The Impact of the Internet on Advertising Markets for News Media

by

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In this paper, we explore the hypothesis that an important force behind the collapse in advertising revenue experienced by newspapers in the past decade is the greater consumer switching facilitated by online consumption of news. We introduce a model of the market for advertising on news media outlets whereby news outlets are modeled as competing two-sided platforms bringing together heterogeneous, partially multi-homing consumers with advertisers with heterogeneous valuations for reaching consumers. A key feature of our model is that the multi-homing behavior of the advertisers is determined endogenously. The presence of switching consumers means that, in the absence of perfect technologies for tracking the ads seen by consumers, advertisers purchase wasted impressions: they reach the same consumer too many times. This has subtle effects on the equilibrium outcomes in the advertising market. One consequence is that multi-homing on the part of advertisers is heterogeneous: high-value advertisers multi-home, while low-value advertisers single-home. We characterize the impact of greater consumer switching on outlet profits as well as the impact of technologies that track consumers both within and across outlets on those profits. Somewhat surprisingly, superior tracking technologies may not always increase outlet profits, even when they increase efficiency. In extensions to the baseline model, we show that when outlets (e.g. blogs) that show few or ineffective ads attract readers from traditional outlets, the losses are at least partially offset by an increase in ad prices. Introducing a paywall does not just diminish readership, but it furthermore reduce advertising prices (and leads to increases in advertising prices on competing outlets).

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1 Introduction

The issue of whether the Internet will destroy the news media is currently a big news topic. The news industry as a whole has seen large declines in advertising revenue, while traditional media has simultaneously faced increased competition for attention from new media (including web-only news, blogs and news aggregators). Policy-makers have expressed concerns that declining revenue per consumer as well as fragmentation in the media might undermine incentives to invest in quality journalism.

While new technologies and competition can often explain why revenue may be redistributed among industry players, the adverse impact of the Internet on the news media is widespread: industry-wide revenue has declined.[1] This represents an economic puzzle because, in many respects, the fundamental drivers of supply and demand appear to be as favorable for the industry if not more favorable than before. We argue that this is true despite assertions to the contrary in the popular press that advertising revenues are being destroyed by the Internet because of the flood of available advertising space. From the *New York Times*,

> *… online ads sell at rates that are a fraction of those for print, for simple reasons of competition. "In a print world you had pretty much a limited amount of inventory — pages in a magazine," says Domenic Venuto, managing director of the online marketing firm Razorfish. "In the online world, inventory has become infinite." (Rice, 2010)*

While there may be space for every advertiser on the Internet, those ads must still be viewed by an actual consumer. The attention of those consumers is still limited, and scarcity limits the

[1] According to the Newspaper Association of America (www.naa.org), since 2000 total advertising revenue earned by its member US newspapers declined by 57% in real terms to be around $27 billion in 2009. Much of this decline was in revenue from classifieds but total display advertising revenue fell around 40%. In contrast, circulation over the same period declined by 18%. Ad revenue as a share of GDP also declined by 60%. According to ComScore, total US display advertising revenue online was around $10 billion in 2010 which includes all sites and not just newspapers.

available advertising capacity. Since advertisers compete for scarce consumer attention, it is unlikely that the price of ads will go to zero.

It has been observed that internet-provided services (such as classified ads and movie listings) have displaced revenue streams from services that previously were provided by newspapers. However, the decline in advertising revenue is much larger than the loss due to classifieds.[2] Another change brought on by the Internet that could be considered as a problem for newspaper advertising revenues is that the Internet had created new types of advertising opportunities (e.g., internet search ads). However, observers and regulators have noted that these new forms of advertising are complements rather than substitutes for the kinds of advertising typically used by the news media.[3]

On the positive side of the equation, the Internet has enabled improved measurement of advertising performance and created new opportunities to improve the targeting of advertising to consumers (Evans, 2009).[4] Another change in fundamentals is that the delivery of content and advertising has become less costly. Although cost reductions are favorable for a fixed industry structure, they may lead to entry. However, as we explain below, the benchmark model of media economics predicts that advertising prices should not fall in response to entry.

The benchmark models of media economics (e.g., Anderson and Coate, 2005) have media outlets competing for consumers by showing fewer ads (a force that will not be the focus of our analysis). Consumers are assumed to *single-home* (view just one outlet in a relevant time period), and so once an outlet has attracted consumers, it acts as a monopolist on the advertising

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[2] According to the Newspaper Association of America (www.naa.org), since 2000, newspaper 'display' advertising revenue independent of classified ads, has declined almost 40 percent in real terms.

[3] Evans (2008, 2009).

[4] Some hypothesize that online or digital ads are far less effective than ads that are on paper. However, to date, the evidence is not consistent with that hypothesis (see Dreze and Hussherr, 2003; Lewis and Reiley, 2009; Goldfarb and Tucker, 2010).

side of the market when selling advertisers access to those consumers. Thus, advertising revenue reflects monopoly prices, independent of the number of outlets. Indeed, competition amongst media outlets in this model would lead to higher ad prices, as those outlets scale back levels of annoying advertising as they compete to attract consumers. In contrast to the predictions of the model, however, there is evidence that competition is associated with falling ad prices including mergers that increase them (Anderson, Foros and Kind, 2010).

Another prediction of the benchmark model is that ad revenue per consumer should equalize across outlets (that is, attention is worth the same regardless of where it is allocated); in contrast, there is evidence that larger outlets command a premium.[5] Finally, rather than welcome policy moves to require public broadcasters to raise revenue from ads rather than be subsidized, existing media outlets have typically opposed the lifting of advertising restrictions.[6] All of these factors suggest that competition in advertising markets is not working in the manner that traditional media economics predicts.

This paper presents a formal analysis of the prospects for advertising-funded content on the Internet. Our analysis is grounded by carefully accounting for the fundamentals of supply and demand: our model set-up (in Section 2) holds fixed the total supply of consumer attention as well as the constant demand from advertisers for that attention. We then derive advertising revenue from a market equilibrium.

We demonstrate that there are two model elements – imperfect consumer tracking *and* increased consumer switching – that can together lead to outcomes that match the stylized facts described above. First, consider the problem of consumer switching.

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[5] Recently, this has been referred to as the "ITV Premium Puzzle" (Competition Commission, 2003). However, the relationship has been noticed previously by Fisher et.al. (1980) and Chwe (1988).

[6] Ambrus and Reisinger (2006) document the opposition of German broadcasters to allowing public television broadcasters to show advertisements after 8pm.

> *Newspaper readers are "better" than Web visitors. Online readers are a notoriously fickle bunch, and apparently are getting more so by the day. Web visitors barely stick around, yet they are counted in broad traffic statistics as if they were the same as the reader who lingers over his Sunday paper. (Farhi, 2009)*

This reflects the proposition that the web enables consumers to more readily switch between outlets. In the offline world, consumers of print and other media would face some constraints in accessing news and other content from multiple sources. This is not to say that consumers literally allocated all of their attention to one outlet, but just that their ability to switch between outlets and bundle a variety of content was limited in comparison to their options today. Thus, while consumers may have spent 25 minutes reading the morning print newspaper, they may spend on average 90 seconds on a news website (Varian, 2010). This is not a reduction in the amount of consumption, but instead a reduction in 'loyalty' to any one outlet. Web browsers make it easy for consumers to move between outlets while free access removes other constraints. But, going beyond this, intermediaries such as search engines, aggregators and social networks facilitate switching. Indeed, we examined empirically the news consumption patterns of several million internet users, and found that among users who consumed at least 10 news articles per week, the concentration of a user's consumption among different news outlets, as measured by a news consumption Herfindahl index, was strongly and negatively associated with the users' frequency of using Google news and Bing news.[7]

Second, consider the problem of imperfect tracking. We postulate that outlets have a superior ability to track the behavior of consumers within their outlets rather than between them.[8] When consumers are each loyal to a single outlet, imperfect tracking would not be an issue for

[7] See also Chiou and Tucker (2010) for additional evidence that news aggregators facilitate consumer switching between outlets.
[8] This is consistent with current practice (Edelman, 2010).

advertisers. To reach many consumers, advertisers could purchase impressions on a wide number of outlets (i.e., multi-home) and achieve those goals. However, when consumers switch between outlets, advertisers have a harder task. An advertiser who multi-homes will find that it impresses the same consumer more than once, potentially wasting expensive advertising.[9] Maximizing the "reach" of advertising now carries the additional cost of paying for wasted impressions. In contrast, an advertiser who single-homes will miss some proportion of consumers entirely.

We show that consumer switching and imperfect tracking together interact to generate an outcome whereby an increase in consumer switching (holding fixed the number of outlets and their market shares) leads to a reduction in impression prices, as advertisers are not willing to pay as much due to the potential waste. For similar reasons, increasing the number of outlets also reduces total advertising revenues. However, in the absence of switching, our model reduces to the standard media economics model, whereby outlets set monopoly prices to advertisers irrespective of the competition among outlets.

With only a few exceptions, the literature on two-sided markets assumes that each side of the market either fully single-homes or fully multi-homes.[10] While most models in the media economics literature assume that consumers single-home – that is, choose to allocate attention to only one outlet – there are some that have considered what happens when consumers multi-home. Gabszewicz and Wauthy (2004) and Anderson and Coate (2005) considered this but demonstrated that advertisers would all single-home in this case resulting in no change in overall advertising revenues.[11] Recently, Ambrus and Reisinger (2006) considered a model of

[9] Some advertisers target an optimal number of impressions per consumer that is greater than one. Imperfect tracking makes it difficult to target that optimal number of impressions, however, for concreteness in our model we study the case where the optimal number of impressions is equal to one.

[10] Although it has received less attention in the economics literature, fixed costs of engaging with alternative outlets are important in practice in the advertising industry. We do not consider such fixed costs in this paper.

[11] Ashlagi, Edelman & Lee (2010) examine competing ad auctions for search engines where consumers single-home but advertisers face costs that make multi-homing costly.

horizontally differentiated outlets whereby only some share of consumers multi-homed; specifically, consumers who are on the margin of choosing one outlet or the other. They then posited that those consumers were less valuable to outlets than consumers who single-homed. Anderson, Foyos and Kind (2010) endogenized the value of multi-homing consumers, and demonstrated that outlets would receive lower prices for ads shown to multi-homing consumers than loyal ones. Consequently, outlets adjust their advertising levels (creating more annoying ads) to reduce consumer multi-homing. The overall impact on prices is ambiguous, but competition does reduce outlet profits in their model.

As noted earlier, we move away from the notion that consumers come to outlets with an associated revenue stream and instead model revenue as arising from the effective impressions advertisers are able to procure. This involves constructing a model whereby consumers may switch outlets within the time period advertisers want to place impressions in front of them. Importantly, this means that an outlet can place more ads over loyal consumers (who consume more content on an outlet) than they can over switching consumers, who only visit the output for some fraction of the relevant time period.[12] This requires us to consider the mixed single and multi-homing consumer outcomes and to solve for the resulting equilibrium in the advertising market.[13] The modeling challenge arises because the price that clears the market also impacts on the "quality" of likely matches between consumers and advertisers (that is, the likelihood of a wasted impression). We demonstrate that a sorting equilibrium exists, whereby high value

[12] Both Ambrus and Reisinger (2006) and Anderson, Foyos and Kind (2010) assume that the ad-capacity associated with single and multi-homing consumers are identical. As is demonstrated below, the fact that loyal (single-homing) consumers will allocate more attention to an outlet and hence, view more ads, than switching (multi-homing) consumers has a significant impact on the resulting equilibrium and the set of strategies outlets may pursue to maximize profits.

[13] This method of dealing with two-sided markets is itself novel. Rather than the outlet (or platform) choosing prices in a monopolistic or oligopolistic fashion (e.g.., see the general result of Weyl, 2010), on the advertising side, revenues to outlets are determined by market clearing prices. Thus, we can analyze how technology and other factors impact on the efficiency of advertising market outcomes and, in turn, how this impacts on outlet revenues.

advertisers multi-home and, in some cases, increase the frequency of impressions so as not to miss consumers, while lower value advertisers single-home. As the share of switching consumers rises, advertisers prefer to single-home rather than multi-home. This frees up ad capacity on each outlet for lower valued advertisers, who set the price in the market. Consequently, prices and total ad revenue decline.

