Do You See What I See? Ad Viewability and the Economics of Online Advertising[*]

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Abstract

Between 40% and 50% of online ads served by publishers are actually never seen by Internet users, resulting in ineffective branding campaigns and a considerable waste of money for advertisers. In reaction, more and more advertisers use technologies to measure the viewability of advertising campaigns on publisher websites. This paper provides the first comprehensive economic analysis of the impact of the adoption of such technologies on the economics of online advertising. We construct a two-sided market model for advertising where publishers manage their website to attract Internet users and advertisers. We show that the adoption of ad viewability technology affects the number of viewable ads displayed by publishers, the price of ads and publisher profits, and user experience. We finally analyze the total welfare impact of ad viewability and examine how ad-blockers constrain publishers from both sides of the market.

Key Words: Online advertising; Ad viewability; Ad effectiveness; Ad-blockers.
JEL Classification: L82; L86; M3.

1   Introduction

Digital media are grabbing more and more advertising spending. According to eMarketer, the UK became in 2015 the first country in the world where digital media took a 50% share of advertising spending.[1] In the US, also according to eMarketer's forecast, online ad spending will surpass TV ad spending in 2017 for a total of about $77 billion, driven mostly by mobile that accounts for more than 50 per cent of total online digital spending (eMarketer, Digital Ad Spending to Surpass TV Next Year, 2016).

The rapid development of mobile usage alone does not explain the growth of online advertising spending. Programmatic advertising and the ability to collect data on consumers and ad

impressions[2] allow advertisers to automate the buying and selling of ads and to achieve an effective personalized targeting of audiences. They are therefore in a better position with respect to the TV and print media to estimate how successful a particular ad is in driving a purchase decision or in raising brand awareness over time.

However, the promises of online advertising in the case of branding campaigns that rely on serving millions of ads to Internet users are today challenged. Indeed, the promises rest on the assumption that the served ad impressions are *viewable* by Internet users, i.e. "contained in the viewable space of the browser window, on an in-focus browser tab, based on pre-established criteria such as the percent of ad pixels within the viewable space and the length of time the ad is in the viewable space of the browser" (Internet Advertising Bureau Europe, Viewable Impressions, 2015). Viewable in this context simply means that Internet users have the opportunity to see the ad, regardless of whether they have actually seen it.

This simple assumption is however challenged by companies such as Google, comScore, Nielsen, etc., that daily analyze billions of impressions from campaigns over thousands of publishers: most of served impressions are actually never seen by Internet users. A well-known commented statistic released by comScore in 2013 indicates for example that half of the publishers' inventory is not seen by Internet users.[3] In 2016, as the Section 2 of this paper will show, the proportion of ads being seen by people in most of the countries around the world is still relatively low, between 40% and 50%.[4] The most popular social network website Facebook that attracts the major part of ad investments is also subject to criticisms: "Facebook ads are far less viewable than people [advertisers] were expecting" (Business Insider, December 28, 2016).

Ad viewability became therefore in recent months one of the top priorities on the agenda of advertisers (Wall Street Journal, "It's How Long Ads Are Viewed That Really Matters", February 4, 2016).[5] The concerns are perfectly understandable. In the case of branding campaigns, advertisers pay for ads by the number of impressions that a publisher has *served* (this trading

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[2]The display of an ad in a page view is called an ad impression.

[3]Different reasons explain why ad impressions are not viewed by Internet users. Firstly, the browsing behavior encompasses many possibilities to avoid the sight of an ad such as scrolling the page, resizing the window, using an ad blocker, etc. Secondly, publishers may adjust the viewability of ads to preserve user experience. In Section 2 of this paper, we review some of the main factors that could explain the low level of ad viewability.

[4]Ad viewability is not a new issue in media but because of the size of online markets, the problem has definitely grown and becomes a serious threat for the advertising industry. For print media, the likelihood that a reader actually sees an ad on a given page is not precise (except with QR codes). Regarding television, a commercial is supposed to be seen as soon as there is a person in a room with a TV set on. The measure is not perfect (people walking out of the room during commercial breaks, fast-forwarding through recorded ads, etc.), but the opportunity for exposure exist.

[5]During the last edition of the annual Digital & Social Media Conference in 2016, the CEO of the US Association of National Advertisers touched on media's "Big Four" concerns: ad blocking, ad fraud, media transparency and viewability/measurement.

currency is called "Cost-Per-Mille" (CPM)).[6] But as half of ads purchased by advertisers are never seen by Internet users, they potentially waste half of their budgets every time they pay for display ads. Consequently, more and more advertisers demand to pay only for *viewable* impressions and not for served impressions. A new trading currency is therefore emerging: the viewable CPM (vCPM) that prices ads by the number of impressions that can be viewed by Internet users, instead of just being served.

The adoption of technologies to measure the viewability of ads served by publishers, and subsequently the shift towards a new trading currency, may entail serious changes in the economics of online advertising. To begin with, publishers need to redesign their websites[7] to make ads more viewable and satisfy advertisers' requests to remain competitive. A large part of the current inventory with very low viewability could therefore not be sold anymore, or at a lower rate, which should decrease the revenue streams of publishers. But as publishers may have less inventory to sell, some rates might also increase (premium inventory), affecting in turn advertisers competition for high ad viewability.[8] Furthermore, as websites are redesigned to enlarge the amount of space for viewable ads to the detriment of editorial contents, the audience could shrink and the price of ads drops accordingly. There is therefore a trade-off for publishers to be found between user experience and revenues from online advertising.

The objective of this paper is to analyze how the adoption of an ad viewability measurement technology can affect the economics of online advertising. More precisely, we want to answer the following question: will Internet users, publishers and advertisers be better off with the adoption of an ad viewability measurement technology?

To answer this question, we propose a two-sided market model where competitive publishers display an editorial content to attract Internet users on one side and advertisers on the other side. More precisely, we develop a model of "competitive bottlenecks" à la Armstrong (2006), where Internet users choose to join a single publisher platform (single-home) and advertisers wish to join all publishers (multi-home). Publishers are only financed by advertisers (no subscription) who pay them to display ads that are perceived by Internet users as a nuisance. We compare two situations. In the first situation, advertisers do not have a technology to measure the viewability of ads on the publisher website. They just anticipate a global level of ad viewability. In the second situation, advertisers have a technology to precisely measure

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[6]Performance-based online campaigns use another well-known metrics which is the Click-Through-Rate, i.e. the percentage of ad impressions that have lead to clicks. In this paper, we only focuses on branding-based online campaigns.

[7]The Guardian is a typical example. The British media website redesigned his website to render more visible ad placements (The Guardian, Optimising for viewability, 2016).

[8]According to Quantcast in 2016, inventory with viewability above 75 per cent can be up to two times more expensive than the average (Quantcast, The Road to Viewability, 2016).

ad viewability.

We find that the adoption of a technology to measure ad viewability tend to increase the number of viewable ads displayed by publishers, the prices of ads and publisher profits, but in return degrades user experience. To sum-up, the advertising industry (publishers and advertisers) is better-off with the adoption of ad viewability to the detriment of Internet users. Overall, the welfare analysis indicates that the total welfare can be greater with viewability technology when the competition between publishers is not too intense and the nuisance cost of ads is not too high.

The drop in user experience due to a higher ad viewability can be however restored by adopting ad-blockers. In this case, publishers are constrained by both sides of the market: on the one hand, they must increase the number of viewable ads to satisfy advertisers' requests, and on the other hand, they need to lower the number of viewable ads to discourage people from installing ad-blockers. Extending the initial model, we find that the final impact of ad-blockers on total welfare depends on the relative cost of ad-blockers compared with the nuisance cost of viewable ads. When the cost of ad-blockers is greater than the nuisance cost of viewable ads, the situation is equivalent to a situation without ad-blockers. However, when the cost of ad-blockers is lower than the nuisance cost of viewable ads, publishers are forced to reduce the viewability of ads to account for user experience, whether or not there is a viewability technology on the market.

This paper contributes to the economics and management literature on online advertising on two points. Firstly, this paper provides the first comprehensive economic analysis of the thorny issue of ad viewability largely debated in the advertising industry but absent from the academic research. Secondly, our paper enriches the literature on Internet media (Peitz and Reisinger, 2016), and online ad effectiveness (Goldfarb and Tucker, 2011; Manchanda et al., 2006; Lambrecht and Tucker, 2013; Goldfarb and Tucker, 2015). In previous contributions, consumers like ads when they are targeted (de Cornière, 2016; Johnson, 2013), or dislike ads when they are too much intrusive (Ghose and Yang, 2009; Agarwal et al., 2011; Rutz and Bucklin, 2011; Blake et al., 2015), resulting respectively in a higher or lower demand of Internet users. But as Section 2 of this paper will show, there are many reasons for which targeted or intrusive ads are never seen by Internet users, regardless of whether they like ads or not. Taking ad viewability into account is therefore crucial as ads that are not or partially seen are still paid by advertisers and do not have any chance to reach consumers and to be effective.

The remainder of the paper is structured as follows. In Section 2, we first define the concept of ad viewability and provide some market insights. In Section 3, we review the academic lit-

erature. In Section 4 we present the setup of the model. In Section 5, we analyze a competition between publishers. In Section 6, we calculate the impact of ad viewability on total welfare. In Section 7, we extend the model to account for ad-blockers. Section 8 presents our conclusion.

2   Ad Viewability: Definition and Market Insights

Online advertising requires the Internet to deliver marketing messages to promote a brand to consumers, to sign up for membership or to make purchases. To do so, marketers can use many types of ads (or creatives) such as banners, videos, etc., on desktop (personal computer) and mobile environments.

Different participants are involved in online advertising such as the publisher who places ads into his online content, the advertiser, who provides the ads to be displayed on the publisher's website, and potentially many other intermediaries (ad networks, data management platforms, media agencies, etc.). With the recent development of advertising technologies (adtech), publishers and advertisers manage less and less manually the ads on websites. Ads are served automatically by ad servers. To measure how often impressions are delivered to Internet users, publishers, advertisers and ad servers mostly use tags, a piece of HTML or JavaScript code placed on each creative to provide a complete view of campaign delivery. The tags are usually provided by a viewability vendor.

The mission of a viewability vendor is to measure the number of served and viewed impressions. The number of served impressions is just the number of tagged impressions. But not all served impressions are necessarily measured by vendors because of network failures and invalid (non-human) traffic issues.[9] For example, some ads can be tagged but not correctly delivered or fraudulently served to spiders and bots to manipulate legitimate ad serving. As a consequence, a second measure named the "number of measured impressions" is important to consider as it cleans up invalid traffic and non-served impressions. Finally, ads can be correctly served and measured but not seen by users for several reasons. For example, the ad can be served below the fold (i.e. outside the viewable browser space) far down at the bottom of a web page. Consequently, "a served ad impression can be classified as a viewable impression if the ad is contained in the viewable space of the browser window, on an in focus browser tab, based on pre-established criteria such as the percent of ad pixels within the viewable space and the length of time the ad is in the viewable space of the browser" (Media Rating Council (MRC), Viewable Ad Impression Measurement Guidelines (Dekstop), 2014). The rate of ad viewabil-

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[9]One of the largest studies was conducted and published in December 2014 by the Association of National Advertisers (ANA) in the US and an online fraud detection firm, White Ops. According to the numbers, 11% of display and 23% of video impressions were bot-driven.

ity is therefore the ratio of the number of viewable impressions over the number of measured impressions.

