Attention Retention

Targeted Advertising and the Provision of Media Content

Greg Taylor*

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Abstract

As well as attracting consumer attention ex ante, media content serves an important ex post role in holding that attention. I show that publishers wish to invest in content for this purpose in order to increase the market power of their advertisers. Introducing accurate ad targeting technology intensifies product market competition as advertisers compete to serve consumers with precisely targeted needs, and the imperative to rapidly arrest consumer (content) search with high quality content is thus increased. This dynamic is not unambiguously positive: enhanced content can lead to increased product prices—offsetting any welfare gains enjoyed by consumers—and can prove so costly that publishers would benefit if they could coordinate around implementing lower targeting accuracy or higher content costs.

1 Introduction

Publishers of media products have long provided content to consumers whose attention is subsequently sold to advertisers. In this spirit, the media economics literature has developed a tradition of focusing on the use of content as a device for *ex ante* competition to attract attention. In such models, media publishers make observable decisions about the type or quality of content to provide and consumers determine which platform to patronise based upon these decisions. Papers in this tradition include Anderson and Coate (2005), Crampes, Haritchabalet, and Jullien (2009), Dukes (2006), Ellman and Germano (2009), Gabszewicz, Laussel, and Sonnac (2001), Peitz and Valletti (2008), and Rutt (2011).

In this paper I consider another function of content that has received relatively little attention, namely its *ex post* role as an 'attention retention' device. The basic idea is that offering improved content increases the likelihood that a visitor is satisfied by (or stays on, or returns

*Oxford Internet Institute, University of Oxford. Address: OII, 1 St Giles, Oxford, UK, OX1 3JS. Email: greg.taylor@oii.ox.ac.uk. I am grateful to Lisa George, Justin P. Johnson, Tommaso Valletti, Dan Svantesson, David Waterman, various seminar participants, and participants at *WIEM2011* and the 2011 *Télécom ParisTech conference on the economics of Information and Communication Technologies* for useful comments and suggestions. The latest version of this and other papers is available at http://www.greg-taylor.co.uk.

to) the publisher in question—thereby increasing the publisher's share of consumers' total attention. Thus, a 'high-quality' information provider is one that is relatively likely to carry the information that a given information-seeking consumer needs, and a consumer might be expected to cease their information search once such an outlet has been found. Likewise, a consumer that is idly browsing for entertainment content is relatively more likely to stop surfing between providers and spend time consuming a single publisher's content if that publisher offers original, high-quality entertainment. More broadly, websites (e.g. Facebook) that do not provide content per se can invest in expanding their range of affordances (e.g. photo sharing) to reduce users' propensity to also use alternative providers (e.g. Flickr) of those services and thus capture more of consumers' attention. Indeed, the attention retention role of content is particularly interesting in online contexts: On demand content available at the click of a mouse (and typically at no pecuniary cost) has drastically reduced barriers to switching, resulting in consumers who 'surf' between websites in a manner that may appear fickle, and who use tools such as web search or hyperlinks to discover new content whose quality is difficult to observe ex ante (i.e. before clicking the link) but is easily verified ex post.

Advertisers, for their part, value exclusive access to a consumer's attention as this eliminates competing offers from the consumer's consideration set and leaves the advertiser with more market power. Rauch (2011), for example, exploits an Austrian natural experiment to demonstrate that consumer prices increase when consumers are exposed to fewer informative ads. This implies that an advertiser can increase its price if it is able to reduce the frequency with which consumers observe ads for its rivals' products. In light of this, it is not surprising that the forming of bilateral exclusivity deals between publishers and advertisers is a widespread phenomenon—see Dukes and Gal-Or (2003) for an analysis and discussion. Guaranteeing this kind of exclusivity in accessing consumers' attention when consumers surf between media platforms becomes more difficult, however, because publishers typically have no direct influence over impressions taking place elsewhere.

In garnering a greater share of consumer attention for themselves, publishers can seek to indirectly provide such exclusivity by denying other publishers the opportunity to impress an ad upon consumers—increasing the value of their own advertisement resource in the process. I show that this compels publishers to invest in the provision of content for the purpose of attention retention. An interesting question concerns how the changing technology of advertisement delivery—and, in particular, the growing importance and precision of ad targeting—affects this content provision incentive. When advertisements are not well-targeted, the attention retention incentive is relatively weak since most ads will be posted by firms that are not a good match for the consumer and therefore do not present a competitive threat to each other. However, as ad targeting becomes more precise it will increasingly be the case that rival ad platforms expose consumers to advertisers that are competing to serve the same targeted need; as a result, consumers who view more than one publisher are increasingly likely to be exposed to a viable alternative to any individual merchant's offer. Exclusive access to a consumer's attention then becomes particularly valuable and publishers respond by investing more in content provision, which reduces the number of advertised offers that consumers' are exposed to—yielding an increase in producer profits that can be appropriated in the form of higher ad prices. Although targeting is thus linked with an increase in content quality, this dynamic is not unambiguously positive: upward shifts in content quality can lead to increased product market prices that completely offset any welfare gains enjoyed by consumers or society at large. Moreover, by intensifying competition, improved ad targeting can cause ad prices to *fall* and lead to excessive investment in content, leaving publishers worse-off overall.

1.1 Notes on the targeting of advertisements

Traditionally, ad targeting has involved the tailoring of media content to attract a specific consumer demographic whose homogeneity is attractive to advertisers. For example, women's magazines are filled with advertisements for ladies' fashion and cosmetic products, whilst computing magazines carry ads for computer hardware and software.[1] Esteban and Hernández (forthcoming) argue that a proliferation of specialised magazines, cable channels, websites and other niche media products has contributed to a growing precision and importance for such contextual targeting.

More recently, sophisticated technologies that allow the 'behavioural' targeting of advertisements independently of content have become a persistent and salient feature of the online media space. Cookies are a pervasive technology used by many publishers to track a user's path across the web. By observing a consumer's browsing history, publishers can draw inferences about his or her interests or characteristics for the purpose of ad targeting.[2] Similarly, firms such as Facebook are increasingly using their comprehensive knowledge of a person's personality and social context to enable the serving of targeted ads within their site, and may one day do so across the entire web. The firm's technology enables it to, for example, advertise Nike shoes to individuals whose 'friends' have indicated that they 'like' Nike.[3] The growing importance of these kinds of technologies and the uncertainty surrounding their implications make them an important subject for research.

Much online advertising—and targeted advertising in particular—is focused on generating a direct consumer response and is extremely sensitive to timing. For example, Lambrecht and Tucker (2011) show that specifically targeted advertisements are only effective at generating sales if their delivery is carefully timed to coincide with a high level of consumer engagement in the product category concerned. This is significant because the average U.S. internet user

[1]Another case in point: several economics journals routinely publish advertisements for STATA statistical analysis software in their backmatter.

[2]A more recent development is the advent of 'device fingerprinting', whereby uniquely identifying combinations of characteristics of a computer such as the installed fonts, browser version, and screen resolution are compiled into a database that is then used to profile users over time and target ads accordingly. See http://online.wsj.com/article/SB10001424052748704679204575646704100959546.html, accessed 4th November 2011. Unlike the use of cookies this is a passive tracking technique (making no modification to a user's computer and requiring no user input), making it more difficult to block.

[3]Friendship is a generic, bilateral social tie in the Facebook network that may also be made between family members, colleagues, complete strangers, etc. Liking is an affordance of Facebook that allows its users to observably and unilaterally declare that they 'like' a piece of content either on the Facebook site itself or on a third party website that makes this facility available.

visits only 3.2 different website domains in a given day and an average of just 1.6 domains per browsing session.[4] Thus, the number of publishers that are able to deliver an ad in the appropriate time-window is often small, and policies that increase an individual publisher's share of attention can have a relatively important impact upon the overall distribution of attention.

1.2 Related literature

This model adopts the informative view of advertising, whose study was pioneered by Butters (1977); as in Butters' model, consumers' consideration sets consist of those products that they have seen advertised. A more recent take on this kind of advertising environment is given in Anderson and de Palma (2012), who consider competition amongst advertisers who face consumers with finite attention spans.

A recent literature has considered the effect of targeting on advertising markets. Athey and Gans (2010) consider the effect of targeting on niche and mainstream media outlets; Bergemann and Bonatti (2011) model advertising market competition amongst media with differing abilities to target advertisements; and Johnson (2009) provides an equilibrium and welfare analysis of targeted advertising and ad avoidance. My work contributes to this literature by explicitly introducing three new factors: endogenous content provision, product market competition, and endogenous consumer multi-homing. This yields new results on the relationship between targeted advertising, content provision, and product market pricing. Papers by Brahim, Lahmandi-Ayed, and Laussel (2011), de Cornière (2011), Esteban, Gil, and Hernández (2001), Esteban and Hernández (forthcoming), Gal-Or, Gal-Or, May, and Spangler (2010), Galeotti and Moraga-Gonzlez (2008), and Iyer, Soberman, and Villas-Boas (2005) model targeted advertising's effects upon product-market competition. My work extends this literature by modelling the relationship between targeting's effects in the product market and the provision and consumption of media content.

