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Whitelisting versus Advertising-Recovery: Strategies to Overcome Advertising Blocking by Consumers

Ashutosh Singh
Department of Marketing, University of Leeds, Leeds, LS2 9JT, UK,
A.Singh1@leeds.ac.uk

S. Sajeesh
Department of Marketing, College of Business, University of Nebraska-Lincoln, Lincoln, NE 68555,
ssajeesh2@unl.edu

Pradeep Bhardwaj
Department of Marketing, University of Central Florida, Orlando, FL 19122 pbhardwaj@ucf.edu

The significance of online advertising as a primary revenue stream for digital media cannot be understated. However, the rising adoption of ad-blocking software by users has adversely affected these revenues. In response to this challenge, digital publishers are exploring various strategies not only to maintain their revenues, but also to enhance them through online advertising, in addition to paid subscriptions. We discuss three potential strategies to overcome ad-blocking. The first is the subscription fee strategy, termed the benchmark strategy in the paper, wherein users pay a subscription fee to access content without encountering any ads. The second strategy is whitelisting, which involves publishers seeking users' consent to display acceptable ads that support the website. The third approach is ad-recovery, which employs a third-party service to continue displaying ads even to users employing ad-blocking software. We utilize a duopolistic game-theoretical framework and identify conditions under which digital publishers might adopt either symmetric or asymmetric strategies to counter ad-blocking usage. We find that both firms tend to opt for whitelisting when the advertising revenue parameter is relatively low, and the proportion of consenting ad-block users is relatively high. On the other hand, when the advertising revenue parameter is high, and the proportion of consenting ad-block users is low, both firms benefit from an ad-recovery strategy. Further, under some conditions, firms utilize asymmetric strategies. The analysis suggests that a number of consumer- and firm-level factors represent important determinants of the digital marketing strategies of media firms.

Keywords: OR in marketing, Digital marketing strategies, Ad-blocking, Consumer valuation, Whitelisting, Ad-recovery.

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1. Introduction

For the increasing number of Internet users and media readers, online media firms often provide the primary source of standardized or customized news. These publishers generate revenue by charging subscription fees to end-users and showing advertisements alongside their provided content. Studying newspaper publishing economics, Varian (2010) asserts that a large proportion of revenues come from advertising, and online advertising contributes substantially to total advertising revenue.

However, such online advertising is not perceived favorably by readers (Anderson & Coate 2005; Anderson & Gabszewicz 2006; Peitz & Valletti 2008; Stourm & Bax 2017; Shen & Villas-Boas 2018; Li *et al.* 2024). Consumers instead find ways to block these advertisements by downloading software that prevents or removes online advertising from phones, tablets, and computers. Ad-blocking software rely on filter rules to know what to block (or hide), and what is allowed to appear on the web pages that an individual visits. The software compares every web page request to a filter list (a vast collection of known ads on English-language websites all over the Web) and, based on the match between the request and the filter, blocks the download of ads onto the webpage. Figure 1 depicts an example of a website of a digital media firm with and without AdBlock software.

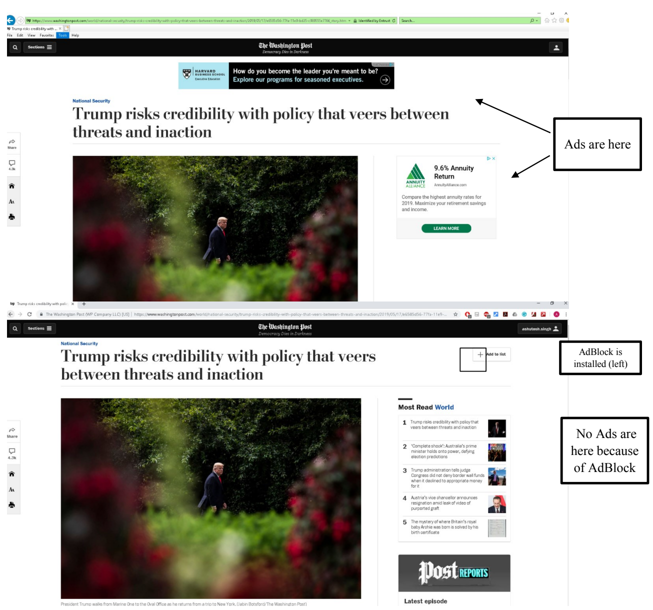

Figure 1 Washington Post webpage without and with ad-blocking

Ad-blocking software penetration has increased from about 16% in 2014 to about 27% of users in 2021 in the United States (Shankland 2021). Furthermore, the usage of such ad-blocking software is much higher in many European countries (Statista Research 2022). By the end of 2019, an estimated 763 million devices worldwide had blocking software, approximately 69% (527 million) of which were mobile devices (Business Insider 2020). As these trends suggest, advertising as a source of revenue for digital publishers is threatened by the availability of blocking software such as AdBlock. The loss in revenue due to AdBlock applications was estimated to be $3.8 billion in 2016, with predictions of $35 billion in losses by 2020 (Davies 2016).

In response, many of these publishers have begun evaluating various solutions to bypass ad-blocking software, and three notable options have gained prominence in recent years: subscription fee only (now onwards benchmark B), whitelisting (WL) and ad-recovery (AR).

Benchmark

We consider a subscription-based model as our baseline scenario, where consumers pay a subscription fee to access ad-free content. The importance of subscription fees as a revenue source for digital publishing businesses is fairly apparent. A recent study examining 212 news outlets across various countries in the European Union and the United States revealed that only 27 percent of media providers offer free content to their audience (Simon & Graves 2019). Consequently, charging subscription fees has become a crucial means for numerous media publishers to monetize their content production. However, in addition to subscriptions, digital media publishers are also seeking ways to enhance their revenues through advertising. In this paper, our objective is not solely focused on the subscription fee strategy. We also concentrate on exploring other supplementary strategies, such as whitelisting and ad-recovery, which numerous media companies are adopting to boost their advertising earnings.

Whitelisting

We define whitelisting strategy as one in which a firm requests consumers' consent to show acceptable ads to them to support the website. Some forms of advertisements (e.g., thin rectangular ads on the side of a computer screen) appear less annoying to readers than full-screen advertisements with countdown timers (MacMillan 2018). In a survey, AdBlock Plus found that 25% of its users reject all advertising, but the other 75% are willing to accept some advertising to support websites (as posted on the company webpage), as long as those ads do not disrupt the flow of content. Therefore, AdBlock Plus has developed an acceptable ads policy that considers ad placement on the content page, ad coverage, ad type, and display properties.[1] Publishers that follow this acceptable ad policy are "whitelisted" by AdBlock and thus may display ads to readers.

[1] This acceptable ads policy states that the ads must be placed on the top, side, or below the content. If located above or below the webpage content, the ad cannot occupy more than 15% or 25%, respectively, of the visible portion of the webpage. Textual and image ads should not use excessive colors; the in-feed ads should not take too much space or load new ads, autoplay video ads, overlay ads, or pop-up new ads. Rich media ads also are not considered acceptable.

On such a whitelisted platform, AdBlock users will see a pop-up window requesting that they accept the publisher's whitelisted status and see its content. Once they do so, they will see ads that follow the acceptable ad criteria (Figure 2). These less intrusive ads are "permitted" to pass the ad-blocking filters, in exchange for compliance with quality standards. However, note that not all consumers may consent to whitelisting.

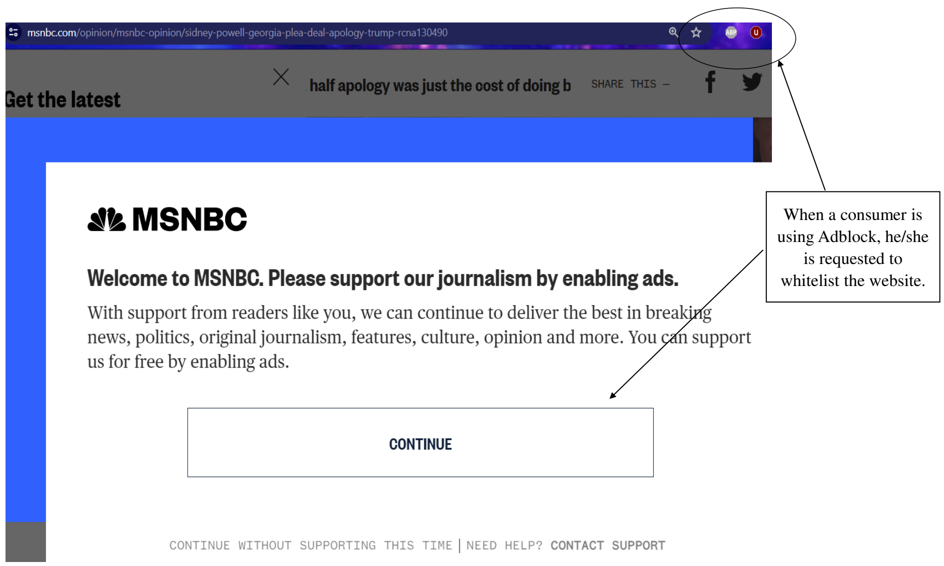

Figure 2 **How whitelisting works**

Ad-Recovery

"The opportunity for an anti-ad blocking solution to remove publisher monetization obstacles while unlocking receptive, targeted audiences to advertisers already overwhelmed by gaps in viewability, transparency, and forecasting, all without diminishing user viewing experiences, has never been more significant — or more crucial." (Ooyala 2019)

The above quote by Rebecca Paoletti, CEO and co-founder of Cakeworks, highlights the benefits of technology-based response to ad-blocking. Using industry terminology, we call it ad-recovery (AR).[2] The emergence of this technology has been driven by data that shows the loss in ad revenues even after whitelisting. In a study using Google's Investor Data, e-marketer and ComScore revealed that although whitelisting mitigates ad revenue loss to some extent, Google loses 10% of its total revenues with the ad-blocking rate of 13.6% in the US (O'Reilly 2015). Although consumers recognize that viewing sponsor messages advertising products or services subsidizes content costs, consumers may not consent to whitelisting. Consequently, companies such as AdDefend, Admiral,

[2] Ad-recovery strategy is also referred to as ad-block circumvention strategy in many popular press articles.

