American Economic Journal: Microeconomics 3 (November 2011): 1–34
http://www.aeaweb.org/articles.php?doi=10.1257/mic.3.4.1

Platform Siphoning: Ad-Avoidance and Media Content[†]

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Content providers rely on advertisers to pay for content. TiVo, remote controls, and pop-up ad blockers are examples of ad-avoidance technologies that allow consumers to view content without ads, and thereby siphon off the content without paying the "price." We examine the content provider's reaction to such technologies, demonstrating that their adoption increases advertising clutter (leading to a potential downward spiral), may reduce total welfare and content quality, and can lead to more mass-market content. We cast doubt on the profitability of using subscriptions to counter the impact of ad-avoidance. (*JEL* L82, L86, M37)

Commercial television bundles entertainment content with advertising messages serving two groups. Viewers enjoy the content and advertisers reach prospective customers with their messages. Similar two-sided markets drive traditional business models in radio, newspapers, magazines, and many commercial websites (including search engines). This model has evolved because, without a lure, consumers would not consume ads. The "price" for content provision is the advertising clutter.

New technologies have enabled consumers to "have their cake and eat it too" by avoiding ads. Ad-avoidance technologies (AATs) allow consumers to siphon off content and strip out the advertising. In television, this is exemplified by the digital video recorder (TiVo is the most famous), which allows consumers to easily skip or "zap" ads.[1] Likewise, plug-ins for web browsers block advertising to provide clutter-free content, denying sites advertising revenue. Such technologies have raised concerns that ad-finance may become unviable as a business model. "It's obvious how rampant ad blocking hurts the Web: If every passenger siphons off a bit of fuel from the tank before the plane takes off, it's going to crash," (Farhad Manjoo 2009). In extremis, if all ads are avoided, no revenue will be earned and content cannot be funded.

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[1] This has provoked a strong industry reaction. In 2002, Turner Broadcasting CEO, James Kellner, termed this behavior "… theft. Your contract with the network when you get the show is you're going to watch the spots. Otherwise you couldn't get the show on an ad-supported basis. Any time you skip a commercial or watch the button you're actually stealing the programming" ("Skipping Commercials is Stealing According to Turner CEO," *2600*, May 1, 2002, accessed August 28, 2011, http://www.2600.com/news/view/article/1113). A TiVo can skip ads at a few button presses.

This paper analyzes how such platform siphoning affects the choices of platforms that rely upon revenues from one set of consumers to fund services to another set.[2] This requires us to go beyond the usual analysis of two-sided markets and to consider how choices made prior to participation in those markets impact their operation.

In analyzing platform siphoning, this paper makes several contributions. First, we determine the impact of AATs on advertising levels. We start from the observation that AATs are a fundamentally different form of siphoning from traditional avoidance (as exemplified by "going to the bathroom" or tuning out during ad breaks; Sandra E. Moriarty and Shu-Ling Everett 1994; Paul Surgi Speck and Michael T. Elliot 1997).[3] The adoption of AATs involves sunk costs (e.g., purchasing a DVR or installing software). Once adopted, their impact is durable as they reduce the ongoing cost (perhaps to zero) of avoiding ads. AAT penetration changes the mix of consumers that view ads because AATs are likely to be adopted by those most averse to advertising. Consequently, greater AAT penetration may cause content providers to raise advertising clutter–not to recoup lost revenues per se, but because marginal ad-viewers are less sensitive to ads. This may help explain the rise in ads broadcast in the United States over recent years (as documented in Kenneth C. Wilbur 2005), as a response to increasing adoption of bypass technology.[4]

Second, this set-up presents a non-trivial equilibrium existence issue as AAT penetration may lead to more advertising that itself drives further AAT penetration. Given that consumers must anticipate advertising levels in making their AAT adoption decisions, it needs to be shown that there exists an equilibrium whereby content providers choose an advertising level based on AAT penetration that is consistent with consumer forecasts about that advertising level. A key contribution of this paper is to demonstrate that such a unique equilibrium exists, and the market does not completely unravel, so AATs do not necessarily drive the aforementioned "doomsday" scenario.

Third, having established a unique equilibrium outcome, we then examine content provider responses to increased AAT penetration and the welfare consequences of platform siphoning. The welfare economics of the two-sided market with bypass weigh the benefits to consumers who screen out the ads with the costs to those who are subjected to more ads and lost content provider profit. Advertisers lose from a reduction in the effective consumer base, but gain from the lower price per ad per viewer as the content provider raises ad levels.

Finally, we examine two other potential responses to AAT penetration. First, while AAT penetration diminishes incentives to invest in vertical quality, the type

[2] While we frame our analysis in terms of AAT devices, the effects of a siphon are similar no matter where the consumers are lost to, as long as the remaining consumers are less ad-averse.

[3] The long-standing response to traditional ad avoidance has been to reduce the amount of "clutter" to consumers (e.g., shorter ad breaks to reduce incentives to leave the room). There have also been continual calls to improve ad quality to improve the incentive to watch ads (e.g., Jack Myers 2009).

[4] Ad levels (per hour) rose quite substantially after the entry of Fox television. Ceteris paribus, entry might be expected to reduce ad levels: ads are a nuisance to viewers (who would rather see an extra 30 seconds of content than an ad) and content providers compete in nuisance levels. More competition would usually be expected to reduce nuisance, just like equilibrium oligopoly prices (price is a nuisance) typically fall with more competition. This effect could be offset by an increase in siphoning causing the higher ad levels.

of programming may be altered as well. AAT penetration favors providing average quality program for a broader (or mass) market segment over developing high quality programming for a niche segment. Second, in response to financial pressure (in part due to AAT penetration) some content providers are looking to impose or increase user fees for content. We show that, while higher AAT penetration might eventually drive increased user fees and lower advertising levels, the reverse is true initially. This suggests that moves to raise fees might be premature.