Interestingly, we demonstrate that this result is not straightforward. It depends critically on the total available ad capacity. When capacity is very high, while single-homing advertisers are always the marginal advertiser in the market, high value advertisers have an incentive to purchase multiple impressions and absorb inframarginal capacity. The balance between the marginal and inframarginal means that, in some cases, for fixed (and large) ad capacity, increased consumer switching between outlets may be associated with higher, not lower, outlet profits. Indeed, profits may exceed levels that can be achieved when either switching or imperfect tracking is not a problem.[14]

Our baseline model assumed that outlets were symmetric. We relax this and derive conditions under which outlets earn higher advertising revenue per consumer than their rivals. This happens when one outlet has a lower ad capacity than the other, although it may not increase their total profits. Significantly, an outlet with a higher readership can, in the face of

[14] We note below that this result relies on levels of ad capacity on each outlet that are higher than the equilibrium levels that would be chosen in a Cournot-like ad capacity game. In this paper, we assume that ad capacity on each outlet is fixed and exogenous. This captures a world where outlets stick to a “standard” format for where advertising appears on a news page, and do not vary it as consumer switching increases. Incorporating endogenous ad capacity would potentially raise two effects. One effect is the standard Cournot effect: higher advertising capacity leads to lower prices, and increased competition among outlets leads to higher equilibrium capacity. A second effect is the one identified in the prior literature on media economics: users dislike ads, and so outlets compete for users by providing fewer ads. Most of our results are qualitatively robust to incorporating Cournot-style competition in capacity; however, specific functional forms play a role in deriving comparative statics on the role of switching, for the usual reason that capacities are strategic substitutes, while exogenous parameters might shift the returns to capacity in similar directions for all outlets, leading to competing effects in the equilibrium analysis. Incorporating the negative effect of competition on ad capacity due to competition for users would moderate some of our findings. Our choice to leave this out of the model reflects the desire to focus on the novel effects in our model, together with our observation that, while internet advertising does impact the user experience, the content of the sites rather than the level of advertising is the driving force behind online news media market shares.

consumer switching, command a higher impression price than its rival. This is because the marginal advertiser who is a single-homer in that case will prefer to purchase impressions on the outlet with the higher readership share and is willing to pay a premium to do so. Consequently, higher valued, single-homing advertisers sort onto the high readership outlet first, giving them a "positional advantage."

On the policy-side, we demonstrate that a reduction in competition (say through a merger) always results in higher industry ad revenues. Next, we consider several applications of the model. We demonstrate that when some outlets cannot sell ads (as they might if they are regulated public broadcasters or smaller blogs) ad prices will be higher. When outlets capture consumer attention without selling ads, this reduces the supply of capacity that can be sold to advertisers in the market. Further, because movements to and from such outlets do not created wasted impressions, efficiency and prices go up. Thus, our model provides a rationalization of private media outlet objections against public broadcasters being allowed to sell ads.

Finally, we explore strategic implications arising from our model. We demonstrate that positional advantage arising from outlet asymmetries in readership share can drive competition for those consumers and, indeed, may cause outlets to invest more in quality than they would under benchmark cases or perfect tracking. This result is consistent with the stylized fact that media outlets that provide greater "reach" command higher ad prices, all else equal. We also demonstrate that an outlet can gain a positional advantage by having limited content, but content that consumers visit reliably – something we term magnet content. If outlets can ensure that a high share of consumers will at some point allocate attention to them, those outlets can command a premium in advertising markets. This suggests that outlets may focus their efforts on producing offerings that regularly attract the attention of many consumers rather than the focused attention of fewer consumers.[15] Relatedly, we demonstrate that paywalls unilaterally imposed by an outlet can have the effect of reducing their positional advantage or giving their rivals a positional advantage in advertising markets. As a result, we identify additional competitive costs to outlets from introducing paywalls.

2 Model Set-up

We begin by setting out the fundamentals of consumer and advertiser demand and behavior that drive our model. These are the core elements that do not change as consumers face lower costs of switching between outlets. We then consider benchmarks before turning to the equilibrium outcome in the advertising market in the following section.

2.1 Consumer Attention and Advertiser Value

Consumers both allocate scarce attention to media consumption and are potential purchasers of products and can be matched with firms through advertising. Consumers are assumed to purchase products at a slower rate than they consume media; e.g., a consumer might purchase one soda in a day but have numerous opportunities to consume media over that same period of time. A soda-maker is concerned about putting an impression in front of a consumer sometime during the day and so is indifferent as to which period of the day that occurs.

Formally, suppose there are T periods, where the defining feature of a period is that a consumer can only read one unit of content per period (so it would correspond to something like a view of an online web page). We let a_i be the exogenous ad capacity that outlet i presents to consumers per unit of time.[16] In each period that a consumer visits outlet i, a consumer is

[15] A counterveiling effect outside our model is that with more data about consumers, outlets can sell more targeted advertising. See Athey and Gans (2010) for an analysis of the impact of targeting technology on ad prices.
[16] The robustness of our results to this assumption is discussed below.

impressed by a_i ads. Thus, Ta_i is the total (maximum possible) amount of *advertising inventory* introduced to the market by outlet *i* and it is achieved if a consumer visits that outlet for all T periods.[17]

An advertiser who puts an impression in front of a consumer in a period receives a value (strictly, the expected value of a lead), $v \in [0,V]$.[18] v is the same for all consumers and independent of the number of consumers receiving an impression. The value to the advertiser does not increase if the same consumer sees more than one ad impression from a given advertiser. Advertisers are heterogeneous in their valuations, and the cumulative distribution function of advertiser valuations is $F(v)$.[19] If Ta_i is the total supply of consumer attention, and advertisers are ranked by value in terms of rationing of access to consumer attention, then the marginal advertiser, v_i, is defined by $1-F(v_i)=Ta_i$. We restrict attention, therefore, to cases where $\max_i a_i < 1/T$ so there is an interior solution.

2.2 Outlet Demand and Advertising Inventory

How do consumers allocate attention to different media outlets? We assume that whenever a consumer has an opportunity to choose, outlet *i* is chosen with probability x_i. Thus, x_i is a measure of an outlet's intrinsic quality.[20] If a consumer chooses an outlet, $i \in \{1,...,I\}$, and has no opportunity to switch thereafter, outlet *i*'s advertising inventory would be $x_i a_i T$.

[17] If advertisers placed only a single ad on an outlet, Ta_i is also the maximum quantity of advertisers who could possibly reach an *individual* consumer that stays with outlet *i* for all periods.
[18] We assume that all advertising is equally effective regardless of the quantity, and we assume away consumer disutility of ads (cf: Anderson and Coate, 2005).
[19] An alternative specification might have advertisers desiring to reach a specific number of consumers (Athey and Gans, 2010) or a specific consumer type (Athey and Gans, 2010; Bergemann and Bonatti, 2010).
[20] In our baseline model it is exogenous, but in Section 5.1 we endogenize the quality

We assume, however, that an opportunity for a consumer to switch outlets arrives (independently) each period with probability, ρ.[21] For convenience, throughout this paper we assume that $T = 2$ so, in effect, there is, at most, a single opportunity to switch. Thus, the total expected amount of attention going to *i* is $x_i + x_i\left((1-\rho)+\rho x_i\right)+(1-x_i)\rho x_i = 2x_i$. We let $D_i^l = x_i - x_i(1-x_i)\rho$ denote the share of consumers loyal to *i* (i.e., single-homers) and $D_{ij}^s = 2\rho x_i x_j$ denote the share consumers who switch between outlets *i* and *j* (i.e., multi-homers) in any given period. When there are no switching opportunities (i.e., $\rho = 0$), $D_i^l = x_i$ and $D_{ij}^s = 0$ for all $\{i, j\}$. In this model, if outlets have asymmetric capacity, then different consumer "switching types" will generate different advertising capacities. Consumers loyal to an outlet *i* will generate $2a_i$ in advertising inventory while a consumer switching between outlets *i* and *j* will generate $a_i + a_j$ in advertising inventory.

2.3 Benchmark

Given this set-up, it is useful to consider an efficient outcome for the allocation of advertisers to consumers. A first-best allocation would ensure that highest value advertisers are allocated with priority to scarce advertising inventory. Let v_i denote the marginal advertiser allocated to consumers loyal to outlet *i* and let $v_{s,ij}$ denote the marginal advertiser allocated to consumers who switch between outlets *i* and *j*. An efficient allocation of advertisers to consumers involves allocating all advertisers with $v \geq v_i$ to outlet *i*'s loyal consumers and those

[21] Here we treat this probability as independent of history (i.e., outlets a consumer may have visited earlier) or the future (i.e., outlets that they may visit later). In Section 5.2, below, we explore the implications of relaxing this assumption.

with $v \geq v_{s,ij}$ to those who switch between *i* and *j*. Thus, the marginal advertisers will be determined by: $2a_i = 1 - F(v_i)$ and $a_i + a_j = 1 - F(v_{s,ij})$.

To see how this first best might be implemented, consider an ad platform with a technology – the elements of which currently exist (at least online) but the implementation is far from achieving its ideal – whereby consumers can be tracked both within and across outlets with information kept as to the ads they have seen. In this situation, a consumer could be impressed by an ad at most once and advertisers could, with certainty, pay for an impression to a consumer and receive it.[22] We term this *perfect ad-tracking*, as the ad platform (or broker or exchange) is able to track consumers across web-sites and control the ads they see in a given period of time. Suppose that what this allowed was for outlets to set prices specific to the type of consumer that visits them – loyal or switching. That is, the platform can *price discriminate* based on consumer-type (the platform can do this, because it sees behavior of consumers on all outlets). We assume that the outlets have a single level of ad capacity for all consumers and sell those impressions using the ad platform.[23,24]

[22] Of course, some advertisers may have an optimal number of impressions per consumer other than one. The technology could ensure that optimum so, without loss in generality, we restrict that optimum to one here.

[23] To see how this would work, consider the allocation and pricing problem faced by the ad platform. Consumers who end up loyal to the highest-capacity outlet see ads from the largest interval of advertisers, while consumers who end up loyal to the lowest-capacity outlet see ads from the smallest interval of advertisers, but allocative efficiency requires that all consumers see ads from the highest-value advertisers. The challenge is that before the resolution of switching behavior, the total set of advertisers a consumer should see and the market-clearing price cannot be determined. In a stable environment, the ad platform can offer a set of prices for each type of consumer, such that supply equals demand for each type. In the first period, the platform allocates the highest-value advertisers first to each consumer (as revealed by their willingness to place an order for the most expensive consumer types). Then in the second period, the ad platform knows the total supply of ad space for each consumer and allocates the remainder of the advertisers who place an order for those types of consumers.

[24] An alternative (but probably less realistic) assumption would be that the ad platform shares information with the outlet about the consumer type, so that the outlet can set different capacities for different types.[24] This additional flexibility would lead to a scenario with essentially distinct markets, so that firms compete for switchers and but have a monopoly over access to loyal users. It is a bit more complicated to think how this would work in practice, since consumer types would only be fully determined in the second period, after the consumer had already experienced a first-period ad capacity. We omit the formal analysis of this case.

A consumer who is loyal to outlet *i*, will generate $2a_i$ in advertising inventory. Advertisers will choose to advertise to a consumer so long as their value exceeds the impression price. Consequently, the price per impression to a single-homer on outlet *i*, p_i, will be determined by $1-F(p_i)=2a_i$ or $p_i = P(1-2a_i) \equiv F^{-1}(1-2a_i)$. In contrast, a multi-homing consumer, switching between outlets *i* and *j*, generates $a_i + a_j$ units of advertising inventory and so the price per impression on them is determined by $1-F(p_{ij}) = a_i + a_j$. Note that this is an efficient allocation of advertisers to consumer. Note also that if $a_i = a_j$, then $p_i = p_j = p_{ij}$ while if $a_i > a_j$, then $p_i < p_{ij} < p_j$.

In a given period, outlet *i* receives all of its loyal consumers, D_i^l, and half of the switchers between it and a given outlet *j*, D_{ij}^s. Given this specification, the producer surplus attributable to outlet *i*'s is: $\pi_i = \sum_{j \neq i} P(a_i + a_j)a_i D_{ij}^s + P(2a_i)2a_i D_i^l$. From this, it is clear that outlet surplus is impacted upon by the type of consumers it attracts only if its ad capacities differ from other outlets. If $a_i = a$ for all *i*, then $\pi_i = P(2a)a\left(\sum_{j \neq i} D_{ij}^s + D_i^l\right) = 2x_i P(2a)a$. Note that these profits do not depend on the shares of loyal and switching customers.

3 Market Equilibrium

We now turn to consider the market equilibrium that arises when tracking is not perfect. We focus here on the case where there are two outlets, 1 and 2; consequently we let $D_{12}^s = D^s$. First, we discuss what properties imperfect tracking technologies have before turning to the impact of consumer switching on the advertising market equilibrium.

3.1 Tracking technologies

Above we considered a certain offer that might be put to advertisers when there was perfect tracking: "over the two attention periods, we will impress a given set of consumers just once regardless of where their attention is allocated at a price of p per consumer/impression." This offer was made by an ad platform and was outlet independent.