AdRecover, Adtoniq, BlockAdBlock, Blockthrough (PageFair), BlockIQ (AdSupply), Secretmedia, Uponit etc., have developed an alternative solution that enables publishers to keep showing ads even to consumers who use AdBlock. Using software with Javascript that contains bait elements, these companies can detect and retrieve blocked ads. Such an ad-recovery (AR) strategy ensures that only ads relevant to each consumer, according to her ad-viewing history, get reinserted into the webpage. By customizing the displayed ads, ad-recovery attempts to improve the user experience. Figure 3 provides a visual example of ad-recovery in action on the Forbes webpage. Even when the consumer is using ad-blocker, advertisements can be seen on the top and right side of the webpage.

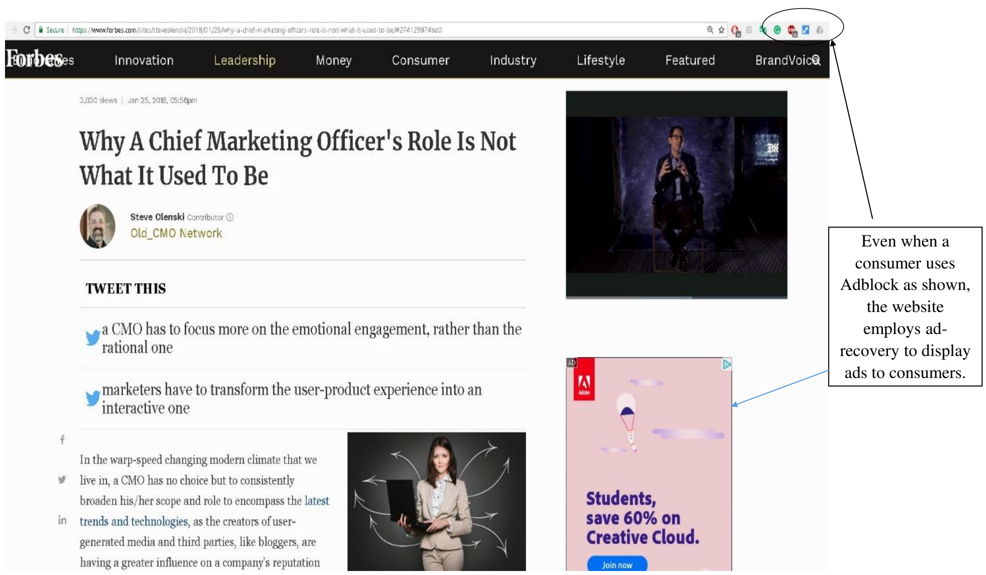

Figure 3 Forbes webpage showing how ad-recovery works

In contrast to whitelisting, which relies on consumer consent to display ads, ad-recovery technology works primarily by detecting the ad-serving URLs and cloaking or concealing the calls that trigger ad-blockers (Buzzfeed News 2015). We distinguish between these two strategies based on whether consumer consent is obtained or not. When firms use AR strategy, they are optimizing advertising for all consumers. In contrast, with whitelisting, advertising is restricted to those consumers who consent.

To obtain this solution, online media firms pay a usage fee to the ad-recovery provider. An example of company offering ad-recovery services is Blockthrough. Blockthrough's fee is the equivalent of the publisher's revenue, multiplied by the technology percentage, in addition to a 30% share of the advertising revenue the publisher earns through using Blockthrough (Blockthrough website 2022). There are a number of firms providing AR-type anti-adblocking technology to their clients based on publicly available information. For example, publicly available sources indicate that many firms in US and Europe use the anti-adblocking technology offered companies such as AdRecover, Admiral, AdDefend, BlockAdBlock, and Pagefair to obtain additional digital advertising revenue. Many popular websites may be utilizing their own version of anti-adblocking technology to circumvent adblocking by consumers.[3]

A whitelisting strategy focuses only on making ads visible to consenting consumers whereas the AR strategy exposes all consumers to advertising. However, ad-blocking consumers are more annoyed when advertising exposure occurs without their consent raising interesting questions about the conditions under which each strategy is optimal for a digital publisher in a competitive market. We explore this question, as well as the conditions under which asymmetric outcomes exist in a competitive environment in which one publisher adopts whitelisting but a competing publisher chooses to adopt the AR strategy. We also consider the publisher profitability implications of a benchmark strategy in which firms do not adopt either of these strategies. To do so, we develop a horizontal differentiation model of duopolistic competition, accounting for publisher characteristics (e.g., ad-recovery or whitelisting value parameters) and consumer characteristics (e.g., relative proportion of ad-block users and non-users, extent of disutility due to advertising exposure).[4]

We contribute to the digital advertising literature by highlighting strategies that digital publishers could pursue to extract advertising revenues in a competitive setting. Our analysis is useful for digital publishers interested in studying the impact of changes in the digital landscape on firm profitability. Our paper makes the following three important contributions of practical significance: First, to tackle ad-block, the extant literature focuses on strategies such as banning ad-block users, showing content to ad-block users without extracting any ad revenue from them, charging subscription fees, or whitelisting. In contrast, we compare benchmark, whitelisting, and AR strategies in markets in which three consumer types exists: (i) ad-block non-users, (ii) ad-block users who consent to ads, and (iii) ad-block users who don't consent to advertising exposure. Unlike whitelisting, AR technology doesn't require consumer consent. We highlight conditions under which a digital publisher would wish to pursue a given strategy (benchmark, whitelisting, or AR) in a competitive setting. Second, previous studies have focused on subscription fees or whitelisting as distinct strategies. However, we observe that many firms in practice use subscription strategies in conjunction

[3] A few platforms use other strategies; for example, *Business Insider* asks users to pay an additional dollar or turn off ad-block to view content. The $1 fee gives readers access to limited prime content, for a limited time, followed by a higher fee per month. Publications and platforms such as *The Atlantic* and *AdAge* also request that users subscribe or disable ad-block software. Some publishers ban ad-block users from viewing their content whereas publishers, such as CNBC, request that users disable ad-block software but still allow them to see content even if they don't. These short-term strategies may be temporarily helpful, but in the long-term, platforms need an appropriate overall solution to ad-blocking using either whitelisting or ad-recovery which is the focus of our paper.

[4] Many ad-blockers themselves have shifted to allowing a limited display of ads, called limited-ad-blocking (LAB). Although from a consumer perspective, both AR and LAB lead to consumers being exposed to ads, note that the publisher implements AR for a fee, whereas the ad-blocking firm implements LAB.

with advertising strategy (using either whitelisting or AR) in order to boost revenues. Thus, our analysis provides a more nuanced understanding of the strategies available to tackle ad-block and our framework is consistent with the notion that many publishers adopt strategies that combine subscription fees and advertising revenue as their business model (Kumar & Sethi 2009). Finally, incorporating multiple dimensions of consumer utility, such as disutility due to ads allows us to highlight why firms might follow asymmetric strategies to tackle ad-blocking in equilibrium.

More specifically, in addition to analytically deriving the profits of the digital publishers, to interpret these findings, we study the outcomes of our modeling exercise in two distinct scenarios that capture possible settings, in terms of the data available, when publishers must decide whether to adopt a specific strategy to tackle ad-blocking. In the first scenario, the proportion of ad-block non-user and revenues due to advertising from ad-block users are two key parameters that might vary in the market, but we assume the disutility due to ads is known to the firms. Publishers can typically obtain such information by conducting surveys among target consumers. In this case, both firms adopt the benchmark strategy when the advertising revenue parameter is relatively lower. Further, both firms adopt a whitelisting strategy when the value of the advertising revenue parameter is in the intermediate range and the proportion of ad-block non-users exceeds a threshold. In contrast, when the advertising revenue parameter is relatively high and the proportion of ad-block non-users is relatively low, both publishers adopt an ad-recovery strategy in equilibrium.

In another scenario, we consider the proportion of consenting ad-block users and the advertising revenue parameter (corresponding to non-users) are the two key parameters that might vary in the market, but choose specific values for other key parameters. In this setting, we find that both publishers adopt a whitelisting strategy when the advertising revenue parameter is low and the proportion of consenting ad-block users is high. In contrast, when the value of advertising revenue parameter is high and proportion of consenting ad-block users is relatively low, both firms benefit from using an ad-recovery strategy. The asymmetric equilibrium holds for intermediate values of the advertising revenue parameter and when the proportion of consenting ad-block users is in the intermediate range.

The rest of the paper is organized as follows. We review the literature in Section 2. The model setup is described in Section 3. Section 4 and 5 present the analysis and the results respectively. In Section 6, we present two extensions to the base model and in Section 7, we summarize the main contributions of this research. The details of the analysis and the proofs of the propositions are given in the Appendix.

2. Literature review

Our paper relates broadly to the literature on competition among digital platforms (Boudreau 2010; Constantinides *et al.* 2018; Gal-Or & Dukes 2003; Greenwood & Agarwal 2016; Kannan &

Li 2017; Lambrecht & Tucker 2019; Wu & Chiu 2023), and more specifically to the research on advertising avoidance and the impact of ad-blocking on digital publishers, which we describe below.

Advertising avoidance

Gabszewicz *et al.* (2004) analyze competition in media industries under a free-to-air provision. They find that viewers react negatively in the presence of advertisements, and this negative externality then induces channels to differentiate their content to obtain revenue from advertisers. In analyzing systems in which viewers can access broadcasts without any costs, Anderson & Coate (2005) find that under duopolistic competition, broadcasters care about the nuisance costs of advertisements up to the level that induces viewers to switch. This cost depends on the substitutability of the channels. Hann *et al.* (2008) instead examine the case of marketing avoidance by consumers. Solicitations by sellers create a threat to their privacy, so they opt for concealment and deflection strategies to reduce that threat. Such concealment effort by low-benefit consumers (i.e., consumers with low demand for products) induces the seller to increase its marketing activities and enhance the effectiveness of the solicitations when their marginal cost is low. Efforts by high-benefit consumers (i.e., consumers with high demand for products) instead induce sellers to reduce their marketing activities.