Several recent papers consider the effect of consumer multi-homing on the advertising market. The literature here has mostly abstracted from competitive product market forces and focused on the idea that non-exclusive viewers are less valuable because an advertiser only requires one impression on each consumer. Ambrus and Reisinger (2006) and Anderson, Foros, Kind, and Peitz (Forthcoming) focus on platforms' control of advertising levels or ad prices in order to minimise audience overlap; Athey, Calvano, and Gans (2011) consider the equilibrium effects of tracking technologies that allow media firms to determine whether a consumer has been exposed to an ad elsewhere; and George and Hogendorn (2012) model the effect of search tools and content aggregators in the face of consumer multi-homing. In contrast to these papers, I introduce product market competition amongst the advertisers and endogenous media content provision, and consider publishers' resulting additional motive to limit the extent of consumer multi-homing—namely, the minimisation of the competition faced by advertisers in the product market. My paper is also different in its focus: I introduce the notion that content

[4]Data from Nielsen's "Top US Web Brands": http://blog.nielsen.com/nielsenwire/online_mobile/november-2011-top-u-s-web-brands/ (accessed 20th April 2012), which reports an average of 98 domain visits per month across 63 browsing sessions.

investment can be used as a policy tool to manipulate consumer browsing behaviour in this fashion, and consider the role of advances in targeting technology in driving quality provision. I therefore view these papers and my own as complementary.

Several empirical studies motivate the model below. Rauch (2011) exploits an Austrian natural experiment to demonstrate that consumer prices increase when consumers are exposed to fewer informative ads. This implies that an advertiser can increase its price if it is able to reduce the frequency with which consumers observe ads for its rivals. Chandra (2009), Chandra and Kaiser (2010), Goldfarb and Tucker (2010a), Goldfarb and Tucker (2010b) and van Dalen (2010) provide empirical evidence for the effectiveness and value of targeted advertising. Lastly, Sun and Zhu (2011) provide evidence for a link between the advertising market and media content quality: showing that sites that participate in an ad revenue sharing programme provide higher quality content than those that do not. One should, then, expect that publishers' content provision decisions are sensitive to the prevailing advertising environment.

2 Model

There are two content *publishers* (e.g. websites) that provide content to a mass, μ, of *consumers* who wish to satisfy a particular desire for content (or similar) consumption. Examples of such desires include the desire to consume national news, the desire to find a good local restaurant, or the desire for a few minutes of entertainment. I will generically label the publishers as i and $-i$. Consumers derive positive surplus from content consumption and (possibly) from trade with advertisers, but incur a cost, $k \in (0,1)$, for each publisher that they visit.

Content can be accessed for free, but the production of content is costly: each publisher, i, must independently decide on its level of investment, $q_i \in [0,1]$, in the content it provides. The associated cost, $C(q)$, is increasing and convex and (to ensure an interior solution) satisfies $C(0) = C'(0) = 0 < \mu/2 < C'(1)$. I refer to q_i as the content's 'quality'[5]—where content of quality q satisfies a given consumer's desire with probability q—and suppose that consumers visit platforms in turn either until their need is satisfied or both platforms have been visited.[6,7]

In building a model of publisher switching I am primarily motivated by world wide web usage, which is characterised by the frequent use of hyperlinks and search engines to discover new content whose quality is verified ex post. I therefore begin by modelling content as a search good so that consumers visit platforms at random and observe q_i only after they have arrived at i. This assumption, whilst not crucial, allows for a clear exposition of attention retention as a motive for content provision above and beyond the well-known desire to compete in quality ex ante to increase audience share. I relax this assumption in Section 4.3 and permit consumers

[5] q can also be interpreted as the quantity of content provided.

[6] I will, for the most part, avoid restricting the precise form of the consumers' utility from content consumption. A simple example of such a function consistent with the behaviour described above is given in Section 4.3.

[7] In particular, once satisfied, consumers do not visit an additional publisher solely to consume its advertisements. Introspection suggests that this is a reasonable assumption in typical media environments—that is, in environments where the consumption of media content is the consumer's primary motivation. Such behaviour naturally emerges when the cost, k, of visiting a site exceeds the expected benefit of viewing an ad there. It will be seen that this expected benefit does not exceed $M[1-E(p)]$, where M and $E(p)$ are defined/calculated below.

to endogenously decide which of the platforms to visit based upon their observable content qualities.

In order to generate revenue, the publishers sell advertising opportunities to *firms*. Each consumer has a latent (product market) consumption desire, θ, uniformly distributed over the set, Θ, of desires, and there is a market consisting of a mass, n, of retailer-firms for each θ. A firm is said to 'match' with those consumers who share its θ and firm marginal costs are assumed to be zero. Trade occurs between a matched consumer-firm pair if the consumer sees an advertisement for the firm and the firm's chosen price, p, is the lowest that the consumer observes amongst their (matched) advertised offers. If trade does occur then the consumer receives surplus $1-p$, and the firm receives revenue of p.[8] If an advertiser and consumer do not match then trade between the two does not occur. There exists a common ad targeting technology (e.g. browser cookies, user accounts, device fingerprinting, etc.) available to the publishers that allows them to systematically match ads to consumers. Specifically, the platform receives a 'signal' of each consumer's type that is accurate with probability M and is otherwise pure noise.[9] Write I_i for the volume of impressions that publisher i makes for each θ, and ρ_i for the price it charges per-impression.[10]

To make the role of attention retention as a device for controlling consumers' exposure to competing ads as clear as possible I assume that publishers draw advertisements from separate pools of firms so that, conditional on receiving the correct signal, the two publishers show different ads to the consumer. In particular, this ensures that any attention retention in the model can be attributed entirely to competitive product market forces and not to the alternative motivations to limit multi-homing discussed in Ambrus and Reisinger (2006), Anderson, Foros, Kind, and Peitz (Forthcoming), Athey, Calvano, and Gans (2011), and George and Hogendorn (2012). In practice, there is likely to be some non-zero probability that a consumer will be exposed to the same ad at multiple publishers. However, the intuition of the model below remains valid so long as consumers are sometimes exposed to competing advertisers when surfing between platforms. In Section 4.2 I show how results identical to those below emerge naturally as a limit point of a more general model in which the two publishers select advertisers from a shared pool of firms—sometimes showing the same advertisement.

[8] The model can be extended to allow for downward sloping consumer demand with little qualitative change.

[9] It is possible to endogenise the level of targeting accuracy by supposing a convex cost for adoption of targeting technology. Publishers then have a pair of reaction functions that exhibit the strategic substitutes property for a reasonable range of costs—giving rise to a symmetric equilibrium choice of M that increases as targeting technology becomes cheaper.

[10] I suppose per-impression pricing for concreteness. An equivalent version of the model can be written with per-click pricing. Together, these two pricing models account for the majority of online advertising. See Taylor (2011) for a discussion of alternative advertising fee structures.

3 Equilibrium Analysis

3.1 Advertiser pricing

Begin by considering the sub-game in which each advertiser-firm, l, must set its price, taking as given the behaviour of publishers and the strategies of other firms. A publisher will never elect to show to a consumer advertisements from two or more firms that are direct competitors with each other since doing so will induce Bertrand competition between them. One can therefore normalise the number of ads shown to each consumer to 1 by redefining M accordingly. Given signal θ, the publisher selects randomly from amongst its n_i type θ advertisers to impress on a consumer. Thus, a fraction M of the ads result in a match, whilst the remaining $1-M$ are of a random unmatched type. Some consumers will match only with l (either because they are satisfied by the first publisher's content and visit only one publisher, or because the ad at a second publisher does not match their interests) and l can behave as a monopolist towards such individuals. However, some consumers will visit both publishers and match with both l and a second advertiser. The two matched firms then become Bertrand competitors for the consumer's business. Standard arguments imply that any pricing equilibrium in this kind of environment must be in mixed strategies,[11] and such pricing behaviour is typically interpreted as a theoretical analogue for the empirical phenomenon of price dispersion.

Lemma 1 *For given publisher qualities, there exists a mixed strategy equilibrium of the advertiser pricing sub-game in which each firm that advertises at i chooses prices from distribution G_i with support $[\underline{p}_i, 1]$.*

Proof. See Appendix A. ■

Lemma 1 tells us that the monopolist price, $p = 1$, lies within the support of the equilibrium price distributions. Since a firm that advertises at i must be indifferent across all prices lying on the equilibrium path, such a firm must make an expected revenue equal to that from setting the monopolist price. Moreover, since a firm that sets $p = 1$ is certain to have a higher price than any rival advertiser,[12] such a firm sells only in the event that it is a de facto monopolist (viz. when it is the only matched firm in the consumer's consideration set). There are two ways that this might come about: firstly, a consumer may be satisfied by the content at the first publisher they visit—in which case they view only one publisher (and, more to the point, only one advertisement)—or, secondly, a consumer may visit both publishers, but find that they only match with one advertiser. These two possibilities are respectively reflected in terms (ii) and

[11] If there is a single market price, $\tilde{p}$, at which firms make positive profit then each firm has an incentive to undercut $\tilde{p}$ by a small margin. Likewise a uniform zero-profit price cannot be supported in equilibrium since each firm would prefer to increase its price and sell (for positive profit) to those consumers who view no other matched ad.

[12] We can be sure that there is no mass point in the price distribution at $p = 1$ (ruling out ties) because firms at the rival publisher could then profit by undercutting: shifting mass from $p = 1$ to $p = 1 - \epsilon$ in their price distribution.