Platform siphoning has not been considered in the prior theoretical literature on two-sided markets. That literature loosely falls into two categories.[5] One branch, following Bernard Caillaud and Bruno Jullien (2001), addresses platforms that bring on board two groups of agents who each directly benefit positively from the other group. This case is less relevant for platform bypass.[6]

The second branch involves one party that benefits positively from the other, and one party that benefits negatively. The leading example is in media economics, and commercial broadcasting in particular. This literature (reviewed in Anderson and Jean J. Gabszewicz 2006) treats the advertisers as benefiting from viewers (who are prospective customers), but the ads are a net nuisance to viewers. We use a micro-founded approach that builds up from aggregating individuals' preferences.[7]

Wilbur (2008a) conducts a structural empirical analysis of content provider behavior (building on Wilbur 2005).[8] Our results that ad levels rise in response to AAT are consistent with his.[9] Of course, in our case, the level of AAT penetration is endogenous to the model (something we show has important impacts on the resulting equilibrium).

Theoretically, the closest paper to this one is Sunit N. Shah (2011). Like Wilbur (2008a), he assumes that viewers with AAT are still exposed to a (fixed) fraction of the ads. Then AAT can benefit a content provider, as some ads are now seen by viewers who switch from not watching TV to watching with AAT: free-to-air viewers see more ads than would be aired if there were no AAT (and hence bear a larger ad burden), whereas AAT users see fewer ads.[10]

Section I considers a monopoly content provider that sells advertising. The model builds on Anderson and Coate (2005) by considering viewer heterogeneity in their distaste for advertising. This is crucial in generating demand for ad-avoidance. We here consider traditional ad-avoidance, and then examine the introduction of AATs

[5] See the overview by Jean-Charles Rochet and Jean Tirole (2006) and following *RAND Journal of Economics* papers, most notably Mark Armstrong (2006); see Armstong and Helen Weeds (2007) for an overview of the changing face of public broadcasting. E. Glen Weyl (2010) provides a synthesis and extension of the main theoretical models.

[6] One example might be store credit cards, which siphon some clients away from regular credit cards.

[7] This is the broad approach pursued by Anderson and Stephen Coate (2005); Armstrong and Weeds (2007); Jay Pil Choi (2006); Claude Crampes, Carole Haritchabalet, and Jullien (2009); Gabszewicz, Didier Laussel, and Nathalie Sonnac (2004); and Weyl (2010).

[8] Wilbur (2008b) gives an informal discussion of the likely effects of AAT from a marketing perspective.

[9] Wilbur (2008a) also gives useful numbers on the size of viewer turn-off effects in the absence of AAT: he estimates that a 10 percent increase in ads will cause a 25 percent decrease in viewership.

[10] Joacim Tag (2009) provides an alternative perspective of AAT as a second degree price discrimination device. He considers a website where an internet surfer can pay for an ad-free version or surf an ad-filled version for free. Paying for an ad-free version is like paying the TV company for AAT to watch a TV show ad-free. Justin P. Johnson (2008) considers the role of consumer blocking technologies like AAT. However, he addresses equilibrium without a platform that rations access.

in Section II. Sections III and IV consider the content provider responses to AAT penetration in their content choices and user fees respectively. Section V looks at several extensions, and Section VI concludes.

I. Baseline Model

Our baseline case concerns a monopolist provider that provides content to consumers and sells advertising space to firms. We will refer to this firm as the *content provider* throughout the paper referring to broadcasters (of television and radio), publishers (of newspapers, magazines, journals, books, or websites), or a studio (for movies and DVDs). *Consumers* are either *viewers* (as in television, DVDs, or movies), *readers* (as in print or digital media) or simply *eyeballs/impressions* (for web content). Finally, the purchasers of advertising space will be referred to as *advertisers*.

A. *Content Provider*

We assume that there are no marginal costs to the content provider for expanding viewership or advertising. There may be costs associated with acquiring media content. However, we leave the specification of these until they become material in our analysis.

B. *Consumers*

A consumer of type $(x, \gamma) \in [0, \overline{x}] \times [0, \overline{\gamma}]$ will receive utility

$$U_{x,\gamma} = \theta + \lambda(1 - x) - s - \gamma a \tag{1}$$

if choosing to consume content, and zero otherwise.[11] Common to all viewers is a horizontal quality component ($\lambda > 0$), a vertical quality component $\theta \in [-\lambda, \lambda(\overline{x} - 1)]$,[12] a subscription fee ($s \geq 0$ if applicable), and a level of advertising ($a \geq 0$). The latter two variables are (short-run) choices of the content provider while in parts of the model we allow the quality components to be (long-run) choices of the content provider. Consumers are differentiated by their preference for the horizontal quality component (which is a function of their position, x) and their marginal disutility from advertising (γ). Initially, we assume that x is distributed uniformly on $[0, \overline{x}]$ (where $\overline{x} > 1$) while γ is distributed uniformly on $[0, \overline{\gamma}]$. We will also normalize the population space to unity by dividing through by $\overline{x}\,\overline{\gamma}$. This setup is similar to that of Anderson and Coate (2005) except that we here allow the disutility of advertising to differ amongst consumers.

[11] Setting $\theta + \lambda$ as a vertical "quality" component, and λ as a linear transport cost rate yields a familiar utility form. We retain the current version because we endogenize these parameters in Section III.

[12] The bounds imply that some, but not all, viewers with a zero advertising nuisance cost would watch were advertising and subscription fees zero.