At the other extreme is what we could term *no tracking*. This arises when neither outlets nor a common platform are unable to internally (or externally) track impressions and to control matching between advertisers and consumers. In the early days of the Internet (circa 2000), websites had no ability to track consumers even within outlets, and even today with privacy settings such tracking may not be possible. The models of Butters (1977) and, more recently, Bergemann and Bonatti (2011) assume that advertisers choose the intensity of their advertising on an outlet, but that advertising messages (impressions) are distributed independently (across messages) and uniformly across consumers. This means that a given consumer might see the same advertisement multiple times, which involves waste and offers to advertisers would be of the form: "over the two attention periods, we will place a given number of impressions on our outlet for a price of p per impression."[25]

We focus here on a more realistic intermediate situation where outlets can track impressions internally but not externally. Thus, outlets cannot offer inter-outlet arrangements (such as different prices for different switching categories of consumer) that would be possible under perfect tracking because they cannot track consumers across outlets.

[25] In such models, the expected number of unique impressions received by an advertiser with advertising intensity n in a market of size x is given by $x\left(1-(1-\tfrac{1}{x})^n\right) \approx x(1-e^{-n/x})$, where $\tfrac{1}{x}$ is the probability that a given consumer is selected for a given ad impression.

There are many possibilities when one considers imperfect tracking that treats internal and external tracking asymmetrically. For instance, one could image a technology that provided **perfect internal tracking**, whereby no consumer receives more than one impression from an advertiser on a given outlet. In this situation, one possible offer an outlet might make is "over the two attention periods, we will impress each unique consumer on the outlet once at a price of p per impression/consumer." Thus, an advertiser could accept this deal and purchase impressions on $D_i^l + D^s$ consumers on outlet i. However, this creates a capacity management issue if the outlet cannot distinguish loyal from switching consumers. If an outlet does not impress all consumers in the 'first period' it will have to impress them in the second period. However, unless it can distinguish between loyals and switchers in the first period, some consumers may move to the other outlet and it will be unable to fulfill its contract. Alternatively, it could impress all consumers in the first period and perhaps identify the new switchers as unique consumers to impress in the second period. But, even in that case, loyals, who remain through the second period, will have additional capacity that can be sold. In principle, that capacity could be sold under a "impress all unique consumers" contract but this would mean that the outlet would have to offer a range of distinct products to advertisers. This is an interesting and potentially realistic scenario, however, due to its additional complexity we do not explore that here and leave the analysis to Section 5 below.

Instead, we consider here tracking technologies where outlets offer a single 'product' or contract type to advertisers. One possible contract offer might be "we will associate an ad with a given piece of content and you will pay a price of p each time that ad is viewed." This is effectively the offer made for offline content and, so long as consumers read a piece of content at most once, it has a natural form of tracking embedded within it. If an advertiser purchased ads alongside a single piece of content on a single outlet they would expect to impress $D_i^l + \frac{1}{2}D^s$ customers. If they purchased an ad alongside content on both outlets they would expect to impress $D_1^l + D_2^l + \frac{3}{4}D^s$ unique customers. Note that an advertiser, placing ads on both outlets, would be able to impress all loyal consumers but may miss some switching consumers while impressing other consumers more than once. The more switchers an advertiser would want to target, the more pieces of content they would have to place ads alongside. Thus, they would be paying for multiple impressions on loyal consumers that, under our assumptions, would not generate additional value for them. The notion that to impress more switchers, advertisers need to pay for more wasted impressions is a common feature of imperfect tracking. If an advertiser pays for *n* content-based ads, it will impress $(1-\frac{1}{2^n})D^s$ switchers. That said, the waste involved is limited if advertisers single-home and confine their ads to one outlet.

An alternative offer, available to online outlets, would be: "over the two attention periods, we will place at most *x* impressions per consumer at a price of *p* per impression." For instance, if an advertiser chose a rate of at most one impression per consumer over the two periods, the outlet could show an ad to all consumers in the first or to all consumers in the second period for a total of $D_i^l + \frac{1}{2}D^s$ impressions. If the advertiser chose a rate of two impressions, the outlet would impress all consumers in each period resulting in $2D_i^l + D^s$ impressions. Of course, like ads associated with content, if an advertiser were to accept this contract on both outlets – say, at a rate of one ad each, it would impress $D_1^l + D_2^l + \frac{3}{4}D^s$ consumers with a total of $D_1^l + D_2^l + D^s$ impressions. There would be missed switchers as they moved between outlets and for the same reason some wasted impressions on switchers. If the advertiser increased the ad rate to two on just one of the outlets, say outlet 1, it would impress all consumers but pay for

$2D_1^l + D_2^l + \frac{3}{2}D^s$ impressions. Table 1 lists the expected advertiser surplus associated with various advertising purchases, (n_1, n_2) where n_i is the number of impressions purchased per customer on outlet *i* over the two attention periods. For simplicity, we have assumed that $D_1^l = D_2^l = D^l$ and that the impression price, *p*, is the same across both outlets.

Table 1

Advertiser Choice	**Expected Number of Impressions Purchased**	**Expected Reach**	**Expected Advertiser Surplus**
Single home: (1,0) or (0,1)	$D^l + \frac{1}{2}D^s = \frac{1}{2}$	$D^l + \frac{1}{2}D^s = \frac{1}{2}$	$(D^l + \frac{1}{2}D^s)(v - p)$
Intense single home: (2,0) or (0,2)	1	$D^l + D^s$	$(D^l + D^s)v - (2D^l + D^s)p$
Multi-home: (1,1)	1	$2D^l + \frac{3}{4}D^s$	$(2D^l + \frac{3}{4}D^s)v - p$
Targeted multi-home: (2,1) or (1,2)	1 + ½	1	$v - (3D^l + \frac{3}{2}D^s)p$
Intense multi-home: (2,2)	2	1	$v - 2(2D^l + D^s)p$

We will use this 'frequency cap' specification for internal tracking in what follows as it represents the simplest form of imperfect tracking that does not create a capacity management issue for outlets. Its key feature is that there are diminishing returns to increasing the rate of impressions placed both within and across outlets. For this reason, the marginal advertiser in the market will single-home and multi-homers, if they exist, will be high value advertisers. This fact tells us something about the resulting market equilibrium.

Table 1 illustrates the advertiser's dilemma that arises when consumers switch between outlets. A multi-homing advertiser accesses all of the loyal consumers on each outlet, but it may only reach a fraction of the switchers. While some switchers may see distinct ads when they traverse between outlets, others may see the same ad from a multi-homing advertiser twice and others, not at all. The advertiser then faces a trade-off. It may prefer to single-home, sacrificing loyals on another outlet but not wasting any impressions. On the other hand, it may decide to multi-home, and even go further, increasing the number of impressions across all outlets. This increases their number of wasted impressions in return for impressing a greater proportion of switchers.

Given the two period structure of attention, one might think that this dilemma could be resolved by *coordinating on a time period*. For instance, an advertiser could pay for impressions only in the first period across all outlets and none in the second. However, this would require that consumers were overlapping completely in time in terms of the reading habits.[26] There is nothing in the two period structure that requires such synchronization, and we find it unrealistic for online browsing. Consequently, we assume that coordination of impressions in a given period of time is not possible.[27]

3.2 Pure Single-Homing Consumers

To begin, it useful to assume – as does most of traditional media economics – that consumers are all loyal and single-home on a single outlet (e.g., Anderson and Coate, 2005); that is, where $\rho = 0$. When there is no switching, outlets have a monopoly over access to a share of consumers and advertising pricing will reflect that.[28]

[26] In the context of coordinating attention, the Superbowl commands such a large share of attention at a given period of time that advertisers can be assured of impressing that share of consumers. Consequently, the coordination opportunity afforded by this may be a reason why ad space commands such high payments per viewer during that event. We explore a similar effect below.

[27] One might wonder whether a pay-per-click model of advertising would alleviate the advertiser's dilemma. The answer is no: whatever the payment model, displaying one advertisement necessarily displaces another. For this reason, most pay-per-click advertising networks charge advertisers a price per click that is inversely proportional to the click-through rate of the ad. Thus, the overall payment of the advertiser is "per impression"—an ad that is not clicked on often (perhaps because it is wasted, if the advertiser multi-homes) has to pay a proportionally higher price per click to justify displacing another advertiser.

[28] Note that this is the usual assumption in many models of media competition. For example, Anderson and Coate (2005) assume that broadcasters compete for viewers and then are able to earn an advertising revenue, $R(a)$ per consumer contingent upon the number of ads shown to them.

To see this, recall our assumption that advertisers place the same marginal value per consumer on reaching any number of consumers. Given that there are no fixed costs of advertising with different outlets, an advertiser, v, will multi-home, advertising on any outlet whose impression price, p_i, is less than v.

There is an issue, however, in that when an outlet has many consumers, it needs to track *when* an ad is placed in front of a given consumer. Our assumption regarding internal tracking means outlets can track consumers within their own outlets and so to access all an outlet's consumers an advertiser need only pay for one impression per consumer. Thus, if it has advertising inventory of a_i per period, the market clearing price for outlet i is the p_i that satisfies $1-F(p_i)=2a_i$. If $P(z)\equiv F^{-1}(1-z)$ then $p_i=P(2a_i)$. Outlet i's profits will be: $\pi_i=x_iP(2a_i)2a_i$; the same profits as the perfect tracking benchmark. Thus, contingent upon the assumption that $\rho = 0$, this is an efficient allocation of advertisers to consumers.[29] Moreover, profits are invariant to the number of outlets.[30]

3.3 Switchers and Outlet Advertising Demand

We now consider advertiser demand when there are switching consumers and imperfect tracking. When advertisers choose their advertising intensity and outlet allocation, the decreasing incremental reach of purchasing an additional impression implies that advertisers will sort, in equilibrium, with higher value types purchasing weakly more impressions. Table 2 demonstrates this with relation to sorting cut-offs (continuing our assumption of symmetric outlets with $D_1^l=D_2^l=D^l$ and $a_1=a_2=a$).

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[29] Of course, if capacity were endogenous, each outlet has an incentive to restrict capacity relative to what might be socially optimal.

[30] As discussed in the introduction, we assume that the readership share x_i does not depend on the number of ads. The standard models of media economics focus on this effect, and show that competition for users reduces the equilibrium output of ads. We do not formally model this effect as it has been well-studied in the existing literature.

Table 2: Advertiser Indifference Points

Choice	Additional expenditure	Value from additional reach	Indifferent advertiser $D^s \leq \frac{2}{3}$	Indifferent advertiser $D^s > \frac{2}{3}$
From (0,0) to (1,0)	$p/2$	$v(D^l + \frac{1}{2}D^s)$	$v_i = p$	$v_i = p$
From (1,0) to (1,1)	$p/2$	$v(D^l + \frac{1}{4}D^s)$	$v_{12} = \frac{2}{2-D^s}p$	-
From (1,0) to (2,0)	$p/2$	$v\frac{1}{4}D^s$	-	$v_{ii} = \frac{1}{D^s}p$
From (1,1) or (2,0) to (2,1)	$p/2$	$v\frac{1}{4}D^s$ or $v\frac{1-D^s}{2}$	$v_3 = \frac{2}{D^s}p$	$v_3 = \frac{2}{1-D^s}p$

Note that no advertiser will choose a rate of 4 (intense multi-homing) as a rate of 3 generates the maximal expected reach – all consumers will see their ad. Relatively high value advertisers will be less willing to miss consumers and will choose a rate of 3; e.g., (2,1). However, this will only occur if the price is low enough for the highest value advertiser in the market, call this advertiser, *V*, to engage in a targeted multi-home strategy; that is, $v_3 \leq V \Rightarrow p \leq \frac{1}{2}D^sV$ or $p \leq \frac{1}{2}(1-D^s)V$. Relatively medium value advertisers will choose a rate of 2; say, (2,0) or (1,1) depending upon whether D^s is higher or lower than 2/3. Finally, lower value customers will target loyal customers and hence, single-home with a rate of 1.