(iii) in the below expression for the expected revenue of a firm from advertising at i:

$$(1) \qquad R_i \equiv \underbrace{\frac{\mu}{2n_i|\Theta|}}_{\text{(i)}} M[\underbrace{q_i}_{\text{(ii)}} + \underbrace{[(1-q_{-i})+(1-q_i)](1-M)}_{\text{(iii)}}].$$

Term (i) accounts for the mass of impresions that are to be allocated; division by $n_i|\Theta|$ reflects the fact that the mass of matched type θ consumers' impressions must be shared amongst i's type θ advertisers. In order to sell to a consumer, firm l must match with him or her, which accounts for the leading M term.

3.2 Content provision

Since advertisers must be indifferent across all prices set with positive probability, R_i characterises the equilibrium value of an ad to advertisers. It turns out that publishers are able to extract all of this expected firm profit. Clearly, a publisher will not set price above this level since it would then attract no advertisers. Moreover, the finite nature of consumer attention effectively imposes a capacity constraint on publishers' supply of impressions. Any publisher that has at least one advertiser of each θ and deviates to a below-full extraction ad price earns less per-impression but sells the same number of impressions so that such a deviation is not optimal.[13]

Lemma 2 *Full profit extraction ($\rho_i = R_i n_i / I_i$) is an equilibrium ad pricing strategy. That the number of firms is large implies that this strategy is unique.*

Proof. See Appendix A. ■

Publisher i's profit is, then, given by the difference between its advertiser's revenues (summed over all advertisers for each θ) and its own expenditure on content provision:

$$(2) \qquad \Pi_i = n_i R_i |\Theta| - C(q_i) = \frac{\mu}{2} M[q_i + ((1-q_i)+(1-q_{-i}))(1-M)] - C(q_i)$$

and the first order condition for maximisation of (2) implies that the optimal quality, q_i, must satisfy

$$(3) \qquad C'(q_i) = \frac{\mu M^2}{2}.$$

Writing c^{-1} for the inverse of C',[14] the optimal quality level is therefore given by

$$(4) \qquad q_i = q_{-i} = q^* \equiv c^{-1}\left(\frac{\mu M^2}{2}\right).$$

[13] Note that even if we relax the assumption that there is a continuum of firms for each θ, full profit extraction can still be supported in equilibrium. Moreover, since this equilibrium maximises profits, one mighr expect it to be focal under such circumstances.

[14] This inverse exists since C is convex.

Now, when publishers set quality q^*, it is clear from (1) that a generic advertiser that sets a price of 1 makes revenue

$$\frac{\mu}{2n_i|\Theta|}M\left[q^*+2\left(1-q^*\right)(1-M)\right].$$

By extension, when a firm sets a price $p<1$ its revenues are

$$\frac{\mu}{2n_i|\Theta|}M\left[q^*+2\left(1-q^*\right)(1-M)+\underbrace{2\left(1-q^*\right)M(1-G(p))}_{A}\right]p,$$

where G is the distribution of prices set by rival advertisers. This equation is analogous to (1), with an extra term (term A) to account for those consumers who view two matched ads and buy from the firm that offers the lower price—which is the firm in question with probability $1-G(p)$. We know that in order for firms to mix over their choice of price, it must be the case that every price in the support of G yields equal expected revenue. Setting the two revenue expressions equal for such indifference and solving for $G(p)$ yields an expression for the price distribution:

$$G(p)=\frac{1}{p}\left(1-\frac{1-p}{1-\underline{p}}\right) \tag{5}$$

on support $[\underline{p},1]$, where

$$\underline{p}\equiv 1-\frac{2M(1-q^*)}{2-q^*}$$

is found as the solution to $G(\underline{p})=0$.

To find the equilibrium impression prices that correspond to quality q^*, we take publisher revenue and divide it by the number of impressions sold, which is

$$\frac{\mu}{2}+\frac{\mu}{2}\left(1-q^*\right).$$

Thus, the impression price is given by

$$\rho=\frac{M[q^*+2(1-M)(1-q^*)]}{2-q^*}. \tag{6}$$

Lastly, note that since publishers and advertisers behave symmetrically in this equilibrium, and since an individual consumer has a small impact on the overall market, is is indeed optimal for rational expectations consumers to visit each publisher first with probability 1/2. The induced quality and prices are therefore consistent with consumer rational expectations.

Proposition 1 *In the symmetric equilibrium of the game considered, publishers set content quality according to* (4) *and impression prices at* (6)*. This induces product market prices dispersed on support* $[\underline{p},1]$ *according to* (5)*.*

3.3 On the relationship between quality, prices, and targeting accuracy

One striking thing about Proposition 1 is that publishers wish to invest in positive levels of content quality even when that quality is not ex ante observable for consumers. The reason for this is that a publisher that offers higher quality content holds consumers' attention more successfully and is, therefore, in a better position to endow its advertisers with exclusive access to that attention. Thus, as higher content qualities reduce the average number of sites that a consumer must visit in order to satisfy their (content consumption) desire, those advertisers whose ads *are* viewed have fewer competitors in expectation. This creates market power for the advertisers, allowing them to charge (and be charged) more; it is this increase in an ad's value that makes content provision worthwhile. This relationship between quality and product market pricing manifests as a first order stochastic dominance shift in the price distribution as made precise in the following result:

Lemma 3 *A ceteris paribus increase in equilibrium content quality results in a new distribution for advertised prices that first-order stochastically dominates the old one.*

Proof. This can be seen quite straightforwardly by differentiating (5):

$$\frac{\partial G(p)}{\partial q^*} = -\frac{(1-p)(2-q^*)}{Mp(2-2q^*)^2} < 0.$$

■

It is clear from (4) that more popular content (with a higher μ) will attract more publisher investment and generally be associated with higher quality than niche content: The marginal return from an increase in content quality comes from the fact that impressed advertisers are willing to pay a premium for the protection from competition that such an increase affords them. As the size of the audience increases, the number of impressions on which this premium can be collected multiplies so that any increase in quality becomes more attractive. Of perhaps greater interest is the fact that optimal content quality is also increasing in the accuracy of targeting technology. This result emerges immediately as a corollary to Proposition 1.

Corollary 1 *Equilibrium content quality is increasing in the level of targeting accuracy and in content popularity.*

Proof. This result can easily be seen by differentiating:

$$(7) \qquad \frac{\partial q^*}{\partial M} = \frac{\mu M}{C''(q^*)}; \; \frac{\partial q^*}{\partial \mu} = \frac{M^2}{2C''\left(q_i^*\right)};$$

both expressions are positive for any convex C. ■

There are two reasons why an increase in targeting accuracy should cause content quality to increase. Firstly, note that, *conditional on having matched with a consumer*, an advertiser would be willing to pay its publisher to increase quality so as to obtain more market power. However, an advertiser that does not match with a consumer has no such interest in improving content quality. A higher targeting accuracy increases the number of matched impressions and, therefore, the number of impressions for which quality investment attracts an ad price premium. It is, then, natural that publishers should want to invest more in quality when targeting is very precise.

To understand the second cause for the positive relationship between targeting and content provision it is useful to think about the direct effect of an improvement in targeting technology upon advertiser pricing.

Lemma 4 *Holding content quality constant, the effect of an increase in targeting accuracy is a new distribution for advertiser prices that is first-order stochastically dominated by the old one.*

Proof. Differentiating (5):

$$\frac{\partial G(p)}{\partial M} = \frac{(1-p)(2-q^*)}{M^2 p(2-2q^*)} > 0.$$

■

Thus, targeting technology works in the opposite direction to content investment: depressing finished goods prices by increasing the frequency with which two rival advertisers match and must subsequently compete in price. This intensified product market competition undermines the value of an ad impression and, in equilibrium, publishers attempt to offset this effect by investing more in their content—giving rise to the positive relationship between targeting accuracy and content quality. Intuitively, better targeting technology makes rival publishers' ads more 'dangerous' by increasing the likelihood that they match. This strengthens the imperative to keep consumers away from rival publishers to the greatest extent possible—a feat that can be achieved by providing better content to hold consumers' attention for longer. Figure 1 summarises the effect of content quality and targeting accuracy on prices.

Product market prices are beginning to emerge as an important mediator of shifts in other markets. From (5), it is possible to calculate the density for advertiser prices as

$$G'(p) = g(p) = \frac{2-2M(1-q^*)-q^*}{2M(1-q^*)p^2}.$$

It is immediately clear that $G''(p) < 0$ so that low prices occur relatively more frequently—much as in Butters (1977) and Anderson and de Palma (2012). The expected product market price then has the usual form:

$$(8) \qquad E(p) = \int_{\underline{p}}^{1} g(p)p\,dp = -\frac{2-2M(1-q^*)-q^*}{2M(1-q^*)}\ln\left(\underline{p}\right).$$

Figure 2 presents a contour plot for this expected price along with (for the purposes of illustration) some equilibrium quality loci for the case of quadratic quality costs ($C'(q) = \overline{c}q$). Thus, the centre dashed line in Figure 2 corresponds to equilibrium quality when $\overline{c} = \mu$, the upper dashed curve to $\overline{c} = \mu/2$, and the lower dashed curve to $\overline{c} = 2\mu$. Lemma 3 describes