C. *Advertisers*

Advertisers wish to communicate with prospective customers and differ according to how much each individual reached through the platform is worth. For each advertiser, gross profits are proportional to the number of individuals reached. Following Anderson and Coate (2005), we assume that a single ad suffices to reach all individuals on the platform, and so an advertiser will place an ad as long as the profit per prospective individual is no smaller than the price paid for an ad per individual reached. We can, therefore, rank advertisers from highest to lowest willingness to pay per individual to derive the advertiser (inverse) demand curve $r(a)$ where a is the number of advertisers. In effect, $r(a)$ yields the price *per individual* for the advertiser with the ath highest willingness to pay. We approximate the resulting step function by a twice-differentiable and concave function, with $r'(a) < 0$ when $r(a) > 0$. Since we assumed that $r(a)$ is concave, the corresponding total advertising revenue earned *per individual*, $R(a) = r(a)a$, is concave too.[13] Since advertisers are heterogeneous, some enjoy surplus in equilibrium: advertiser surplus per prospective consumer is simply the standard area under the demand curve.

When we come to the welfare analysis, we assume that the private demand for advertising is also the social demand for advertising. This is a useful benchmark against which we can judge differing views on externalities in advertising.

D. *Equilibrium without Ad-Avoidance*

In this paper, our main focus is on the case of free provision (F) where $s = 0$. This naturally fits free-to-air television, free newspapers, or open websites. Below we consider how the analysis changes when s can be positive. Under free provision, for a given advertising level, a, the number of consumers is:

$$(2) \qquad N_F = \begin{cases} \dfrac{(\theta + \lambda)^2}{2\lambda a \overline{\gamma}\,\overline{x}} & \text{if} \quad \theta + \lambda < \overline{\gamma}\, a \\[2ex] \dfrac{2(\theta + \lambda) - \overline{\gamma} a}{2\lambda \overline{x}} & \text{if} \quad \theta + \lambda \geq \overline{\gamma}\, a. \end{cases}$$

The two cases are distinguished upon whether at $x = 0$, some or all consumers across the range of advertising dis-utilities consume the content or not. When $\theta + \lambda \geq \overline{\gamma} a$, some viewers with the maximum possible advertising dis-utility still watch. It will turn out that, in equilibrium, this is always the case.

Define $\varepsilon_a \equiv (\partial R/\partial a)(a/R)$ as the (per consumer) elasticity of advertising revenue, and $\varepsilon_N \equiv -(\partial N/\partial a)(a/N)$ as the aggregate consumer demand elasticity (with respect to advertising). The simple relation between these two variables encapsulates

[13] We present some proofs for the weaker property that $r(a)$ is log-concave (which means simply that $\ln r(a)$ is concave). Log-concave $r(a)$ implies log-concave $R(a)$ (and hence, that $R'(a)/R(a)$ is decreasing) since the product of two log-concave functions (here $r(\cdot)$ and a) is log-concave.

the structure of the two-sided market structure. The content provider chooses a to maximize $R(a)N_F$. This problem also solves the problem $\max_a \ln R(a) + \ln N_F$, this immediately yields the first order condition:

$$\varepsilon_a(a) = \varepsilon_N(a). \tag{3}$$

This condition equates the relevant elasticities on the two sides of the market, which are the revenue elasticity and the consumer elasticity. It determines the equilibrium level of advertising, $\hat{a}_{NoAAT}$.

Using (2), the consumer elasticity is given as:

$$\varepsilon_N(a) = \begin{cases} 1 & \text{if} \quad \theta + \lambda \leq \overline{\gamma} a \\ \dfrac{\overline{\gamma} a}{2(\theta + \lambda) - \overline{\gamma} a} & \phantom{\text{if}} \quad \theta + \lambda > \overline{\gamma} a \end{cases}. \tag{4}$$

Recall now that the advertising revenue elasticity is $\varepsilon_a(a) = \big(r'(a)a + r(a)\big)/r(a)$. This elasticity is always less than 1 for a positive since $r'(a)$ is negative. Hence, the relevant case of (4) that satisfies the first order condition (3) is the second one, i.e., $\theta + \lambda > \overline{\gamma} a$. There is necessarily at least one solution to the first-order condition in the relevant range since $\varepsilon_a(a)$ and $\varepsilon_N(a)$ are continuous functions with $\varepsilon_a(0) = 1 > \varepsilon_N(0)$ and $\varepsilon_a\big((\theta + \lambda)/\overline{\gamma}\big) < \varepsilon_N\big((\theta + \lambda)/\overline{\gamma}\big) = 1$. It remains to show the solution is a maximum and is unique. Both tasks are accomplished by showing that $\varepsilon_a(a)$ must cross $\varepsilon_N(a)$ from above at any crossing point; i.e., $\partial\varepsilon_a(\hat{a})/\partial a < \partial\varepsilon_N(\hat{a})/\partial a$ for any a satisfying (3). This is done in the Appendix, which also contains the proofs of the subsequent Propositions.

PROPOSITION 1: *With free provision and in the absence of AAT, there is a unique equilibrium level of advertising,* $\hat{a}_{NoAAT}$. *It equates the revenue elasticity of the advertiser side of the market to the elasticity on the consumer side, with:*

$$\varepsilon_a(\hat{a}_{NoAAT}) = \varepsilon_N(\hat{a}_{NoAAT}) = \frac{\overline{\gamma}\hat{a}_{NoAAT}}{2(\theta + \lambda) - \overline{\gamma}\hat{a}_{NoAAT}} < 1.$$

While the equality of the two elasticities is clearly a general condition in such a two-sided market structure, the specific value of the viewer elasticity on the LHS depends on the precise parameterization of the model. Notice that consumers with lower advertising nuisance dis-utilities are more likely to watch. Advertising nuisance acts like a “price” for consuming content, although an individual-specific price that is lower to low-γ consumers. Put differently, a subscription price on top of the advertising level depicted in Figure 1 would shift the dividing line inwards in parallel, but an ad-level increase would pivot the line down around the horizontal intercept. The subscription price analysis is explored further later in the paper.