Given this, for each consumer it expects to attract, an outlet receives a share of single-homing advertisers ($F(v_{12})-F(v_i)$) and, if D^s is relatively low, an impression from each multi-homer ($1-F(v_{12})$ or $F(v_3)-F(v_{12})$ as the case may be) and a further half (under symmetry) of multi-homers (if any) who have 2 impressions on one outlet ($1-F(v_3)$). Thus, outlet demand is:

$$\begin{array}{ll} (D^l + \frac{1}{2}D^s)\left(\sigma_i(F(v_{12})-F(v_i)) + (1-F(v_{12})) + \frac{1}{2}(1-F(v_3))\right) & \text{if } V > v_3 \\ (D^l + \frac{1}{2}D^s)\left(\sigma_i\left(F(v_{12})-F(v_i)\right) + (1-F(v_{12}))\right) & \phantom{\text{if }} V \leq v_3 \end{array} \quad (1)$$

where

$$\sigma_i = \begin{cases} \max\left[\frac{2a_i-(F(v_3)-F(v_{12})+\frac{3}{2}(1-F(v_3)))}{2a_i-(F(v_3)-F(v_{12})+\frac{3}{2}(1-F(v_3)))+2a_j-(F(v_3)-F(v_{12})+\frac{3}{2}(1-F(v_3)))},0\right] & \text{if } V > v_3 \\ \max\left[\frac{2a_i-(1-F(v_{12}))}{2a_i-(1-F(v_{12}))+2a_j-(1-F(v_{12}))},0\right] & V \le v_3 \end{cases} \tag{2}$$

That is, σ_i is outlet *i*'s spare capacity after sales to multi-homing advertisers and we assume that single-homers are allocated in equilibrium to each outlet according to their spare capacity (if any). Under symmetry, note that $\sigma_i = \frac{1}{2}$.

This allows us to prove our first proposition.

Proposition 1. *Outlet (and aggregate) demand is decreasing with* D^s *around* $D^s = 0$.

The proof is relatively straightforward. Note first, that as $D^s \to 0$, $v_3 \to \infty$. Thus, around $D^s = 0$, no advertiser chooses to purchase more than two impressions across outlets. Note also that at $D^s = 0$, $v_{12} = v_i = p$ and, total demand for an outlet, $q(p) = 1 - F(p)$. If $D^s > 0$ while $v_3 > V$, then $v_{12} > v_i = p$ and $q(p) = 1 - F(p) - \frac{1}{2}\left(F(v_{12}) - F(p)\right)$. Thus, outlet demand falls; that is, for any given price, *p*, fewer impressions are purchased.

3.4 Switchers and Outlet Profit

We are now in a position to examine the impact of a greater share of switchers on outlet profit. To solve for the market equilibrium, each outlet's demand has to equal its supply. For an outlet, its total supply of advertising inventory is given by:

$$2a_i D_i^l + a_i D^s \tag{3}$$

It will often be convenient in what follows to express variables in a per customer basis. In this case, advertising inventory on outlet *i* is $2a_i$.

Given this supply, we now consider possible equilibrium allocations of advertisers to outlets. First, is it possible that $\sigma_1 = \sigma_2 = 0$ and there are only multi-homing advertisers in the market? For this to be an equilibrium, the willingness to pay of a multi-homing advertiser for an impression on an outlet must exceed the willingness to pay of a single-homing advertiser for an impression on an outlet. That is, the following two inequalities must hold:

$$(D_1^l + \tfrac{1}{4}D^s)v_{12} - (D_1^l + \tfrac{1}{2}D^s)p_1 \geq (D_1^l + \tfrac{1}{2}D^s)(v_1 - p_1) \quad (4)$$

$$(D_2^l + \tfrac{1}{4}D^s)v_{12} - (D_2^l + \tfrac{1}{2}D^s)p_2 \geq (D_2^l + \tfrac{1}{2}D^s)(v_2 - p_2) \quad (5)$$

Note that the marginal advertiser on each outlet would have to be a multi-homer and so $v_i = v_{12}$. Note also that because the 'just excluded advertiser' (with value $v_{12} - \varepsilon$) would be willing to pay that for a single impression on an outlet, $p_i > v_{12} - \varepsilon$ for each outlet. It is clear that as ε goes to zero, the willingness to pay of the just excluded advertiser to single-home exceeds the willingness to pay of the marginal multi-homing advertiser for its marginal impression. That is, the LHS of (4) and (5) becomes negative while the RHS is zero if $D^s > 0$. If $D^s > 0$, at least one outlet must, in equilibrium, sell to single-homing advertisers. That advertiser sets the marginal price in the market. If $D^s = 0$, (4) and (5) hold with equality and so a pure multi-homing equilibrium can arise.

Second, is an equilibrium where each outlet has both multi-homing and single-homing advertisers possible? That is, an equilibrium involving $\sigma_i > 0$ for all *i*. For this to arise, demand from (1) must equal supply from (3) with symmetry implying that $\sigma_i = \frac{1}{2}$.

Finally, is it possible that there are only single-homing advertisers in equilibrium? This would arise if for the highest value advertiser (*V*), its willingness to pay for an additional impression on an additional outlet were negative; that is, $v_{12} = \frac{1}{1-\frac{1}{2}D^s} p > V$. In this case, $\sigma_i = 1$ and equating supply to demand implies $2a = \frac{1}{2}(1 - F(p))$ or $p = F^{-1}(1-4a)$. Thus, this equilibrium will arise if $1 - F(V(1 - \frac{1}{2}D^s)) > 4a$. Note, however, that as D^s approaches 0, this equilibrium allocation cannot arise.

Using this, we can prove the following.

Proposition 2. *Equilibrium prices and profits are decreasing in* D^s *around* $D^s = 0$.

This directly follows from Proposition 1 and (3); that is, aggregate demand decreases while supply stays constant for each outlet. Intuitively, when there are switchers, as we move from no-switching, the marginal impression of a higher valued advertiser (on a second outlet) is out-bid by the first impression of the just excluded advertiser. Consequently, the marginal advertiser in the market is of lower value as D^s rises. Note also that this implies that the total number of advertisers purchasing impressions increases.

While Propositions 1 and 2 characterize changes in prices and profits as the number of switchers increases from $D^s = 0$, it is also the case that a greater number of switchers changes the composition of advertiser choices. In particular, an increase in D^s increases v_{12} (with marginal multi-homers becoming single-homers) and decreases v_3 (with high value multi-homers increasing their frequency on one outlet). Depending upon the rate of changes of these sets, aggregate demand may increase or decrease. Indeed, an increase could occur such that profits eventually become higher than profits when $D^s = 0$.

To demonstrate this, we assume here a specific uniform distribution of advertisers, $F(v) = v$ with V = 1. Under this assumption, market clearing impression prices are:

$$p = \begin{cases} \frac{D^s(2-D^s)}{4+D^s(2-D^s)}(3-4a) & \text{if } \frac{1}{2}D^s > p \\ \frac{2(2-D^s)}{4-D^s}(1-2a) & \quad\ \ \frac{1}{2}D^s \le p \end{cases} \tag{6}$$

Note that under symmetry, $D^s = 2\rho x^2 < \frac{1}{2}$. Thus, the number of switchers cannot exceed that level. When there are no advertisers purchasing multiple impressions on a single outlet, price declines with D^s. However, as D^s rises, there comes a point at which price is low enough that advertisers do purchase multiple impressions. The ones that do so are the inframarginal advertisers, and so as D^s rises beyond this point, price, and hence, outlet profits, $p(D^l 2a + D^s a) = pa$, rise.[31]

The following proposition summarizes how equilibrium profits depend on D^s.

Proposition 3. *Assume that F(.) is uniform on* [0,1] *and there are two symmetric outlets. Suppose also that* $a_1 = a_2 = a$. *Then an outlet's equilibrium profits are as follows:*

(i) *For* $D^s \leq \min\left\{8a, 4(1-a) - 2\sqrt{2(1-2a)+4a^2}\right\}$, $\pi_i = \frac{1}{2}\frac{2(2-D^s)}{4-D^s}(1-2a)2a$ *;*

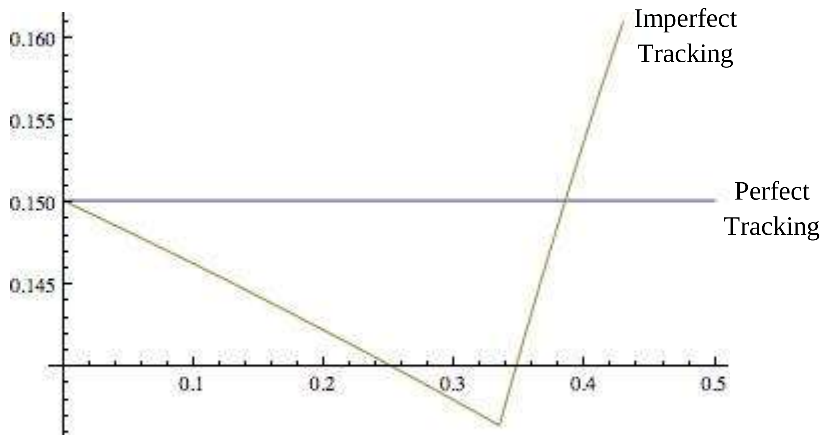
(ii) *For* $D^s > 4(1-a) - 2\sqrt{2(1-2a)+4a^2}$ *and* $D^s < 8a$, $\pi_i = \frac{1}{2}\frac{D^s(2-D^s)}{4+D^s(2-D^s)}(3-4a)2a$

(iii) *For* $D^s \geq 8a$, $\pi_i = \frac{1}{2}(1-4a)2a$.

This characterization of equilibrium profits provides some insight into the impact of the Internet on the news media. To the extent that the Internet has facilitated switching, these results suggest that profits will decline but will eventually rise as switching becomes easier (see Figure One). When the share of switchers is low, competition for the marginal advertiser pushes down total outlet ad revenue. However, as the switcher share becomes large, the comparative static changes sign and profits rise with the number of switchers. This is because high value advertisers begin to purchase multiple impressions on individual outlets. This takes up scarce capacity and excludes lower valued advertisers who were setting the impression price. The end result is that more switchers drive higher impression prices and profits.

[31] It is useful to check whether multiple equilibria are possible. To rule this out as a concern note that market clearing prices in both cases above are equal if: $\frac{D^s(2-D^s)}{4+D^s(2-D^s)}(3-4a) = \frac{2(2-D^s)}{4-D^s}(1-2a) \Rightarrow D^s = 2\left(2(1-a) - \sqrt{2(1-2a)+4a^2}\right)$. At this level of D^s, $p = 2(1-a) - \sqrt{2(1-2a)+4a^2}$; i.e., $D^s/2$. So, for given ad capacities, there is no issue of multiple equilibria.

Figure One: Outlet Profits as a function of D^s ($a = 0.4$)



It is important to note, however, that the result that profits will rise with D^s relies on ad capacity being high enough. If ad capacity is scarce, impression prices never fall to a level that makes it worthwhile for infra-marginal advertisers to purchase multiple impressions on individual outlets. The possibility that advertisers will purchase multiple impressions at a rate that likely leads to likely waste is borne out by the ComScore data. For instance, they estimate that in the first quarter of 2011, almost 1.1 trillion display ads were delivered in the US.[32] Of these, 19.5 billion were purchased by AT&T, 16.6 billion by Experian Interactive and 11.2 billion by Scottrade. If the entire US population surfed the net daily during that time, they would see one AT&T ad per day.

3.5 Asymmetric ad capacities

While the above analysis allowed for some differences between outlets in ad capacities, the main results on imperfect tracking assumed symmetry. Here we consider what happens when ad capacities can be asymmetric. We study whether asymmetry can permit a single market clearing price for advertising and, if not, what do prices look like? Importantly, does an outlet

32 http://www.comscore.com/Press_Events/Press_Releases/2011/5/U.S._Online_Display_Advertising_Market_Delivers_1.1_Trillion_Impressions_in_Q1_2011

have an incentive to reduce ad capacity in order to exercise market power in advertising markets?

The following proposition summarizes the equilibrium outcomes.

Proposition 4. *Suppose that outlets are symmetric in readership,* $F(v) = v$ *and V = 1 but that* $a_1 < a_2$. *If* $a_1 \in [0, \frac{4a_2 - D^s}{2(2-D^s)}]$ *and* $a_2 \in [\frac{1}{4}(2a_1(2-D^s)+D^s, 1]$, *then, in equilibrium,* $p_1 > p_2$. *Otherwise,* $p_1 = p_2$.

The proof (in the appendix) demonstrates that profits are:

$$\pi_1 = (1-\tfrac{1}{2}D^s)(1-2a_1)2a_1 \tag{7}$$

$$\pi_2 = \begin{cases} (1-2a_2)2a_2 & \text{if } a_2 \le \frac{2-D^s}{4} \\ \frac{2D^s}{2+D^s}(1-a_2)2a_2 & \quad\; a_2 > \frac{2-D^s}{4} \end{cases} \tag{8}$$

Here it is clear that having a smaller ad capacity is not necessarily an advantage for outlets even if it does result in a higher impression price.