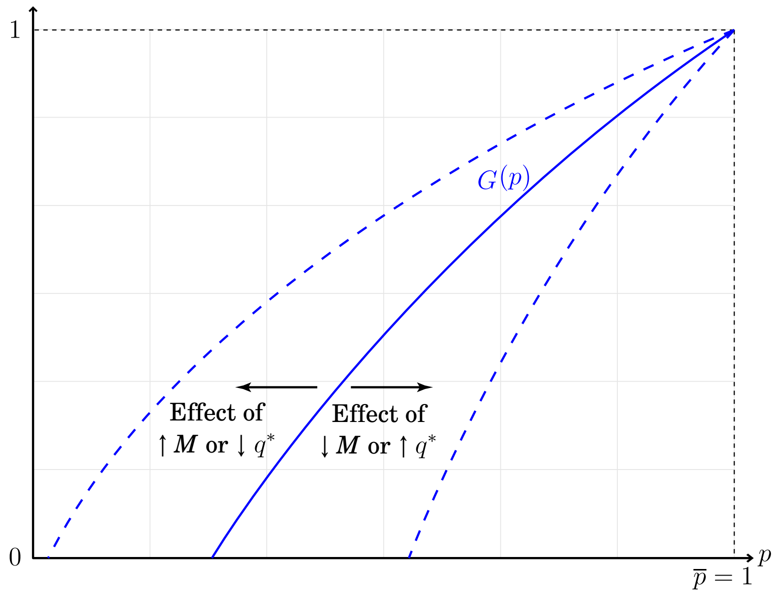

FIGURE 1
The ceteris paribus effects of changes in targeting accuracy or content quality manifest as first order stochastic dominance transformations of the equilibrium price distribution. These two effects work in opposite directions.

the effect of a vertical movement in this figure, whilst Lemma 4 establishes the consequences of a horizontal movement. In equilibrium, an increase in M causes a rightward shift along the relevant quality locus in this figure, which can be seen to result in a net change in final goods prices as a product of the interaction of these two effects. It is clear from Figure 2 that convexity of C implies that if a small increase in targeting accuracy causes prices to increase then so will all subsequent increases in M. Figure 2 also suggests that prices are more likely to decrease in M when quality costs are (locally) very convex. More precisely

Lemma 5 *The expected product market price, $E(p)$, is decreasing in the level of targeting accuracy, M, if and only if costs are sufficiently convex or the audience sufficiently small—specifically if $C''(q^*)/\mu \geq M^2/(2-q^*)(1-q^*)$.*

Proof. See Appendix A. ■

To understand the reason for this result note that, whilst Lemma 4 describes the direct effect of targeting accuracy on price, there is also an indirect, countervailing effect: a higher targeting accuracy induces better content provision and this in turn results in upward pressure on consumer goods prices (Lemma 3). The net effect of M on $E(p)$ depends upon which of these two effects is stronger. If the audience, μ, is small, or if content costs are very convex then quality responds slowly to changes in targeting accuracy (i.e. the quality locus is relatively flat) so that the direct effect dominates. Otherwise, equilibrium quality increases quickly enough to completely offset the downward pressure of targeting technology on prices. These two possibilities are illustrated in Figure 2: if $\overline{c}/\mu = 1/2$ then an increase in M from 0.7 to 0.8 causes prices to increase (from A to A'), whilst for $\overline{c}/\mu = 2$ the same change in targeting accuracy causes equilibrium prices to fall ($B \to B'$).

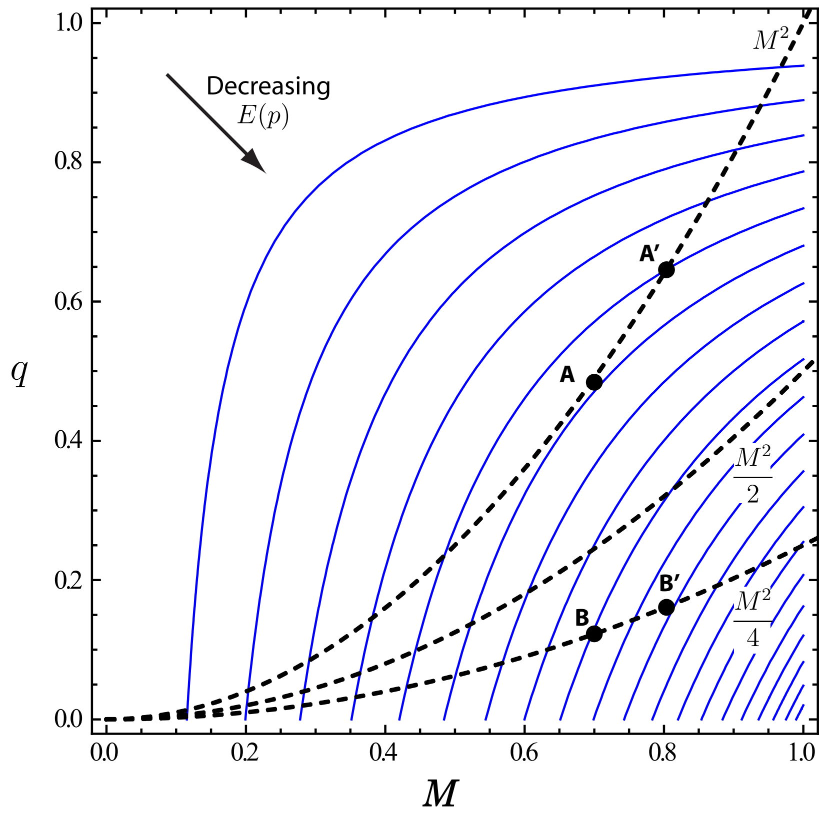

FIGURE 2
Contour plot of expected final goods prices ($E(p)$, solid lines). The dashed lines show some example loci of the equilibrium relationship between ad targeting accuracy (M) and content quality (q) for the case of quadratic content costs—with higher curves corresponding to lower content costs. An increase in targeting accuracy causes a rightward shift along the equilibrium quality function, so that quality increases and prices change.

3.4 Welfare analysis

An interesting question is whether publishers provide the socially optimal level of content quality. This amounts to asking: if platform i were to 'surprise' consumers by deviating from its equilibrium quality, what would be the effect on overall welfare? Total social welfare can be written as the sum of consumer surplus (from content and product market consumption, net of search costs) along with publisher and advertiser profits. Let $u(q_i, q_{-i})$ be the per-consumer expected utility of content consumption for consumers visiting platform i first, and write $U'(q^*) \equiv u_1(q^*, q^*) + u_2(q^*, q^*) > 0$.[15] We then have

Proposition 2 *Publishers under- (over-) provide quality whenever*

$$U'\left(q^*\right) > (<) M - k \tag{9}$$

Proof. See Appendix A. ■

It is curious to find the possibility of over-provision given the public good nature of content. This possibility arises because of an externality: the publishers do not fully internalise the fact that an increase in their content quality deprives their rival of the opportunity to impress an

[15] As usual, u_j means the derivative of u with respect to its j^{th} argument.

advertisement on some consumers. This is bad from a welfare perspective to the extent that it eliminates possibilities for welfare-enhancing trade between some consumer-advertiser pairs. Precisely how much of a cost this represents for society depends upon how many of the forgone impressions would have resulted in a match between consumer and advertiser—captured by the M term in (9).

On the other hand, Proposition 2 says that content is more likely to be under-provided when (i) it is highly valued by consumers or (ii) searching for and viewing content is particularly onerous. If $k > M$, it follows from Proposition 2 that quality is always under provided because the forgone trade from an increase in quality is more than offset by the reduction in search costs incurred by consumers whose content desire is more rapidly satisfied. Note that if content consumption is a relatively small piece of the welfare pie then technological improvements that increase M relative to k may cause a transition from an under- to an over-provision regime.

More generally, one can also ask: what is the overall welfare effect of an increase in targeting accuracy? The answer is given in the following expression:[16]

$$\text{(10)} \quad \frac{\partial W}{\partial M} = \underbrace{\mu\left[2 - 2M\left(1-q^*\right) - q^*\right]}_{>0} + \frac{\partial q^*}{\partial M}\underbrace{\mu\left[U_i'\left(q^*\right) - M + k\right]}_{\text{cf. (9)}}.$$

Equation 10 has two parts, the first being the direct effect of targeting technology on welfare: more accurate targeting means that a larger fraction of ads match, which creates opportunities for welfare-improving trade in the product market. This effect is always positive. The second term in (10) captures the indirect effect that M induces higher quality provision. This second effect is precisely that described in Proposition 2 and has the same properties as those discussed above. In particular, under any condition in which content is under-provided (10) will be positive so that an increase in M has a net benefit for society.

Corollary 2 *If content is under-provided from a social welfare perspective then an increase in targeting accuracy increases welfare.*

Consumers, for their part, match with precisely one advertiser with probability $2(1-q^*)M(1-M)+Mq^*$, in which case the expected price paid is that given in (8). With probability $(1-q^*)M^2$ the consumer visits both platforms and matches with two advertisers—paying the lower of the two observed prices:

$$\begin{aligned} E(\min p) &\equiv 2\int_{\underline{p}}^{1}(1-G(p))g(p)p\,dp \\ &= \frac{[2-2M(1-q^*)-q^*]\left[2M(1-q^*)+(2-2M(1-q^*)-q^*)\ln\left(\underline{p}\right)\right]}{2M^2(1-q^*)^2}. \end{aligned}$$

The representative consumer, then, receives an expected utility of

$$\text{(11)} \quad \left(1-q^*\right)M^2[1-E(\min p)] + \left[2(1-M)M\left(1-q^*\right)+Mq^*\right][1-E(p)]$$

[16]This equation follows straightforwardly from the proof of Proposition 2.

from engaging in trade with advertisers. Substituting $E(p)$ and $E(\min p)$ into this expression and simplifying reveals that (11) can be rewritten as $M^2(1-q^*)$. Each consumer's expected surplus from participating in trade with final goods firms is therefore simply given by the probability that they view two matched advertisements, and a consumer's total expected surplus is

$$(12) \qquad \underbrace{u\left(q^*,q^*\right)}_{\text{Content consumption}} + \underbrace{M^2\left(1-q^*\right)}_{\text{Trade surplus (11)}} - \underbrace{k\left(2-q^*\right)}_{\text{Search costs}}.$$

Substituting equilibrium quality from (4) into the expression for consumer surplus and differentiating with respect to M, it is straightforward to see that an increase in targeting accuracy is beneficial to consumers if

$$(13) \quad M^2 - k - U'\left(q^*\right) \leq 2\left(1-q^*\right)\frac{C''(q^*)}{\mu}.$$

If search costs or the marginal value of content consumption are relatively high so that $k + U'(q^*) \geq M^2$ then (13) is satisfied for any C, μ. An increase in M is then unambiguously good for consumers—who enjoy increased content quality that is both directly beneficial and also reduces search costs. These benefits more than offset any adverse product market effects in the form of higher prices.