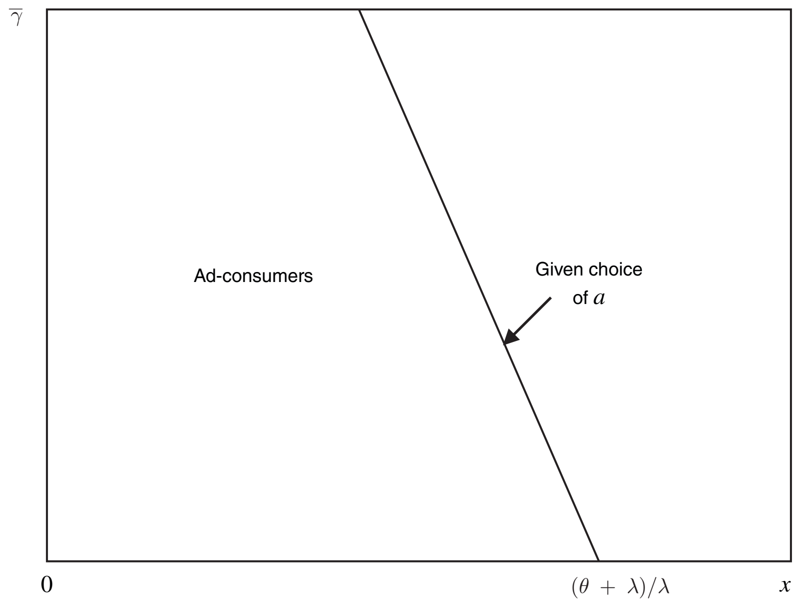

Figure 1. Consumer Partition, No AAT

E. *Traditional Ad-Avoidance*

Prior to the emergence of technologies to facilitate or allow ad-avoidance, marketers were concerned about behavioral avoidance of ads (e.g., going to the bathroom, etc.). We exposit this case here to provide a point of comparison with AAT adoption analyzed in the next section.

Suppose that, at a cost of c (e.g., the cost of getting up, channel flipping, or concentrating), a consumer can completely avoid advertisements. If the number of ads presented is a, a consumer with disutility, γ, will choose to avoid ads if $\gamma a > c$, otherwise they will see the ads. We assume throughout that, if a consumer chooses to avoid ads, all ads will be avoided.

Importantly, when consumer responses to ads are behavioral, it is appropriate to assume that the content provider takes this response into consideration *before* choosing the advertising level. Thus, the timing involves a being chosen first and consumers observing it before deciding whether to incur the cost c. The following proposition shows there is no interior equilibrium with non-trivial ad-avoidance.

PROPOSITION 2: *If consumers can avoid ads in a traditional manner at a cost of* c, *either the unique equilibrium advertising level is as described in Proposition* 1 *and there is no ad avoidance or* $\hat{a} = c/\overline{\gamma}$ *and there is no non-trivial ad avoidance: then ads levels are lower when* c *is lower.*

Proposition 2 says that, for any given c, either the avoidance costs are so high that no consumer would avoid ads, or else the advertising level is set to deter ad avoidance.[14] However, the potential for ad avoidance does impact content provider behavior by reducing advertising levels when the cost is low enough. This result is a consequence of the ability of the content provider to commit to advertising levels prior to consumers choosing whether to avoid ads or not. AATs alter the possibility of this commitment with significant equilibrium consequences (as we demonstrate next).

II. Ad-Avoidance

As argued in the introduction, utilizing an ad-avoidance technology often involves consumers undertaking a costly, sunk action that allows them to avoid many or most advertisements subsequent to its adoption.[15] The sunk cost assumption gives us a particular timing structure for the order of moves. First, consumers choose whether or not to buy an AAT at price p.[16] Then, taking as given the number of consumers who have bought the AAT (and their types), the content provider then chooses its ad level. The structure of the game is interesting because it means that consumers must rationally anticipate the subsequent choice of equilibrium ad levels. This means that the consumers must figure out the types of other consumers who have AATs. As we note below, individual choices impose externalities on others.[17]

A. *Equilibrium Outcome*

In equilibrium, consumers anticipate a level of advertising: call it $\hat{a}(p)$. We first need to find how many (and which) consumers adopt the AAT, at price (or, more generally, cost), p, and then we must determine the content provider's advertising choice. Finally, we must ensure that the advertising level chosen is indeed $\hat{a}(p)$, the one anticipated by the consumers. Given this structure, we first present a preliminary result that now follows from Proposition 1.

COROLLARY 1: *Suppose that the price*, p, *of the AAT satisfies* $\overline{\gamma}\hat{a}_{NoAAT} \leq p$ *where* $\hat{a}_{NoAAT}$ *is defined in Proposition* 1. *Then there is an equilibrium at which AAT is not adopted by anyone.*

Clearly, no one will buy AAT if the price is too high, and the Corollary gives the exact condition for the current model's parameters. As will become apparent from the analysis below, this is the unique equilibrium: there can be no equilibrium for the same parameter values at which some consumers do adopt AAT. Conversely, if

[14] Clearly this extreme result is relaxed if c is distributed in the population, or with other distributions of γ. We present it to juxtapose the outcome with the main model of AAT.

[15] AATs may also require an on-going subscription fee. Section V examines that situation.

[16] Initially, we hold p constant, assuming it is driven by, say, cost considerations only.