What does this imply for the incentive of an outlet to use capacity to exercise market power? When ad capacities are symmetric, outlets have incentives akin to those of quantity duopolists in choosing their ad capacities. However, while locally this may be the case, each can unilaterally generate an asymmetric equilibrium of the form described in Proposition 4. When its rival's capacity is low, an outlet has an incentive to expand capacity so that there are no single-homers on the rival outlet. In contrast, when a rival outlet has very high capacity, an outlet may choose a low capacity so as to only sell to multi-homing advertisers. Over a non-trivial range of D^s, no pure strategy equilibrium exists.[33] However, if outlets choose capacities sequentially, the resulting equilibrium is asymmetric with one outlet choosing a low and the other a high ad capacity converging to symmetry as D^s becomes small. Nonetheless, if each ad capacity is

[33] A proof is available from the authors.

constrained to be no greater than ¼, then that is the resulting equilibrium and no asymmetric outcome occurs.

3.6 Asymmetric outlets

Asymmetric capacity choices can lead to differential prices but do not confer absolute positional advantages on outlets. We now consider what happens when outlets have different content quality with one outlet being able to generate a higher readership share than the other; in particular, when $x_1 > x_2 \Rightarrow D_1^l > D_2^l$. In this case, we demonstrate that outlet 1 commands a positional advantage in the advertising market that leads to it being able to earn higher impression prices than outlet alongside having a higher readership share.

To see this, observe that, if there is sufficient capacity on both outlets, single homing advertisers will sort on to outlet 1 first. This is because, for a given *v*, if impression prices were the same on each outlet (equal to *p*) then $(D_1^l + \frac{1}{2}D^s)(v-p) > (D_2^l + \frac{1}{2}D^s)(v-p)$. However, as impression prices will differ in equilibrium (specifically, it must be the case that $p_1 > p_2$ if there are single homers on outlet 2), the marginal single-homer on outlet 1 will be given by $v_1 = \frac{2(D_2^l p_2 - D_1^l p_1) + D^s(p_2 - p_1)}{2(D_2^l - D_1^l)}$ while $v_2 = p_2$. Note that $v_1 > v_2 \Rightarrow (2D_1^l + D^s)(p_2 - p_1) < 0$.[34]

It is important to emphasize that it is the existence of switching consumers (i.e., $D^s > 0$) that generates this sorting. If there are no switchers, then the marginal advertiser on each outlet is competing with a multi-homing advertiser for their marginal impression. In this case, as there are no diminishing returns to additional impressions, a higher value multi-homing advertiser will outbid a smaller value single-homing advertiser for that slot. It is only when there are switchers

[34] Of course, there may be no single-homers on outlet 2 which will alter this intuition as we discuss below.

that single-homing advertisers – competing against one another – determine the impression price on an outlet.

Some set of advertisers will multi-home with one impression on each outlet. The marginal multi-homing advertiser will be determined by:

$$\begin{aligned}&(D_1^l + D_2^l + \tfrac{3}{4}D^s)v_{12} - (D_1^l + \tfrac{1}{2}D^s)p_1 - (D_2^l + \tfrac{1}{2}D^s)p_2 \\ &= \max\left[(D_1^l + \tfrac{1}{2}D^s)(v_{12} - p_1), (D_2^l + \tfrac{1}{2}D^s)(v_{12} - p_2)\right]\end{aligned} \tag{9}$$

Note that if $p_1 \leq p_2$ or there are single-homers on outlet 1, then $(D_1^l + \frac{1}{2}D^s)(v_{12} - p_1) \geq (D_2^l + \frac{1}{2}D^s)(v_{12} - p_2)$ implying that $v_{12} = \frac{D_2^l + \frac{1}{2}D^s}{D_2^l + \frac{1}{4}D^s} p_2$. Of course, it is also possible that some advertisers will multi-home with 2 impressions on one outlet. Note that, in this case, the outlet receiving the additional impression will be outlet 2 as it has the smallest number of loyal consumers. Hence, $v_3 = \frac{2(2D_2^l + D^s)}{4(1 - D_2^l - D_1^l) - 3D^s} p_2$.

Given this, market clearing implies that the following equations (for each outlet) be simultaneously satisfied:

$$\underbrace{1 - F(v_1)}_{\text{Demand for 1}} = 2a \tag{10}$$

$$\underbrace{2(1 - F(\min\{v_3, V\})) + F(\min\{v_3, V\}) - F(v_{12}) + F(v_1) - F(v_2)}_{\text{Demand for 2}} = 2a \tag{11}$$

The following proposition characterizes the equilibrium outcome when ad capacities are symmetric. The derived profits are found by solving (10) and (11) for outlet prices and substituting them into outlet profits while checking to see what allocations of advertising choices these imply (in the same manner as those derived in Proposition 3).

Proposition 5. *Assume that F(.) is uniform on* [0,1], $a_1 = a_2 = a$ *and* $x_1 > x_2$. *Then each outlet's equilibrium profits are as follows:*

(i) *For* $\frac{8-x_1\rho(8-x_1\rho)}{8(2-x_1\rho)} < a < \frac{2-x_1\rho(2-x_1\rho)}{4-x_1\rho(2-x_1\rho)}$ *or* $\frac{2-x_1\rho(2-x_1\rho)}{4-x_1\rho(2-x_1\rho)} < a < \frac{1}{2}$,

$\pi_1 = \left(2(1-a) - x_1 - \frac{4(3-4a)(1-x_1)}{4+x_1\rho(2-x_1\rho)}\right)2a$ *and* $\pi_2 = x_2 \frac{x_1\rho(2-x_1\rho)}{4+x_1\rho(2-x_1\rho)}(3-4a)2a$;

(ii) *For* $\frac{x_1\rho}{8} < a < \frac{8-x_1\rho(8-x_1\rho)}{8(2-x_1\rho)}$, $\pi_1 = x_1 \frac{4-\rho}{4-x_1\rho}(1-2a)2a$ *and* $\pi_2 = x_2 \frac{2(2-x_1\rho)}{4-x_1\rho}(1-2a)2a$

(iii) *For* $\frac{x_1\rho}{8} \geq a$, $\pi_1 = x_1(1-\frac{2a}{x_1})2a$ *and* $\pi_2 = x_2(1-4a)2a$.

The asymmetric outlet case operates similarly to the symmetric outlet case but with an important difference: in general, the 'larger' outlet in terms of readership share can command a premium for its ad space. This is a known puzzle in traditional media economics as it is usually thought that consumers are equally valuable regardless of the outlet they are on. Here, because ads are tracked more effectively internally, placing ads on the larger outlet only involves less expected waste than when you place ads on the other outlet or spread them across outlets. Hence, the larger outlet can command a premium.

However, we also find one exception to this pattern when (a, ρ) are large (Proposition 5 (i)). In this case, outlet 2 is a more attractive outlet for high value advertisers who multi-home with an additional impression on one outlet. These advertisers out bid single homing advertisers on outlet 2. Hence, the lowest value advertisers reside, in that case, on outlet 1 that, in turn, implies that, in equilibrium, $p_1 < p_2$. Thus, outlet 1's profit per reader may be lower than outlet 2's.

4 Policy Implications

4.1 The impact of prohibiting tracking

In 2010, the Federal Trade Commission was exploring a policy that would give consumers the right to 'opt out' of tracking of any kind by websites. If widely adopted, this would eliminate tracking options for media outlets. The analysis here allows us to examine the impact of that on advertising markets.

The impact of prohibitions on tracking depends on incentives to adopt such tracking in the first place. Our analysis provides some insight into this by examining what happens to outlet profits as we move from imperfect to perfect tracking.

Proposition 6. *Assume that F(.) is uniform and there are two symmetric outlets. Suppose also that* $a_1 \approx a_2$. *For low levels of* D^s*, outlet profits under perfect tracking exceed profits without tracking. For high levels of* D^s*, profits under perfect tracking may be lower than profits without tracking.*

This result is depicted in Figure One. Our earlier analysis identified that outlets with symmetric capacities, perfect tracking yields the benchmark profit outcome. Nonetheless, here we have demonstrated that when ad capacities are sufficiently high, profits for both outlets may be higher under no tracking than under perfect tracking. The reason is that higher value advertisers are induced to purchase more impressions. This crowds out lower value advertisers who are setting price at the margin and consequently, impression prices are higher. This suggests that perfect tracking technology might not be adopted despite their ability to generate efficient outcomes in advertising markets.[35]

It is useful to note that outlets do not have a unilateral incentive to adopt perfect tracking as it has no value unless the other outlet is on board. This fact also makes it challenging for a provider of perfect tracking services to appropriate the rents from that activity as we would expect each outlet to have some hold-out power.

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[35] Of course, this also highlights the importance of how ad capacities are chosen; something we analyze in the appendix. That analysis demonstrates that it is, in fact, an inability to commit to not selling advertisements when ad capacity is relatively high that permits the outcome that perfect tracking may lead to lower profits than imperfect tracking.

4.2 The Impact of Mergers

The evaluation of mergers between media outlets has always posed some difficult issues for policy-makers. On the one hand, if it is accepted that outlets have a monopoly over access to their consumers, then such mergers are unlikely to reduce to competitive outcomes in advertising markets. On the other hand, it is argued that a merger may indeed reduce competitive outcomes in advertising markets, increasing ad revenue, and stimulating outlet's incentives to attract consumers. While a full delineation of these views is not possible here, the analysis thus far can speak to the question of whether a merger between outlets would reduce competitive outcomes (i.e., increase total revenue) on the advertising side of the media industry.

To begin, suppose that a merger between two outlets allows them to improve inter-outlet tracking. In this case, this will reduce the number of wasted and missed impressions in the advertising market. While impression prices would rise, so would allocative efficiency. As noted earlier, a move to perfect tracking will generate, for a fixed ad capacity, the first best outcome. Interestingly, by Proposition 6, it is not clear that outlets would choose to merge in order to facilitate this. While allocative efficiency may rise, total advertising profits could fall in cases where D^s and a are sufficiently high.

Alternatively, it may be that the technology is not readily available to improve inter-outlet tracking (even with common ownership). In this case, if the merged outlet charges a single price to advertisers on each outlet, the total ad revenue generated will be the same as the case where both outlets are separately owned. That follows because we have assumed that ad capacity is exogenous, so there is (by assumption) no mechanism for exercising market power: the number of outlets affects equilibrium outcomes only through the impact on tracking and thus the efficiency of advertising on multiple outlets. A full analysis of mergers would thus need to consider the extension of our model to endogenous capacity; something beyond the scope of the current paper.

Another constraint that joint ownership relaxes is on the contracting side. A single entity can discriminate between single-homers and multi-homers. To see this, suppose that, on each outlet, the monopoly owner can commit to an ad capacity allocated to multi-homers, a_m, and an ad capacity allocated to single homers, a_s. Price discrimination is achieved by charging all advertisers the same price for their first impression on one of the outlets and a different price for their second impression. Suppose also that no advertiser wants to purchase multiple impressions on one outlet and that outlet readership quality is symmetric. The price the outlet can charge multi-homers, p_m for their second impression and single-homers, p_s, for their single impression are determined by:

$$a_m = 1 - v_{12} \text{ and } a_s = \tfrac{1}{2}(v_{12} - v_i) \tag{12}$$

where it is assumed $F(v)$ is uniform on [0,1], $v_i = p_s$ and v_{12} is determined by: $v_{12} = \frac{2}{2-D^s} p_m$ given the symmetric readership assumption. Solving for prices and substituting into the profit function, $(p_s + p_m)a_m + p_s a_s$, gives:

$$\tfrac{1}{4}\left((1-2a_s - a_m)(2a_s + a_m) + a_m \tfrac{12-D^s}{2}(1-a_m)\right) \tag{13}$$

Maximizing with respect to (a_m, a_s) and subject to $a_s + a_m = 2a$ yields:

$$a_m = \tfrac{16a - D^s}{2(4-D^s)} \text{ and } a_s = \tfrac{D^s}{2(4-D^s)}(1-4a) \tag{14}$$

so long as $16a > D^s$.[36] Profits are: $\frac{64a(2-D^s)(1-2a)+D^{s2}}{32(4-D^s)}$ which are greater than profits in the absence of price discrimination.

[36] If this condition does not hold, the outlet would not choose to price discriminate.

Price discrimination allows the outlet to separate advertisers' types exploiting a sorting condition: higher types value attention relatively more. With differential prices comes a different allocation of attention. Specifically, note that, for a given D^s with no discrimination we achieve allocative efficiency; i.e., there is no way to re-allocate attention to different advertisers to increase total surplus. What the price discrimination analysis shows is that a monopoly will introduce a further allocative distortion. Although characterizing this "rent-extraction / allocative efficiency of user attention" trade-off is beyond the scope of this paper, we believe this issue is important and should be addressed at the level of merger control.