Likewise, if quality costs are sufficiently convex or the audience relatively small then consumers benefit from an improvement in targeting accuracy. The intuition follows that of Lemma 5: if the marginal cost of quality provision grows very quickly (or the marginal benefit—which is scaled by μ—very slowly) then equilibrium quality adjusts slowly to changes in targeting accuracy. This effectively shuts down the indirect positive effect of targeting on prices described in Lemma 3; only the direct (increased product market competition, reduced price, and more frequent matching) effects of improved targeting accuracy are then significant so that consumers enjoy these benefits without the burden of significantly higher product market prices.

If $C''(q^*)$ is small (so that costs grow almost linearly in quality in the neighbourhood of q^*), or if μ is large then small increases in the marginal benefit of quality provision—brought about by a change in M—result in large increases in content quality. When, in addition, $M^2 > k + U'(q^*)$ this rapid increase in q can cause prices to increase to such an extent that the fall in consumer surplus from viewing ads more than offsets gains from improved content and reduced search costs. Consumers are then harmed by targeting technology.

Remark 1 *Improved targeting can make consumers worse off. Consumers are most likely to benefit from targeting when search costs and the marginal utility of content are high, and* $k + U'(q^*) > M^2$ *is a sufficient condition for improved targeting to benefit consumers.*

On balance, the conditions needed to make an increase in M harmful to consumers seem quite demanding. How can this be reconciled with the casual observation that many consumers seem to be openly hostile to targeted advertising (see, for example, Turow, King, Hoofnatle, Bleakley, and Hennessy, 2009)? One possible answer is that, for a suitably high marginal utility of content, it is possible for (13) to be satisfied even when an increase in M lowers consumer trade surplus, (11). Such circumstances give rise to a certain kind of ambivalence on the part of consumers who benefit in overall terms from enhanced targeting once the consequent improvements in content are accounted for, but nevertheless despair at the underlying changes in the advertisements supporting that content. Ultimately, this may lead to consumers seeking to enjoy the benefits of improved content whilst simultaneously increasing their level of ad avoidance in response to increased targeting accuracy—effectively free-riding on others' willingness to endure targeted advertisements. In Section 4.1 I model the effects of such ad avoidance on equilibrium quality provision.

Another interesting implication of the model is that publishers do not necessarily gain from improved targeting technology. To see this, consider the example of quadratic quality costs—given by $C(q) = \overline{c}q^2/2$. Substituting q^* into (2) then reveals platform profits to be

$$\Pi = \mu\frac{1}{2}M\left[\frac{M^2\mu}{2\overline{c}} + 2(1-M)\left(1-\frac{M^2\mu}{2\overline{c}}\right)\right] - \underbrace{\frac{M^4\mu^2}{8\overline{c}}}_{C(q^*)}, \tag{14}$$

and differentiating this expression immediately reveals

Proposition 3 *With quadratic quality costs, publisher profit is decreasing in targeting accuracy over the non-degenerate interval* $M \in \left(1/2, 2\sqrt{\overline{c}}/\sqrt{3\mu}\right)$. *In particular, when* $\overline{c} > 3\mu/4$, *publisher profits decrease in* M *for all* $M > 1/2$.

Thus, equilibrium profits are increasing in targeting accuracy for $M < 1/2$, but begin to decrease in M above this level. There are several factors that exert downward pressure on Π after an increase in targeting accuracy. Firstly, as M increases, platforms are compelled to invest heavily in content quality to mitigate the ever-worsening competitive side effects of their rival's targeting in the product market (Corollary 1); such investment is costly. Secondly, the higher content quality induced by an increase in M decreases the total number of visitors to each publisher because consumers 'surf' around less so that the number of impressions sold falls. Lastly, if content is sufficiently costly (note that the size of the interval over which $\partial\Pi/\partial M < 0$ is increasing in $\overline{c}$) then publishers are unwilling to invest enough in content to prevent prices from falling and this fall in product market prices reduces the value of each matched impression.

This last point can be seen more clearly by looking at the effect of targeting innovations upon the impression price. From (6):

$$\frac{\partial\rho}{\partial M} = \frac{2-4M-(1-4M)q^*}{2-q^*} + \underbrace{\frac{2M^2}{(2-q^*)^2}\frac{\partial q^*}{\partial M}}_{\geq 0}. \tag{15}$$

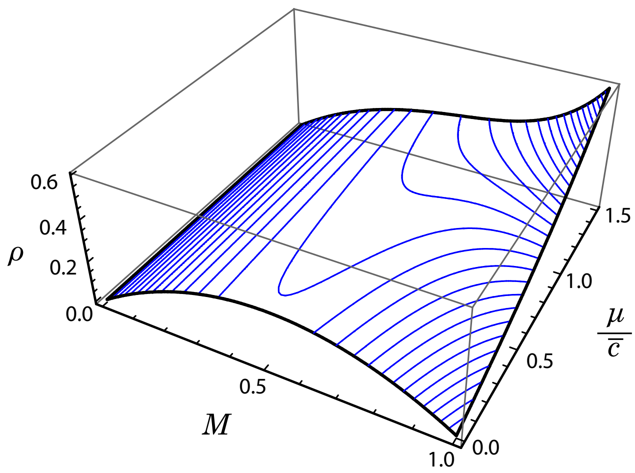

FIGURE 3
Impression prices for quadratic costs, $C'(q) = \bar{c}q$. For high μ or low $\bar{c}$ ad prices are everywhere increasing in targeting accuracy (M) since the low cost of content provision induces publishers to invest heavily in protecting advertisers from external competition. When the cost of content provision is high or the audience small, little investment in content takes place: consumers then surf around more and are exposed to more competing advertisers when targeting accuracy increases—causing the value of an ad to eventually fall with M.

Since $\partial q^*/\partial M > 0$, it is easy to verify that ρ is sure to be increasing in targeting accuracy for any $M < 1/2$. This is intuitive since $M = 0$ necessarily implies that the value of an impression is zero and can only grow from this point. However, as targeting grows very precise the competitive effect described in Lemma 4 exerts strong downward pressure on product market prices and revenues. At this point there is a bifurication of market behaviour depending upon how publishers respond. The publisher can, of course, mitigate this pressure by investing more in content. However, when audience size, μ, is sufficiently small or content sufficiently costly the publisher does not find large investments worthwhile. Without the protection that content provision provides, per-impression advertiser revenues (and with them the equilibrium impression price) are eventually eroded as M increases. Thus, with modest audiences, impression prices are non-monotonic in the accuracy of targeting technology.[17] By contrast, for a large audience and sufficiently low cost, publishers respond to the downward pressure on revenues by investing heavily in content provision in order to protect their advertisers. This investment prevents falls in impression prices. As an example, Figure 3 shows impression prices for the quadratic case in which $C'(q) = \bar{c}q$.

It is also possible to calculate how publisher profits change with the cost of content provision. Calculating the derivative of (14) with respect to $\bar{c}$ yields

$$\frac{\partial \Pi}{\partial \bar{c}} = \frac{(2-3M)M^3\mu^2}{8\bar{c}^2},$$

[17]Bergemann and Bonatti (2011) also find a non-monotonic relationship between targeting and ad prices, and argue that this is broadly in keeping with the current empirical evidence. In Bergemann and Bonatti's model, ad prices are determined competitively; the results presented above demonstrate that external pressures from the product market can also cause ad prices to fall—even when publishers have price setting power.

which is *positive* for $M < 2/3$. Increasing the cost of quality causes both platforms to reduce their equilibrium quality provision. This reduces publisher profits insofar as it reduces each platform's share of the representative consumer's attention and thus causes greater product market competition. There are, however, two countervailing effects that benefit publishers: firstly, each publisher spends less in total on content provision (see the last term of Equation 14) and, secondly, a larger total number of consumers will visit each platform. When $M < 2/3$, the adverse effect of an increase in $\bar{c}$ is moderated by the fact that fewer than half of all visitors to both publishers will view a matched ad at both, and consequently the positive effects of a cost increase dominate. Summarising:

Remark 2 *An improvement in targeting accuracy or a reduction in the costs of content provision can both make publishers worse-off. Impression prices need not be monotonic in M.*

It is interesting to note that publishers can find themselves in a kind of prisoner's dilemma, with each finding it individually optimal to unilaterally adopt a cost-reducing innovation or new targeting technology—even though they would be collectively better off if they were to coordinate around non-adoption.