[17] The model is equivalently described as a game in which consumers choose simultaneously whether to buy AAT and the content provider chooses an advertising level. In equilibrium, each agent rationally and correctly anticipates the actions of the others. Consumers anticipate the advertising choice of the content provider, and the content provider anticipates which consumers choose AAT. It is this particular game structure that makes the current setup quite different from the rest of the literature in broadcasting and media economics (reviewed in Anderson and Gabszewicz 2006). Indeed, in much of the literature, consumers are passive followers (price takers, say): here they are not strategic players, since each is "small," but the expectation of their collective action determines the content provider's action.

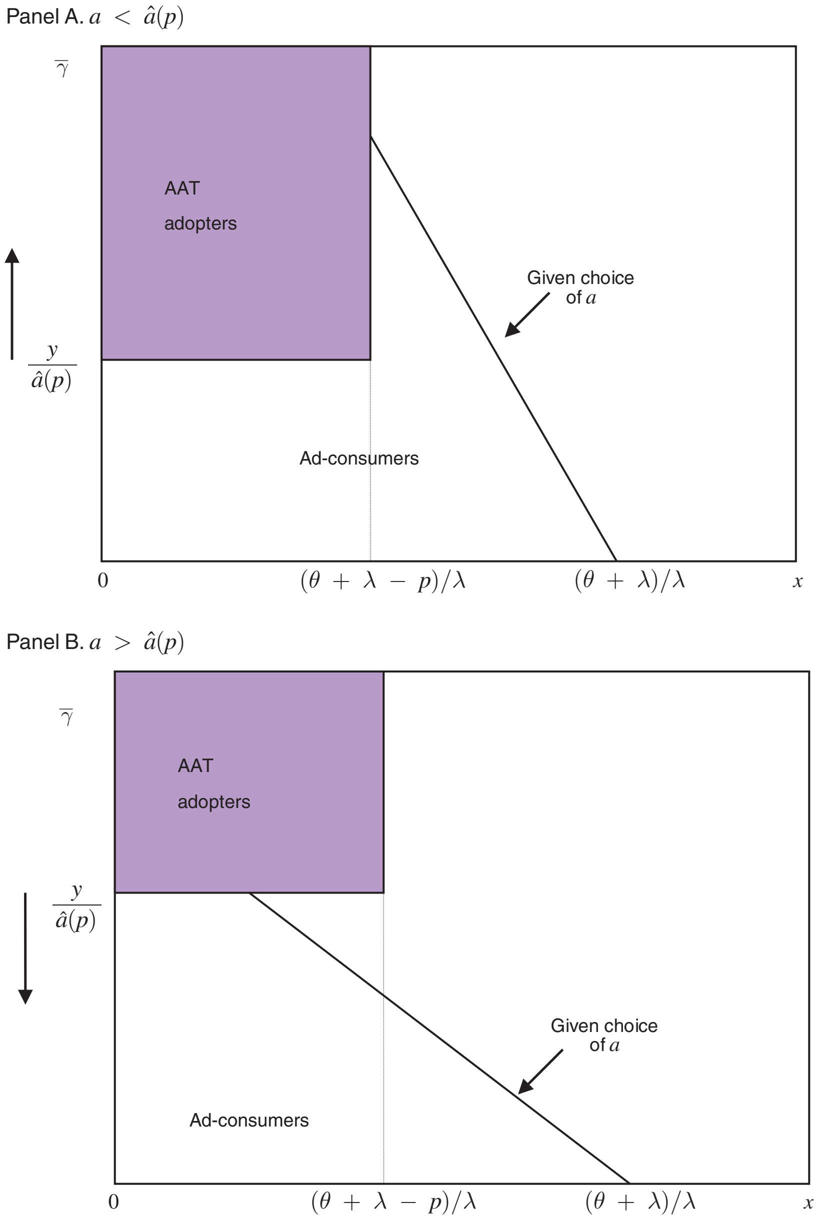

Figure 2. Non-Equilibrium Outcomes

$\overline{\gamma}\hat{a}_{NoAAT} > p$, the only equilibrium will involve AAT usage. This condition implies (from Proposition 1) that $\theta + \lambda > \overline{\gamma}\hat{a}_{NoAAT} \geq p$, so that $\theta + \lambda > p$ in order to have AATs used in equilibrium. We henceforth assume this condition.

To build intuition, suppose that an advertising level of $\hat{a}(p)$ is anticipated by consumers. Then, all consumers for whom $\gamma\hat{a}(p) \geq p$ and $\theta + \lambda(1 - x) > p$ will find it is worth incurring p to avoid the nuisance of ads. This leaves the consumers with