4.3 The Impact of Blogs and Public Broadcasting

One of the factors that traditional newspapers have argued are contributing to their decline is the rise of blogs and also competition from government-subsidized media. Both of those types of outlets have in common that they either do not accept advertising or accept very little of it. Somewhat in contradiction to this position, newspapers and television broadcasters have objected to plans to allow public broadcasters to sell advertisements rather than rely on subsidies. This latter objection remains a puzzle from the perspective of traditional media economics, because requiring competing public broadcasters to sell ads will cause more annoyance for their consumers and benefit other outlets. Here we explore the impact of competition from non-advertising media outlets.

We do this by assuming that the probability that consumers visit such outlets if given the choice is x_b. We also assume that the two mainstream (advertising) outlets have symmetric readership shares with $x_1 = x_2 = \frac{1}{2}(1-x_b)$. This implies that:

$$D^l = \tfrac{1}{2}(1-x_b)\left(1-\tfrac{1}{2}(1+x_b)\rho\right) \tag{15}$$

$$D^s_{12} = \rho \tfrac{1}{2}(1-x_b)^2 \tag{16}$$

$$D_{ib}^{s} = \rho x_b (1 - x_b) \tag{17}$$

Given this, we can prove the following:

Proposition 7. *For* $\rho > 0$ *and exogenous* $a_1 \approx a_2$*, equilibrium impression prices are increasing in the popularity of the ad-free outlet,* x_b.

Intuitively, an increase in x_b has two effects. First, it decreases the effective supply of advertising capacity in the market. Because blog readers do not see advertisements, as attention is diverted to blogs, less attention is available for ads to be placed in front of. Second, unlike switchers between mainstream outlets, switchers between blogs and mainstream outlets do not contribute to the wasted impressions problem. Consequently, a greater share of blog readers increases the share of blog-mainstream switchers as well and so improves the efficiency of matching. This increases the demand for advertisements. These two effects – a decrease in supply and an increase in demand – combine to raise equilibrium impression prices. It is instructive to note that, even under perfect tracking, the supply-side effect remains and so impression prices would be expected to rise with blog readership share in that case too.

Nonetheless, in terms of the impact on overall outlet profits, the price effect of an increased blog share may not outweigh the quantity effect (in terms of lost readers). If it is the case that we are comparing a situation where one output sells advertising to one where it does not (absent any quantity changes in readership), then it is clear that advertising-selling outlets prefer the situation where its rival is prohibited from selling ads. This resolves the puzzle posed by traditional media economics.

5 Strategic Implications

We now examine the implications of our model for various strategies that might be pursued by media outlets.

5.1 Incentives to compete for readers

We now turn to examine a simple game designed to illustrate the incentives to compete for readers under imperfect tracking versus perfect tracking. We suppose that prior to consumers and advertisers making any choices, outlets can invest an amount, $c(\sigma_i) = \frac{1}{2}\sigma_i^2$ which generates a probability $\sigma_i \in (0,1)$ of being a high rather than a low quality outlet. The probabilities are independent across outlets. Therefore, if outlets choose (σ_1, σ_2) then with probability $\sigma_1(1-\sigma_2)$ only outlet 1 has high quality and so $x_1 > x_2$ while with probability $\sigma_2(1-\sigma_1)$ the reverse is true. With probability $\sigma_1\sigma_2 + (1-\sigma_1)(1-\sigma_2)$ both outlets have the same quality (high or low as the case may be) and $x_1 = x_2$.

The outlet's choose their 'qualities' simultaneously. When outlets have different qualities, the high quality outlet earns π^H while the low quality outlet earns π^L. If they have the same quality an outlet earns π. The profits here are as given in Propositions 3 and 5 when there is imperfect tracking and $\pi_i = x_i P(2a_i)2a_i$ if there is perfect tracking. Thus, in each case, $\pi^H > \pi > \pi^L$. It is straightforward to determine that the unique equilibrium 'qualities' are:

$$\sigma_1 = \sigma_2 = \frac{\pi^H - \pi}{1 + \pi^H + \pi^L - 2\pi} \tag{18}$$

The following proposition characterizes the intensity of investments in quality as a function of the tracking technology adopted.

Proposition 8. *For a given* x_i *achieved by a uniquely high quality outlet, the equilibrium level of* σ_i *is higher under imperfect tracking than under perfect tracking so long as a is not too high.*

The proof involves a simple comparison of equilibrium quality choices and is omitted. The cost of being a low competing against a high quality outlet rises with the number of switchers. This differential creates a strong incentive to compete for a quality position.

5.2 Magnet content

The analysis thus far has assumed that outlets have sufficient content to attract attention of loyal consumers throughout the relevant attention period. Of course, on the Internet, much content is provided on a smaller scale. For providers of that content, there is no possibility of attracting loyal consumers. However, here we demonstrate how such providers may have a positional advantage in advertising markets; that is, what they lose in their inability to attract frequent visits from consumers, they can make up in terms of their reach across all consumers – acting as a magnet for attention in the relevant advertising period.

Suppose that outlet 2, in our current formulation, has only limited content; i.e., that consumers visiting that outlet will stay at most one period. To assist in identifying it notationally, let's rename it outlet *f*. Outlet 1 is unchanged. In this situation, the total expected traffic (over both periods) to outlet 1 is $x_1 + (1-\rho)x_1 + \rho x_1^2 + \rho x_f$ and to outlet 2 is $x_f + \rho x_1 x_f$. Using, this we can identify loyal and switching consumers in this context for any given period: $D_1^l = x_1 - \rho x_f x_1$, $D_f^l = x_f - \rho x_f$ and $D^s = \rho x_f (1 + x_1)$. Of course, there is an important sense in which the description 'loyal to outlet *f*' is a misnomer as consumers can consume one period of content. Consequently, this is more appropriately described as 'exclusive to outlet *f*.' Nonetheless, to focus on the impact of limited content, we will confine ourselves here to the case where $\rho = 1$. In this situation, $D_f^l = 0$ and outlet *f* only has consumers who are switchers. Thus, while outlet 1 supplies ad capacity of $D_1^l 2a + D^s a$ into the market, outlet *f* only supplies $D^s a$.

The following table identifies the surplus to an advertiser with value *v* from pursuing different choices.

Advertiser Choice	**Frequency-Based Tracking**
Single home on 1, 1 impression	$(D_1^l + \frac{1}{2} D^s)(v - p_1)$
Single home on 1, 2 impressions	$(D_1^l + D^s)v - (2D_1^l + D^s) p_1$
Single home on *f*, 1 impression	$\frac{1}{2} D^s (v - p_f)$
Single home on *f*, 2 impressions	$D^s (v - p_f)$
Multi-home, 1 impression each	$(D_1^l + \frac{3}{4} D^s)v - (D_1^l + \frac{1}{2} D^s) p_1 - \frac{1}{2} D^s p_f$
Multi-home, 2 on *f* and 1 on 1	$(D_1^l + D^s)v - (D_1^l + \frac{1}{2} D^s) p_1 - D^s p_f$
Multi-home, 2 on 1 and 1 on *f*	$(D_1^l + D^s)v - (2D_1^l + D^s) p_1 - \frac{1}{2} D^s p_f$

Notice that there are now three options for an advertiser to cover the entire consumer market – single homing on 1 with 2 impressions, and multi-homing with two impressions on at least one outlet. Of course, it is clear that multi-homing with 2 impressions on outlet 1 is dominated by single-homing on outlet 1 (as the former involves paying for impressions on *f* without any benefit). In addition, note that any advertiser who wants to single homing on outlet *f* will prefer to do so with two impressions as there is no waste from the additional impression. More subtly, we can always rule out multi-homing with one impression on each outlet. For this to be preferred to single-homing on outlet 1 (with one impression) it must be the case that $\frac{1}{4} D^s v > \frac{1}{2} D^s p_f$. However, this condition also means that by moving from multi-homing with single impressions to multi-homing on outlet *f* with 2 impressions is preferable. Consequently, if an advertiser wants to capture an additional $\frac{1}{4}D^s$ by purchasing an impression on outlet *f*, it will also want to do this by purchasing two additional impressions on outlet *f*.

This still leaves four choices that might be undertaken by advertisers. Importantly, as a means of covering the entire market, single-homing on outlet 1 with 2 impressions and multi-homing with 2 impressions on *f* are substitutes. Indeed, multi-homing will only be chosen if $(D_1^l + \frac{1}{2}D^s)p_1 > D^s p_f$; a condition that must hold if D^s is very small. Importantly, at any point in time, we will only observe one of these strategies being chosen. In each case, it will be the highest value advertisers who pursue them.

For the remaining choices, advertisers single homing on *f* (with 2 impressions) or on 1 (with 1 impression) are candidates to be the marginal advertiser in the market. If $\frac{1}{2}D^s > D_1^l$, higher value advertisers prefer (holding prices constant) purchasing impressions on *f* rather than 1. Under this condition, the marginal advertiser, with value p_1, would earn $D^s(p_1 - p_f)$ by switching to outlet *f* which is negative if $p_1 < p_f$. Similarly, if the marginal advertiser has value, p_f, it will earn $(D_1^l + \frac{1}{2}D^s)(p_f - p_1)$ by switching to outlet 1. This reduces its surplus if $p_f < p_1$. Hence, the marginal advertiser will be on the lowest priced outlet.

Given this, we can prove the following proposition.

Proposition 9. *Suppose that $\rho = 1$. Equilibrium profits for outlets 1 and f are:*

$$\begin{array}{ll} \pi_1 = (D_1^l + \tfrac{1}{2}D^s)\frac{6D_1^l(1-2a)+D^s}{3(2D_1^l+D^s)}2a \text{ and } \pi_f = D^s\left(\tfrac{2}{3}-a\right)a & \text{if } \tfrac{1}{2}D^s \le D_1^l \\ \pi_1 = (D_1^l + \tfrac{1}{2}D^s)\left(aD_1^l + D^s(1-2a)\right)2a \text{ and } \pi_f = D^s\left(1-2a-2(1-3a)\frac{D_1^{l2}}{D^s}\right)a & \phantom{\text{if }} \tfrac{1}{2}D^s > D_1^l \end{array}$$

The structure of the equilibrium is interesting. When *f*'s share is low ($\frac{1}{2}D^s < D_1^l$) and begins to rise, outlet 1, who was exclusively selling to single-homing advertisers (1 impression) continues to do so but high valued advertisers also purchase 2 impressions on outlet *f*. The same is true of low valued purchasers who now become the marginal advertisers in the market at a price of p_f. Consequently, $p_f < p_1$ but as x_f rises outlet 1's profit falls as does total profits from advertising in the industry. This changes when x_f reaches a critical level (i.e., 0.42265 so that $\frac{1}{2}D^s > D_1^l$). At that point, marginal advertisers prefer to bid for 2 impressions on outlet *f* and so single-homing advertisers with a single impression on outlet 1 become the marginal advertisers at a price of p_1. This implies that $p_f > p_1$. In addition, the high valued advertisers no longer choose to multi-home and become exclusive to outlet 1 with 2 impressions. Nonetheless, as x_f rises outlet 1's profits continue to fall. In this case, however, industry profits rise again and indeed, when $x_f \to 1$ they approach the same level as when $x_f = 0$. In this case, the profits are split evenly between the two outlets rather than held entirely by outlet 1. Intuitively, at this point, all consumers are switchers and so there is no longer any inefficiency resulting from wasted impressions.

Where there is inefficiency at this limit is as a result of outlet 1's content. It now arguably too much as the small content outlet can earn exactly the same profits as it can with content sufficient to capture attention for only a single attention period. Indeed, when x_f is such that $\frac{1}{2}D^s > D_1^l$, outlet *f* earns more than half of outlet 1's profits. Thus, the rate of return for providing that additional content is lower for outlet 1 than for outlet *f*.

We can get a sense as to whether limited but magnet content is becoming relatively more important by looking at the type of outlets that now attract display ad impressions. ComScore reports that in the first quarter of 2011, Facebook (arguably a limited content provider) attracted over 30 percent of all display ad impressions in the US; around 350 billion impressions. In contrast, traditional, in-depth, news outlets such as Turner International, Fox Interactive and CBS Digital Attracted between 11 and 18 billion impressions.

5.3 Paywalls

Paywalls have been proposed as a means by which outlets with falling advertising revenue may restore profitability. Of course, there are several different types of paywalls that may be employed. One possibility is a paywall – sometimes termed 'micropayments' – whereby consumers pay whenever they visit a website; similar to payments for physical newspapers at the newstand. Another type is a subscription whereby consumers pay once and can access a site for a length of time. Finally, some outlets have experimented with limited paywalls that permit limited reading on websites but if consumers want to consume more they have to subscribe. Here we analyze each of these types of strategies focusing on what it does to advertising revenue for each outlet. In so doing, we focus on a situation where one outlet, in this case outlet 1, introduces a paywall while the other outlet remains free.