4 Discussion

4.1 Consumer ad avoidance

It has thus far been assumed that the number of consumers, μ, viewing advertisements is fixed and invariant to the prevailing environment. In practice, consumers should be expected to forecast equilibrium outcomes, and act accordingly. One response of consumers might be to ignore, block, or otherwise avoid ads when viewing ads is undesirable. The desire to avoid online advertisements has spawned an entire industry of ad blockers.[18] The volume of ad viewers, μ, thus becomes an equilibrium variable that adjusts in response to the equilibrium levels of content quality and final goods prices. To the end of modelling such a phenomenon, suppose that a unit mass of consumers may take the ex ante decision to block all advertisements for an idiosyncratic cost, κ_j, that is distributed in the consumer population according to F with positive density on its support, $[0,1]$.[19] Let μ denote the proportion of users that do not block advertisements. For simplicity, it is convenient to identify k solely with the nuisance costs of viewing an ad. Thus, one can write

$$(16) \quad \kappa^*(q) \equiv -M^2(1-q) + k(2-q)$$

for the κ_j that makes a consumer just indifferent between blocking and not blocking when consumers expect quality q (see Equation 12). The value for μ implied by consumer best res-

[18] *Adblock Plus*, for example, reported more than thirteen million unique daily users for its Firefox plugin at the time of writing—see https://addons.allizom.org/en-US/statistics/addon/1865 (accessed 11th April 2011).

[19] There is no reason to suspect that the results would be any different if heterogeneity were in k instead of κ. However, such a configuration turns out to be considerably more algebraically onerous.

ponse is then of the form

$$(17)\quad \mu^*(q) = \begin{cases} 0 \text{ if } \kappa^*(q) > 1 \\ 1 - F(\kappa^*(q)) \text{ if } 1 \geq \kappa^*(q) \geq 0 \\ 1 \text{ if } \kappa^*(q) < 0. \end{cases}$$

Note that any $\mu^* < 1$ implies that, from an ex ante perspective, *all* consumers would strictly prefer not to view advertisements. However, only those with a sufficient technological awareness and competence have a low enough κ to make blocking ads viable. It is immediately apparent that consumers will block too many ads from a social welfare perspective—failing to internalise the revenues enjoyed by firms with which they trade.

Rational expectations require that the q used to calculate (17) be consistent with the firm's optimal choice of quality, given in (4). Such a mutually consistent μ, q pair along with the price distribution (5) is then an equilibrium.

Proposition 4 *There exists an equilibrium of the endogenous consumer participation game. Equilibrium quality provision must satisfy (4), where μ is given by (17), and κ^* by (16). Prices are dispersed according to (5).*

Proof. See Appendix A. ■

Equilibrium multiplicity is not uncommon in models with equilibria supported by agent expectations. In particular, there is often a 'bad' equilibrium in which one group expects the market to shut down and this belief becomes a self-fulfilling prophecy so that *all* agents elect not to participate. In the following lemma I establish conditions under which such market unravelling cannot occur.

Lemma 6 *For $M > 0$, $q_i = 0$ is an equilibrium quality level if and only if $\mu^*(0) = 0$, which, in turn, is true if and only if $k \geq (1+M^2)/2$.*

Proof. See Appendix A. ■

Lemma 6 states that, even though content quality is not ex ante observable for consumers, equilibrium quality provision (and participation) must be positive provided that nuisance costs are not too high. In particular, if $k < 1/2$ then Lemma 6 implies that $q_i = q_{-i} = 0$ cannot be part of an equilibrium for any M. Blocking is a costly activity and consumers with the very highest blocking costs always prefer not to block advertisements when $k < (1+M^2)/2$. Provided that there are some consumers that choose not to block, publishers have an incentive to set a positive quality in order to increase the market power of their advertisers. Consumers understand this incentive, and set their expectations accordingly.

This reasoning also implies that an exogenous innovation in ad targeting technology (that causes M to increase above the threshold described in Lemma 6 necessary to guarantee an active market) can create new kinds of content market that were previously not viable. As an example, in early 2003 Google began to provide syndicated advertisements to be shown on third party websites, but targeted by Google technology. This culminated with the announcement of *Google AdSense* in June 2003. This sudden availability to small websites of a cheap, yet precise advertising technology is often cited as an important factor in facilitating the growth of professional and semi-professional blogging as an industry—giving rise to an entirely new class of media market.[20]

A pertinent question is whether the intuition of Corollary 1 extends to the endogenous participation case; *viz.* does an increase in M necessarily cause an increase in content quality for a given equilibrium? We have the following result:

Proposition 5 *Under a mild regularity condition (that equilibrium conditions form a vector with a non-singular Jacobian), the effect of a change in M on any interior equilibrium is*

$$(18)\quad \frac{\partial q^*}{\partial M} = \frac{M\left(F'(\kappa^*)M^2(1-q^*)+\mu^*\right)}{C''(q^*)+F'(\kappa^*)M^2\left(M^2-k\right)/2}.$$

Similarly,

$$(19)\quad \frac{\partial q^*}{\partial k} = -\frac{M^2(2-q^*)F'(\kappa^*)/2}{C''(q^*)+F'(\kappa^*)M^2\left(M^2-k\right)/2},$$

so that $\mathrm{sgn}(\partial q^*/\partial M) = -\,\mathrm{sgn}(\partial q^*/\partial k)$.

Proof. See Appendix A. ■

Note that when $F'(\kappa^*) = 0$, changing M does not affect the number of ad-viewing consumers and (18) collapses to the simple case described in (7). The numerators of (18) and (19) are positive. From Proposition 5 it is therefore clear that an increase in M must lead to an increase in quality if nuisance costs are sufficiently small—specifically if $k < M^2$. In fact, $M^2 \geq k$ turns out to be a sufficient condition for uniqueness of the equilibrium quality level so that quality must unambiguously increase with targeting accuracy under such circumstances.

Proposition 6 *When $M^2 \geq k$ there is a unique equilibrium q^*, which is unambiguously increasing in M and decreasing in k.*

Proof. See Appendix A. ■

Similarly, if $C''(q)$ is sufficiently large in the neighbourhood of q^* then a small increase in M is always accompanied by an increase in q. Intuitively, if C'' is large then increases in the marginal benefit of providing quality result in relatively small quality increases (because marginal cost increases quickly with q). When quality increases are sufficiently small, any reduction in product market competition that they induce is more than offset by the effects of an accompanying increase in M (see Lemma 5 and Figure 2) so that fewer consumers will block. The increase in μ and M then provide the increase in the marginal benefit of quality provision necessary to induce the posited increase in q. If marginal quality costs increase slowly enough (if C'' is small enough) and $k > M^2$ then only a decrease in quality is compatible with equilibrium behaviour in the wake of an increase in M.

[20] Indeed, in 2009 the Wall Street Journal reported that more Americans earn their primary income by operating blogs than do so as fire-fighters or computer programmers. See http://online.wsj.com/article/SB124026415808636575.html (accessed 12th October 2011).

4.2 Repeat impressions

In the model above I have maintained the assumption that the two publishers never impress the same advertiser upon a given consumer. In this section, I show how the results above emerge naturally as a limit point of a more general model in which the publishers select at random from a shared pool of $N \in \mathbb{Z}$ advertisers. Thus, advertisers sometimes find that they are repeatedly exposed to the same consumer, eliminating potential competition; however, the imperfect ability of the publishers to coordinate implies that this is not a wholly effective way to block other advertisers from contacting a consumer. Indeed, there are various practical barriers to any attempt to consistently expose a consumer to the same advertisement, amongst them: (i) consumers have highly idiosyncratic media consumption habits and consume media products in a wide variety of permutations so that it is hard to predict where a consumer will surf to next (and hence where a firm must advertise in order to make another impression); (ii) managing an ad campaign is costly (Evans, 2008), so 'advertise everywhere' is not a viable solution in most cases; and (iii) there are many rival advertisers vying for access to the finite resource of each consumer's attention.

It is fairly straightforward to verify that pricing is analogous to the case described in Section 3.1: in particular, there exists a mixed strategy equilibrium of the advertiser pricing subgame in which prices are drawn from a distribution having support $[\underline{p}, 1]$. The proof here is essentially the same as that for Lemma 1. Expected advertiser revenues for any equilibrium choice of p must then be equal to those of setting $p = 1$ in order to induce mixing. Total expected advertiser revenues are thus

$$\frac{\mu}{2|\Theta|}M\left[\frac{q_{-i}}{N}+\frac{q_i}{N}+[(1-q_i)+(1-q_{-i})]\left[2(1-M)\frac{1}{N}+\frac{M}{N^2}\right]\right],$$

where division by N reflects the likelihood of an advertiser being impressed upon each given consumer when there are N potential advertisers of type θ for each publisher to choose from. The last M/N^2 term reflects the fact that some consumers who visit both publishers will now see the same firm's ad twice.

Any advertiser could always opt to advertise only at $-i$, in which case its revenue would be

$$R_{-i} = \frac{\mu}{2|\Theta|}M\left[\frac{q_{-i}}{N}+((1-q_{-i})+(1-q_i))\frac{1-M}{N}\right].$$

If firms are to advertise at both publishers then such deviations must be unprofitable. Publisher i thus cannot extract more from each advertiser than the increase in profits that multi-homing provides, which is the difference between these two revenue expressions, ΔR_i. Thus, i's revenue is $|\Theta| N \Delta R_i$, giving rise in the limit to a marginal benefit of content provision

$$\lim_{N\to\infty}\frac{\partial|\Theta|N\Delta R_i}{\partial q_i} = \lim_{N\to\infty}\frac{M^2\mu}{2}\frac{N-1}{N} = \frac{M^2\mu}{2},$$

which is the same as the right hand side of (3).