The pre-established criteria mentioned in the quotation above have been formally defined for different ad formats by the MRC in 2014 and 2016. A display ad is considered viewable when 50 per cent of an ad's pixel are in view on the screen (on an in-focus browser tab on the viewable space of the browser page) for a minimum of one continuous second. This standard is valid for most banners but has been extended for large ad size banners: a viewable impression may be counted if 30 per cent are in view for a minimum of one continuous second. Regarding videos, it is required that 50 per cent of an ad's pixel are in view on the screen and that two continuous seconds of the video are played. Finally, regarding mobile ads, the MRC has issued its first set of guidelines last April 2016 and recommends to treat smartphone (excluding apps) and desktop ads the same: 50 per cent of an ad's pixel are in view on the screen for a minimum of one continuous second.[10]

Since 2012, numerous studies conducted by viewability vendors have measured the viewability of publishers' ad inventories. All studies conclude that a significant proportion of delivered ad impressions are never visible to the end user, resulting in relatively low viewability rates. comScore has been the first viewability vendor to conduct such analysis over thousands of campaigns spanning a mix of global advertisers who ran their ads across a variety of publisher sites and ad networks from May 2012 through February 2013. The key finding was that 54 per cent of display ads do not have the opportunity to be seen by a consumer (comScore, Viewability Benchmarks Show Many Ads Are Not In-View but Rates Vary by Publisher, 2013). Since this first and well commented statistic, other studies have confirmed this finding even if significant increases have been observed in countries like France more recently: +7.4 points between Q4 2015 and Q1 2016, and +13.1 points in one year (Integral Ad Science report: Q1 2016 International Media Quality Report). In addition, high viewability inventories are relatively rare. Quantcast for example finds that "there is a very limited supply of very high viewability inventory, with viewability above 80% constitutes just two to three percent of all RTB inventory in Europe (Quantcast, Viewability: What Smart Marketers Need to Know, 2016)." In the specific case of videos, Google conducted in 2015 a study of the video advertising platforms, including Google, DoubleClick, and YouTube (Google, Are Your Video Ads Making an Impression?, 2015). He finds that 54 per cent of the videos are viewable on the web across desktop, mobile and tablets (not including YouTube).

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[10]As indicated, the MRC standards value a one second impression the same as a five second impression. As a consequence, alternative trading currencies such as the 'Cost Per Hour' are being experimented by large publishers such as The Financial Times to value ad exposure time as a key dimension (Sanghvi, 2015).

Ad viewability also varies significantly across countries. According to Meetrics, another viewability vendor, the viewability rate for digital display ads in France stood at 65 per cent in Q4 2015, compared with 50 per cent in the UK, the lowest viewability rate than for any other country in Europe tracked by the firm (Meetrics, Viewability Benchmark, 2016). In the case of videos, Google also reports that viewability drastically varies between countries from 86 per cent for Russia for example to 54 per cent for the United States (Google, Are Your Video Ads Making an Impression?, 2015).

The gaps in viewability between countries may be due to several reasons. To begin with, the technologies used by viewability vendors differ in many ways as they do not use the same technologies to control for invalid traffic issues for example. In 2016, the syndicate of internet sales (SRI) as well as the association of media agencies (UDECAM) in France commissioned the CESP to review and compare eight different viewability measurement solutions, namely Adloox, Adledge, comScore, Integral Ad Science, Meetrics, MOAT, and two tools natively implemented in platforms (AppNexus and Google). Based on tests made by four major viewability vendors about ads placed above the fold on well-known websites,[11] CESP has reported discrepancies about the average rate of viewability between the four actors up to 36 percentage points (CESP, Mission visibilité de la publicité digitale, 2016).

Next, the publishers' strategies about the placement of ads within webpages and websites may considerably affect the viewability of ads. This is one of the first conclusions drawn by comScore early in 2013. Regardless of the publisher type, the reports emphasized that it is important to evaluate the individual publisher or network on its own merits. "The wide viewability range suggests that regardless of the publisher type, there are some members of the sell-side of the market who are delivering very strong in-view rates and others who are falling short on their intention to deliver valuable ad inventory to advertisers." For example, for premium websites having an average CPM above USD 5.00$ and 100,000 in monthly ad revenue, the viewability ranged between 10 and 80 per cent.

Ads placed at different page depths are therefore central for viewability as ads have different likelihoods of being viewed by users. Traditionally, above the fold (ATF) has been considered as the top location by advertisers because the ad is supposed to be directly viewable in a browser window when the page first loads. But recent studies tend to refute this common belief. Quantcast, in 2015, shows for example that "ATF is a poor proxy for viewability, with one exchange at only 44% viewability rate on ATF inventory" (Quantcast Report: High Viewability Expectations Can Harm Campaign Performance). Several reasons may explain this result: first, users

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[11]Above the fold is the upper half of the front page of a webpage.

quickly scroll down to reach their desired destination, and second hyperlinks do not always link to the top of a page. In this respect, the format of the ad may help publishers and advertisers to attract consumers.

Viewability also varies between static banner ads and dynamic rich media. Sizmek Research analyzed in 2016 viewable data from more than 240 billion measured impressions from more than 840,000 ads and 120,000 campaigns served in 74 countries and six continents to more than 22,000 publishers and 43 programmatic partners from January 1 to December 31, 2014 (Sizmek, Viewability Benchmarks, 2016). Sizmek notes that "flash rich media ads were 18% more likely to be seen than standard banners. This was most pronounced in North America, where rich media was 29% more likely to be seen than standard banners." This finding is also confirmed by an Adform study in 2015 that found that "rich media display ads performed especially well in the UK, with such ads on its platform seeing a 71.2 per cent viewability rate. In particular, those ads saw some of the best engagement rates and times compared with other countries covered in the study." Moat analytics finally also confirms that bigger ads are more likely to be seen than smaller ones.

Ad viewability also varies by device. For example, the same report by Sizmek Research shows that mobile is generally more viewable than desktop sizes to the exception of Flash rich media. The gaps are substantial and up to 31 points of percentage for HTML5 standards banners in desktop and mobile environments. This finding is also corroborated by Google about video ads. The study reports that video ads are significantly more viewable on mobile (83 per cent, excluding apps) and tablet (81 per cent) than on desktop (53 per cent) (Google, Are Your Video Ads Making an Impression?, 2015).

To conclude this section, it is worth noting that the lack of ad viewability is not only a big waste of budgets for advertisers as indicated in Introduction, but also a matter of brand and sales impact. For example, a recent study conducted by comScore, Millward Brown & Kantar Worldpanel in April 2016 finds evidence that ads in view for longer periods increase both awareness and purchase intent metrics compared to those in view for less time (comScore, Millward Brown & Kantar Worldpanel, 2016, How Delivery and Brand/Sales Effectiveness Can Drive Digital Advertising ROI in a Cross-Media World). Understanding the issue of ad viewability is therefore a key challenge for advertisers, but also for publishers who need to demonstrate the quality of their inventory.

3   Related Literature

Very few academic papers have been devoted to the issue of ad viewability even though this topic is of special importance for the advertising industry. To the best of our knowledge, two papers only have been published in computer science and only one in advertising research.

The objective of the two papers in computer science is to better understand and improve ad viewability. For example, Wang et al. (2015) propose a model supposed to better predict the viewability of any given scroll depth for a user-page pair compared with other systems. In particular, they identify two features such as user geo-location and device type that have a significant impact on the maximum scroll depth. Zhang et al. (2015) investigate what percentage of viewable pixels and length of exposure time may encourage users' ad recall. They find that 75% of the ad's pixels being shown at least two seconds in the active page insure the ad to be seen by users.

Regarding research in advertising, Flosi et al. (2013) use a 2-million-person panel and census server data (cookie data) provided by comScore in 2013 to understand the extent to which ads are delivered to the right target audience. Several empirical generalizations are proposed from the study findings about cookie-related issues, viewability, geo-targeting, and non-human traffic (fraud). For the authors, viewability is a critical component of campaign validation. Several findings are commented. Firstly, the authors find that "on average, 30 percent to 37 percent of all served advertising impressions in the United States, Europe, and Canada were never actually viewable by the end user." Secondly, viewability rates vary significantly across sites and campaigns and, finally, the prices of ads are not correlated to viewability rates. This last finding may be today surprising but it is worth noting that, at the time of this study, the technologies to measure ad viewability had not yet been adopted by advertisers and publishers.

Despite the lack of research dedicated to ad viewability, online advertising has been largely studied in economics and management science (Anderson and Coate, 2005), especially with the popularity of two-sided markets (Caillaud and Jullien, 2001, 2003; Rochet and Tirole, 2002; Anderson and Gabszewicz, 2006). An excellent survey on the evolution of the online advertising business is provided by Evans (2009). The author describes how online advertising has transformed media businesses and allowed pure Internet players to compete with traditional firms. New technologies emerged allowing a better match between advertisers and consumers, transforming in turn online advertising into a reliable source of revenue. A more recent contribution by Anderson and Jullien (2016) surveys recent models of advertising in media markets developed around the concept of two-sided markets. Our paper does not directly contribute to the theory of two-sided markets but simply relies on this powerful tool to understand how

publishers manage to coordinate the two sides of the market, Internet users and advertisers.

Our paper pertains more precisely to the relatively new literature on the effectiveness of online advertising in management and marketing science.[12] Manchanda et al. (2006) measure the impact of banner advertising on purchasing patterns on the Internet. The results show that the number of exposures, number of websites, and number of webpages all have a positive effect on repeat purchase probabilities, whereas the number of unique creatives has a negative effect. Goldfarb and Tucker (2011) explore the factors that influence the effectiveness of online advertising. They find that matching an ad to website content and increasing an ad's obtrusiveness independently increase purchase intent. However, in combination, these two strategies are ineffective. Lambrecht and Tucker (2013) measure and compare the effectiveness of dynamic retargeting (information from internal browsing data from consumers who previously visited the advertisers' website) to simple generic brand ads. They find that dynamic retargeting is less effective than generic ads. Goldfarb and Tucker (2015) examine how the memorability of banner advertising changed with the introduction of new standard formats. They find evidence that for most ads, ad effectiveness falls as the use of standard formats rises. Finally, Andrews et al. (2016) investigate how hyper-contextual targeting with physical crowdedness, i.e. the degree of population density per unit area, may affect consumer response to mobile ads. Based on a sample of mobile phone users that mobile operators can target in subway trains, they find that commuters in crowded subway trains are about twice as likely to respond to a mobile offer by making a purchase vis-à-vis those in non-crowded trains.

Our paper particularly contributes to this literature by examining a further dimension of ad effectiveness: ad viewability. Viewability is a crucial component of ad effectiveness as an ad that is not seen or only partially does not have any chance to reach consumers. In brief, the higher the ad viewability, the higher consumer attention and ad recall. In the aforementioned studies, banner ads and other ad formats are supposed to be always viewed by Internet users. This implicit assumption is contradicted by numerous studies documented in Section 2.

4   Online Ad Viewability: Model SetUp

We construct a model that involves three types of agents: Internet users, advertisers/media agencies[13] and publishers.

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[12]Ad effectiveness is a great concern for marketers with advances in technologies; see for example Ghosh and Stock (2010) for a case related to television with the digital video recorder.

[13]To keep the model as simple as possible, advertisers and media agencies that represent the same interests are grouped altogether.

Publishers offer the same quality of editorial content[14] and manage their website (or platform) to attract Internet users on one side and advertisers on the other side. This is therefore a classical two-sided market in which two groups of agents interact through a platform. We assume, for the sake of simplicity, that publishers are only financed by advertising (and not by subscription). Advertisers pay therefore publishers to display ads and attract consumers that are interested in their products. Advertisers are concerned about paying for ads that are seen by users and not just served, as non-viewable ads do not raise brand awareness and do not promote the visibility of the products company.