The exploration here will be conducted within the context of the model thus far to gain some insight on these issues. A full exploration would embed a proper model of consumer behavior in the consumer choice side of the market. Instead, we argue that one important effect of paywalls is to impact on switching behavior and through that on advertising markets. Specifically, we now propose that outlets are asymmetric in the probabilities that a consumer might have an opportunity to switch *away* from them. That is, we define ρ_{ij} as the probability that a consumer who has visited outlet *i*, has an opportunity to switch from it. Consequently, the three consumer classes are now determined by:

$$D_1^l = x_1 - x_1(1-x_1)\rho_{12} \tag{19}$$

$$D_2^l = x_2 - x_2(1-x_2)\rho_{21} \tag{20}$$

$$D_{12}^{s} = (\rho_{21} + \rho_{12})x_1 x_2 \tag{21}$$

A higher ρ_{ij} may result from the consumer having a higher cost associated with remaining with outlet *i*. Of course, a paywall may impact upon x_i. However, for the most part, we will hold that effect fixed and comment on the impact of such movements below.

We begin by considering *micropayments* whereby outlet 1 charges consumers for each period they visit its website. Holding the impact on x_1 fixed, a micropayment makes it less likely that visitors to outlet 1 will stay on that outlet another period (increasing ρ_{12}) while making it less likely visitors to outlet 2 will switch to outlet 1 (decreasing ρ_{21}). This has two impacts on advertising markets. First, D_{12}^{s} could rise or fall depending upon what happens to $\rho_{21} + \rho_{12}$. If it falls, then this will put upward pressure on advertising prices if ad capacity is relatively low. Second, recall that when readership shares were asymmetric, an outlet commanded a positional advantage if its expected share of loyal consumers was relatively high. However, holding x_1 fixed and starting from a symmetric position prior to the paywall, micropayments on outlet 1 will cause $D_2^l > D_1^l$. Consequently, outlet 2 will be given a positional advantage in the advertising market so that $p_2 > p_1$. Add to that the likelihood that 1's paywall will reduce x_1 and this effect is only reinforced. Outlet 1 would have to not only make up for lost advertising revenues as a loss in visitors but also from the loss in positional advantage while outlet 2 clearly benefits on both of these dimensions from the paywall.

In contrast to a micropayment system, a *subscription* system will have a more directed impact. In such a system, a visitor to outlet 1 only pays on their first visit and not thereafter. This means that a subscriber to outlet 1 may be just as likely – should the opportunity and desire arise – to switch to outlet 2 (i.e., ρ_{12} will not change). However, a non-subscriber who had visited outlet 2 previously would be less likely to then subscribe to outlet 1 for what remained of the attention period (i.e., ρ_{21} would fall). Once again, starting from a position of symmetry, this implies that $D_2^l > D_1^l$ and so the paywall would not only lead to relatively more visitors to outlet 2 but a positional advantage for it in advertising markets. This is an interesting result as one of the claims associated with subscription paywalls is that they will increase consumer loyalty to an outlet. While it is true that such loyalty, if generated, would increase an outlet's advertising revenues per consumer, here a subscription generates increased loyalty for the rival outlet rather than the outlet imposing the paywall. Of course, this effect could be mitigated if, say because they are subscribers, consumers are more inclined to be loyal to outlet 1 thereby increasing ρ_{12}. The point here is that that outcome is not straightforward.

Finally, some outlets have proposed a *limited paywall*.[37] In this case, outlets allow access to some content for free and then charge should a consumer wish to consume more. In the context of the model here, such a paywall would only be imposed, say, if a consumer chose to stay on outlet 1 for both attention periods. This type of paywall would be unlikely to have any impact on those who had previously visited outlet 2 as they could still freely switch to outlet 1 (i.e., ρ_{21} would be unchanged). However, this paywall would impose a penalty for staying on outlet 1 making consumers there more inclined to switch (i.e., ρ_{12} would rise). It is clear again, that other things being equal, the paywall would result in $D_2^l > D_1^l$.

The analysis here demonstrates that putting in a paywall may give an outlet a positional disadvantage in advertising markets. Of course if an outlet already has a positional advantage, the likelihood that this occurs is lower. Nonetheless, the impact of a paywall does confer benefits

[37] This has been implemented by the *Financial Times* and, more recently, the *New York Times*.

on rivals in advertising markets as well as increasing their readership. These consequences may explain the low use of paywalls for online news media.

5.4 First Look versus Last Look Advertising

Thus far, we have modeled advertising markets with outlets offering a single and common product to all advertisers. While different tracking technologies altered the nature of the product offering, we did not consider multiple product offerings that would allow outlets to engage in price discrimination.

In this section, we explore one aspect of alternative products that might be offered; specifically, that advertisers bid separately for 'first look' and 'last look' consumers. A first look ad for a consumer is an ad placed in front of the consumer when they first visit an outlet. In contrast, a last look ad is one placed in front of consumers at the end of the relevant attention period. In the context of our model, a first look ad would be one consumers see in period 1 whereas a last look ad is one consumers see in period 2. It assumed here that outlets can track consumers perfectly and so distinguish, at any point of time, first and last (second) look consumers. Outlets offer advertisers the following deal: "over the two attention periods, we will place an impression in front of first look consumers at a price of p_{1st} per impression and an impression in front of last look consumers at a price of p_{2nd} per impression." In practice, this might be implemented by associating advertising with particular content that is likely to be viewed sequentially (e.g., a front page).

What is advertiser demand for these alternative products? If an advertiser purchases 'first look' ads on, say outlet 1, it will impress $D_1^l + D^s$ consumers. Notice that, given this, an advertiser will not find it optimal to also purchase 'last look' ads on the same outlet. In addition, if $p_{1st} \geq p_{2nd}$, an advertiser would not find it optimal to also purchase 'first look' ads on outlet 2.

If it did this, their expected surplus would be $v-(D_1^l+D^s)p_{1st}-(D_2^l+D^s)p_{1st}$ as it impressed all consumers. However, the alternative would be to purchase impressions on last look consumers on outlet 2. This would generate surplus of $v-(D_1^l+D^s)p_{1st}-D_2^l p_{2nd}$ as no switcher on an outlet could be considered a last look consumer.

This insight leads to the following result:

Proposition 10. *Assume that there are two symmetric outlets. Suppose also that* $a_1=a_2=a$. *If outlets offer distinct first and last look products, then outlet profits are the same as under perfect tracking.*

Consider the following allocation of advertisers to outlets. All advertisers above a certain threshold, $\underline{v}$, pay for first look consumers on one outlet and last look consumers on the other. In this case, both outlets set $p_{1st}=p_{2nd}=\underline{v}$. Notice that the marginal advertiser, $\underline{v}$, earns zero expected surplus on each outlet. Hence, no advertiser with lower value will bid for their consumers on either outlet. Consequently, each outlet can accommodate a distinct advertisers with each of its products so that $p_{1st}=p_{2nd}=P(2a)$. Thus, an outlet's profits become: $P(2a)(D_i^l+D^s)a+P(2a)D_i^l a=P(2a)a$.

Significantly, for the symmetric outlet case, this outcome results in allocative efficiency. Quality differences between outlets will not change this outcome. For instance, if $x_1>x_2$, then high value advertisers will bid more for a bundle of first and last look consumers. However, as each component of the bundle is set by different outlets, the ability to substitute between them will cause prices to be bid to equality. Hence, no sorting will occur.

What will change the outcome is if there are differences in ad capacities between outlets. In this case, the bundle across outlets could only be offered up to the minimum ad capacity. Beyond that point, additional capacity could not be sold as a part of the bundle and so the higher capacity outlet would sell the excess consumers to single-homing advertisers. This outcome is still allocatively efficient, however but sorting means that the profits differ from the outcome under perfect tracking.

Finally, if there are more than two outlets (or specifically if the number of outlets is greater than the number of attention periods), then multi-homing advertisers will face diminishing returns to expanding impressions across outlets. Consequently, the same issues that arise under imperfect tracking will emerge. However, if the number of outlets is less than the number of attention periods (say, if the latter is a continuum) then it is possible that price discrimination could restore efficiency. We leave an exploration of this for future research.

6 Conclusions and Directions for Future Research

This paper resolves long-standing puzzles in media economics regarding the impact of competition by constructing a model where consumers can switch between media outlets and those outlets can only imperfectly track those consumers across outlets. This model generates a number of predictions including that as consumer switching increases total advertising revenue falls, that outlets with a larger readership share command premiums for advertisements, that greater switching may lead advertisers to increase the frequency of impressions purchased on outlets, that an increase in attention from non-advertising sources will increase advertising prices, that mergers may allow outlets to price discriminate in advertising markets, that ad platforms may not increase outlet profits, that investments in content quality will be associated with the frequency with which advertisers purchase impressions and that outlets that supply magnet content may be more profitable than outlets offering a deeper set of content. These predictions await thoughtful empirical testing but are thusfar consistent with stylized facts associated with the impact of the Internet on the newspaper industry.

While the model here has a wide set of predictions, extensions could deepen our understanding further. Firstly, the model involves two outlets usually modeled as symmetric with a distribution of advertisers with specific qualities. Generalizing these could assist in developing more nuanced predictions for empirical analysis; specifically, understanding the impact of outlet heterogeneity on advertising prices, incentives to invest in quality and incentives to invest in tracking technology.

Related, in this paper, we focused on frequency-based tracking noting that other forms of tracking have been part of the news industry. An open question is what the incentives are for firms to unilaterally improve their internal tracking of consumers. As noted throughout this paper, the adoption of more efficient matching may increase marginal demand but reduce inframarginal demand from advertisers. When ad capacity is scarce, it is not clear that such moves will prove profitable for outlets.

Finally, throughout this paper we have assumed that advertisements were equally effective on both outlets. However, in some situations, it may be that the expected value from impressing a consumer on one outlet is higher than that from impressing consumers on another. For instance, consider (as in Athey and Gans, 2010), a situation where all advertisers are in a given local area. One outlet publishes in that local area only while the other is general and publishes across local areas.[38] Absent the ability to identify consumers based on their location, a consumer impressed on the local outlet will still generate an expected value of v to advertiser v whereas one impressed on the general outlet will only generate an expect value of θv with $\theta < 1$.

[38] Location is only one aspect upon which consumers and advertisers might sort according to common interests. Any specialized media content can perform this function and give an outlet a matching advantage over more general outlets.

In this situation, even if there are no switching consumers, advertisers on the general outlet will be paying for wasted impressions.

While this situation may be expected to generate outcomes similar to when readership shares are asymmetric, the effects can be subtle. A general outlet may have fewer consumers who are of value to advertisers but also may have a larger readership.[39] Also, when consumers switch between outlets, the switching behavior is information on those hidden characteristics. Thus, switching behavior may actually increase match efficiency. Consequently, the effects of tailored content, self-selection and incentives to adopt targeting technologies that overcome these are not clear and likely to be an area where future developments can be fruitful.

[39] Levin and Milgrom (2010) argue that targeting may be limited because it conflicts with goals of achieving market thickness (see also Athey and Gans, 2010).