Anderson & Gans (2011) analyze the effect of siphoning on platforms and show that if consumers use ad-avoidance technologies, they can easily siphon off the ads, so the platform responds by raising the advertising levels such that the consumers who are not using ad-avoidance technologies see more ads. Johnson (2013) examines targeted advertising according to an advertising avoidance scenario and finds that improved targeted advertising increases profits, even if consumers make advertising avoidance decisions. More advertisements might induce greater use of advertising avoidance technologies by consumers, but consumers still might underutilize them in equilibrium. In a similar vein, Chakraborty *et al.* (2021) determine the optimal mix of skippable and non-skippable ads for the platform. We build on this stream of literature by accounting for the use of ad-blocking and the disutility of advertising exposure. In contrast to the above papers, we account for consumer heterogeneity in the extent of disutility due to advertising exposure and endogenously derive the subscription fees, and compare multiple strategies that firms could use to tackle ad-blocking by consumers in a competitive setting.

Peitz & Valletti (2008) compare pay-TV, in which the platform gets revenues from advertisers and viewers, with free-to-air, in which the platform gets revenues only from advertising. Under symmetric equilibrium, these platforms differentiate their content more as the nuisance due to ads increases. In addition, an asymmetric equilibrium exists in which the free-to-air platform shows less advertising than pay-TV under maximal content differentiation if the nuisance due to ads is low. We extend this research to incorporate firms' reactions to ad-block usage by readers, which may adversely affect profits, thereby forcing platforms to adopt either whitelisting or AR strategy as a solution. Building on extant literature on advertising avoidance, whitelisting may reduce consumer utility through ad exposure. When publishers use ad-recovery strategy, consumers are exposed to ads even if they do not provide consent. We use an additional parameter to capture the increase in disutility due to advertising exposure without consent. We also incorporate the revenue generated through advertising exposure.

Ad-blocking

A few papers analyze the impact of ad blocking on digital publishers (Aseri *et al.* 2020; Despotakis *et al.* 2021; Gritckevich *et al.* 2022; Ray *et al.* 2017; Subramanian & Zia 2019). Aseri *et al.* (2020) analyze the problem of monopolistic platforms when viewers use ad-block. They consider both regular users and ad-block users, and they divide the decision problem into a first-level decision, which requires the platform to determine whether to allow ad-block users or ask them to whitelist, and a second-level decision, related to the level of ad intensity for users. They focus on whether ad-free content access be offered to consumers who use ad-blockers? They show that the platform can increase its revenues by using different ad intensities for regular versus ad-block users. However, they do not incorporate the role of competition. Ray *et al.* (2017) analyze a two-stage game with four players (website, ad-blocker, advertisers, and users) and find that the platform might pay users to view the ads under equilibrium. Furthermore, content quality decreases with greater usage of whitelisting. Despotakis *et al.* (2021) also analyze the platform response to consumers using ad-block and develop three suggestions: If users are ad sensitive, platforms should adopt a subscription plan, but it should ban ad-block users if the ad sensitivity of ad-block and ad-block non-users are similar, and finally, if ad-block users are highly heterogeneous, a whitelisting option is more profitable. Consistent with Despotakis *et al.* (2021) and Aseri *et al.* (2020), we analyze a duopolistic competition model. However, in contrast to the above papers, we highlight conditions under which ex-ante identical firms may utilize asymmetric strategies in equilibrium.

In their assessment of the effect of ad-blocking on digital publishing, Gritckevich *et al.* (2022) find that consumers can adopt ad-block to improve their experience, and then AdBlock can negotiate a higher fee from the publisher to maintain its advertising revenues. If this fee is high, it disrupts the publisher's profit, which leads to reduced quality and affects consumer welfare. Subramanian & Zia (2019) examine the game where content quality and advertising intensity are decided by the platform and consumer decides the usage of ad-blocker. They find that limited ad-blocking gives benefit to the readers by encouraging publishers to provide good quality content. However, they do not account for competition between publishers or endogenously determine the subscription fees. In addition, we seek a more nuanced solution by comparing specific applications of whitelisting and ad-recovery as possible solutions to ad-blocking by consumers.

3. Model

We consider two competing digital media firms (publishers) that charge subscription fees to consumers.[5] In addition to subscription fees, publishers generate additional revenues through advertising under some of the scenarios that we consider. Publishers' profitability depends on subscription revenues as well as the advertising revenues from the proportion of ad-block users who consent to advertising and ad-block non-users who are exposed to advertising. We analyze competition between firms using the Hotelling framework (Hotelling 1929; Marianov & Eiselt 2016) and building on the model proposed by Peitz & Valletti (2008).

3.1. Characteristics that determine the profit of online digital publishers

Publisher characteristics

The two publishers are located at opposite ends of a Hotelling line of unit length. They charge subscription fees s_i $(i = 1, 2)$ to readers in the market. We assume that the market is horizontally differentiated and the cost of content production for both publishers is identical and set to zero. All readers are informed about the locations of the firms and vice versa (Armstrong 2006; Peitz & Valletti 2008). The publishers also provide good quality content to the readers, which increases their utility. For simplicity, we assume that each publisher provides same quality content, from which readers receive a value equal to V. Further, we assume that readers can only access one publisher at a time (i.e., single-homing). This assumption seems reasonable in the context of any digital news website (e.g., Washington Post, The Wall Street Journal) because most readers prefer to access the content of only one website at a time. In addition, we assume both publishers are equally popular, so the amount of traffic to each is not affected by network effects due to popularity. Given that a fraction of readers use ad-blockers, firms tackle the issue using only subscription fees or in conjunction with either whitelisting, or ad-recovery.

Online advertising can generate revenue in two ways: pay-per-view or pay-per-click (Cao & Ke 2019). In pay-per-view or display advertising, publishers get revenues when ads are displayed to users on the website (Fridgeirsdottir & Najafi-Asadolahi 2018) whereas with pay-per-click, publishers get revenues when a user clicks ads on the website. We recognize that whitelisting as well as ad-recovery strategies allow publishers to use either pay-per-view or pay-per-click to generate ad revenues. If the publishers adopt whitelisting or AR strategies, the publishers have to pay a whitelisting fee or ad-recovery fees to a third-party firm.[6] Therefore, we define γ as the net revenue

[5] Our analysis of a monopoly publisher is available in the Online Appendix.

[6] If the publisher is a particularly large entity (i.e., attracts more than 10 million ad impressions per month), it pays a whitelisting fee to AdBlock Plus. Digital companies such as Google, Amazon, Microsoft, and Taboola commit approximately 30% of the revenues generated through these advertisements to gain the right to whitelist their webpages (Taylor 2020)

from whitelisting/AR strategies from ad-block users. The parameter ρ captures the advertising revenues from ad-block non-users. The total profits depend on the fraction of ad-block non-users. We consider it reasonable to assume that, for the publisher, the incremental benefit of click-through advertising accrues only from ad-block users; ad-block non-users do not pay sufficient attention to advertising. Although we do not impose any restriction on the parameter space, it seems reasonable to expect γ to be greater than ρ as the revenue from consenting ad-block users may most likely be higher than that from ad-block non-users.

Reader characteristics

Consistent with prior models of horizontally differentiated markets studied using a Hotelling framework, we assume that consumers are distributed uniformly over a unit interval $[0, 1]$, and the total number of consumers is normalized to 1. Each reader views content only from publisher 1 or publisher 2, depending on which content provides the highest utility. A consumer's position on the line represents the ideal point of her preferences. If a consumer purchases content positioned at a distance y away from her ideal point and priced at s, she gets utility of $V - s - ty$, where V is the reservation price of this consumer for the product, and t (> 0) is the transportation or mismatch cost parameter which represents the degree to which the content of the two publishers can be substituted. In our duopolistic model, V is assumed to be sufficiently high so that every consumer gets positive utility from purchase from one of the two publishers. This also ensures complete market coverage in our model.

As discussed previously, with whitelisting strategy, the ad-block users may give consent to ad exposure, which reduces their utility (Peitz & Valletti 2008). We use a parameter η to capture the net disutility for ad-block users with whitelisting. When the firms use an ad-recovery strategy to circumvent adblocking, the extent to which the consumer utility decreases is higher since consumers have not provided consent for advertising exposure. We use λ as a scale parameter which captures the higher disutility due to advertising exposure without consent which is consistent with the notion that consumers are more annoyed viewing ads without consent (Digital Information World 2021).[7]

Consumer heterogeneity

Peitz & Valletti (2008) assume that everyone dislikes ads because they interrupt and lengthen television programs. In their setup, this assumption is relevant, but for digital media publishers, readers could be heterogeneous in their valuation of content with and without ads. We incorporate reader heterogeneity by modeling three types of readers: ad-block users who consent to advertising

[7] Since our focus is on content publishers' strategies (and not advertisers), we do not account for the amount of advertising shown to consumers and use just parameters λ and η to capture the nuisance of advertising. One could imagine that the parameters λ and η are affected by the amount of advertising.

exposure based on firms' request, ad-block users who object to firms' request and ad-block non-users. The assumption of consumer heterogeneity is based on the AdBlock Plus company survey finding, which shows that there are multiple types of internet users: those who use AdBlock (and may agree to certain non-obtrusive advertising exposure) and others who do not use AdBlock (Pagefair Report 2021). Further, we complement the prior literature on this topic (Despotakis *et al.* 2021) by considering ad-block users at a finer level of granularity - those who consent to advertising exposure and those who do not.

Ad-block non-users: A fraction of consumers in the market may be unaware of technologies that can block ads. Consequently, they do not use ad-blocking technology. Further, such readers may be indifferent to advertisements (since they do not use ad-blocking softwares even when the cost of such softwares may be negligible); we refer to them as ad-block non-users. Let α $(0<\alpha<1)$ denote the fraction of ad-block non-users in the market. Thus, the utility of an ad-block non-user, located at x, who views the content of publisher i $(i=1,2)$ is given by,

$$U^{\alpha}=V-s_i-t_1\left|x-l\right|. \tag{1}$$

where l $(l=i-1)$ represents the location of publisher $i=1,2$ and t_1 represents the mismatch cost parameter for the adblock non-users[8] In our model, the utility of ad-block non-users remains the same across all three strategies: the benchmark case, whitelisting, and AR strategy. The remaining $(1-\alpha)$ consumers are ad-block users, and we consider the following two sub-groups of ad-block users.