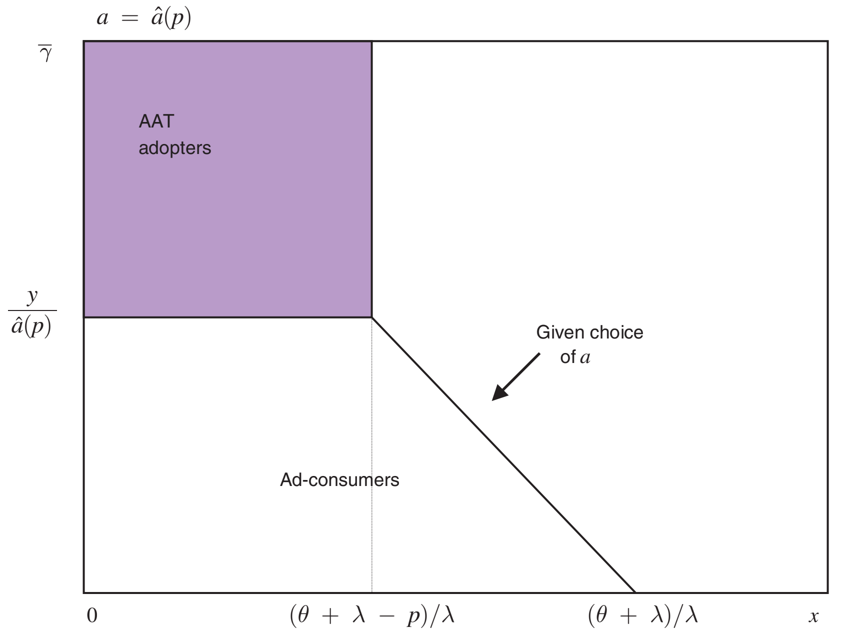

Figure 3. Equilibrium Outcome with AAT

$\gamma \hat{a}(p) < p$ who will choose either to watch with ads or not watch at all. Figure 2, panel A and panel B depict the division between the three groups.

Neither panel of Figure 2 depicts an equilibrium situation. In Figure 2, panel A, the choice of a by the content provider is less than $\hat{a}(p)$. In this case, the number of AAT adopters would fall. In Figure 2, panel B, the choice of a by the content provider is greater than $\hat{a}(p)$. In this case, the number of AAT adopters would rise. An equilibrium requires that the choice of a by the content provider is indeed equal to $\hat{a}(p)$. This outcome is depicted in Figure 3.

Notice that, given the potential out-of-equilibrium advertising choices, this equilibrium is qualitatively different from the outcome without AATs. Importantly, there is a potential existence issue for an interior equilibrium. For example, when the content provider chooses a greater than $\hat{a}(p)$, consumers will respond by increasing their AAT purchases. However, if this causes the advertising level to rise further, this will drive more AAT purchases. It is, therefore, possible that an interior equilibrium may not exist and that a sufficiently low p may lead to very high advertising levels and no ads being seen by consumers. Similarly, a high p may lead to no take up of AATs at all.

Nonetheless, Proposition 3 demonstrates that such vicious cycles do not arise: an interior equilibrium exists and it is unique. To characterize the equilibrium outcome requires working backwards. We can restrict attention to the analysis of the choice of advertising whereby some rectangular space of consumers has adopted an AAT (namely consumers with advertising dis-utilities above some threshold, $\hat{\gamma} = p/\hat{a}(p)$, and who have content preferences below $(\theta + \lambda - p)/\lambda$). Given the sunk nature of AAT adoption, the content provider will take this as given when choosing its advertising level.

Given this, the number of ad-consumers (that is, those who consumer content with ads) will be qualitatively different depending upon whether the content provider chooses a greater than or less than $\hat{a}$ (where for ease of exposition we drop the qualifier (p)). For a choice $a \geq \hat{a}$, the number of ad-consumers is:

$$N_{a \geq \hat{a}} = \frac{\hat{\gamma}}{\lambda \overline{\gamma x}} \left(\theta + \lambda - \frac{1}{2} \hat{\gamma} a \right). \tag{5}$$

In contrast, if $a \leq \hat{a}$, we have:

$$N_{a \leq \hat{a}} = \frac{1}{\lambda \overline{\gamma x}} \left((\theta + \lambda - p)\hat{\gamma} + \frac{1}{2a} p^2 \right). \tag{6}$$

Notice that (5) and (6) are the same for $a = \hat{a}$. Thus, given $\hat{\gamma}$, the content provider will choose a to maximize:

$$\begin{array}{lcl} R(a) N_{a \leq \hat{a}} & \text{for} & a \leq \hat{a} \\ R(a) N_{a \geq \hat{a}} & & a \geq \hat{a}. \end{array} \tag{7}$$

The solution is as follows.

PROPOSITION 3: *For a given AAT price*, p, *there exists a unique advertising level* $\hat{a}(p) > 0$ *such that the content provider is maximizing profits and consumers for whom* $\{(x, \gamma) \,|\, \gamma \geq p/\hat{a}(p)$ and $x \leq (\theta + \lambda - p)/\lambda\}$ *adopt an AAT. Moreover*, $\hat{a}(p)$ *satisfies:*

$$\varepsilon_a(\hat{a}(p)) = \frac{p}{2(\theta + \lambda) - p}. \tag{8}$$

The logic of the solution (as seen through the sequence of diagrams) applies beyond the specific parameterization. Namely, the advertiser revenue elasticity should equal the consumer elasticity at the rationally anticipated ad level. The properties of the solution are described below.

B. *Impact on Advertising Levels*

We are now in a position to examine the comparative statics of the advertising level with respect to the penetration of AAT. Their penetration level is indexed by $-p$ (the lower the AAT price, the more AAT will be adopted). Note, first, that when $p \geq \overline{\gamma} \hat{a}(p)$, where $\hat{a}(p)$ is defined as in Proposition 3, there are no AAT consumers. When this condition holds with equality, the ad level in Proposition 3 (see (8)) becomes:

$$\varepsilon_a(\hat{a}) = \frac{\overline{\gamma} \hat{a}(p)}{2(\theta + \lambda) - \overline{\gamma} \hat{a}(p)} \tag{9}$$

which is the same outcome as the equilibrium in Proposition 1. Thus, as p falls from a high level to a level where there is some positive demand for AATs, the equilibrium impact on advertising levels is smooth.

The equilibrium relation between the AAT price and advertising is given in (8). The RHS is clearly increasing in p. The LHS, ε_a is decreasing in a. This implies:

PROPOSITION 4: *A lower price of AAT increases the equilibrium amount of advertising.*

In many respects, this result seems counter-intuitive. AATs represent a substitution possibility for consumers and one might consider them, therefore, as competing with content providers: that is, in response to cheaper AATs content providers would have to work harder to attract consumers by lowering advertising levels and hence, consumer disutility. This is, indeed, what occurred with traditional ad-avoidance where content providers could commit to advertising levels prior to other decisions being made (Proposition 2).