We analyze two situations. In the first situation, advertisers do not have a technology to measure the viewability of ads on the publisher website. They just anticipate a global level of ad viewability. In the second situation, advertisers have a technology to measure ad viewability. We can therefore compare the impact of the adoption of a technology to measure ad viewability on the demands and profits of Internet users, publishers and advertisers.

We compare the two situations - with or without the adoption of an ad viewability technology - in the case of a competition between symmetric publishers to attract Internet users and advertisers.[15] This framework allows to understand how publishers may compete in advertising nuisance to attract a larger audience and charge higher prices. General news websites such as the *Financial Times* or the *Wall Street Journal* operate in a competitive environment and also choose their advertising and viewability level accordingly. We develop a model of "competitive bottlenecks" inspired from Armstrong (2006), where Internet users choose to join a single platform (single-home) and advertisers wish to join all platforms (multi-home).

Before analyzing the two situations, we describe in more details the preferences and objectives of Internet users, advertisers and publishers as well as the timing of the game.

Publishers. Publishers operate on the market as platforms and manage their websites to display ads. To maximize his profits, a publisher k ($k \in \{i, j\}$) chooses the price of ad p_k, the level of ad viewability b_k ($b_k \in [\underline{b}, \overline{b}]$), and the number of ads purchased by advertisers a_k to be displayed on the website k. This assumption is consistent with what we reported in Section 2: a publisher (like The Guardian for example) may design his website to ensure that advertisements are more visible to users. In a sense, the publisher can determine the level of viewable ads on his website. The editorial content displayed on the publisher website k has a quality denoted q_k, which is

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[14]We do not consider a quality investment game where publishers may invest in quality content to increase the level of ad viewability and charge higher prices. Although interesting, this approach would not change the main mechanisms analyzed in this paper regarding the impact of ad viewability.

[15]We also developed the same model with only one publisher in a monopoly situation. The results are very close to those of the competition game and are not reported in the paper. They are however available upon request.

exogenous. The profit function of a publisher k takes the following form:

$$\Pi_k = a_k p_k. \tag{1}$$

Advertisers. Advertisers derive some benefits from reaching consumers through publishers. There is a unit mass of advertisers. Advertisers multi-home, i.e. can decide to place an ad on different publisher websites. For the sake of simplicity, each advertiser pays for one ad to be placed on a publisher website k. Advertisers have also homogenous preferences with respect to the editorial content of a publisher website k. The profit function of an advertiser displaying an ad on the publisher website k, R_k, increases with the demand of Internet users N_k and the viewability of ad b_k, and decreases with the price of ad p_k:[16]

$$R_k = b_k N_k - p_k. \tag{2}$$

As discussed in Section 2, without viewability technology, advertisers have no idea about the level of ad viewability. We therefore use the concept of *passive expectations* first developed in Katz and Shapiro (1985) and analyzed in the context of two sided markets by Hagiu and Halaburda (2014). However, our advertisers only formulate an expectation on the level of advertising viewability and not on the number of potential Internet users visiting the website. We assume in the sequel that when there is no technology to measure the level of an ad viewability, all advertisers have the same guess about ad viewability on the publisher k website, denoted by $b_{k,e}$. In the sequel, we assume $\underline{b} \le b_{k,e} \le \overline{b}$.[17] In this case, Eq. (2) is:

$$R_k = b_{k,e} N_k - p_k. \tag{3}$$

Internet users. Internet users single-home, i.e. choose to visit (or not) only one publisher website. They are uniformly distributed over an Hotelling line with unit length with respect to the editorial content of a publisher k. Their utility can be defined as follows:

$$U_k = q_k - \gamma b_k a_k - t^u \left| x^u - \ell_k \right|, \tag{4}$$

with q_k the quality of editorial content of publisher k, γ the nuisance cost of ads, $b_k a_k$ the number of ads displayed on publisher k, and t^u the cost to visit a website. Firstly, the utility of Internet users increases with the quality of editorial content q_k. Secondly, the utility decreases

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[16]The price of an ad in our setup can be understood as the price of an advertising campaign. We also could consider that advertisers pay each time the ad is displayed to an Internet user, i.e. an impression, which would redesign the profit function as $R_k = (b_k - p_k)N_k$. This latter specification would not change the analysis as advertisers are homogenous in the model.

[17]We do not focus on the case of *rational expectations* as it is a subcase of *passive expectations*.

with the number of displayed ads $b_k a_k$, and the nuisance cost of ads γ; the parameter γ is the same for all Internet users and strictly positive ($\gamma>0$),[18] meaning that Internet users perceive ads as a nuisance. The utility also decreases at a cost t^u when a user visits publisher k located at ℓ_k that differs from his preferred editorial content x^u; the parameter t^u represents the degree to which publishers' websites are substitutes or, in other words, the intensity of competition between publishers.

Timing. The timing of the game is in four stages:[19]

1. Publishers design their website and choose the level of ad viewability accordingly as well as the number of ads to be displayed on their website.
2. Publishers set the price of ads.
3. Advertisers choose to display or not an ad on the publisher website(s).
4. Internet users choose to visit or not the publisher website(s) and see ads.

In the following, we look for the subgame perfect equilibrium, and solve the game by backward induction.

5 Solving the Model

We analyze the case of a competition between two publishers i and j who compete to attract consumers and advertisers. The two publishers are both located at the endpoints of the line $[0, 1]$, i.e., $\ell_i = 0$ and $\ell_j = 1$. Publishers i and j are symmetrical; we therefore only conduct the analysis for publisher i in the sequel.

Stage 4

In stage 4, Internet users single-home and choose to visit either publisher i or j.[20] We assume that the quality of the editorial content of each publisher is equal, i.e. $q_i = q_j = q$, and high enough to encourage Internet users to visit at least one publisher website.[21] Internet users care about the actual level of ad viewability, b_{nv}, and not the estimated level of ad viewability b_e considered by advertisers. Consequently, the demands of Internet users addressed to publisher i without and with viewability technology are:

$$N_{i,nv} \equiv x_{i,nv}^u = \frac{1}{2} - \frac{\gamma(b_{i,nv}a_{i,nv} - b_{j,nv}a_{j,nv}) + (q_j - q_i)}{2t^u}, \qquad (5)$$

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[18]We adopt the standard advertising disutility paradigm (Zhang and Sarvary, 2015; Dukes and Gal-Or, 2003).

[19]To better understand the choices of each player in the game, we decide to break down the game in four stages. However, stages 2, 3 and 4 could be grouped, leaving the analysis unchanged.

[20]Internet users single-home if $t_u > -\gamma(b_j + b_i)$ and if $\gamma b_j < 0$. As $\gamma > 0$, $b_i > 0$ and $b_j > 0$, Internet users always single-home.

[21]The indifferent Internet user is the one having the lowest utility. We assume $q > \frac{t_u}{2} + \gamma\bar{b}$. The indifferent Internet user therefore visits at least one publisher regardless the level of ad viewability chosen by the other publisher, hence allowing a positive utility for all the other Internet users.

and,

$$N_{i,v} \equiv x_{i,v}^u = \frac{1}{2} - \frac{\gamma(b_{i,v}a_{i,v} - b_{j,v}a_{j,v}) + (q_j - q_i)}{2t^u}. \tag{6}$$

Eqs. (5) and (6) show that the demand of Internet users addressed to publisher i decreases with the nuisance cost of ads γ, and the number of viewable ads displayed on website i ($b_{i,nv}a_{i,nv}$ and $b_{i,v}a_{i,v}$), but increases with the number of viewable ads displayed on the competitive publisher j ($b_{j,nv}a_{j,nv}$ and $b_{j,v}a_{j,v}$). This result is intuitive: when the number of viewable ads increases on the competitive website j, Internet users prefer to visit the publisher website i.

Stage 3

At stage 3, advertisers choose to display ads or not on the publisher website. When there is no technology to measure ad viewability, they have a guess on the level of ad viewability denoted b_e. As advertisers are homogenous, they are all willing to display an ad as long as its price is lower that their willingness to pay, i.e. $p_{i,nv} \leq b_{i,e}N_{i,nv}$. Similarly, when there is a technology to measure ad viewability, advertisers know the actual level of ad viewability $b_{i,v}$ of an ad placed on the publisher website and are willing to place an ad as long as $p_{i,v} \leq b_{i,v}N_{i,v}$.

We note that the anticipated level of ad viewability on publisher i, $b_{i,e}$, has a clear impact on the ad price charged by publisher i. As the game is symmetrical, this result is also valid for publisher j. To simplify the analysis, we hypothesize that $b_{i,e} = b_{j,e} = b_e$, i.e. the estimated level of ad viewability is the same for publisher i and j.

Stage 2

Publishers maximize their profits with regard to their respective prices. Both publishers would make zero profits if they did not charge low enough prices to attract advertisers. Therefore, the equilibrium price charged by publisher i under duopoly is:

$$p_{i,nv}^* = \frac{b_e\big(t^u - \gamma(b_{i,nv}a_{i,nv} - b_{j,nv}a_{j,nv})\big)}{2t^u}. \tag{7}$$

Lemma 1: $p_{i,nv}^*$, the optimal price of an ad charged by publisher i [j] without viewability technology increases with the estimated level of ad viewability b_e and the competitor's ad viewability level $b_{j,nv}$ [$b_{i,nv}$], but decreases with his own level of ad viewability $b_{i,nv}$ [$b_{j,nv}$].

Lemma 1 highlights three interesting points. Firstly, the higher the advertiser's belief on the viewability level b_e of the publisher i's website, the higher the willingness to pay for an ad. Secondly, the price charged by publisher i increases with the level of the competitor's ad viewability j. Indeed, when the competitive publisher j increases his level of viewability, some

Internet users prefer to visit publisher i, which attracts in turn advertisers and causes a rise in the price of ads of publisher i. Thirdly, the optimal price charged by publisher i decreases with his own level of ad viewability. This intuitive finding is related to the previous point: increasing his own viewability level leads a part of consumers to visit the competitive publisher j, hence increasing the demand of advertisers.

Likewise, the optimal price charged by publisher i with viewability technology is:

$$p_{i,v}^* = \frac{b_{i,v}\big(t^u - \gamma(b_{i,v}a_{i,v} - b_{j,v}a_{j,v})\big)}{2t^u}. \tag{8}$$

Lemma 2: $p_{i,v}^*$, the optimal price of an ad charged by publisher i [j] with viewability technology increases with his competitor level of viewable ads $b_{j,v}a_{j,v}$ [$b_{i,v}a_{i,v}$].

The optimal price of an ad charged by a publisher in competition with viewability technology defined in Eq. (8) depends on the number of viewable ads $b_{j,v}a_{j,v}$ displayed by the competitive publisher whereas the optimal price of an ad without viewability technology defined in Eq. (7) is only related to the estimated level of ad viewability b_e.

Stage 1

Publishers maximize their profits by choosing their respective number of viewable ads. Inserting (7) into Eq. (1), the publisher i's profit function at the equilibrium of stage 1 without viewability technology is:

$$\max_{b_{i,nv},a_{i,nv}} \Pi_{i,nv}(.|p_{i,nv}^*, p_{j,nv}^*) = a_{i,nv} \frac{b_e\big(t^u - \gamma(b_{i,nv}a_{i,nv} - b_{j,nv}a_{j,nv})\big)}{2t^u}. \tag{9}$$

Solving Eq. (9) for $b_{i,nv}$, we find that publisher i (as well as publisher j) sets the level of ad viewability at its minimum:[22]

$$b_{i,nv}^* = b_{j,nv}^* = \underline{b}. \tag{10}$$

Lemma 3: $b_{i,nv}^*$ [$b_{j,nv}^*$], the optimal level of ad viewability displayed by publisher i [j] without viewability technology is the lowest.