Consenting ad-block users: A fraction β of consumers consent to non-obtrusive advertising exposure when requested by firms. Such consumers' utility reduces by η, due to advertising exposure. Although consumers are willingly reducing their utility, it is still in the consumer's interest to whitelist as long as the intrinsic utility of the content, relative to an outside option, is sufficiently high. The outside option represents some other website or source where similar content can be accessed. If no such outside option exists, the utility of the outside option is zero, and as long as V is sufficiently high to overcome the disutility due to ads (η), consumers will still find it in their best interest to whitelist a website. It is also possible that such consenting ad-block users do not have any knowledge about whitelisting and are merely agreeing to firms' request to whitelist without too much thought.

Non-consenting ad-block users: Consistent with the findings of the AdBlock Plus survey, a fraction of readers strictly object to requests from publishers to display advertisements, so they try to use

[8] We use t_2 to represent the mismatch cost parameter for the adblock users. Using distinct parameters to capture the mismatch costs for the two segments allows us to also account for differential price sensitivity of the two segments for the content.

ad-blockers to eliminate any exposure to ads. These non-consenting (or objecting) ad-block users may have some knowledge about whitelisting and such consumers recognize that they can continue viewing the website's content without whitelisting. Thus, these readers obtain higher utility with the use of ad-blockers. The total fraction of objecting adblock users in the market is represented by $(1-\alpha-\beta)$.

The utility of the ad-block users in all three cases is as follows:

1. In the benchmark case, the utility of the ad-block user (consenting or objecting) is

$$U^{\beta} = U^{1-\alpha-\beta} = V - s_i - t_2\,|x-l|\,. \tag{2}$$

2. In the whitelisting case, the two types of ad-block users obtain distinct utilities from consuming the content as given below. The first type users don't give consent to watch ads. Hence, they will not see any ads. The second type of ad-block users who give consent to watch ads. Hence, the consenting users' utility decreases to $V-\eta$. Therefore, the consumer utilities are given by

$$U_{iW}^{(1-\alpha-\beta)} = U_{iW}^{O(1-\alpha)} = V - s_i - t_2\,|x-l|\,. \tag{3}$$

$$U_{iW}^{(\beta)} = U_{iW}^{C(1-\alpha)} = V - \eta - s_i - t_2\,|x-l|\,. \tag{4}$$

in which we use superscripts, $O(1-\alpha)$ and $C(1-\alpha)$, to represent the objecting and consenting ad-block users respectively.

3. In the AR case, all ad-block users are exposed to ads due to the technology used by the digital publisher. The net consumer utility changes further to $V-(1+\lambda)\eta$ in which the λ is a scaling parameter which captures increased disutility incurred by the ad-block users due to advertising exposure without consent. The utility for the ad-block users (consenting or objecting) is given by

$$U_{iAR}^{C(1-\alpha)} = U_{iAR}^{O(1-\alpha)} = V - (1+\lambda)\eta - s_i - t_2\,|x-l| \tag{5}$$

Table 1 summarizes the notation used in the paper.

Parameter	Description
α	Proportion of ad-block non-users
β	Proportion of ad-block users who consent to whitelisting
V	Base utility obtained by ad-block users/non-users from publishers' content
η	Disutility due to ad exposure under whitelisting
λ	Parameter capturing higher disutility due to advertising exposure without consent
ρ	Advertising revenue parameter for ad-block non-users
γ	Advertising revenue parameter under whitelisting or ad-recovery strategies
t_1 and t_2	Mismatch cost parameters for adblock non-users and users respectively

Table 1 Notation for parameters

3.2. Publisher profitability under various strategies

In our model, we set the costs associated with content creation as well as the costs associated with implementing whitelisting and ad recovery strategies to zero. Thus, the revenue and profitability metrics are equivalent. In addition, although the cost of implementing a whitelisting or AR strategy could be distinct, we use one single value parameter (γ) to capture the net revenue from each user for each of these strategies so that cost differences are not the driving force behind our results. However, the total revenues (or profits) under each strategy will depend on the proportion of consenting or objecting ad-block users. The profitability under the various strategies are enumerated below:

1. Benchmark case: (Subscription fees) × (demand from ad-block non-users + demand from ad-block users) + Advertising revenue parameter × (demand from ad-block non-users).
2. Whitelisting case: (Subscription fees) × (demand from ad-block non-users + demand from ad-block users) + Whitelisting advertising revenue parameter × (demand from consenting ad-block users)+advertising revenue parameter × (demand from ad-block non-users).
3. AR case: (Subscription fees) × (demand from ad-block non-users + demand from ad-block users) + AR advertising revenue parameter × (demand from adblock users)+advertising revenue parameter × (demand from adblock non-users).

Note that the subscription fees in each case are endogenously derived. Although the cost of implementing a whitelisting or AR strategy could be distinct, we use one single value parameter (γ) to capture the net revenue for each user from each of these strategies so that cost differences are not the driving force behind our results. However, the total revenues under each strategy will depend on the proportion of consenting or objecting ad-block users.

3.3. Sequence of decisions

In our duopolistic competition model, publishers choose to adopt among benchmark, whitelisting or ad-recovery strategies followed by their subscription fee decisions. The game has the following three stages, and we solve the game using backward induction.

1. *Stage 1*: Publishers simultaneously decide to adopt one of the strategies (benchmark, whitelisting, or ad-recovery).
2. *Stage 2*: Publishers simultaneously choose content subscription fees s_i $(i=1,2)$. The cost of the content is assumed to be 0.
3. *Stage 3*: Each reader in the market views content only from the publisher that provides the highest utility.

4. Analysis

We analyze 3x3 scenarios in which each publisher can adopt benchmark, whitelisting, or ad-recovery strategies. The possible combinations of strategies for competing publishers are given in Table 2.

In scenarios 1, 2, and 3, both publishers adopt symmetric strategies, which we analyze in Sections 4.1, 4.2, and 4.3. In scenarios 4, 5, and 6, publishers adopt asymmetric strategies, which we analyze in Section 4.4.

		Publisher 2		
		Benchmark	Whitelisting	Ad-recovery
Publisher 1	Benchmark	π_{1BB}, π_{2BB} (Scenario 1)	π_{1BW}, π_{2BW} (Scenario 5)	π_{1BAR}, π_{2BAR} (Scenario 6)
	Whitelisting	π_{1WB}, π_{2WB} (Mirror of Scenario 5)	π_{1WW}, π_{2WW} (Scenario 2)	π_{1WAR}, π_{2WAR} (Scenario 4)
	Ad-recovery	π_{1ARB}, π_{2ARB} (Mirror of Scenario 6)	π_{1ARW}, π_{2ARW} (Mirror of Scenario 4)	π_{1ARAR}, π_{2ARAR} (Scenario 3)

Table 2 Possible scenarios in our analysis

4.1. Both publishers adopt benchmark strategy

We use the consumer utility functions for both ad-block non-users and ad-block users to solve endogenously for equilibrium subscription fees and determine publisher profitability. The profits for publishers 1 and 2 are given by,

$$\pi_{1B} = \alpha x_B^\alpha s_{1B} + (1-\alpha)\, x_B^{(1-\alpha)} s_{1B} + \rho\alpha x_B^\alpha, \text{ and} \tag{6}$$

$$\pi_{2B} = \alpha\,(1-x_B^\alpha)\, s_{2B} + (1-\alpha)\left(1-x_B^{(1-\alpha)}\right) s_{2B} + \rho\alpha\,(1-x_B^\alpha)\,. \tag{7}$$

in which x_B^α and $x_{2B}^{(1-\alpha)}$ represent the marginal ad-block non-user and ad-block user, respectively and s_{iB} represents the subscription fees charged by publisher i $(i=1,2)$ in the benchmark scenario. The revenue parameter ρ captures the advertising revenues from the ad-block non-users. We calculate the first-order conditions by differentiating the profit functions of the publishers with respect to the content subscription fees. The equilibrium subscription fees and firm profits are given by $(i=1,2)$:

$$s_{iB}^* = \frac{t_2(t_1-\alpha\rho)}{t_1+(t_2-t_1)\alpha}, \text{ and} \tag{8}$$

$$\pi_{iB}^* = \frac{t_1t_2+(t_2-t_1)(1-\alpha)\alpha\rho}{2t_1(1-\alpha)+2t_2\alpha}. \tag{9}$$

4.2. Both publishers adopt whitelisting strategy

When publishers adopt whitelisting strategy, the utility functions of the ad-block non-user, located at x_W^α, from each publisher is given by:

$$U_{1W}^\alpha = V - s_{1W} - t_1 x_W^\alpha, \text{ and} \tag{10}$$

$$U_{2W}^\alpha = V - s_{2W} - t_1(1-x_W^\alpha). \tag{11}$$

We separate the utility function of ad-block users into objecting and consenting ad-block users. Hence, consenting ad-block users will see ads along with the content because they voluntarily disable the ad-blocker for that website.