Remark 3 *The equilibrium described in Proposition 1 emerges in the limit of a game in which publishers are unable to coordinate in selecting advertisers from a shared pool (and sometimes show the same advertisement) as the number of firms grows large.*

4.3 Observable content quality and endogenous publisher choice

In the model above, consumers visit platforms at random so that the publishers do not have to compete for consumer visits. This serves to emphasise the 'attention retention' role of content quite apart from any competition for readers/viewers. However, in the long-run one might expect higher quality content to attract more consumers as publishers' reputations spread and consumers return to publishers they have previously found to be of value. To endogenise consumer loyalty, suppose that content qualities are ex ante observable so that consumers can take them into account when deciding which publisher to visit first. Let an exogenous mass μ of consumers have tastes for content distributed uniformly (and independently of final good consumption preferences) along a Hotelling line of unit length, with i situated at the point indexed by zero and $-i$ at the point indexed 1. I assume that consumers incur a transport cost, k, to search for and visit content one unit of distance from their location, and that k is sufficiently small to ensure that consumers are prepared to visit both platforms in equilibrium.[21] For the purpose of constructing the Hotelling model some additional structure is required: I assume that content consumption surplus is given by the utility function $\min\{u_i + u_{-i}, \overline{u}\}$, where u_i denotes the utility from consumption of content at platform i and takes value zero when i is not visited. When the consumer does visit i, $u_i = \underline{u}/2$ with probability $(1-q_i)$, and $u_i = \overline{u} \geq \underline{u}$ with probability q_i. Thus, in the spirit of the model of content provision, $\overline{u}$ (respectively $\underline{u}$) is the utility from consumption of content that does (respectively, does not) fully satisfy a given consumer's desire. Lastly, for the sake of tractability, and following Dukes (2006), I assume that consumers consider content utility but not product market surplus when making platform visit decisions. Consumers must now decide which platform to visit first and the indifferent consumer, located at $\alpha_i \in [0,1]$, has

$$\overbrace{[q_i + (1-q_i)q_{-i}]\overline{u} + (1-q_i)(1-q_{-i})\underline{u}}^{\text{Content consumption when visiting } i \text{ first}} - k\alpha_i - (1-q_i)k(1-\alpha_i)$$
$$= \underbrace{[q_{-i} + (1-q_{-i})q_i]\overline{u} + (1-q_{-i})(1-q_i)\underline{u}}_{\text{Content consumption when visiting } -i \text{ first}} - k(1-\alpha_i) - (1-q_{-i})k\alpha_i,$$

which implies that

$$\alpha_i = \frac{q_i}{q_i + q_{-i}}$$

[21] One can assign to k the traditional media economics interpretation that it embodies some psychological cost of viewing non-ideal content (such as reading conservative content for a left-leaning voter). Alternatively, it may capture the fact that different consumers use different means/navigation paths to find the content they want. For example, two consumers using different search engines that make different sites more prominent may disagree about how easy it is to locate each publisher.

is the proportion of consumers visiting i first. Using $\mu\alpha_i$ in place of $\mu/2$, and recalculating i's profits from (2) then yields

$$\Pi_i = \mu M\left[\alpha_i q_i + (\alpha_i(1-q_i)+(1-\alpha_i)(1-q_{-i}))(1-M)\right] - C(q_i),$$

so that the first order condition pinning down the optimal q_i is

$$\frac{M\left(q_{-i}^2 + M\left(q_i^2 + 2q_i q_{-i} - q_{-i}^2\right)\right)\mu}{(q_i+q_{-i})^2} = C'(q_i),$$

Imposing symmetry ($q_i = q_{-i}$) reveals that a symmetric quality equilibrium has $\alpha_i = \alpha_{-i} = 1/2$ and

$$q_i = q_{-i} = q_H^* \equiv c^{-1}\left(\frac{M^2\mu}{2} + \frac{M\mu}{4}\right).$$

Comparing this expression to (4) reveals that equilibrium quality is unambiguously higher when that quality it is ex ante observable—this is not surprising since allowing publishers to compete in quality to attract consumers provides an additional marginal incentive to increase quality over and above the attention retention effect.

Calculating the effect of an increase in M on quality provision reveals

$$(20)\quad \frac{\partial q_H^*}{\partial M} = \frac{\mu M}{C''\left(q_H^*\right)} + \frac{\mu}{4C''\left(q_H^*\right)} > 0.$$

The first term is just the partial effect seen in (7)—stemming from the fact that a higher M increases the returns to protecting advertisers from competition. The second term reflects the fact that a higher M makes each consumer impression more valuable, and therefore makes platforms want to compete harder for additional consumers in the hotelling game. Summarising:

Proposition 7 *When consumers observe content quality ex ante, an increase in M results in an increase in quality, and does so at a rate no less than that for the unobserved quality case.*

The first term in (20) is bigger (smaller) than the second when $M > (<) 1/4$. This implies that initially, when M is small, almost all of the incentive for content provision stems from its ex ante role in attracting attention. However, as targeting accuracy increases, the ex post attention retention role of content grows to eventually account for the larger part of the marginal investment incentive. One should therefore expect that attention retention will be an increasingly important consideration in publishers' content provision strategies as technology continues to evolve.

5 Conclusion

Given the close and often symbiotic relationship between the two, it seems natural to expect that a change in the delivery of advertising—such as the growing importance of ad targeting—

will also have implications for the provision of media content. The value of advertising in this model stems from the fact that, by focusing consumer attention on a subset of the active firms, it creates market power. When consumers are more likely to have their content or information desire satisfied by higher quality content sources, content provision facilitates this creation of market power by serving to further concentrate consumer attention. The provision of quality can therefore be used as a policy tool by publishers seeking to retain consumer attention in order to offer their advertisers exclusive access to it. The pay-off for such an investment in quality is that advertisers face less competition for the consumers' business, and are thus willing to pay more for an ad. A technological innovation that increases the ability of publishers to deliver targeted advertisements makes this kind of investment more attractive because any ad viewed at a rival platform is then more likely to be competing to serve the same consumer need. This paper has been couched in terms of product market firms that compete to make direct sales to a consumer, but a similar race for attention should arise when firms seek access to it in order to engage in brand familiarisation. More generally, whenever a firm has an interest in ensuring that consumers are not exposed to its rivals' messages, and whenever publishers are able to appropriate some of the value thus created, publishers have an incentive to invest in increasing their share of attention by providing content.

Publishers' content provision incentives are not, in general, aligned with those of a social planner, and quality may be under- or over-provided. Once one accounts for the relationship between the advertising, product, and content markets, an increase in targeting accuracy or a fall in content provision costs can make a publisher worse-off and ad prices are typically non-monotonic in targeting accuracy. Moreover, advances in precision targeting, whilst typically leading to higher quality content, can result in a fall in overall social and consumer welfare when the adverse product market effects of such technologies are sufficiently strong. This kind of dynamic may cause consumers to respond to improved ad targeting by blocking more advertisements, which can ultimately cause content quality to fall. The nature of these effects depends crucially upon the curvature of the content cost function and the relative size of ad accuracy and ad search/nuisance costs.

Appendix A Omitted Proofs

Proof of Lemma 1. Write $R_l(p_l, \mathbf{p}_{-l})$ for the expected revenue of firm l when it sets price p_l and the other firms' prices are given by $\mathbf{p}_{-l}$ (where the expectation is taken over the number of publishers visited by each consumer). Three properties of R_l are of interest: (1) R_l is bounded to be no less than 0 and certainly no greater than $\mu/|\Theta|$; (2) $\sum_l R_l(p_l, \mathbf{p}_{-l})$ is continuous (this is easily verified by noting that discontinuities in R_l occur when $p_l = p_{l'}$ for some $l' \neq l$—at which point consumers switch en mass, but contribute as much revenue to the firm that they switch to as they take from the firm that they switch from); and (3) $R_l(p_l, \mathbf{p}_{-l})$ is weakly lower semi-continuous in p_l (in the sense of Definition 6 of Dasgupta and Maskin (1986)). Property (3), which in this case states that, for any point of discontinuity $\widetilde{p}$, $\lambda \liminf_{p_l \uparrow \widetilde{p}} R_l(p_l, \mathbf{p}_{-l}) + (1-\lambda)\liminf_{p_l \downarrow \widetilde{p}} R_l(p_l, \mathbf{p}_{-l}) \geq R_l(\widetilde{p}, \mathbf{p}_{-l})$ for some $\lambda \in [0,1]$, holds because any discontinuity in R_l

occurs around $p_l = p_{l'}$ for some $l' \neq l$, where a small decrease in p_l leads to a discontinuous increase in market share for l and hence in R_l. Taken together, these three properties imply that Theorem 5 of Dasgupta and Maskin (1986) can be applied to establish that there exists a mixed strategy equilibrium in the advertiser price-setting sub-game.