Lemma 3 shows that both publishers set the levels of ad viewability at their minimum. Indeed, in this scenario, an advertiser always pays the price of an ad by considering b_e and not $b_{i,nv}$ or $b_{j,nv}$ as he has no means of knowing the actual level of ad viewability. Since a higher level of viewability decreases the demand of consumers and since advertisers have no possibilities to determine the actual level of ad viewability, it is optimal for both publisher to

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[22]Calculations are provided in appendix A.1.

set the viewability level at its minimum.[23]

Solving Eq. (9) for $a_{i,nv}$, we find that both publishers' profit functions are concave in the number of ads displayed on their website:

$$a_{i,nv}(a_{j,nv}) = \frac{t^u + \gamma b_{j,nv} a_{j,nv}}{2\gamma b_{i,nv}}. \tag{11}$$

The optimal number of ads displayed by a publisher depends on the optimal choice of its competitor. We analyze in Appendix A.1 the two possible cases. After computation and insertion of Eq. (10) into Eq. (11), we have:

$$a_{i,nv}{}^* = a_{j,nv}{}^* = \begin{cases} \frac{t^u}{\gamma \underline{b}} \text{ if } t^u < \gamma \underline{b}, \\[2ex] 1 \text{ if } \gamma \underline{b} \leq t^u. \end{cases} \tag{12}$$

The demand of Internet users at the equilibrium of stage 1 is:

$$N_{i,nv}{}^* = \frac{1}{2}. \tag{13}$$

Replacing successively Eqs. (10) and (12) in Eq. (7), and Eqs. (14) and (12) in Eq. (9), the profits of both publishers at the equilibrium of stage 1 are:

$$\Pi_{i,nv}^* = \Pi_{j,nv}^* = \begin{cases} \frac{b_e t^u}{2\gamma \underline{b}} \text{ if } t^u < \gamma \underline{b}, \\[2ex] \frac{b_e}{2} \text{ if } \gamma \underline{b} \leq t^u. \end{cases} \tag{14}$$

Applying the same reasoning, the profit function of publisher i with viewability technology is:

$$\max_{b_{i,v}, a_{i,v}} \Pi_{i,v}(.|p_{i,v}^*, p_{j,v}^*) = \frac{b_{i,v} a_{i,v}\big(t^u - \gamma(b_{i,v} a_{i,v} - b_{j,v} a_{j,v})\big)}{2t^u}. \tag{15}$$

Publishers' profit functions are concave in their respective number of viewable ads:[24]

$$b_{i,v} a_{i,v}(b_{j,v} a_{j,v}) = \frac{t^u + b_{j,v} a_{j,v} \gamma}{2\gamma}. \tag{16}$$

The optimal number of viewable ads cannot be higher than $\bar{b}$, and depends on t^u, γ, and $b_{j,v} a_{j,v}$. We analyze in Appendix A.1 the different possible cases. The resulting optimal number of viewable ads can be written as:

$$(b_{i,v} a_{i,v})^* = (b_{j,v} a_{j,v})^* = \begin{cases} \frac{t^u}{\gamma} \text{ if } t^u < \gamma \bar{b}, \\[2ex] \bar{b} \text{ if } \gamma \bar{b} \leq t^u. \end{cases} \tag{17}$$

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[23] Although intuitive, this strategy could not be necessarily optimal in the long run if advertisers can determine the lack of effectiveness of their ads placed on a website. In this case, it would be optimal for publishers to set $b_{i,nv}^* = b_{j,nv}^* = b_e$ to still doing business with advertisers in the next periods. It could be also the case that as advertisers cannot trust a publisher, they expect the lowest viewability level $b_e = \underline{b}$, which brings correct anticipation as publishers choose $b_{i,nv}^* = b_{j,nv}^* = \underline{b}$. However, following our different interviews conducted with executives from the advertising industry, without ad technologies, it is almost impossible in reality to estimate how successful an ad on a specific website is in raising brand awareness over time as advertisers place at the same time identical ads on many websites.

[24] $\frac{\partial^2 \Pi_{i,v}}{\partial^2 (b_{i,v} a_{i,v})} = -\frac{\gamma}{t^u}.$

Lemma 4: $(b_{i,v}a_{i,v})^*$ $[(b_{j,v}a_{j,v})^*]$, the optimal number of viewable ads displayed by publisher i $[j]$ with viewability technology increases with the intensity of competition t^u and decreases with ad nuisance γ.

Interpretation of Lemma 4 is intuitive. Publishers set the actual number of viewable ads by taking into consideration the intensity of competition between publishers (t^u), and the nuisance cost of ads (γ). When the intensity of competition is high, i.e. when Internet users have the possibility of switching easily between publishers, publisher i has no incentive to set a high number of viewable ads to not discourage Internet users from visiting his website. By contrast, when the intensity of competition is low, i.e. when Internet users are captive or do not find a close substitute to the publisher website i, publisher i can increase the number of viewable ads. To summarize, in the presence of a technology to determine the actual level of ad viewability, publishers can raise the number of viewable ads to charge a higher price to advertisers while keeping Internet users captive. This intuition is summarized in Proposition 1.

Proposition 1: $(b_{i,v}a_{i,v})^* > b_{i,nv}^* a_{i,nv}^*$ if $t^u \geq \underline{b}\gamma$.

The resulting demand of Internet users addressed to publisher i at the equilibrium of stage 1 is:

$$N_{i,v}^* = \frac{1}{2}. \tag{18}$$

Finally, the optimal profits of publishers are:

$$\Pi_{i,v}^* = \Pi_{j,v}^* = \begin{cases} \frac{t^u}{2\gamma} \text{ if } t^u < \gamma\bar{b}, \\\\ \frac{\bar{b}}{2} \text{ if } \gamma\bar{b} \leq t^u. \end{cases} \tag{19}$$

6   Welfare Analysis of Ad Viewability

The objective of this section is to determine whether the introduction of a viewability measurement technology is profitable for the market, i.e. for Internet users, advertisers and publishers. To do so, we calculate and compare the total welfare with and without viewability technology, denoted respectively by W_v^* and W_{nv}^*. The total welfare is the sum of the surplus of Internet users (S_v^{u*} and S_{nv}^{u*}), the surplus of advertisers (S_v^{a*} and S_{nv}^{a*}), and the profits of publishers (Π_v^* and Π_{nv}^*).

Surplus of Internet Users

Internet users do not pay to visit publishers' websites, and therefore the surplus only depends on user experience. The surplus of Internet users without and with viewability technology are respectively:

$$S_{nv}^{u*} = S_{i,nv}^{u*} + S_{j,nv}^{u*} = \begin{cases} q - \frac{5t^u}{4} & \text{if } t^u < \gamma \underline{b}, \\ \\ q - \underline{b}\gamma - \frac{t^u}{4} & \text{if } \gamma\underline{b} \leq t^u. \end{cases} \quad [25] \tag{20}$$

and,

$$S_{v}^{u*} = S_{i,v}^{u*} + S_{j,v}^{u*} = \begin{cases} q - \frac{5t^u}{4} & \text{if } t^u < \gamma\overline{b}, \\ \\ q - \overline{b}\gamma - \frac{t^u}{4} & \text{if } \gamma\overline{b} \leq t^u. \end{cases} \quad [26] \tag{21}$$

Overall, Corollary 1 of Proposition 1 shows that the surplus of Internet users is greater without viewability technology when the cost t^u to visit a website is equal or greater than the cost from seeing ads $\gamma\underline{b}$:

Corollary 1: $S_v^{u*} \leq S_{nv}^{u*}$ if $t^u \geq \gamma\underline{b}$ (See Proof of Corollary 1 in Appendix A.2).

Surplus of Advertisers

The surplus of advertisers without viewability technology, defined in Eq. (22), increases with $\underline{b}$ and decreases with b_e:[27]

$$S_{nv}^{a*} = S_{i,nv}^{a*} + S_{j,nv}^{a*} = \begin{cases} \frac{t^u(\underline{b}-b_e)}{\gamma\underline{b}} & \text{if } t^u < \gamma\underline{b}, \\ \\ \underline{b} - b_e & \text{if } \gamma\underline{b} \leq t^u. \end{cases} \quad [28] \tag{22}$$

However, with viewability technology, the price of ads adjusts to the actual level of ad viewability set up by publisher i, which brings zero profits to advertisers:

$$S_{i,v}^{a*} = S_{j,v}^{a*} = S_v^{a*} = 0. \tag{23}$$

We find that the surplus of advertisers is higher with viewability technology only if the anticipated level of ad viewability b_e is greater than the actual level of ad viewability $b_{nv}^* = \underline{b}$:

Proposition 2: $S_v^{a*} > S_{nv}^{a*}$ if $b_e > \underline{b}$ (See Proof of Proposition 2 in Appendix A.2)

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[25] $S_{i,nv}^{u*} \equiv S_{j,nv}^{u*} = \begin{cases} \frac{4q-5t^u}{8} & \text{if } t^u < \gamma\underline{b}, \\ \\ \frac{4(q-\underline{b}\gamma)-t^u}{8} & \text{if } \gamma\underline{b} \leq t^u. \end{cases}$

[26] $S_{i,v}^{u*} \equiv S_{j,v}^{u*} = \begin{cases} \frac{4q-5t^u}{8} & \text{if } t^u < \gamma\overline{b}, \\ \\ \frac{4(q-\overline{b}\gamma)-t^u}{8} & \text{if } \gamma\overline{b} \leq t^u. \end{cases}$

[27]The surplus of advertisers choosing to buy an ad slot at publisher i is given by the sum of their utilities. As they are all buying from both publishers, the surplus is $S_{i,nv}^{a*} = a_i R_i$ (and $S_{j,nv}^{a*} = a_j R_j$).

[28] $S_{i,nv}^{a*} \equiv S_{j,nv}^{a*} = \begin{cases} \frac{t^u(\underline{b}-b_e)}{2\gamma\underline{b}} & \text{if } t^u < \gamma\underline{b}, \\ \\ \frac{\underline{b}-b_e}{2} & \text{if } \gamma\underline{b} \leq t^u. \end{cases}$

Proposition 2 illustrates that advertisers are better off with viewability technology. Indeed, without viewability technology, the price is adjusted to b_e whereas the optimal level of ad viewability is low ($\underline{b}$). The surplus of advertisers is therefore negative when $b_e > \underline{b}$. By contrast, with viewability technology, the price is adjusted to the actual level of ad viewability as they can now verify it.

Profits of Publishers

The profits of publishers without viewability technology defined in Eq. (14) increase with the estimated level of ad viewability b_e as publishers can charge higher prices to advertisers:

$$\Pi_{nv}^* = \Pi_{i,nv}^* + \Pi_{j,nv}^* = \begin{cases} \frac{b_e t^u}{\gamma \underline{b}} & \text{if } t^u < \gamma \underline{b}, \\ \\ b_e & \text{if } \gamma \underline{b} \leq t^u. \end{cases}$$

Likewise, the profits of publishers with viewability technology defined in Eq. (19) are:

$$\Pi_v^* = \Pi_{i,v}^* + \Pi_{j,v}^* = \begin{cases} \frac{t^u}{\gamma} & \text{if } t^u < \gamma \overline{b}, \\ \\ \overline{b} & \text{if } \gamma \overline{b} \leq t^u. \end{cases}$$

Proposition 3: $\Pi_v^* \geq \Pi_{nv}^*$ if $\frac{(b_{.,v} a_{.,v})^*}{a_{.,nv}^*} \geq b_e.$[29] (See Proof of Proposition 3 in Appendix A.2).