The utility functions of consenting and objecting users located at $x_W^{C(1-\alpha)}$ and $x_W^{O(1-\alpha)}$ from publisher 1 are given by:

$$U_{1W}^{C(1-\alpha)} = V - \eta - s_{1W} - t_2 x_W^{C(1-\alpha)}, \tag{12}$$

$$U_{1W}^{O(1-\alpha)} = V - s_{1W} - t_2 x_W^{O(1-\alpha)}. \tag{13}$$

The utility functions of objecting and consenting users located at $x_W^{C(1-\alpha)}$ and $x_W^{O(1-\alpha)}$, from publisher 2 are given by:

$$U_{2W}^{C(1-\alpha)} = V - \eta - s_{2W} - t_2(1 - x_W^{C(1-\alpha)}), \tag{14}$$

$$U_{2W}^{O(1-\alpha)} = V - s_{2W} - t_2(1 - x_W^{O(1-\alpha)}). \tag{15}$$

Equating the above utility functions, we derive the marginal consumers. The details of the analysis are given in Appendix. We use parameter β to represent the proportion of consenting ad-block users. The whitelisting value parameter (γ) is associated with consenting ad-block users because they give consent to disable the ad-block and view ads along with the content of the platform. In this case, the profit functions of the publishers are given by:

$$\pi_{1W} = \alpha x_W^{\alpha} s_{1W} + \beta x_W^{C(1-\alpha)} s_{1W} + (1-\alpha-\beta) x_W^{O(1-\alpha)} s_{1W} + \rho\alpha x_W^{\alpha} + \gamma\beta x_W^{C(1-\alpha)}, \tag{16}$$

$$\begin{aligned}\pi_{2W} &= \alpha\,(1 - x_W^{\alpha})\, s_{2W} + \beta(1 - x_W^{C(1-\alpha)}) s_{1W} + (1-\alpha-\beta)(1 - x_W^{O(1-\alpha)}) s_{1W} + \rho\alpha\,(1 - x_W^{\alpha}) \\ &\quad + \gamma\beta(1 - x_W^{C(1-\alpha)}).\end{aligned} \tag{17}$$

Substituting the values of x_W^{α}, $x_W^{C(1-\alpha)}$ and $x_W^{O(1-\alpha)}$in the profit functions and using the first order conditions for profit maximization, we get the equilibrium subscription fees and profit functions.

$$s_{iW}^* = \frac{t_1 t_2 - t_1\beta\gamma - t_2\alpha\rho}{t_1(1-\alpha) + t_2\alpha}, \text{ and} \tag{18}$$

$$\pi_{iW}^* = \frac{t_2\alpha(\beta\gamma + \rho\alpha - \rho) + t_1(t_2 - \alpha\beta\gamma + (1-\alpha)\alpha\rho)}{2t_1(1-\alpha) + 2t_2\alpha}. \tag{19}$$

where $i = 1, 2$.

4.3. Both publishers adopt ad-recovery (AR) strategy

In this scenario, publishers obtain advertising revenues from both ad-block users and non-users in addition to subscription fees. When publishers adopt an AR strategy, the utility functions of the ad-block non-user, located at x^{α}_{AR}, from each publisher is given by:

$$U^{\alpha}_{1AR} = V - s_{1AR} - t_1 x^{\alpha}_{AR}, \text{ and} \tag{20}$$

$$U^{\alpha}_{2AR} = V - s_{2AR} - t_1(1 - x^{\alpha}_{AR}). \tag{21}$$

When publishers adopt an AR strategy, the utility to an ad-block user located at $x^{1-\alpha}_{AR}$, from each publisher is given by:

$$U^{1-\alpha}_{1AR} = V - (1+\lambda)\eta - s_{1AR} - t_2 x^{1-\alpha}_{AR}, \text{ and} \tag{22}$$

$$U^{1-\alpha}_{2AR} = V - (1+\lambda)\eta - s_{2AR} - t_2(1 - x^{1-\alpha}_{AR}). \tag{23}$$

Equating the corresponding utility functions, we solve for the marginal consumers in this scenario. The profit functions of publisher 1 and publisher 2 are:

$$\pi_{1AR} = \alpha x^{\alpha}_{AR} s_{1AR} + (1-\alpha)\, x^{1-\alpha}_{AR} s_{1AR} + \rho\alpha x^{\alpha}_{AR} + \gamma\,(1-\alpha)\, x^{1-\alpha}_{AR} \tag{24}$$

$$\begin{aligned}\pi_{2AR} = {} & \alpha\,(1 - x^{\alpha}_{AR})\, s_{2AR} + (1-\alpha)\left(1 - x^{1-\alpha}_{AR}\right) s_{2AR} + \rho\alpha\,(1 - x^{\alpha}_{AR}) \\ & + \gamma\,(1-\alpha)\,(1 - x^{1-\alpha}_{AR}).\end{aligned} \tag{25}$$

Substituting the values of x^{α}_{AR} and $x^{1-\alpha}_{AR}$ in the profit function and using the first order conditions, we get the equilibrium subscription fees and profit functions.

$$s^*_{iAR} = \frac{t_1(t_2 - (1-\alpha)\gamma) - t_2\alpha\rho}{t_1(1-\alpha) + t_2\alpha}, \text{ and} \tag{26}$$

$$\pi^*_{iAR} = \frac{t_1(t_2 - (1-\alpha)(\gamma-\rho)\alpha) + t_2((1-\alpha)(\gamma-\rho)\alpha)}{2t_1(1-\alpha) + 2t_2\alpha} \tag{27}$$

4.4. Publishers adopt asymmetric strategies

4.4.1. Publisher 1 adopts whitelisting and Publisher 2 adopts ad-recovery strategy

We consider a scenario in which publisher 1 adopts whitelisting and publisher 2 adopts ad-recovery. In this scenario, the utility function for the ad-block non-user, located at x^{α}_{WAR}, of purchasing content from publishers 1 and 2 are given by:

$$U^{\alpha}_{1WAR} = V - s_{1WAR} - t_1 x^{\alpha}_{WAR}, \text{ and} \tag{28}$$

$$U^{\alpha}_{2WAR} = V - s_{2WAR} - t_1(1 - x^{\alpha}_{WAR}). \tag{29}$$

The utility functions of consenting and objecting users located at $x_{WAR}^{C(1-\alpha)}$ and $x_{WAR}^{O(1-\alpha)}$, from publisher 1 are given by:

$$U_{1WAR}^{C(1-\alpha)} = V - \eta - s_{1WAR} - t_2 x_{WAR}^{C(1-\alpha)}, \tag{30}$$

$$U_{1WAR}^{O(1-\alpha)} = V - s_{1WAR} - t_2 x_{WAR}^{O(1-\alpha)}. \tag{31}$$

The utility functions of objecting and consenting users located at $1-x_{WAR}^{C(1-\alpha)}$ and $1-x_{WAR}^{O(1-\alpha)}$ from publisher 2 are given by:

$$U_{2WAR}^{C(1-\alpha)} = V - (1+\lambda)\eta - s_{2WAR} - t_2(1 - x_{WAR}^{C(1-\alpha)}) \tag{32}$$

$$U_{2WAR}^{O(1-\alpha)} = V - (1+\lambda)\eta - s_{2WAR} - t_2(1 - x_{WAR}^{O(1-\alpha)}) \tag{33}$$

Equating the corresponding utility functions, we derive the location of marginal consumers. The profit functions of firm 1 and firm 2 are:

$$\begin{aligned}\pi_{1WAR} &= \alpha x_{WAR}^{\alpha} s_{1WAR} + \beta x_{WAR}^{C(1-\alpha)} s_{1WAR} + (1-\alpha-\beta) x_{WAR}^{O(1-\alpha)} s_{1WAR} + \rho\alpha x_{WAR}^{\alpha} \\ &\quad + \gamma\beta x_{WAR}^{C(1-\alpha)}, \end{aligned} \tag{34}$$

$$\begin{aligned}\pi_{2WAR} &= \alpha\left(1 - x_{WAR}^{\alpha}\right) s_{2WAR} + \beta\left(1 - x_{WAR}^{C(1-\alpha)}\right) s_{2WAR} + (1-\alpha-\beta)\left(1 - x_{WAR}^{O(1-\alpha)}\right) s_{2WAR} \\ &\quad + \rho\alpha\left(1 - x_{WAR}^{\alpha}\right) + \gamma\beta(1 - x_{WAR}^{C(1-\alpha)}) + \gamma(1-\alpha-\beta)(1 - x_{WAR}^{O(1-\alpha)}). \end{aligned} \tag{35}$$

Substituting the values of x_{WAR}^{α}, $x_{WAR}^{C(1-\alpha)}$, and $x_{WAR}^{O(1-\alpha)}$ in the profit function and using the first-order conditions, we get the equilibrium subscription fees and profits to be,

$$s_{1WAR}^{*} = \frac{t_1(3t_2 - (1-\alpha+2\beta)\gamma + \eta(1-\alpha-\beta+\lambda-\alpha\lambda)) - 3t_2\rho\alpha}{3t_1(1-\alpha) + 3t_2\alpha}, \tag{36}$$

$$s_{2WAR}^{*} = \frac{t_1(3t_2 - (2-2\alpha+2\beta)\gamma - \eta(1-\alpha-\beta+\lambda-\alpha\lambda)) - 3t_2\rho\alpha}{3t_1(1-\alpha) + 3t_2\alpha}. \tag{37}$$

$$\pi_{1WAR}^{*} = \frac{\left(\begin{array}{c} 9t_2\alpha\left(t_2\beta\gamma + t_2\left(-1+\alpha\right)\rho + \left(-1+\alpha\right)\eta\left(1+\lambda\right)\rho + \beta\eta\left(\gamma\lambda+\rho\right)\right) \\ +t_1\left(\begin{array}{c} 9t_2^2 + \left(1-\alpha-\beta\right)^2\gamma^2 + \eta^2\left(-1+\alpha+\beta+\left(-1+\alpha\right)\lambda\right)^2 \\ -\left(-1+\alpha+\beta\right)\gamma\eta\left(-2+2\alpha-7\beta+2\left(-1+\alpha\right)\lambda\right) \\ +t_2\left(\left(-6+6\alpha+6\beta-9\alpha\beta\right)\gamma + 6\eta\left(1-\alpha-\beta+\left(1-\alpha\right)\lambda\right) + 9\left(1-\alpha\right)\alpha\rho\right) \end{array}\right) \end{array}\right)}{18t_2\left(t_1 - t_1\alpha + t_2\alpha\right)}, \tag{38}$$

$$\pi_{2WAR}^{*} = \frac{\left(\begin{array}{c} -9t_2\alpha\left(t_2\left(-1+\alpha\right) + \eta - \eta\left(\alpha+\beta+\left(-1+\alpha\right)\lambda\right)\right)\left(\gamma-\rho\right) \\ +t_1\left(\begin{array}{c} 9t_2^2 + \left(\left(-1+\alpha+\beta\right)\left(\gamma-\eta\right) - \left(-1+\alpha\right)\eta\lambda\right)^2 \\ +3t_2\left(\left(2+\alpha\left(-5+3\alpha\right)-2\beta\right)\gamma - 2\eta\left(1-\alpha-\beta+\left(1-\alpha\right)\lambda\right) + 3\left(1-\alpha\right)\alpha\rho\right) \end{array}\right) \end{array}\right)}{18t_2\left(t_1 - t_1\alpha + t_2\alpha\right)} \tag{39}$$