If the equilibrium pricing strategies used by advertisers at publisher i induce price distribution G_i there, and if firm l advertising at publisher i uses price distribution G_l then $G_l = G_i$ must be a best response for l—otherwise there would be be some firm at i that could profit by deviating to G_l. Thus, any equilibrium price distribution, G_i can be induce by having all l that advertise at i pricing according to $G_l = G_i$. Now, write $[\underline{p}_i, \overline{p}_i]$ for the support of G_i and use the analogous notation for the price distribution at $-i$. If $\overline{p}_i \leq \overline{p}_{-i}$ then a firm setting $\overline{p}_{-i}$ sells only in the event that it faces no rival, which implies that $\overline{p}_{-i}$ must equal the monopoly price, 1 (we can rule out mass points at $\overline{p}_i = \overline{p}_{-i}$ because firms could then profit by undercutting). Moreover, if the inequality is strict then no advertiser at $-i$ can ever set a price $p \in (\overline{p}_i, \overline{p}_{-i})$ since it then makes a sale with the same probability as a firm that sets price $\overline{p}_{-i}$, but earns less from each sale. An advertiser at i that sets price $\overline{p}_i$ therefore sells with the same probability as one that sets $p \in (\overline{p}_i, \overline{p}_{-i})$, but makes less per-sale so that G_i cannot be a best response. ■

Proof of Lemma 2. Write $r_i \equiv R_i n_i / I_i$ for the per-impression expected revenue of an advertiser that advertises at i. It is clear that $r_i > 0$ must hold since some consumers will view a matched ad only at i and an advertiser that matches with such a consumer could sell at any $p \leq 1$. The I_i impressions at i must be shared amongst the n_i firms of a given θ that advertise there so that each type θ advertiser is allocated I_i / n_i impressions. Since the consumers are divided uniformly over the various $\theta \in \Theta$,

$$I_i = \frac{\mu}{2|\Theta|} + \underbrace{\frac{\mu}{2|\Theta|}(1 - q_{-i})}_{\text{Unsatisfied consumers from } -i} = \frac{\mu}{2|\Theta|}(2 - q_{-i}).$$

Given a putative equilibrium with $n_{-i} > 0$, a firm would prefer to switch to advertising at i from doing so at $-i$ if

$$\text{(21)} \quad \frac{I_i}{n_i}\left(r_i - \rho_i\right) > \frac{I_{-i}}{n_{-i}}\left(r_{-i} - \rho_{-i}\right) \Rightarrow \frac{\left(r_i - \rho_i\right)(2 - q_{-i})}{\left(r_{-i} - \rho_{-i}\right)(2 - q_i)} > \frac{n_i}{n_{-i}}.$$

Now, if $\rho_i < r_i$ then firms could make positive profits by advertising at i so that for $n_i = 0$ to hold it must be the case that all firms advertise at $-i$. However, substituting $n_i = 0$ into (21) reveals that some advertisers would then wish to switch from $-i$ to i. Thus, $n_i > 0$ must hold when $\rho_i < r_i$ and, for any $\rho_i < r_i$, i can increase its impression price a little without driving away all of its advertisers. Thus, $\rho_i < r_i$ cannot be consistent with equilibrium.

Suppose, then, that $n_i, n_{-i} > 0$, $\rho_i = r_i \equiv R_i n_i / I_i$, and $\rho_{-i} = r_{-i} \equiv R_{-i} n_{-i} / I_{-i}$. No advertiser can profit by switching publisher as they make zero profit at both. A publisher that reduces its ρ earns less per-impression but sells the same number, I_i of impressions so that such a deviation is not optimal. The proposed strategies are thus consistent with equilibrium. ■

Proof of Lemma 5. From (5) the equilibrium price distribution is uniquely pinned down by its value of $\underline{p}$. It follows that $E(p)$ decreases in M if and only if

$$\frac{\partial \underline{p}}{\partial M} = \frac{2(3-q^*)q^* + 2M\frac{\partial q^*}{\partial M} - 4}{(2-q^*)^2} < 0.$$

Substituting $\partial q^*/\partial M$ from (7) and solving for $C''(q^*)$ completes the proof. ■

Proof of Proposition 2. Total welfare is given by

$$(22)\quad W = \frac{\mu}{2}\overbrace{\Big[\underbrace{u(q_i,q_{-i})}_{\substack{\text{Content}\\\text{consumption}}} + \underbrace{q_iM + 2(1-q_i)M(1-M) + (1-q_i)M^2}_{\text{Welfare from trade in final goods}} - \underbrace{k(2-q_i)}_{\substack{\text{Search}\\\text{costs}}}\Big]}^{\text{Half of consumers visit } i \text{ first}} +$$
$$\frac{\mu}{2}\left[u(q_{-i},q_i) + q_{-i}M + 2(1-q_{-i})M(1-M) + (1-q_{-i})M^2 - k(2-q_{-i})\right] - C(q_i) - C(q_{-i}),$$

where the $k(2-q_i)$ terms reflect the fact that a consumer visiting i first visits $2-q_i$ sites in expectation, and incurs a search cost of k at each one. The publisher sets q_i to satisfy the first order condition from (2), which implies $(\mu M^2)/2 - C'(q^*) = 0$. Imposing this condition along with $q_i = q_{-i} = q^*$ on the first order condition from (22) yields

$$(23)\quad \left.\frac{\partial W}{\partial q_i}\right|_{q_i,q_{-i}=q^*} = \mu\left[\frac{U_i'(q^*) - M - k}{2}\right].$$

■

Proof of Proposition 4. The optimality of q^* and μ^* follows from the derivation above. Taking consumer behaviour as given, from (3) i wishes to set

$$(24)\quad q_i = \max\left\{0, \min\left\{1, c^{-1}\left[\frac{\mu^*(q_i)M^2}{2}\right]\right\}\right\},$$

where $\mu^*(q)$ is given in (17). A necessary and sufficient condition for equilibrium existence is therefore that there exists some q_i satisfying (24). The right hand side of this expression is a function of q, and it is therefore required that this function has a fixed point in the unit interval. Existence of such a fixed point follows immediately from the fact that the function is continuous and bounded within $[0,1]$ (Brouwer's fixed point theorem). ■

Proof of Lemma 6. From (4) one can deduce

$$q^* \equiv c^{-1}\left(\frac{\mu M^2}{2}\right) = 0 \Leftrightarrow \mu = 0$$

since $M > 0$ and $c^{-1}(\cdot) > 0$ for positive arguments. From (16) and (17), $\mu(0) = 0 \Leftrightarrow \kappa^*(0) \geq 1 \Leftrightarrow k \geq (1+M^2)/2$. ■

Proof of Proposition 5. Write the vector valued function

$$\Gamma(q,\mu) = \left(\gamma_1(q,\mu), \gamma_2(q,\mu)\right) \equiv \left(c^{-1}\left[\frac{M^2\mu}{2}\right] - q,\ 1 - F\left(\kappa^*(q)\right) - \mu\right)$$

so that an interior equilibrium is characterised by $\Gamma(q^*,\mu^*) = (0,0)$. The Jacobian matrix is

$$\mathbf{J}_\Gamma = \begin{pmatrix} \dfrac{\partial\gamma_1(q,\mu)}{\partial q} & \dfrac{\partial\gamma_1(q,\mu)}{\partial\mu} \\ \dfrac{\partial\gamma_2(q,\mu)}{\partial q} & \dfrac{\partial\gamma_2(q,\mu)}{\partial\mu} \end{pmatrix} = \begin{pmatrix} -1 & \dfrac{M^2}{2C''(q^*)} \\ -F'(\kappa^*(q))\left(M^2-k\right) & -1 \end{pmatrix},$$

which is nonsingular when the regularity condition

$$\text{(25)}\quad \det(\mathbf{J}_\Gamma) = 1 + \frac{F'(\kappa^*(q))\left(M^2-k\right)M^2}{2C''(q^*)} \neq 0$$

holds. For convenience, define the modified Jacobian obtained by replacing derivatives with respect to q with those with respect to M:

$$\mathbf{J}_{q,M} = \begin{pmatrix} \dfrac{\partial\gamma_1(q,\mu)}{\partial M} & \dfrac{\partial\gamma_1(q,\mu)}{\partial\mu} \\ \dfrac{\partial\gamma_2(q,\mu)}{\partial M} & \dfrac{\partial\gamma_2(q,\mu)}{\partial\mu} \end{pmatrix} = \begin{pmatrix} \dfrac{M\mu}{C''(q^*)} & \dfrac{M^2}{2C''(q^*)} \\ 2M(1-q)F'(\kappa^*(q)) & -1 \end{pmatrix}.$$

Now, suppose that the regularity condition (25) holds at a given solution (q^*,μ^*). The implicit function theorem then applies: equilibrium characterising functions are locally differentiable and we have $\partial q^*/\partial M = -\det\left(\mathbf{J}_{q,M}\right)/\det(\mathbf{J}_\Gamma)$ (see de la Fuente, 2000, pp202–203), which gives (18). Defining $\mathbf{J}_{q,k}$ analogously to $\mathbf{J}_{q,M}$, we have $\partial q^*/\partial k = -\det\left(\mathbf{J}_{q,k}\right)/\det(\mathbf{J}_\Gamma)$, which yields (19). ■

Proof of Proposition 6. Any equilibrium quality level is a solution of (24). The left hand side of (24) is increasing in q so that there can be at most one solution when the right hand side is non-increasing. Since $c^{-1}(\cdot)$ is increasing, the right hand side of (24) is (weakly) decreasing in q iff $\partial\mu^*(q)/\partial q \equiv -F'(\kappa(q))\left(M^2-k\right) \leq 0$—viz. if $M^2 \geq k$.

That q^* is increasing in M and decreasing in k then follows from this uniqueness argument along with Proposition 5. ■

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