Proposition 3 shows that publishers make higher profits with viewability technology when the optimal number of viewable ads ($(b_{.,v} a_{.,v})^*$) is greater than the estimated level of viewable ads ($b_e a_{.,nv}^*$) when there is no viewability technology.

Total Welfare

The total welfare without and with viewability technology are respectively:

$$W_{nv}^* = \begin{cases} q + \frac{t^u}{\gamma} - \frac{5t^u}{4} & \text{if } t^u < \gamma \underline{b}, \\ \\ q + (1-\gamma)\underline{b} - \frac{t^u}{4} & \text{if } \gamma \underline{b} \leq t^u. \end{cases} \tag{24}$$

and,

$$W_v^* = \begin{cases} q + \frac{t^u}{\gamma} - \frac{5t^u}{4} & \text{if } t^u < \gamma \overline{b}, \\ \\ q + (1-\gamma)\overline{b} - \frac{t^u}{4} & \text{if } \gamma \overline{b} \leq t^u. \end{cases} \tag{25}$$

Proposition 4: Comparing W_{nv}^* to W_v^*, we have:

- when $t^u \leq \gamma \underline{b}$, $W_{nv}^* = W_v^*$.

- when $\gamma \underline{b} < t^u$, $W_v^* > W_{nv}^*$ if $\gamma < 1$.

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[29] We note $(b_{i,v} a_{i,v})^* = (b_{j,v} a_{j,v})^* = (b_{.,v} a_{.,v})^*$ and $a_{i,nv}^* = a_{j,nv}^* = a_{.,nv}^*$.

Proposition 4, illustrated in Figure 1, shows that the total welfare is greater with viewability technology when the competition between publishers is not too intense ($\gamma\underline{b} < t^u$) and the nuisance cost of ads is low ($\gamma < 1$). To understand this result, we propose to analyze how the intensity of competition (t^u) and the nuisance cost of ads (γ) impact the change in total welfare. To begin with, let us denote by $\Delta W^* = W_v^* - W_{nv}^*$, the change in total welfare, which is simply the difference between the total welfare with and without viewability technology. Likewise, let us denote by ΔS^{u*} the change in Internet user surplus (with $\Delta S^{u*} = S_v^{u*} - S_{nv}^{u}{}^*$), by ΔS^{a*} the change in advertisers' surplus (with $\Delta S^{a*} = S_v^{a*} - S_{nv}^{a}{}^*$), and by $\Delta\Pi^*$ the change in publisher profits (with $\Delta\Pi^* = \Pi_v^* - \Pi_{nv}^*$). Finally, we call V^* the sum of publisher profits and advertisers surplus ($V^* = \Pi^* + S^{a*}$) and ΔV^* the change in industry profits (with $\Delta V^* = \Pi_v^* + S_v^{a*} - (\Pi_{nv}^* + S_{nv}^{a}{}^*)$). The change in total welfare is equivalent to: $\Delta W^* = \Delta S^{u*} + \Delta V^*$.

Using Eqs. (20) and (21), the change in Internet user surplus is:

$$\Delta S^{u*} = \begin{cases} 0 \text{ if } t^u < \gamma\underline{b}, \\[2mm] -(t^u - \underline{b}\gamma) \text{ if } \gamma\underline{b} \leq t^u < \gamma\overline{b}, \\[2mm] -\gamma(\overline{b} - \underline{b}) \text{ if } \gamma\overline{b} \leq t^u. \end{cases} \tag{26}$$

It is interesting to note from Eq. (26) that ΔS^{u*} decreases in t^u.[30] Using Eqs. (22), (23), and (1), the change in the industry profits can be written as:

$$\Delta V^* = \begin{cases} 0 \text{ if } t^u < \gamma\underline{b}, \\[2mm] \frac{t^u}{\gamma} - \underline{b} \text{ if } \gamma\underline{b} \leq t^u < \gamma\overline{b}, \\[2mm] \overline{b} - \underline{b} \text{ if } \gamma\overline{b} \leq t^u. \end{cases} \tag{27}$$

Conversely to Eq. (26), ΔV^* in Eq. (27) increases in t^u.[31] To summarize, with viewability technology, an intense competition between publishers ($t^u \leq \gamma\underline{b}$) does not affect either the surplus of Internet users or the profits of the industry ($\Delta S^{u*} = \Delta V^* = 0$), leaving the total welfare unchanged ($\Delta W^* = 0 \equiv W_{nv}^* = W_v^*$). However, when the competitiveness softens ($t^u > \gamma\underline{b}$), Internet users are worse off $\Delta S^{u*} < 0$, whereas industry profits are larger $\Delta V^* > 0$. The intensity of competition has therefore a mixed effect on the total welfare, and the final impact depends on the nuisance cost of ads. More precisely, the total welfare is greater with

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[30]ΔS^{u*} decreases in t^u as $-(t^u - \gamma\underline{b})$ is always greater than $-\gamma(\overline{b} - \underline{b})$ for $\overline{b}\gamma \leq t^u$.

[31]ΔV^* increases in t^u as $\frac{t^u}{\gamma} - \underline{b}$ is always lower than $(\overline{b} - \underline{b})$ for $\overline{b}\gamma \leq t^u$.

viewability technology only if the nuisance cost of ads is not too high ($\gamma < 1$). In this latter case, the industry profits are always greater than the loss of Internet users: $\Delta W^* > 0 \equiv W_v^* > W_{nv}^*$. This result holds when $\gamma \underline{b} < t^u < \gamma \overline{b}$ and $\gamma \overline{b} \leq t^u$.

Firstly, when $\gamma \underline{b} < t^u < \gamma \overline{b}$ (which is the case of the local solution), the publisher takes into account the nuisance cost of ads when setting the optimal level of ad viewability (i.e $(b_{.,v} a_{.,v})^* = \frac{t^u}{\gamma}$). This makes the cost from viewing ads to be equal to t^u.[32] In that case, a high nuisance cost of ads γ reduces the loss of Internet users ($\frac{\partial \Delta S^{u*}}{\partial \gamma} > 0$). However, the prices and profits of publishers decrease with a higher nuisance cost of ads γ (as they are function of the optimal level of ad viewability). Hence, the industry profits are reduced with a high nuisance cost of ads ($\frac{\partial \Delta V^*}{\partial \gamma} < 0$). In conclusion, with viewability technology, when the nuisance cost of ads is not too high ($\gamma < 1$), the rise in the industry profits offsets the drop in the surplus of Internet users, resulting in an increase in the total welfare ($\Delta W^* > 0$).

Secondly, when $\gamma \overline{b} \leq t^u$ (which is the case of the upper corner solution), the publisher sets the optimal level of ad viewability at its maximum (i.e $(b_{.,v} a_{.,v})^* = \overline{b}$) and does not take into account the nuisance cost of ads.[33] In that case, a high nuisance cost of ads increases the loss of Internet users ($\frac{\partial \Delta S^{u*}}{\partial \gamma} < 0$).[34] However, in that case, the prices and profits of publishers does not vary with the nuisance cost of ads ($\frac{\partial \Delta V^*}{\partial \gamma} = 0$)[35] As in the previous case, when the nuisance cost of ads is low ($\gamma < 1$), the rise in the industry profits offset the drop in the surplus of Internet users, resulting in an increase in the total welfare ($\Delta W^* > 0$).
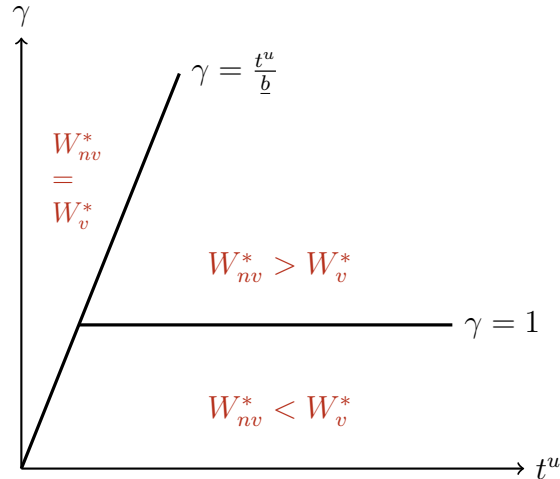

Figure 1: W_{nv}^* and W_v^* as a Function of Competition Intensity (t^u) and Nuisance Cost of Ads (γ)

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[32]The utility of Internet users is $U_{i,v} = q - \gamma(b_{i,v} a_{i,v})^* - t^u x$, hence the cost is $\gamma(b_{i,v} a_{i,v})^* = t^u$.

[33]The utility of Internet users is $U_{i,v} = q - \gamma(b_{i,v} a_{i,v})^* - t^u x$, hence the cost is $\gamma(b_{i,v} a_{i,v})^* = \overline{b}\gamma$.

[34]The cost of viewable ads faced by Internet users with and without viewability technology are $\overline{b}\gamma$ and $\underline{b}\gamma$, respectively. As $\overline{b} > \underline{b}$, the cost of seeing ads with viewability technology increases faster than without viewability technology.

[35]As we are in a symmetrical case, and as the demand of Internet users is $\frac{1}{2}$, the profits are not dependent from the nuisance cost of ads.

7 Ad Viewability and Ad-Blockers

Up to now, we assumed that Internet users cannot avoid seeing ads. However, more and more people are using ad-blockers to skip viewable ads. Ad viewability and ad-blockers are therefore intimately related.[36] A recent survey conducted by the IAB with C3Research finds for example that 26% of desktop users block ads online (IAB, Who Blocks Ads, Why, and How to Win Them Back, 2016). And their impact is significant. Research firm Ovum estimates that publishers lost $24 billion in revenue globally in 2015 due to ad blocking (Wall Street Journal, "New York Times Readies Ad-Free Digital Subscription Model," June 20, 2016).

In this extension, we introduce the possibility for consumers to block ads so as to get rid of the nuisance costs of viewable ads.[37] Installing an ad-blocker is costly for users (c), as they need to search for and to install the software.[38] We assume in the sequel that users choose to install an ad-blocker as soon as its cost c is lower or equal than the nuisance cost of viewable ads $\gamma b_k D_k$ when visiting the website k. By definition, the installation of ad-blockers prevents ad servers to serve ads, which delivers zero revenue for publishers. To make positive profits, publishers have therefore to lower the number of viewable ads to discourage people installing ad-blockers. Consequently, ad-blockers are introduced in the model as a constraint on the maximization problem of publishers when they strategically set the number of viewable ads in stage 1 of the previous game.

We study the introduction of ad-blockers and analyze their impact on total welfare.

7.1 Extension of the Model

Both publishers have to practice $\gamma b_k D_k \leq c$ to make positive profits. When there is no viewability technology, the profit function of publishers can be written as follows:

$$\max_{b_{i,nv}, a_{i,nv}} \Pi_{i,nv}(.|p_{i,nv}{}^*, p_{j,nv}{}^*) = a_{i,nv} \frac{b_e\left(t^u - \gamma(b_{i,nv}a_{i,nv} - b_{j,nv}a_{j,nv})\right)}{2t^u}, \tag{28}$$

subject to $\gamma b_{i,nv} a_{i,nv} \leq c$.

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[36] An article entitled "Solving for Viewability Might Be a Reason People are Ad Blocking" published in Digiday UK on November 11, 2016, discusses the interactions between ad-blockers and ad-viewability.