However, this simple intuition does not take into account *who* would be purchasing AATs and how this would alter the content provider's uncommitted advertising level. When there is heterogeneity amongst consumers in terms of their preferences against advertising, those who prefer the content the most and who dislike advertising the most will purchase AATs. From the content provider's perspective, it was these consumers who—in the absence of AATs—caused it to restrain advertising levels; they were the marginal consumers. With AATs, their disutility no longer matters and the mean marginal disutility of a consumer without AATs is lower. Hence, the content provider faces lower costs to expanding advertising levels and does so.

We noted in the introduction that the proliferation of ad avoidance technology over the past two and a half decades (from VCRs to DVRs) has occurred at the same time as increased levels of advertising on television (especially, the share of non-program to program content). Our result here that a lower price for AATs leads to higher advertising levels suggests that these trends may be linked: the penetration of AATs may be driving the greater levels of advertising on television.[18]

C. *The Ad-Avoidance/Circulation Spiral*

One of the more interesting aspects of the above results, that is obscured by the equilibrium analysis, is a downward spiraling or multiplied effect from AAT penetration. To see this, start at the equilibrium as depicted in Figure 3. Now let the price p of the AAT fall, and consider an adaptive adjustment path; supposing that the consumers expected that the ad level would not change. Then the rectangle of adopters (in Figure 3) would expand down and right along the downward-sloping

[18] We have painted the difference between traditional and AAT-based ad-avoidance as stark. In reality, while pop-up blockers on web pages require no additional action from consumers to avoid ads, the use of a DVR can require active ad-skipping even if this is made far less costly as a result of having an AAT. Thus, for a DVR, it may be that these are adopted primarily for reasons other than ad-avoidance and are not used in this manner. Consequently, as an empirical matter, our baseline prediction may be reversed with DVR penetration. We note, however, that our finding is consistent with the empirical evidence (Wilbur 2008a).

line. Note that the vertical segment at $x = (\theta + \lambda - p)/\lambda$ represents those consumers who are indifferent between viewing without ads and paying p to screen them out, and not viewing at all. Therefore, this line will henceforth remain the same (as long as p does not fall further).

However, the content provider, given the new lower consumer cut-off level, $\hat{\gamma}$, will increase its ad level, following the intuition that the consumer base is now less sensitive to ads.[19] This pivots downward the line representing indifference between consuming with ads and not. The consumer response to this higher level of ads is to buy more AAT. This, in turn, induces the content provider to increase ads, which causes more avoidance, etc.

Breaking down the reactions, therefore, uncovers the downward spiral. Note that circulation drops with each step, both when the provider raises ads *and* when more consumers then avoid them. Ad revenues drop with each step of consumers avoiding, but are only partially recouped (because of the lower consumer base) when the provider hikes ad levels. The latter involves a lower price per advertisement per consumer, in conjunction with the smaller consumer base.

D. *Impact on Welfare*

Turning now to welfare, it is instructive to consider who are the broad winners and losers as AAT penetration increases.[20] Figure 4 overlays Figures 1 and 3. Notice that the impact of AATs is to shrink the total volume of ad-consumers but it also means that some consumers, previously not consuming the content, do so (the shaded triangle). The impact on this group is a strict welfare gain from the introduction of AATs.

For other consumers the effect may be negative. For those still consuming and not adopting an AAT, the effect of AATs is strictly negative. This is because additional AAT consumers cause the content provider to increase advertising levels, so increasing viewers' disutilities from advertisements. Some opt out of consuming the content altogether. Others choose to adopt an AAT. However, for this group, the presence of AATs may be negative in that they might not have chosen to purchase AAT but for the consequent advertising level. In Figure 4, AAT consumers in the light-shaded rectangle are worse off as a result of the presence of AATs while others are better off.

The following proposition demonstrates that the impact of AAT penetration on the content provider is strictly negative. While this might appear to be obvious, technically, demonstrating this is difficult as we cannot simply apply the envelope

[19] The formal proof of this property is quite straightforward. (5) implies that $N_{a \geq \hat{a}} = (\hat{\gamma}/\lambda\overline{\gamma}\,\overline{x})(\theta + \lambda - ½\hat{\gamma}a)$. The content provider's choice of a is given by the elasticity condition, $\varepsilon_a = \varepsilon_N$. The latter, for $N_{a \geq \hat{a}}$ is given as $\hat{\gamma}a/2(\theta + \lambda - ½\,\hat{\gamma}a)$. The immediate properties are that this expression is increasing in both a and $\hat{\gamma}$. Now, recall that ε_a is decreasing in a. This means we have a unique solution for the content provider's ad choice best response to $\hat{\gamma}$, given $a \geq \hat{a}$. Moreover, as $\hat{\gamma}$ falls, this means that $\hat{\gamma}a/2(\theta + \lambda - ½\,\hat{\gamma}a)$ falls, and so the content-provider's desired ad level rises.

[20] We do not consider the welfare of AAT providers. Thus far, we have assumed AAT is provided under competitive conditions: if it is produced with constant marginal costs, AAT providers' welfare will be unchanged. If there is imperfect competition or monopoly, AAT penetration would rise if the costs of AAT provision fell, as would the surplus accruing to AAT providers.