7 Appendix

7.1 Proof of Proposition 4

Suppose that $a_1 < a_2$ and that $\sigma_1 = 0$. Also, assume for the moment that $v_{12'} > 1$. In this case, the conditions for outlet supply to equal outlet demand become:

$$2a_1 = 1 - v_{12} \tag{22}$$

$$2a_2 = 1 - v_{12} + v_{12} - v_2 \tag{23}$$

as outlet 1 only sells to multi-homers while outlet 2 sells to all of the single-homers. For this to be an equilibrium, prices in each outlet (which may be different) must be at a level where the marginal multi-homer is indifferent between multi-homing and single-homing on outlet 2.[40]

$$(D_1^l + \tfrac{1}{4}D^s)v_{12} - (D_1^l + \tfrac{1}{2}D^s)p_1 > (D_1^l + \tfrac{1}{2}D^s)(v_2 - p_1) \tag{24}$$

$$(D_2^l + \tfrac{1}{4}D^s)v_{12} - (D_2^l + \tfrac{1}{2}D^s)p_2 \geq (D_2^l + \tfrac{1}{2}D^s)(v_2 - p_2) \tag{25}$$

Note, first, that this requires that $p_1 \geq p_2$, otherwise, as we demonstrated above (24) could not hold, as single-homers would successful bid for impressions on 1. Instead, if $p_1 < p_2$, $(D_1^l + \tfrac{1}{4}D^s)v_{12} - (D_1^l + \tfrac{1}{2}D^s)p_1 = 0$ as multi-homers will bid up 1's impression price. Given this and (22), we can determine that in any equilibrium of this kind,

$$p_1 = \tfrac{D_1^l + \frac{1}{4}D^s}{D_1^l + \frac{1}{2}D^s}(1 - 2a_1) \tag{26}$$

Hence, $v_{12} = 1 - 2a_1$. Note also, that single-homers will set the impression price on outlet 2 (so that $p_2 = v_2$) and hence, the RHS of (25) will equal zero. Substituting in $v_{12} = 1 - 2a_1$ on the LHS we have:

$$p_2 \leq \tfrac{D_2^l + \frac{1}{4}D^s}{D_2^l + \frac{1}{2}D^s}(1 - 2a_1) \tag{27}$$

Note, however, we also have from (23) that $p_2 = 1 - 2a_2$. Thus, for this to be an equilibrium outcome requires:

$$1 - 2a_2 \leq \tfrac{D_2^l + \frac{1}{4}D^s}{D_2^l + \frac{1}{2}D^s}(1 - 2a_1) \tag{28}$$

Note that if $a_1 \approx a_2$ and $D^s > 0$ this cannot hold. Thus, 2's ad capacity must be significantly greater than 1's. Thus, with symmetric readerships, the asymmetric equilibrium will occur for $a_i \in [0, \tfrac{4a_j - D^s}{2(2 - D^s)}]$ and $a_j \in [\tfrac{1}{4}(2a_i(2 - D^s) + D^s, 1]$. Note that if $a_j = \tfrac{1}{2}$, $a_i \in [0, \tfrac{1}{2}]$ while if $a_i = \tfrac{1}{2}$, then $a_j \in [\tfrac{1}{2}, 1]$. Thus, if each outlet has capacity of $\tfrac{1}{2}$, any asymmetry will generate the asymmetric equilibrium.

[40] With symmetric readership shares, the marginal multi-homer would not choose to single-home on outlet 1 if $p_1 > p_2$ which will turn out to be the case.

This derivation assumes that $v_{12'} > 1$. If this was not the case and if $p_1 > p_2$ then the market clearing conditions for the asymmetric equilibrium would become:

$$2a_1 = 1 - v_{12} \tag{29}$$

$$2a_2 = 2(1 - v_{12'}) + v_{12'} - v_2 \tag{30}$$

as only outlet 2 sells additional impressions to some multi-homers. Thus, outlet 1's price would remain as in (26) while outlet 2's pricing condition would satisfy (substituting $v_{12'}$ into (30)):

$$p_2 = \tfrac{2D^s}{2+D^s}(1 - a_2) \tag{31}$$

This would be an equilibrium so long as $v_{12'}(p_2) < 1$ or $a_2 > \tfrac{2-D^s}{4}$ in addition to the ad capacity asymmetries as identified earlier. It is easy to confirm in this case that $p_1 > p_2$.

7.2 Proof of Proposition 6

When D^s is low, outlet 1's profits under no tracking are $\tfrac{2(2-D^s)}{4-D^s}(1-(a_1+a_2))a_1$ whereas outlet 1's profits under perfect tracking are $(1-a_1-a_2)a_1D^s + (1-2a_1)2a_1D^l$. Profits under perfect tracking exceed those under no tracking if: $(a_1-a_2)D^s(4-D^s) + (1-2a_1)(4-D^s) > 2(2-D^s)(1-(a_1+a_2))$. With $a_1 = a_2$, this becomes: $D^s > 0$.

When D^s is high, outlet 1's profits under no tracking may be $\tfrac{D^s(2-D^s)}{4+D^s(2-D^s)}(3-2(a_1+a_2))a_1$. Comparing these to the profits under perfect tracking and imposing $a_1 = a_2 = a$, perfect tracking will yield higher profits if: $\tfrac{2(1-2a)}{1-a} > D^s(2-D^s)$. Examining the case where $D^s = \tfrac{1}{2}$, note that these profits will be an equilibrium if the equilibrium price they are based on $\tfrac{2(2-D^s)}{4-D^s}(1-2a)$ is less than ¼. That is, if $\tfrac{6}{7}(1-2a) < \tfrac{1}{4} \Rightarrow a > \tfrac{17}{48}$. At $D^s = \tfrac{1}{2}$, we have $\tfrac{2(1-2a)}{1-a} > \tfrac{3}{4} \Rightarrow a < \tfrac{5}{13}$ so for $a \in [\tfrac{17}{48}, \tfrac{5}{13}]$, perfect tracking yields superior profits but for $a > \tfrac{5}{13}$, profits are higher under no tracking.

7.3 Proof of Proposition 7

The advertiser expected surplus from given advertising strategies are:

Advertiser Choice	**Frequency-Based Tracking**
Single home on i, 1 impression	$(D_i^l + \tfrac{1}{2}D_{12}^s + \tfrac{1}{2}D_{ib}^s)(v-p)$
Single home on i, 2 impressions	$(D_i^l + D_{12}^s + D_{ib}^s)v - (2D_i^l + D_{12}^s + D_{ib}^s)p$

Multi-home, 1 impression each	$(D_1^l + D_2^l + \frac{3}{4} D_{12}^s + \frac{1}{2}(D_{1b}^s + D_{2b}^s))v$ $-p(D_1^l + D_2^l + D_{12}^s + \frac{1}{2}(D_{1b}^s + D_{2b}^s))$
Multi-home, 2 on *i* and 1 on *j*	$(D_i^l + D_j^l + D_{12}^s + D_{ib}^s + \frac{1}{2} D_{jb}^s)v$ $-(2D_i^l + D_j^l + \frac{3}{2} D_{12}^s + D_{ib}^s + \frac{1}{2} D_{jb}^s)p$
Multi-home, 2 impressions on each	$(D_i^l + D_j^l + D_{12}^s + D_{ib}^s + D_{jb}^s)v$ $-(2D_i^l + 2D_j^l + 2D_{12}^s + D_{ib}^s + D_{jb}^s)p$

The main difference between this case and the previous two outlet model is that some advertisers may choose to multi-home with two impressions on each outlet so as to impress a greater share of those switching between blogs and mainstream outlets. Indeed, under symmetry, the threshold advertiser rates become (under symmetric ad capacities):

$$v_i = p \tag{32}$$

$$v_{12} = 2\frac{2D^l + D_{12}^s + D_{ib}^s}{4D^l + D_{12}^s + 2D_{ib}^s} p \tag{33}$$

$$v_{12'} = 2\frac{2D^l + D_{12}^s + D_{ib}^s}{D_{12}^s + 2D_{ib}^s} p \tag{34}$$

$$v_{12''} = \frac{2D^l + D_{12}^s + D_{ib}^s}{D_{ib}^s} p \tag{35}$$

where $v_{12''}$ is the threshold between multi-homing with 2 on one outlet and multi-homing with 2 impressions on each outlet. It is clear that, under symmetry, $v_{12''} > v_{12'} > v_{12} > v_i$ when $\rho > 0$. This implies that there are three demand 'cases' but that supply in the market is $D_1^l 2a_1 + D_2^l 2a_2 + D_{12}^s(a_1 + a_2) + D_{1b}^s a_1 + D_{2b}^s a_2$. So long as ad capacities are symmetric, the market clearing price is given by:

$$p = \begin{cases} 1-4a & \text{if } 0 < a < \frac{1}{16}\rho(1-x_b) \\ \frac{2(4-(1-x_b)\rho)}{8-(1-x_b)\rho}(1-2a) & \frac{1}{16}\rho(1-x_b) < a < a^L \\ \frac{(1+3x_b)\rho(4-(1-x_b)\rho)}{16+4(1+7x_b)\rho-(1+2x_b-3x_b^2)\rho^2}(3-4a) & a^L \le a < a^H \\ \frac{x_b(1+3x_b)\rho(4-(1-x_b)\rho)}{4-\rho+x_b^2(31-2\rho)\rho+3x_b^3\rho^2+xb(28+2\rho-\rho^2)}4(1-a) & a \ge a^H \end{cases} \tag{36}$$

where $a^L = \frac{32-\rho(16+2x_b(8-\rho)+\rho-3x_b{}^2\rho)}{64-16(1-x_b)\rho}$ $a^H = \frac{3(4-\rho)+x_b(20+\rho(-10+\rho+x_b(-19+(2-3x_b)\rho)))}{4(1+3x_b)(4-(1-x_b)\rho)}$. It can be seen here that as the number of blog readers increases and/or the probability of switching rises, that inframarginal advertisers will demand more impressions.

The proof of the proposition follows from a simple examination of (36).

7.4 Proof of Proposition 9

Case 1: $\frac{1}{2}D^s > D_1^l$. Suppose that $(D_1^l + \frac{1}{2}D^s)p_1 < D^s p_f$. Then consider a candidate equilibrium where high value advertisers sort as single-homers (2 impressions) on 1, then single-homers (2 impressions) on *f* and finally as single-homers (1 impression) on 1. In this case, equilibrium prices will be the solution to:

$$D_1^l 2a + D^s a = (D_1^l + \tfrac{1}{2}D^s)\left(2(1-v_{1f}) + (v_f - p_1)\right) \quad (37)$$

$$\tfrac{1}{2}D^s 2a = \tfrac{1}{2}D^s 2(1-v_{1f}) \quad (38)$$

where $v_{1f} = \frac{(2D_1^l + D^s)p_1 - D^s p_f}{D_1^l}$ and $v_f = \frac{2D^s p_f - (2D_1^l + D^s)p_1}{D^s - 2D_1^l}$. Solving this gives:

$$p_1 = \frac{aD_1^l + D^s(1-2a)}{D_1^l + D^s} \quad (39)$$

$$p_f = 1 - 2a - 2(1-3a)\tfrac{D_1^{l2}}{D^s} \quad (40)$$

(recalling that we assume that $a \le \frac{1}{4}$). It is easy to demonstrate that $p_f > p_1$ and that $(D_1^l + \frac{1}{2}D^s)p_1 < D^s p_f$. This confirms the equilibrium.

Is it possible that $(D_1^l + \frac{1}{2}D^s)p_1 > D^s p_f$? In this case, a candidate equilibrium would have high value advertisers sort as multi-homers (2 impressions) on *f* and then single-homers (2 impressions) on *f*. In this case, no advertiser will choose single-homing on 1. Thus, equilibrium prices will be the solution to:

$$D_1^l 2a + D^s a = (D_1^l + \tfrac{1}{2}D^s)(1-v_{1f}) \quad (41)$$

$$\tfrac{1}{2}D^s 2a = \tfrac{1}{2}D^s 2(1-p_f) \quad (42)$$

where $v_{1f} = \frac{(D_1^l + \frac{1}{2}D^s)p_1}{D_1^l}$. Solving this gives:

$$p_1 = \frac{D_1^l(1-2a)}{2D_1^l + D^s} \quad (43)$$

$$p_f = 1 - a \quad (44)$$

It is easy to demonstrate that $p_f > p_1$ but that $(D_1^l + \frac{1}{2}D^s)p_1 - D^s p_f = (\frac{1}{2} - a)D_1^l - D^s(1-a) > 0 \Rightarrow \frac{D^s}{D_1^l} < \frac{\frac{1}{2}-a}{1-a}$ which cannot hold as the LHS is greater than 2 while the RHS is less than 2. Thus, this cannot be an equilibrium.

Case 2: $\frac{1}{2}D^s < D_1^l$. Suppose that $(D_1^l + \frac{1}{2}D^s)p_1 > D^s p_f$. Then consider a candidate equilibrium where high value advertisers sort as multi-homers (2 impressions) on *f*, then single-homers (1 impression) on 1 and finally single-homers (2 impressions) on *f*. In this case, equilibrium prices will be the solution to:

$$D_1^l 2a + D^s a = (D_1^l + \tfrac{1}{2}D^s)(1-v_1) \quad (45)$$

$$\tfrac{1}{2}D^s 2a = \tfrac{1}{2}D^s 2(1-v_{1f} + v_1 - p_f) \quad (46)$$

where $v_{1f} = 2p_f$ and $v_1 = \frac{(2D_1^l + D^s)p_1 - 2D^s p_f}{2D_1^l - D^s}$. Solving this gives:

$$p_1 = \frac{6D_1^l(1-2a)+D^s}{3(2D_1^l+D^s)} \quad (47)$$

$$p_f = \tfrac{2}{3} - a \quad (48)$$

(recalling that we assume that $a \le \frac{1}{4}$). It is easy to demonstrate that $p_f < p_1$ and that $x\left(1-(1-\frac{1}{x})^n\right) \approx x(1-e^{-n/x})$. This confirms the equilibrium.

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