[37] Ad-avoidance technologies have been largely studied (Anderson and Gans, 2011; Johnson, 2013). In line with these studies, we consider that ad-avoidance technologies involve consumers reducing the negative impact of ads.

[38] We can also interpret c as the minimum user experience threshold required by the ad-blocker to display an ad on a website even if an ad-blocker is installed. For example, the software *Ad-blockplus* allows acceptable ads that comply with specific criteria to be shown to users of ad-blocking software.

Following Eqs. (10) and (12), $\gamma b_{i,nv}^{*} a_{i,nv}^{*}$ can take on two values, t^{u} or $\gamma\underline{b}$. Two cases therefore can be considered. Firstly, if $c > \min(t^{u}, \gamma\underline{b})$, the cost to install an ad-blocker is higher than the cost of seeing viewable ads for Internet users. Hence publishers are not constrained and can set the optimal number of viewable ads without considering ad-blockers. Secondly, if $c \leq \min(t^{u}, \gamma\underline{b})$, the cost to install an ad-blocker is lower than the nuisance cost of viewable ads for Internet users. Consequently, publishers are forced to lower the number of viewable ads to prevent Internet users from installing ad-blockers. To keep the analysis straightforward, we only focus in this part on the second case (we however consider all the cases when computing the total welfare later), and use the superscript *adb* to characterize the situation where publishers are constrained.[39]

When publishers are constrained by ad-blockers, the optimal level of ad viewability and the optimal number of viewable ads are:

$$b_{i,nv}^{adb} = b_{j,nv}^{adb} = \underline{b}, \tag{29}$$

and

$$a_{i,nv}^{adb\,*} = a_{j,nv}^{adb\,*} = a_{.,nv}^{adb\,*} = \frac{c}{\gamma\underline{b}}. \tag{30}$$

Lemma 5: $a_{.,nv}^{adb}$, the optimal number of ads displayed by competitive publishers constrained by ad-blockers without viewability technology increases with the cost of ad-blockers c and decreases with ad nuisance γ.

Lemma 5 is intuitive. Publishers are less constrained when the cost of ad-blockers increases and can display a higher number of viewable ads. In the end, publishers must however provide a high enough user experience to prevent Internet users from installing ad-blockers. They therefore internalize the costs of installing ad-blockers and display a lower number of viewable ads.

Reintroducing Eqs. (29) and (30) in Eq. (28), the profits of publishers without viewability technology are:

$$\Pi_{i,nv}^{adb\,*} = \Pi_{j,nv}^{adb\,*} = \frac{b_e c}{2\gamma\underline{b}}. \tag{31}$$

---

[39]For example, $b_{i,nv}^{adb\,*}$ is the optimal level of ad viewability without technology when publishers are constrained by ad-blockers ($c \leq \min(t^{u}, \gamma\underline{b})$).

The optimal choices of publishers differ with viewability technology:

$$\max_{b_{i,v},a_{i,v}} \Pi_{i,v}(.|p_{i,v}{}^*, p_{j,v}{}^*) = \frac{b_{i,v}a_{i,v}\big(t^u - \gamma(b_{i,v}a_{i,v} - b_{j,v}a_{j,v})\big)}{2t^u},$$

(32)

subject to $\gamma b_{i,v}a_{i,v} \leq c$.

Following the same reasoning as before, we only conduct the analysis for which $c \leq \min(t^u, \gamma\bar{b})$. We find that publishers must limit the number of viewable ads to encourage Internet users to visit the websites:

$$\big(b_{i,v}^{adb} a_{i,v}^{adb}\big)^* = \big(b_{j,v}^{adb} a_{j,v}^{adb}\big)^* = \big(b_{.,v}^{adb} a_{.,v}^{adb}\big)^* = \frac{c}{\gamma}.$$

(33)

Lemma 6: $\big(b_{.,v}^{adb} a_{.,v}^{adb}\big)^*$, the optimal number of ads displayed by competitive publishers with viewability technology and ad-blockers increases with the cost ad-blockers c and decreases with ad nuisance γ.

Lemma 6 is similar to Lemma 5. Publishers are constrained by the adoption of ad-blockers. They therefore internalize the cost of installing the software and improve the user experience in lowering the number of viewable ads.

Reintroducing Eq. (33) in Eq. (32), the optimal profits of publishers without viewability technology are:

$$\Pi_{i,v}^{adb*} = \Pi_{j,v}^{adb*} = \frac{c}{2\gamma}.$$

(34)

7.2   Welfare Analysis of Ad Viewability with Ad-Blockers

The total welfare without and with viewability technology with ad-blockers can be written as:[40]

$$W_{nv}^* \begin{cases} q - \frac{t^u}{4} + \frac{c(1-\gamma)}{\gamma} \equiv W_{nv}^{adb*} \text{ if } c < \min(t^u, \gamma\underline{b}), \\[2mm] q + \frac{t^u}{\gamma} - \frac{5t^u}{4} \text{ if } t^u \leq \min(c, \gamma\underline{b}), \\[2mm] q + (1-\gamma)\underline{b} - \frac{t^u}{4} \text{ if } \gamma\underline{b} \leq \min(c, t^u). \end{cases}$$

(35)

and,

---

[40]The calculations are similar to those in Section 6 and are not reported. Calculations are available upon request.

$$
W_v^* = \begin{cases} q - \frac{t^u}{4} + \frac{c(1-\gamma)}{\gamma} \equiv W_v^{adb*} & \text{if } c < \min\left(t^u, \gamma\bar{b}\right), \\[3mm] q + \frac{t^u}{\gamma} - \frac{5t^u}{4} & \text{if } t^u \leq \min\left(c, \gamma\bar{b}\right), \\[3mm] q + (1-\gamma)\bar{b} - \frac{t^u}{4} & \text{if } \gamma\bar{b} \leq \min\left(c, t^u\right). \end{cases} \tag{36}
$$

The impact of ad-blockers on total welfare depends on the relative cost of ad-blockers c with respect to the intensity of competition t^u and the level of ad nuisance γ. Proposition 5 compares the total welfare with and without ad viewability with ad-blockers on the market.

Proposition 5: Comparing W_v^* to W_{nv}^* with ad-blockers, we have:

- when $c < \min\left(t^u, \gamma\underline{b}\right)$, $W_v^* = W_{nv}^* = W_{nv}^{adb*} = W_v^{adb*} \equiv W^{adb*}$,

- when $\gamma\underline{b} \leq c < \min\left(t^u, \gamma\bar{b}\right)$, $W^{adb*} = W_v^{adb*} = W_v^* \geq W_{nv}^*$ if $\gamma \leq 1$

- when $c \geq \min\left(t^u, \gamma\bar{b}\right)$, we are in the case as if there were no ad-blockers.

(See Proof of Proposition 5 in Appendix A.3)

Proposition 5 exhibit three cases even though two are more interesting from a welfare standpoint. Firstly, when the cost of installing ad-blockers is high ($c \geq \min\left(t^u, \gamma\bar{b}\right)$), publishers are not constrained when designing their websites and then display the same number of viewable ads as if there were no ad-blockers. Overall, the total welfare is not therefore affected by the introduction of costly ad-blockers. The two other cases are more interesting. We use the same methodology as before and decompose the total welfare between Internet user surplus (S^{u*}) and industry profits (V^*), with $V^* = \Pi^* + S^{a*}$.

The change in the surplus of Internet users can be written as:

$$
\Delta S^{u*} = \begin{cases} 0 & \text{if } c < \min\left(t^u, \gamma\underline{b}\right), \\[3mm] -(c - \underline{b}\gamma) & \text{if } \gamma\underline{b} \leq c < \min\left(t^u, \gamma\bar{b}\right). \end{cases} \tag{37}
$$

It results from Eq. (37) that ΔS^{u*} decreases in c.[41] The change in the industry profits can be written as:

$$
\Delta V^* = \begin{cases} 0 & \text{if } c < \min\left(t^u, \gamma\underline{b}\right), \\[3mm] \frac{c}{\gamma} - \underline{b} & \text{if } \gamma\underline{b} \leq c < \min\left(t^u, \gamma\bar{b}\right). \end{cases} \tag{38}
$$

---

[41]ΔS^{u*} decreases in c as $-(c - \underline{b}\gamma)$ is always lower than 0 for $\underline{b}\gamma \leq c < \min\left(t^u, \gamma\bar{b}\right)$.

Conversely to Eq. (37), Eq. (38) shows that the changes in the industry profits increases in c and two cases have therefore to be analyzed.

Firstly, when the cost of installing ad-blockers is low ($c < \min(t^u, \gamma\underline{b})$), publishers are constrained by ad-blockers whether there is viewability technology or not. Indeed, even when there is no viewability technology, the cost of seeing a lower number of viewable ads displayed by competitive publishers is greater than the cost of installing ad-blockers. In this case, the industry earns the same constrained profits under both situations ($\Delta V^* = 0$), leaving the Internet users surplus unchanged ($\Delta S^{u*} = 0$). Consequently, the total welfare is the same whether there is or not viewability technology ($W_v^* = W_{nv}^* = W^{adb*}$).

Finally, when the cost of installing ad-blockers is relatively high ($\gamma\underline{b} \leq c < \min(t^u, \gamma\bar{b})$), publishers are only constrained by ad-blockers when there is viewability technology. This finding is intuitive as publishers set a higher number of viewable ads when there is viewability technology (see Proposition 1). In this case, the surplus of Internet users is still better off without viewability technology ($\Delta S^{u*} < 0$), even if ad-blockers prevent publishers from practicing a high advertising nuisance when there is such technology. Conversely, the industry profits are greater when there is viewability technology ($\Delta V^* > 0$). Overall, the gain of the industry is higher than the loss in Internet users surplus only if the nuisance cost of ads is not too high ($W^{adb*} = W_v^{adb*} = W_v^* \geq W_{nv}^*$ if $\gamma < 1$).[42]

7.3 Key Results and Discussions

In Section 6, we showed that introducing ad viewability entails globally a loss for Internet users, as the industry tends to increase the number of viewable ads. However, the profits of the industry are higher than the loss of Internet users when the cost of advertising nuisance is low enough and the competition is not too intense. Overall, the ad industry is then better off with viewability technology. However, with the development of ad-blockers, the situation changes. Internet users can block ads and preserve their user experience. Depending on the cost of ad-blockers, publishers can therefore be constrained by the two-sides of the market. In particular, we find a situation where the introduction of ad-blockers may represent an efficient leverage to provide a high enough Internet user experience while keeping the introduction of viewability technology beneficial for society.

Indeed, when advertising markets are characterized by a high advertising nuisance or/and low competition intensity, ad-blockers are constraining for publishers whether or not there is viewability technology. This situation is illustrated in Figures 2, 3 and 4. In the specific

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[42]This is somewhat similar to the analysis without ad-blockers, considering however that publishers are now constrained by the cost of ad-blockers c and not by the competition intensity t^u.

hatched areas, whether or not there is viewability technology, it has no impact on total welfare as publishers are constrained by ad-blockers (Proposition 5).