4.4.2. Publisher 1 adopts benchmark and Publisher 2 adopts whitelisting strategy

The utility to an ad-block non-user, located at x^{α}_{BW}, from each publisher is given by:

$$U^{\alpha}_{1BW} = V - s_{1BW} - t_1 x^{\alpha}_{BW}, \tag{40}$$

$$U^{\alpha}_{2BW} = V - s_{2BW} - t_1(1 - x^{\alpha}_{BW}). \tag{41}$$

The utility functions of consenting and objecting users located at $x^{C\alpha}_{BW}$ and $x^{O\alpha}_{BW}$from publisher 1 are given by:

$$U^{C(1-\alpha)}_{1BW} = V - \eta - s_{1BW} - t_2 x^{C\alpha}_{BW}, \tag{42}$$

$$U^{O(1-\alpha)}_{1BW} = V - s_{1BW} - t_2 x^{O\alpha}_{BW}. \tag{43}$$

Similarly, we consider the utility functions of consenting and objecting users located at $x^{C(1-\alpha)}_{BW}$ and $x^{O(1-\alpha)}_{BW}$, from publisher 2. Equating the utility functions, we derive the marginal consumers. The profit functions of publishers 1 and 2 are:

$$\pi_{1BW} = \alpha x^{\alpha}_{BW} s_{1BW} + \beta x^{C\alpha}_{BW} s_{1BW} + (1-\alpha-\beta) x^{O\alpha}_{BW} s_{1BW} + \rho\alpha x^{\alpha}_{BW} \tag{44}$$

$$\begin{aligned}\pi_{2BW} &= \alpha\left(1 - x^{\alpha}_{BW}\right) s_{2BW} + \beta(1 - x^{C\alpha}_{BW}) s_{2BW} + (1-\alpha-\beta)(1 - x^{O\alpha}_{BW}) s_{2BW} \\ &\quad \rho\alpha\left(1 - x^{\alpha}_{BW}\right) + \gamma\beta(1 - x^{C\alpha}_{BW}).\end{aligned} \tag{45}$$

Substituting the values of x^{α}_{BW}, $x^{C\alpha}_{BW}$ and $x^{O\alpha}_{BW}$ in the profit functions and using the first order conditions, we get the equilibrium subscription fees and profit functions to be,

$$s^*_{1BW} = \frac{3t_1t_2 - t_1\beta(\gamma - \eta) - 3t_2\alpha\rho}{3t_1(1-\alpha) + 3t_2\alpha}, \text{ and} \tag{46}$$

$$s^*_{2BW} = \frac{3t_1t_2 - t_1\beta(2\gamma + \eta) - 3t_2\alpha\rho}{3t_1(1-\alpha) + 3t_2\alpha}. \tag{47}$$

$$\pi^*_{1BW} = \frac{\left(\begin{array}{c} 9t_2\alpha\left(t_2\left(-1+\alpha\right) - \beta\eta\right)\rho \\ +t_1\left(9t_2^2 - 6t_2\beta\left(\gamma-\eta\right) + \beta^2\left(\gamma-\eta\right)^2 - 9t_2\left(-1+\alpha\right)\alpha\rho\right)\end{array}\right)}{18t_2\left(t_1 - t_1\alpha + t_2\alpha\right)}, \tag{48}$$

$$\pi^*_{2BW} = \frac{\left(\begin{array}{c} t_1\left(\begin{array}{c} 9t_2^2 + t_2\beta\left(\left(6-9\alpha\right)\gamma - 6\eta\right) \\ +9\left(-1+\alpha\right)\beta\gamma\eta + \beta^2\left(\gamma^2 + 7\gamma\eta + \eta^2\right) - 9t_2\left(-1+\alpha\right)\alpha\rho \end{array}\right) \\ +9t_2\alpha\left(t_2\beta\gamma + t_2\left(-1+\alpha\right)\rho + \beta\eta\left(-\gamma+\rho\right)\right)\end{array}\right)}{18t_2\left(t_1 - t_1\alpha + t_2\alpha\right)} \tag{49}$$

4.4.3. Publisher 1 adopts benchmark and Publisher 2 adopts ad-recovery strategy

The utility to an ad-block non-user, located at x^{α}_{BAR}, from each publisher is given by:

$$U^{\alpha}_{1BAR} = V - s_{1BAR} - t_1 x^{\alpha}_{BAR}, \tag{50}$$

$$U^{\alpha}_{2BAR} = V - s_{2BAR} - t_1(1 - x^{\alpha}_{BAR}). \tag{51}$$

The utility function of an ad-block user located at $x_{BAR}^{1-\alpha}$ from each publisher is given by:

$$U_{1BAR}^{1-\alpha} = V - s_{2BAR} - t_2 x_{BAR}^{1-\alpha}, \tag{52}$$

$$U_{2BAR}^{1-\alpha} = V - (1+\lambda)\eta - s_{2BAR} - t_2 x_{BAR}^{1-\alpha}. \tag{53}$$

The profit functions of publishers 1 and 2 are:

$$\pi_{1BAR} = \alpha x_{BAR}^{\alpha} s_{1BAR} + (1-\alpha) x_{BAR}^{1-\alpha} s_{1BAR} + \rho\alpha x_{BAR}^{\alpha} \tag{54}$$

$$\begin{aligned}\pi_{2BAR} &= \alpha\left(1 - x_{BAR}^{\alpha}\right) s_{2BAR} + (1-\alpha)(1 - x_{BAR}^{1-\alpha}) s_{2BAR} \\ &\quad \rho\alpha\left(1 - x_{BAR}^{\alpha}\right) + \gamma(1-\alpha)(1 - x_{BAR}^{1-\alpha}).\end{aligned} \tag{55}$$

Equating the utility functions we derive the values of x_{BAR}^{α} and $x_{BAR}^{1-\alpha}$ and substituting them into the profit functions and using the first order conditions, we get the equilibrium subscription fees and profits.

$$s_{1BAR}^{*} = \frac{3t_1t_2 - t_1(1-\alpha)(\gamma - (1+\lambda)\eta) - 3t_2\alpha\rho}{3t_1(1-\alpha) + 3t_2\alpha}, \text{ and} \tag{56}$$

$$s_{2BAR}^{*} = \frac{3t_1t_2 - t_1(1-\alpha)(2\gamma + \eta + \lambda\eta) - 3t_2\alpha\rho}{3t_1(1-\alpha) + 3t_2\alpha}. \tag{57}$$

$$\pi_{1BAR}^{*} = \frac{\begin{pmatrix} 9t_2\left(-1+\alpha\right)\alpha\left(t_2+\eta+\eta\lambda\right)\rho \\ +t_1\begin{pmatrix} 9t_2^2 + \left(-1+\alpha\right)^2\left(-\gamma+\eta+\eta\lambda\right)^2 \\ -3t_2\left(-1+\alpha\right)\left(-2\gamma+2\eta\left(1+\lambda\right)+3\alpha\rho\right)\end{pmatrix}\end{pmatrix}}{18t_2\left(t_1 - t_1\alpha + t_2\alpha\right)}, \tag{58}$$

$$\pi_{2BAR}^{*} = \frac{\begin{pmatrix} -9t_2\left(-1+\alpha\right)\alpha\left(t_2-\eta\left(1+\lambda\right)\right)\left(\gamma-\rho\right) \\ +t_1\begin{pmatrix} 9t_2^2 + \left(1-\alpha\right)^2\left(\gamma-\eta-\eta\lambda\right)^2 \\ +3t_2\left(-1+\alpha\right)\left(\left(-2+3\alpha\right)\gamma+2\eta\left(1+\lambda\right)-3\alpha\rho\right)\end{pmatrix}\end{pmatrix}}{18t_2\left(t_1 - t_1\alpha + t_2\alpha\right)}. \tag{59}$$

5. Results

Comparative Statics of subscription fees across different scenarios

We calculate comparative statics of subscription fees with respect to key parameters under different scenarios. Our analysis shows that

$$\frac{\partial s_{1W}^{*}}{\partial \beta} < 0,\ \frac{\partial s_{1W}^{*}}{\partial \rho} < 0,\ \frac{\partial s_{1AR}^{*}}{\partial \beta} = 0,\ \frac{\partial s_{1AR}^{*}}{\partial \rho} < 0. \tag{60}$$

$$\frac{\partial s_{1WAR}^{*}}{\partial \beta} < 0,\ \frac{\partial s_{1WAR}^{*}}{\partial \rho} < 0,\ \frac{\partial s_{2WAR}^{*}}{\partial \beta} = \frac{t_1\left(\eta-\gamma\right)}{3t_1\left(1-\alpha\right)+3t_2\alpha},\ \frac{\partial s_{2WAR}^{*}}{\partial \rho} < 0. \tag{61}$$

First, we compute the comparative statics of subscription fees in the symmetric whitelisting and ad-recovery cases, focusing on the proportion of consent-giving ad-block users and the revenues generated from this user group. Our analysis reveals that as the proportion of users providing consent and the corresponding revenue increase, the subscription fees decrease in the whitelisting scenario. We also find that as the revenues from consent providing ad-block users increase, the subscription fees decrease in the AR scenario. This reduction in subscription fees can be attributed to the publishers capitalizing on greater economies of scale as the user base expands. With a larger user base, the per-user operational and maintenance costs decrease, allowing the platforms to pass on these savings to consumers through reduced subscription fees in the context of whitelisting/AR.

In the asymmetric scenario, where publisher 1 opts for whitelisting while publisher 2 chooses AR as its model, we observe that as the proportion of ad-block users providing consent increases, the subscription fee for platform 2 rises. This occurs when the disutility experienced by ad-block users due to ads is greater than the revenue generated from non-ad-block users. When ad-block users have a high disutility from ads, they are less likely to interact with or click on ads, resulting in publisher 2 not receiving incremental revenues from advertising. Consequently, publisher 2 increases its subscription fees to generate profits from all users and alleviate the potential loss in advertising revenue.

