be prohibited - rather, they suggest that there is information which is beneficial for consumers to share, and other information which, instead, could be used by others to the consumer's detriment. Furthermore, what emerges

from our model is that different players that operate in the ecosystem may have contrasting interests. In turn, such interests may create incentives for practices that are not transparent. For instance, an intermediary that has the power to control which type of information to highlight to other parties (such as advertising firms) during the auction process, may have the incentive to act strategically by revealing the information that ensure him the highest expected return. According to our analysis, this may be against consumers' best interest.

## APPENDIX 1

PROOF OF LEMMA 2. We assume companies observe a consumer of type  $i$ , with  $i = 1, 2$ .

We start from the pricing strategy.

Firm  $i$  chooses the price to maximize his expected profit, that is:

$$\operatorname{argmax}\{(p_i * \operatorname{Prob.Buying}) - b_j\}$$

where  $p_i$  is the price set by company  $i$ ,  $\operatorname{Prob.Buying}$  is the probability that the consumer is going to buy the product and  $b_j$  is the bid submitted by company  $j$ .

Company  $i$  can set two different prices:  $v_h$  or  $v_l$ . If it sets  $p_i = v_l$ , its expected revenue is

$$(v_l * 1) - b_j \tag{1}$$

Indeed, in that case the probability that the consumer buys is equal to one, as the consumer sees the advertisement for his favorite product and his reservation price is  $\geq v_l$ . If it sets  $p_i = v_h$ , its expected profit is:

$$(v_h * \beta) - b_j \tag{2}$$

In this case, not all the consumers are going to buy the product but only the proportion with high valuation that is  $\beta$ . Putting together equation (1) and (2), we have that company  $i$  sets  $p_i = v_h$  if  $\beta v_h \geq v_l$  and sets  $p_i = v_l$  otherwise.

Next, let us consider the bidding strategy. Our results are based on the fact that in second-price auctions, truthful bidding is a dominant strategy. For the result to hold in this case, it is sufficient to introduce an infinitesimal probability that companies do not know who they are competing with. Holding this condition, company  $i$  strategy will be to bid its truthful valuation for consumer  $i$ , that is equal to the revenue the company expects to gain if that consumer buys the product. When company  $i$  sets a price equal to  $v_l$ , the expected revenue

is also  $v_l$ ; when it sets a price equal to  $v_h$ , its expected revenue is equal to  $\beta v_h$ . Consequently, company  $i$  bidding strategy is to bid

$$b_i = \max\{\beta v_h, v_l\}$$

When companies can observe consumers' horizontal information, firm  $i$  wins the auction for consumer  $i$ . We have to consider four different cases.

Let us assume  $b_i = \beta v_h$  and  $b_j = \beta w_h$ . Then  $b_i \geq b_j$  as, by assumption,  $v_h \geq w_h$ . The same conclusion holds if  $b_j = w_l$ . Indeed, if  $b_i = \beta v_h$ , it means that  $\beta v_h \geq v_l$ ; since, by assumption,  $v_l \geq w_l$ , then it must also be that  $\beta v_h \geq w_l$ . Hence,  $b_i \geq b_j$ .

Next, let us assume that  $b_i = v_l$  and  $b_j = \beta w_h$ . We know that, by assumption,  $v_l \geq w_h$ . Since  $\beta \leq 1$ , we also have that  $v_l \geq \beta w_h$ . The same result holds if  $b_j = w_l$  as again, by assumption,  $v_l \geq w_l$ .

PROOF OF LEMMA 3.a We assume that the consumer is high valuation consumer. Let us start from the pricing strategy. Firm  $i$  chooses the price to maximize his expected profit, that is:

$$\operatorname{argmax}\{(p_i * \operatorname{Prob.Buying}) - b_j\}$$

where  $p_i$  is the price set by company  $i$ ,  $\operatorname{Prob.Buying}$  is the probability that the consumer is going to buy the product and  $b_j$  is the bid submitted by company  $j$  with  $i, j = 1, 2$  and  $i \neq j$ .

Company  $i$  can set two different prices:  $v_h$  or  $w_h$ . If it sets  $p_i = v_h$ , its expected revenue is

$$(v_h * \alpha_i) - b_j \tag{3}$$

Indeed, in that case the probability that the consumer buys is equal to the probability that

the consumer is type  $i$ , that is  $\alpha_i$ . If it sets  $p_i = w_h$ , its expected profit is:

$$(w_h * 1) - b_j \tag{4}$$

In this case, all the high valuation consumers are going to buy the product. Putting together equation (3) and (4), we have that company  $i$  sets  $p_i = v_h$  if  $\alpha_i v_h \geq w_h$  and sets  $p_i = w_h$  otherwise.

Next, let us consider the bidding strategy. Our results are based on the fact that in second-price auctions, truthful bidding is a dominant strategy. For the result to hold in this case, it is sufficient to introduce an infinitesimal probability that companies do not know who they are competing with. Holding this condition, company  $i$  strategy will be to bid its truthful valuation for consumer  $i$ , that is equal to the revenue the company expects to gain if that consumer buys the product. When company  $i$  sets a price equal to  $w_h$ , the expected revenue is also  $w_h$ ; when it sets a price equal to  $v_h$ , its expected revenue is equal to  $\alpha_i v_h$ . Consequently, company  $i$  bidding strategy is to bid  $b_i = \max\{\alpha_i v_h, w_h\}$ .

PROOF OF LEMMA 3.b When companies can observe only the vertical information, firm  $i$  that bids  $b = \alpha_i v_h$  wins the auction and gets a consumer of type  $i$  with probability  $\alpha_i$ .

Let us assume that  $b_1 = \alpha_1 v_h$ , implying that  $\alpha_1 v_h \geq w_h$ . This happens either when  $\alpha_1$  is large enough or  $v_h$  is sufficiently higher than  $w_h$ . If  $\alpha_1 > \alpha_2$ , then firm 1 is always going to win the auction no matter firm's 2 bid. Indeed, if  $b_2 = \alpha_2 v_h$ , then we have that  $b_1 > b_2$  as  $\alpha_1 > \alpha_2$ . If  $b_2 = w_h$ , then, again,  $b_1 > b_2$  as  $\alpha_1 v_h \geq w_h$ .

If  $\alpha_1 = \alpha_2$  then the two firms submit the same bid. Indeed, in that case, we have that  $\alpha_1 v_h = \alpha_2 v_h = \alpha v_h$ . Hence, whenever  $\alpha v_h \geq w_h$ , both firms bid  $\alpha v_h$  and viceversa.

PROOF OF LEMMA 4. Follows trivially from the assumption that  $v_h \geq w_h$  and  $v_l \geq w_l$ .

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