However, ad-blockers may have different effects in the case of a lower nuisance cost of ads.[43] A first simple case, illustrated in Figure 3, arises when the cost of ad-blockers is low ($\frac{c}{\underline{b}} < 1$). In that case, the total welfare is greater with viewability technology than without when the nuisance cost of ads is low enough ($\gamma < \frac{c}{\underline{b}}$). However, the total welfare was already greater with viewability than without, even without ad-blockers (as $\frac{c}{\underline{b}} < 1$). Therefore, from Propositions 4 and 5, ad-blockers affect the introduction of viewability technology on total welfare only when the nuisance cost of ads is high enough ($\gamma > \frac{c}{\underline{b}}$). This is represented in Figure 3 by the hatched part. This is due to the fact that the low cost of ad-blockers impacts a large range of markets which were already increasing the total welfare with viewability technology.
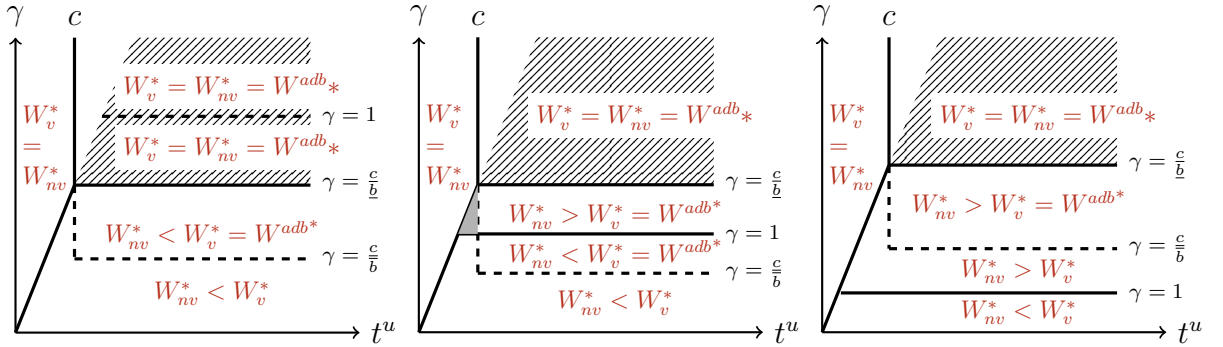

Figure 2: $c < \underline{b}$ Figure 3: $\underline{b} < c < \overline{b}$ Figure 4: $\overline{b} < c$

A second case exists when the cost of ad-blockers is relatively high ($\frac{c}{\overline{b}} < 1 < \frac{c}{\underline{b}}$). We know from Proposition 5 that ad-blockers do not constrain publishers without viewability technology when $\frac{c}{\overline{b}} < \gamma < \frac{c}{\underline{b}}$. When the nuisance cost of ads is relatively high, i.e. when $1 < \gamma < \frac{c}{\underline{b}}$, the introduction of viewability technology is not profitable for the total welfare ($W^{adb*} = W_v^* < W_{nv}^*$) when there are ad-blockers. Indeed, the gain in Internet users surplus from the presence of ad-blockers is immediately compensated by the loss in industry profits. When the nuisance cost of ads is low ($\frac{c}{\overline{b}} < \gamma < 1$), we are in the first case described before where the viewability technology was already profitable to total welfare without ad-blockers. A last part (in light gray in Figure 3) highlights situations where publishers are not constrained by ad-blockers, and the advertising nuisance parameter is high enough to make the total welfare lower with viewability technology ($W_{nv}^* > W_v^*$).

A third case (which is a generalization of the second case) arises when the cost of ad-blockers is high ($1 < \frac{c}{\overline{b}}$). In that situation, the specific area where the introduction of ad-

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[43]We recall from Proposition 4 that when there is no ad-blocker and when $\gamma\underline{b} < t^u$, $W_v^* > W_{nv}^*$ if $\gamma < 1$ and $W_v^* = W_{nv}^*$ if $t^u < \gamma\underline{b}$.

blockers only constrain publishers with viewability technology ($t^u > c$ and $\frac{c}{b} < \gamma < \frac{c}{\underline{b}}$), is located in the area where the total welfare is greater without viewability when there is no ad-blockers. However, when the advertising nuisance parameter belongs in that area, viewability technology is still not beneficial for the total welfare as we know from Proposition 5 that $W^{adb*} = W_v^* < W_{nv}^*$ when there is ad-blockers. However, when the market is facing a lower advertising nuisance parameter ($\gamma < \frac{c}{\underline{b}}$), using Proposition 5, we know that publishers are not constrained by ad-blockers. The total welfare is therefore greater without viewability, as the advertising nuisance is too high and publishers are not constrained by ad-blockers ($W_{nv}^* > W_v^*$) (Proposition 4).

8 Conclusion

Ad technologies provide new opportunities to reach consumers and improve ad effectiveness. In this paper, we studied one dimension of ad effectiveness: ad viewability. The latter offers to advertisers a greater chance to know whether ads are seen by Internet users. In this respect, ad viewability introduces more transparency between publishers and advertisers in a context of serious doubts on digital ads (Wall Street Journal, "Doubts Rise on Digital Ads," September 24, 2016),[44] but at the same time, puts pressure on publishers to enhance their viewability performance.

Following this idea, we studied in this paper how the introduction of ad viewability changes the economics of online advertising. We basically show that ad viewability affects the way publishers price ads, which in turn affects their profits, the demand of advertisers, and user experience.

The optimal number of viewable ads set up by publishers without viewability technology is always the lowest at the equilibrium for two reasons. Firstly, a low level of ad viewability preserves user experience. Secondly, advertisers purchase impressions based on their estimated level of ad viewability and not on the actual level of ad viewability (that they do not know). This mechanism is central: when advertisers anticipate a high level of ad viewability, they are keen to pay a higher price of ads, which increases publisher profits. However, as the actual level of ad viewability is low, the return on investments is also low. Consequently, the higher the difference between the actual and estimated levels of ad viewability, the higher the advertisers' losses and publishers' profits. This situation completely changes with a viewability technology.

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[44]Facebook admitted to have overestimated by up to 80% the average time people spent watching video ads on its platform. This story is not unique. Twitter (Business Insider France, "Twitter's Video Ad Metric Inflation Came at a Terrible Time," December 27, 2016) or Dentsu also acknowledged numerous cases of overcharging, amounting to at least $2.3m (Financial Times, "Ad Scandal Puts Dentsu's Credibility on the Line," September 27, 2016).

Advertisers can determine the actual level of ad viewability and publishers cannot exploit anymore this information asymmetry. The only way to increase the publishers' profits is therefore to raise the level of ad viewability (to charge higher prices). However, Internet users are not always ready to accept a higher nuisance cost of ads.

Under the assumption that the quality of the editorial content is equivalent between publishers, the optimal levels of ad viewability offered by both publishers depend on both the intensity of competition and the nuisance cost of ads. When the intensity of competition is strong, publishers cannot raise their levels of ad viewability to make higher profits and the total welfare is not enhanced with viewability technology. By contrast, when the competition between publishers is less intense, i.e. when the degree of substitution between publishers' websites is higher, Internet users are worse off because publishers can raise ad viewability and prices, inflating in turn the profits of the industry. In that case, the welfare analysis shows that the market of online advertising can be better off with viewability technology provided that the nuisance cost of ads is not too high and the competition between publishers is not too intense.

However, to preserve their user experience, Internet users can block ads by installing ad-blockers. Depending on the cost of installing ad-blockers, publishers are therefore constrained as they cannot degrade user experience by increasing too much the level of ad viewability. Publishers are therefore pressurized from both sides of the market: advertisers demand more viewable ads whereas in the same time Internet users require to preserve user experience. Extending the initial model, we find that when the cost of ad-blockers is lower than the nuisance cost of viewable ads, publishers are forced to reduce the viewability of ads to account for user experience, whether or not there is a viewability technology on the market.

This study can be extended in several directions. Firstly, we modeled the advertising industry as a business that rewards quantity over quality, meaning that publishers derive revenues from the number of ads sold to advertisers, regardless of their quality. This business model is of course dominant on the market. However, due to a drop in ad revenues, many publishers refuse to add more and more ads to offset their losses and preserve user experience. They are therefore pushing advertisers to promote new ad formats to connect with their audience in a non-intrusive way. Native ads are precisely considered as the future of marketing strategy.[45] Native ads have the look and feel of the content of a website on which they are displayed, and hence do not look like simple ads. They are supposed to have higher levels of engagement than traditional non-native ads: native ads were found to deliver a 9% higher lift in brand affinity

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[45] According to Enders Analysis, spending on native advertising in Europe jumped by a third in 2015 alone (eMarketer, "Native Advertising in Western Europe: Paid Content Placements Gain Fans Throughout the Region," 2016).

than banners (Sharethrough, Behind How Native Ads Work, 2016). A nice extension of the model would consist of accounting for the quality of the ad format, as a better ad quality may preserve user experience (even if it is more visible).

Secondly, we also assumed in the model that the demand (traffic) generated on publishers' websites was always valid traffic, and that fraud did not exist. But fraud is a serious concern in the advertising industry: "The World Federation of Advertisers [...] estimates that between 10 and 30% of online advertising impressions are never seen by consumers because of fraud, and forecasts that marketers could lose as much as $50bn a year by 2025 unless they take radical action." (Financial Times, "Digital advertising: Brands versus bots", July 18, 2016.) Fraud can take many forms. Unscrupulous publishers may purchase fake web traffic to inflate the price of ads. Likewise, fraud can be generated by computer programs, or "bots", that simulate users' web browsing behavior. Including this dimension in the analysis would be interesting as ad viewability is affected by fraudulent traffic.[46]

Thirdly, advertisers are supposed to have no preferences with respect to the editorial content of publishers (homogeneous preferences). However, in real business practices, advertisers prefer to display ads on websites aligned with their brand image. In other words, even if ads are viewed by real Internet users, advertisers want to display ads in a brand safe environment. A further extension of the model could include preferences with regard to publishers to account for brand safety.

Finally, in a context of increasing programmatic sales, all users do not have the same value for advertisers. This means that publishers may manage viewability levels differently depending on the value of users in order to protect the user experience of high value more.

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[46]US democratic senators have called on the Federal Trade Commission to protect consumers from digital advertising fraud, including potential regulation of reform of ad exchanges (Multichannel, Democratic Senators Say Digital Ad Fraud Rampant, Nov 7, 2016).

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A Appendices

A.1 Optimal Number of Viewable Ads

A.1.1 Case With no Viewability Technology

We analyze the optimal number of viewable ads displayed by publishers. The profit function of both publishers admits one extremum as a saddle point as $D = \frac{\partial^2 \Pi_{i,nv}}{\partial^2 b_{i,nv}} \frac{\partial^2 \Pi_{i,nv}}{\partial^2 a_{i,nv}} - \frac{\partial^2 \Pi_{i,nv}}{\partial b_{i,nv} \partial a_{i,nv}} = -(\frac{\gamma b_e a_{i,nv}}{t^u})^2 < 0$. Therefore we have to look at a constrained optimum. We know that $a_{i,nv}(a_{j,nv}) = \frac{t^u + \gamma b_{j,nv} a_{j,nv}}{2\gamma b_{i,nv}}$, and that $\Pi^*_{i,nv}$ and $\Pi^*_{j,nv}$ are decreasing in their respective viewability level and increasing in that of their competitor.

We begin by analyzing the best responses of both publishers regarding t^u:

- First case: if $t^u < \gamma \underline{b}$.

    - A first case arises as publisher i sets $a_{i,nv}^* = \frac{t^u}{b_{i,nv}\gamma}$ if publisher j sets $a_{j,nv}^* = \frac{t^u}{b_{j,nv}\gamma}$. In this case, regardless of the level of viewability set up by publisher j, publisher i gets $a_{i,nv} = \frac{t^u}{b_{i,nv}\gamma}$ and sets $b^*_{i,nv} = \underline{b}$ to increase its demand. Therefore, in this case the equilibrium is $a_{i,nv}^* = a_{j,nv}^* = \frac{t^u}{\underline{b}\gamma}$ and $b_{i,nv}^* = b_{j,nv}^* = \underline{b}$.