In our framework, the publishers' profits are a combination of revenues generated from subscription fees and advertising (depending on the chosen strategy). The subscription fee in our model is positive or zero; however, in specific cases, it could be negative. One can think of the negative subscription fees as the cashback or promotion offer given by the publisher for using its website.

Equilibrium strategies based on equilibrium profits under the various scenarios

In addition to analytically deriving the profits of the digital publishers, to interpret these findings and generate insights, we study the outcomes of our modeling exercise in two distinct scenarios by focusing on two parameters at a time. Given that our model has 5 key parameters, we focus on two interesting combinations out of the 10 possible combinations which we discuss sequentially in the following subsections.

5.1. Equilibrium characterization in the α-γ space

We first consider the scenario in which the proportion of ad-block non-users and advertising revenue parameters are two key parameters that might vary in the market, but choose specific values for the other parameters. We fix the values of few parameters to be: $t_1 = t_2 = 1, \eta = \frac{3}{10}$, $\lambda = \frac{1}{2}, \rho = \frac{1}{4}, \beta = \frac{1}{4}$. To simplify the results, we also assume that $\frac{1}{4} < \gamma < 1$ and $0 < \alpha < \frac{3}{4}$. This allows us to simplify the conditions for the existence of symmetric and asymmetric equilibria. We also checked for second order conditions in all cases and they are satisfied too.

In the first proposition, we show that if the publishers have access to the data of whitelisting and ad-recovery related parameters and transportation cost, then the firm's strategy adoption depends on the proportion of ad-block non-users and advertising revenue parameters.

Proposition 1. *There are regions in the parameter space where both publishers adopt a benchmark strategy or both choose to adopt an ad-recovery strategy in equilibrium. Specifically, both publishers adopt a benchmark strategy when the advertising revenue parameter is relatively lower (i.e., $\gamma \leq \gamma_1$). In contrast, when the advertising revenue parameter is relatively high (i.e., $\gamma > \gamma_2$) and the proportion of ad-block non-users is relatively low (i.e., $\alpha < \alpha_1$), both publishers adopt an ad-recovery strategy in equilibrium. There also exists an equilibrium in which both firms may choose whitelisting strategies in equilibrium. This happens when both the value of advertising revenue parameter is in the intermediate range (i.e., $\gamma_3 < \gamma < \gamma_4$) and the proportion of ad-block non-users exceed a threshold (i.e., $\alpha > \alpha_2$)* [9].

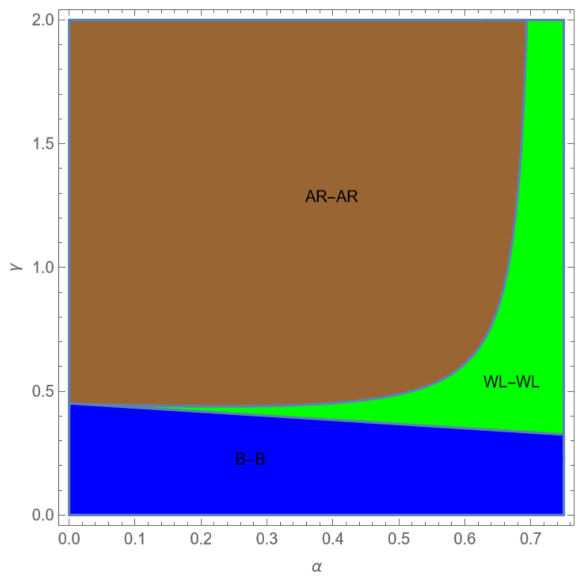

Figure 4 Equilibrium characterization in the α-γ space

The intuition for this result can be easily understood by comparing the scenarios in which the advertising revenue parameter is lower vs. higher. When the advertising revenue parameter is lower, firms generate revenues primarily through subscription fees. Therefore, firms benefit by adopting a benchmark strategy in equilibrium. As the advertising revenue parameter increases, each firm has an incentive to shift to a whitelisting or an AR strategy and this choice is governed by the proportion of ad-block non-users and the extent of advertising revenue. When the ad-block non-users is relatively higher, it implies that the firm loses advertising revenues only from fewer ad-block users, so it prefers to use a whitelisting strategy. In contrast, when the proportion of ad-block non-users is relatively lower and the advertising revenue parameter exceeds a threshold,

[9] The expressions for the thresholds are given in the Appendix

firms circumvent ad-blocking using the AR strategy in order to generate revenue from greater proportion of consumers.

5.2. Equilibrium characterization in the $\beta - \rho$ space

In this subsection, we consider the scenario in which the proportion of consenting ad-block users and the advertising revenue parameter (corresponding to adblock users who are exposed to advertising) are two key parameters that might vary in the market, but choose specific values for other key parameters.

Given that each publisher could choose among three potential strategies, we solve the 3X3 strategy space to derive equilibrium strategies for each firm as the parameters β and ρ change. We have chosen specific values for the proportion of ad-block non-users and the disutility due to ads parameters. Publishers can typically obtain such information by conducting surveys among target consumers. Figure 5 reveals the equilibrium regions for the 3X3 case with respect to the proportion of consenting ad-block users and the advertising revenue parameters.

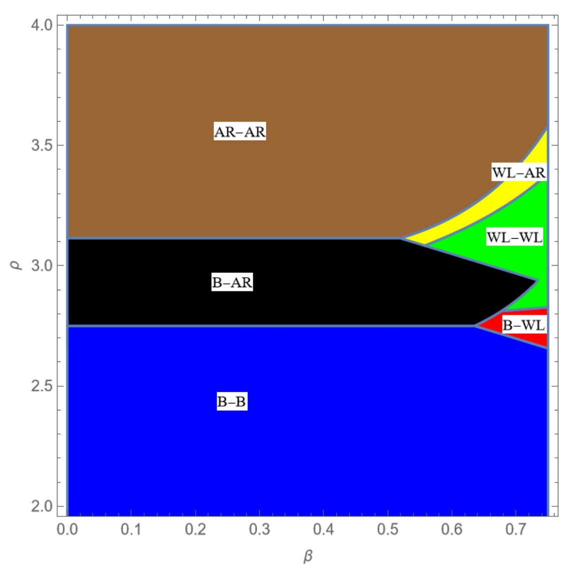

Figure 5 Equilibrium characterization in the β-ρ space

Although Figure 5 is instructive and highlights the various equilibria, we choose narrower regions of the strategy space to develop the propositions and the intuitions for our propositions. We first focus on the region of the parameter space where the advertising revenue parameter (ρ) exceeds a threshold. This allows us to study publishers' strategy of choosing between whitelisting and ad-recovery. Subsequently, we focus on the region of the parameter space such that β is below a threshold and we study publishers' strategy choice between benchmark and ad-recovery stratgies.

5.2.1. Equilibrium characterization in whitelisting and ad-recovery strategy space

In this case, we fix the values of the other parameters. Our analysis of the conditions in which a symmetric or asymmetric equilibrium holds, reveals two symmetric equilibria: one when both publishers use whitelisting and another in which both platforms use ad-recovery, as we detail in Proposition 2.

Proposition 2. *In the β-ρ parameter space, there exists regions in which both publishers adopt a whitelisting strategy. This is more likely when advertising revenue parameter is relatively low and the proportion of consenting ad-block users is relatively high (i.e., $\rho < \rho_1$ and $\beta > \beta_1$). In contrast, when the value of advertising revenue parameter is high and the proportion of consenting ad-block users is relatively low, both firms benefit from an ad-recovery strategy (i.e., $\rho > \rho_2$ and $\beta > \beta_2$).*

The intuition for this result can be easily understood by comparing the scenarios in which the proportion of consenting ad-block users is low vs. high. When the proportion of consenting ad-block users is high, publishers will get sufficient revenues from advertising and subscription fees without imposing a technology-driven solution to circumvent ad-blocking and lowering consumer utility. In this scenario, publishers adopt whitelisting strategy because such a strategy does not lower consumer utility as much and firms are able to extract the higher consumer surplus through greater subscription fees. However, if the proportion of consenting ad-block users is relatively lower, both publishers will adopt an ad-recovery strategy. In this scenario, given the higher advertising revenue parameter, it provides greater incentives for publishers to generate greater advertising revenues from as many consumers as is possible and the AR strategy allows publishers to get profits from higher advertising revenues and subscriptions fees.

We also identify regions in the parameter space in which ex-ante identical firms will adopt asymmetric strategies which we highlight in our next proposition:

Proposition 3. *Publisher 1 adopts a whitelisting strategy and publisher 2 adopts an ad-recovery strategy for intermediate values of the advertising revenue parameter (i.e., $\rho_3 < \rho < \rho_4$) and when the proportion of consenting ad-block users is in the intermediate range (i.e., $\beta_3 < \beta \leq \beta_4$).*

We start with a scenario where the proportion of consenting ad-block users is high, leading to both firms using whitelisting strategy. As the proportion of consenting users starts to decrease, publisher 2 adopts an ad-recovery strategy because it will receive benefit due to high subscription and advertising revenue from a greater proportion of ad-block users. However, publisher 1 continues to prefer the whitelisting strategy, because lower subscription fees, attracts a greater proportion of ad-block non-users leading to higher revenues. Figure 6 reveals the equilibrium regions with respect to the proportion of consenting ad-block users and advertising revenue parameters.