    - A second case arises if publisher j sets $a_{j,nv}^* = 1$, which means that $t^u > \gamma(2b_{j,nv} - b^*_{i,nv})$. In this case, publisher i sets $a_{i,nv}^* = \frac{t^u + \gamma b_{j,nv}}{2b_{i,nv}\gamma}$ only if $t^u < \gamma(2b_{i,nv} - b^*_{j,nv})$. No matter what publisher j sets as viewability level, publisher i gets $a_{i,nv}^* = \frac{t^u + \gamma b_{j,nv}}{2b_{i,nv}\gamma}$ only if $t^u < \gamma(2b_{i,nv} - b_{j,nv})$. In this context, publisher i would choose again $b^*_{i,nv} = \underline{b}$ as it maximizes its profit function in increasing its demand without lowering its price. However, the condition related to the demand of publisher j $t^u > \gamma(2b_{j,nv} - b^*_{i,nv})$ would not be respected anymore and publisher j would decrease its demand below 1, which is treated in the previous case.

- Second case: if $\gamma \underline{b} \leq t^u$

    - A first case arises as publisher i sets $a_{i,nv}^* = \frac{t^u}{b_{i,nv}\gamma}$ if publisher j sets $a_{j,nv}^* = \frac{t^u}{b_{j,nv}\gamma}$. In this case, regardless the level of viewability fixed by publisher j, publisher i gets $a_{i,nv} = \frac{t^u}{b_{i,nv}\gamma}$ and sets $b^*_{i,nv} = \underline{b}$ to increase its demand leading to $a_{i,nv}^* = \frac{t^u}{\underline{b}\gamma}$. However, as we are facing a low level of competition intensity regarding Internet users $\gamma \underline{b} \leq t^u$, publishers are able to attract all the demand of advertisers $a_{i,nv}^* = 1$. Therefore we never face this case.

    - A second case arises if publisher j sets $a_{j,nv}^* = 1$, which means that $t^u > \gamma(2b_{j,nv} - b^*_{i,nv})$. In this case, publisher i sets $a_{i,nv}^* = \frac{t^u + \gamma b_{j,nv}}{2b_{i,nv}\gamma}$ only if $t^u < \gamma(2b_{i,nv} - b^*_{j,nv})$. No matter what publisher j sets as viewability level, publisher i gets $a_{i,nv}^* = \frac{t^u + \gamma \underline{b}}{2b_{i,nv}\gamma}$

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only if $t^u < \gamma(2b_{i,nv} - \underline{b})$. In this context, publisher i would choose again $b^*_{i,nv} = \underline{b}$ as it maximizes its profit function in increasing its demand without lowering its price, therefore making its demand equal to $a_{i,nv}{}^* = \frac{t^u + \gamma\underline{b}}{2\underline{b}\gamma}$ which is greater than 1 as $\gamma\underline{b} \le t^u$. Therefore, in this case the equilibrium is $a_{i,nv}{}^* = a_{j,nv}{}^* = 1$ and $b_{i,nv}{}^* = b_{j,nv}{}^* = \underline{b}$.

As a consequence, the optimal level of viewability is:

$$b_{i,nv}{}^* = b_{j,nv}{}^* = \underline{b},$$

and the optimal number of ads displayed is:

$$a_{i,nv}{}^* = a_{j,nv}{}^* = \begin{cases} \frac{t^u}{\underline{b}\gamma} \text{ if } t^u < \gamma\underline{b}, \\\\ 1 \text{ if } \gamma\underline{b} < t^u. \end{cases}$$

A.1.2 Case With Viewability Technology

When there is viewability technology, we know from Eq. (16) that $(b_{i,v}a_{i,v})^* = \frac{t^u + (b_{j,v}a_{j,v})^*\gamma}{2\gamma}$. The optimal level of ad viewability, that cannot be higher than $\overline{b}$, depends on t^u, γ, and $(b_{j,v}a_{j,v})$. Two cases can be analyzed:

- First case: if $t^u < \gamma\overline{b}$, both publishers set $(b_{i,v}a_{i,v})^* = \frac{t^u + (b_{j,v}a_{j,v})^*\gamma}{2\gamma}$ and $(b_{j,v}a_{j,v})^* = \frac{t^u + (b_{i,v}a_{i,v})^*\gamma}{2\gamma}$, which leads to $(b_{i,v}a_{i,v})^* = (b_{j,v}a_{j,v})^* = \frac{t^u}{\gamma}$.

- Second case: if $\gamma\overline{b} \le t^u$, publisher i sets $(b_{i,v}a_{i,v})^* = \overline{b}$ no matter the action of publisher j. Indeed, if publisher j sets $(b_{j,v}a_{j,v})^* = \frac{t^u + \gamma(b_{i,v}a_{i,v})^*}{2\gamma}$, publisher i would set $(b_{i,v}a_{i,v})^* = \frac{t^u}{\gamma}$ which is greater than $\overline{b}$ in this case. If publisher j sets $(b_{j,v}a_{j,v})^* = \overline{b}$ publisher i sets $(b_{i,v}a_{i,v})^* = \frac{t^u + \gamma\overline{b}}{2\gamma}$ which is higher than $\overline{b}$ in this case. The only Nash equilibrium is then $b^*_{i,v} = b^*_{j,v} = \overline{b}$.

Using Eq. (17), the optimal number of viewable ads is therefore:

$$(b_{i,v}a_{i,v})^* = (b_{j,v}a_{j,v})^* = \begin{cases} \frac{t^u}{\gamma} \text{ if } t^u < \gamma\overline{b}, \\\\ \overline{b} \text{ if } \gamma\overline{b} \le t^u. \end{cases}$$

A.2   Proofs: Corollary and Propositions

Proof of Corollary 1.

Proof.

$$S_{nv}^{u*} = \begin{cases} q - \frac{5t^u}{4} \text{ if } t^u < \gamma \underline{b}, \\ \\ q - \underline{b}\gamma - \frac{t^u}{4} \text{ if } \gamma \underline{b} \leq t^u. \end{cases}$$

and

$$S_{v}^{u*} = \begin{cases} q - \frac{5t^u}{4} \text{ if } t^u < \gamma \overline{b}, \\ \\ q - \overline{b}\gamma - \frac{t^u}{4} \text{ if } \gamma \overline{b} \leq t^u. \end{cases}$$

We analyze different cases according to t^u. Firstly, when $t^u < \gamma \underline{b}$, $S_{nv}^{u*} = S_v^{u*}$. Secondly, when $\gamma \underline{b} \leq t^u < \gamma \overline{b}$, we find that $S_{nv}^{u*} \geq S_v^{u*}$ if $\gamma \underline{b} \leq t^u$, which is always the case. Finally, when $\gamma \overline{b} \leq t^u$, we find that $S_{nv}^{u*} > S_v^{u*}$ as $\overline{b} > \underline{b}$. $\qquad\square$

Proof of Proposition 2.

Proof.

$$S_{nv}^{a*} = S_{i,nv}^{a*} + S_{j,nv}^{a*} = \begin{cases} \frac{t^u(\underline{b}-b_e)}{\gamma \underline{b}} \text{ if } t^u < \gamma \underline{b}, \\ \\ \underline{b} - b_e \text{ if } \gamma \underline{b} \leq t^u, \end{cases}$$

$$S_v^{a*} = 0.$$

It is then straightforward to see that $S_v^{a*} > S_{nv}^{a*}$ when $b_e > \underline{b}$. $\qquad\square$

Proof of Proposition 3.

Proof.

$$\Pi_{nv}^* = \begin{cases} \frac{b_e t^u}{\gamma \underline{b}} \text{ if } t^u < \gamma \underline{b}, \\ \\ b_e \text{ if } \gamma \underline{b} \leq t^u. \end{cases}$$

and

$$\Pi_v^* = \begin{cases} \frac{t^u}{\gamma} \text{ if } t^u < \gamma \overline{b}, \\ \\ \overline{b} \text{ if } \gamma \overline{b} \leq t^u. \end{cases}$$

We analyze different cases according to t^u. Firstly, when $t^u < \gamma \underline{b}$, $\Pi_v^* < \Pi_{nv}^*$ when $\underline{b} < b_e$. Secondly, when $\gamma \underline{b} \leq t^u < \gamma \overline{b}$, we find that $\Pi_v^* > \Pi_{nv}^*$ if $b_e < \frac{t^u}{\gamma}$, which is always the case. Finally, when $\gamma \overline{b} \leq t^u$, we find that $\Pi_v^* > \Pi_{nv}^*$ as $\overline{b} > b_e$. Using Eq. (17), it is straightforward to see that $\Pi_v^* > \Pi_{nv}^*$ when $\frac{(b_{.,v} a_{.,v})^*}{a_{.,nv}^*} > b_e$.[47] $\qquad\square$

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[47] As publishers i and j exhibit symmetrical strategies $a_{.,v}^* = a_{i,v}^* = a_{j,v}^*$ and $b_{.,v}^* = b_{i,v}^* = b_{j,v}^*$. We use the similar notation when there is no advertising viewability technology.

Proof of Proposition 4.

Proof. Different cases can arise according to t^u:

- if $t^u \leq \gamma \underline{b}$, $W_{nv}^* = W_v^*$.

- if $\gamma \underline{b} < t^u < \gamma \overline{b}$:

  - when $t^u = \underline{b}$, $W_{nv}^* = W_v^*$ if $\gamma = 1$ and $W_{nv}^* < W_v^*$ if not,[48]

  - when $t^u < \underline{b}$, $W_v^* > W_{nv}^*$,

  - when $\underline{b} < t^u$, $W_v^* > W_{nv}^*$ if $\gamma < 1$. Two cases here. First, if $t^u \leq \overline{b}$, then the condition holds. Second, if $t^u > \overline{b}$, $W_v^* > W_{nv}^*$.[49]

- if $\gamma \overline{b} < t^u$:

  - when $t^u \geq \overline{b}$, $W_{nv}^* < W_v^*$ if $\gamma < 1$ and $W_{nv}^* = W_v^*$ if $\gamma = 1$,

  - when $t^u < \overline{b}$, $W_v^* > W_{nv}^*$.[50]

$\square$

A.3 Welfare Analysis of Ad Viewability and Ad-Blockers

Proof of Proposition 5.

Proof. Different cases can arise according to c:

- If $c < \min(t^u, \gamma \underline{b})$, the publishers are constrained with or without viewability technology. The profits are equivalent under both situations $W_v^* = W_{nv}^* = W^{adb*}$.

- If $\gamma \underline{b} \leq c < \min(t^u, \gamma \overline{b})$, publishers are only constrained when there is a viewability technology. Therefore, there is a tradeoff between $W_v^* = W^{adb*}$ and W_{nv}^*. We find that $W_{nv}^* < W^{adb*}$ if $\gamma \underline{b} \leq c$, which is always true in this case.

- If $c \geq \min(t^u, \gamma \overline{b})$, the cost of installing an ad-blocker is so large that it does not constrained the choice of publishers which already provides decent user experience under both situations. Therefore, the introduction of an ad-blocker has no impact in this case.

$\square$

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[48]The condition $\gamma < 1$ is always true as we are in the case $\gamma \underline{b} \leq t^u$.
[49]The condition $\gamma < 1$ is not always true as $1 < \frac{\overline{b}}{t^u} < \gamma$.
[50]The condition $\gamma < 1$ is always true as $\gamma < \frac{\overline{b}}{t^u} < 1$.