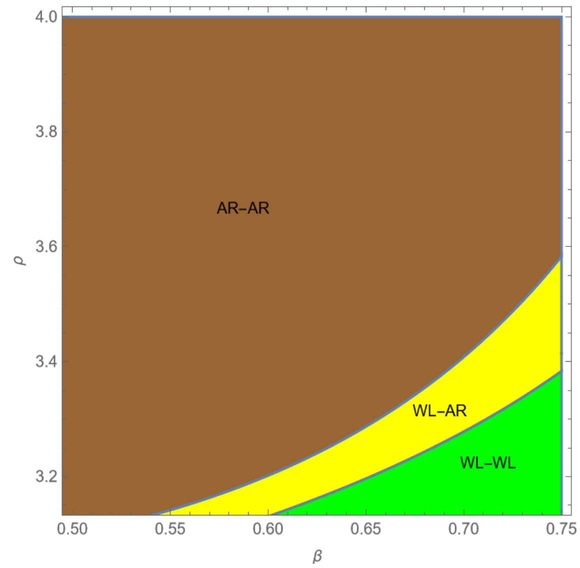

Figure 6 **Equilibrium characterization in the Whitelisting-Ad-recovey strategy space**

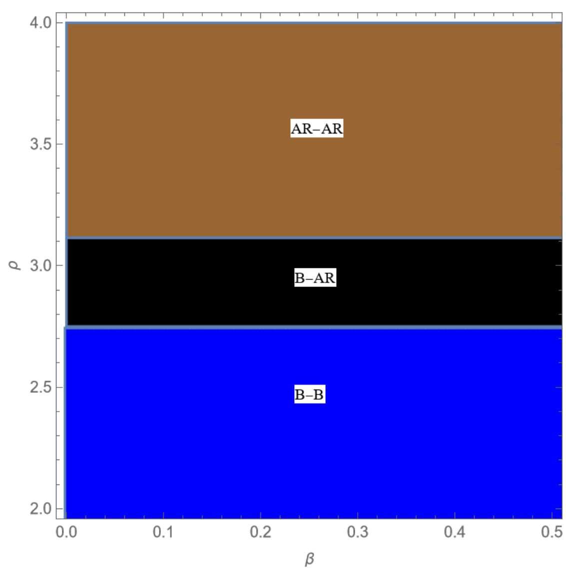

Figure 7 **Equilibrium characterization in the benchmark and Ad-recovery strategy space**

5.2.2. Equilibrium characterization in benchmark and ad-recovery strategy space Next, we consider the conditions in which the publishers may adopt benchmark or ad-recovery strategies. Again, our analysis focuses only on the proportion of consenting ad-block users and the advertising revenue parameters.

PROPOSITION 4. *Both publishers adopt the benchmark strategy when the value of advertising revenue parameter is low (i.e., $\rho \leq \rho_5$). In contrast, both publishers adopt an ad-recovery strategy when the value of the advertising revenue parameter is high (i.e., $\rho > \rho_6$).*

The intuition for this result can be easily understood by comparing the scenarios in which advertising revenue parameter is low vs. high. When the advertising revenue parameter is relatively low, publishers will get sufficient revenues primarily from subscription fees without imposing a technology-driven solution to circumvent ad-blocking and lowering consumer utility. In this scenario, publishers adopt benchmark strategy because such a strategy does not reduce consumer utility due to advertising annoyance. However, if the advertising revenue parameter is relatively higher, both platforms will adopt an ad-recovery strategy. In this scenario, given the higher advertising revenue parameter, it provides the incentive for publishers to generate advertising revenues from as many consumers as is possible and the AR strategy allows publishers to get profits through higher advertising revenues and subscriptions fees.

Our analysis also reveals an asymmetric equilibrium which we discuss in the following proposition.

Proposition 5. *Publisher 1 adopts a benchmark strategy and publisher 2 adopts an ad-recovery strategy for an intermediate range of the advertising revenue parameter (i.e.,* $\rho_6 > \rho > \rho_7$*).*

We start with a scenario where the advertising revenue parameter is relatively low leading to both firms using benchmarking strategy. As the advertising revenue parameter starts to increase, publisher 2 adopts an AR strategy because it will be able to generate greater advertising revenue. However, publisher 1 continues to prefer the benchmark strategy, because it generates revenue primarily through a lower subscription fee. Figure 7 reveals the equilibrium regions with respect to the proportion of consenting ad-block users and advertising revenue parameters.

6. Model Extensions

We consider two specific extensions to the base model.[10]

6.1. Differential ad revenues under whitelisting and ad recovery strategies

In our main model, we consider the ad revenue parameters to be identical under both whitelisting and ad recovery strategies. Thus, we highlight our equilibrium outcome using a more parsimonious model. However, in practice, advertising revenue parameter in whitelisting and ad recovery scenarios could be different. In this extension, we use two distinct parameters to capture advertising revenues in the two scenarios. We use ω as an additional parameter, instead of γ, to capture advertising revenue from Adblock users in the ad recovery scenario. With $\omega = 1/10$ and $\gamma = 1/4$, we verify that the pattern of the results is consistent with our main model.

[10] The analyses for these model extensions are given in the Appendix.

6.2. Distinct utility functions for consenting and objecting adblock users in the ad recovery case

In our main model, we incorporate identical utility functions for consenting and objecting adblock users in the AR case. This assumption makes the model parsimonious. Furthermore, from a more practical perspective, when a publisher uses ad recovery, by design, they cannot separate consenting/objecting users. All consumers will see the ads and the consumers do not have an option to give consent. In this extension, we consider an augmented model in which we utilize distinct utility functions for the two types of consumer in the ad recovery case. Our analysis shows that our results are qualitatively replicated with the augmented model.

7. Summary

Increasing ad-block usage has a negative impact on the profitability of digital publishers. This study considers three possible solutions that might improve publisher profitability: subscription-based (benchmark) strategy, whitelisting, and ad-recovery. We capture the effect of the various important, realistic publisher and consumer factors on firms' equilibrium digital advertising strategies. The digital publishers may adopt any of these three strategies based on the proportion of ad-block non-users, consenting ad-block users, disutility due to ads, and the whitelisting or ad-recovery advertising revenue parameters. Specifically, ex-ante symmetric firms may decide in some conditions to follow asymmetric strategies; we also find conditions in which they may choose to adopt the benchmark strategy.

We recognize that the digital advertising landscape is rapidly evolving. In the modeling approach used in extant research (Aseri *et al.* 2020; Despotakis *et al.* 2021), subscription fees and advertising are two distinct revenue sources that aren't considered simultaneously by digital publishers. In contrast, we model the scenario in which advertising is used in conjunction with a subscription model. Thus, the insights from our paper are more useful in settings in which a subscription-based publisher (e.g., Forbes.com) is considering advertising exposure to its existing subscribers to boost revenues. Forbes.com has previously explored strategies such as whitelisting and ad-free access, but now uses subscription-based access with an ad-light experience.

7.1. Managerial implications

Our research has crucial managerial implications. Our findings provide direction to digital marketing firms on the optimal strategy based on two critical metrics: (i) Proportion of consenting ad-block users and (ii) Advertising revenue parameter. Our propositions suggest that the publishers can adopt a benchmark, AR, or whitelisting strategy based on the proportion of consenting ad-block users. If it is low and the advertising revenue parameter is high, publishers can adopt an AR strategy. However, if the advertising revenue parameter is low, publishers can adopt a whitelisting strategy. If the proportion of consenting ad-block users is medium, publishers can focus on the advertising revenue parameter. If the advertising revenue parameter is medium, publishers should adopt a strategy that complements the competitor's strategy. If it is low, publishers should adopt the benchmark strategy. In contrast, publishers should adopt an AR strategy if the advertising revenue parameter is high. Figure 8 shows a simple way to understand actionable strategies based on our analysis.

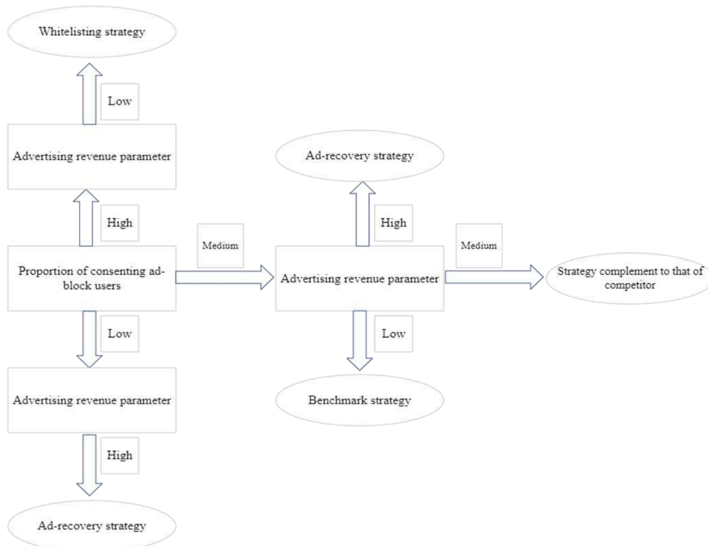

Figure 8 Managerial Implications Flowchart

7.2. Directions for future research

Our game-theoretic model makes a few simplifying assumptions, such as that all consumers subscribe to one of the two digital publishers. In reality, some consumers opt-out of subscribing to either publisher, especially those located closer to the center of the distribution. In such a case, each firm acts as a local monopolist and avoids competition. Related to this, we assume that each consumer subscribes to one and only one media publisher (single homing). But a fraction of consumers could make purchases from both firms. A model that integrates these considerations may be more realistic, and such multihoming could mitigate publisher competition, but we also anticipate that such a model may generate qualitatively similar insights to those we obtain in this paper.

We also assume a uniform distribution of consumers to ensure that our equilibrium strategies are not driven by the shape of the consumer distribution. But in many media markets, a bimodal distribution may arise, with more consumers concentrated around each media publishers' offerings. Studying equilibrium firm strategies with consumer distributions derived from data could be another possible avenue for future research.

Our focus has been on competition between digital publishers, and we do not endogenously derive the advertisers' equilibrium decisions. But in digital markets, advertiser strategies could be crucial. Augmenting the model to account for advertiser strategies could be an interesting avenue for further research. We highlight the effect of ad-blockers on firm profitability and equilibrium strategies. One could further extend the analysis to understand the impact of ad-blockers on consumers' purchasing behavior and welfare to build on the extant empirical research in this context (Todri 2022). Since our focus was on understanding the strategic forces driving competitive outcomes, we utilized a duopolistic competition model to study the unique dynamics prevalent in the digital media industry. Future research could also study optimal firm strategies in oligopolistic settings with more than two competing firms. Our model could also provide a starting point for deriving novel solutions to circumvent ad-blocking, which in turn could create new avenues for future research. Further, we believe that empirically testing the normative guidance provided by our model is a worthwhile endeavor.

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