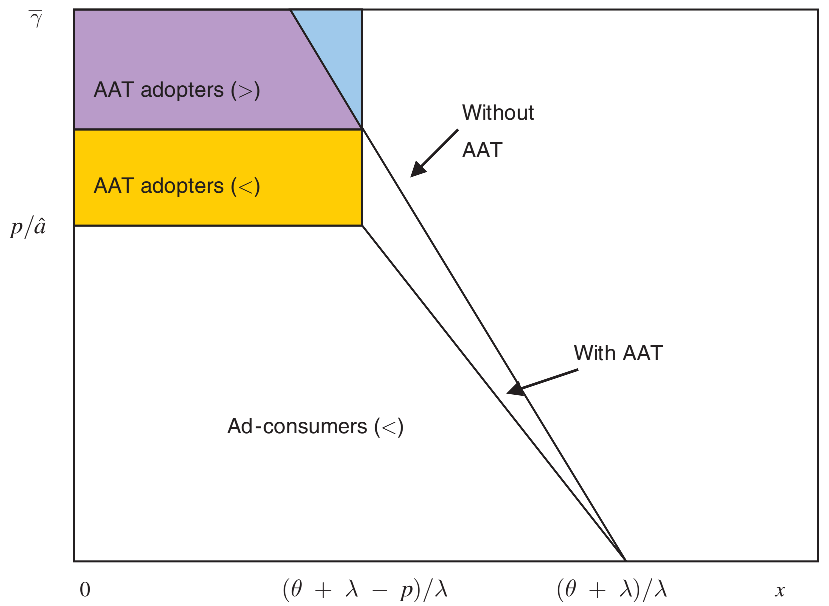

Figure 4. Comparison

theorem as the value of $\hat{a}(p)$ is not determined by the content provider alone. Moreover, as p falls, we know the advertising levels rise. This per se increases profit since we move towards the level that maximizes profit per consumer (i.e., closer to the captive audience). Consumer demand unambiguously falls: there are more ads (the indifferent consumer rotates counter clockwise) and the critical ad disutility ($\hat{\gamma}$) falls further decreasing ad consumers.

PROPOSITION 5: *The content provider's profits are decreasing in AAT penetration.*

This result is sensitive to the assumption we have made that AAT strips out all ads. Shah (2011) shows that AAT may increase profits if not all ads are stripped out. The reason is that AAT brings in more viewers overall, and profits can increase if those now seeing some of the ads compensate for those seeing fewer ads. Notice that this implies that, if there were fixed costs associated with being a content provider, then the content provider may shut down if p falls below some critical level. However, if consumers anticipate the close-down possibility, in equilibrium, some of them will not purchase AATs and the content provider would just earn a break-even profit. Thus, in the context of our model, dire predictions that content provision would be destroyed by AATs do not occur for the simple reason that without broadcasting there is no demand for AATs.

Finally and most interestingly, the effect of AATs on advertisers is ambiguous. AAT penetration reduces total ad-consumer volume and hence, the impact of advertising. However, it also leads the content provider to increase advertising levels and reduce advertising prices. It is, therefore, possible that the price effect could outweigh the volume effect for advertisers.

To demonstrate this possibility, we consider a linear per consumer advertiser demand function, $r(a) = 1 - a$, which yields advertiser surplus per consumer of ½ a^2. With this assumption we can demonstrate the following:

PROPOSITION 6: *For $r(a) = 1 - a$, an increase in AAT penetration can increase advertiser surplus if $\theta + \lambda < 0.65$.*

This parameterized example shows the possibility that advertisers can benefit from a technology that screens out their messages. The reason is lower ad prices set by the content provider. The proof shows for sufficiently low quality $(\theta + \lambda)$, a reduction in p from the highest level that could attract some AAT adopters can raise advertiser surplus. This is because at that level, with low quality, the loss in ad-consumers from AATs is small relative to the fact that those consumers have high ad disutility. Hence, advertisers benefit more from the per consumer increase in surplus across most consumers than the loss in consumers from AATs. Of course, as p falls further, this balance shifts and advertiser surplus will decrease.

Even though advertisers can be better off when AATs are available (Proposition 6), the content provider is necessarily worse off (Proposition 5). This leads us to consider the effects on total surplus from AAT introduction. The following proposition examines total welfare around the point whereby AATs just become attractive for consumers with a disutility close to $\overline{\gamma}$.

PROPOSITION 7: *Let $r(a) = 1 - a$. A marginal reduction in the AAT price, p, that just renders it attractive to some consumers reduces aggregate surplus.*

Hence, total surplus is reduced by AAT penetration in the neighborhood of the preliminary incursion. In that neighborhood too, even aggregate consumer surplus is decreased. To put this result in perspective though, the consumers who (initially) sign up are broadly indifferent between adopting AAT and not, and so it is scarcely surprising that total consumer surplus falls as all the other consumers suffer from the increased ad levels. As the price of AATs falls below the initial incursion level, there is more consumer surplus from the lower AAT price, and more "high-nuisance" consumers now tune in, registering a greater surplus gain. However, not only is the content provider harmed by AAT (at all levels), but so is total advertiser surplus (at all levels). As we noted in Proposition 6 though, there may be advantages to advertisers from lower ad prices, even though the content provider suffers.

Some important caveats are in order regarding Proposition 7. First, it is for a specific ad demand function, and for a particular model of preferences. Second, it is not a global result, but in the neighborhood of no AATs. Nevertheless, it does indicate that the business model of free-to-air might be quite vulnerable to welfare-reducing siphoning. Note that this is quite different from individuals who pirate cable television, or shoplifting, or other forms of stealing, legalized or not. First, one might argue that the monopoly of the airwaves given to certain select content providers is abused by bundling content with ads and not letting consumers "opt-out," so that

AATs offers them a break on the force-feeding of commercials. Second, though, the interesting economic effect for the economics of platforms in two-sided markets, is the selection effect. This is that AATs allow opt-out for those most put off by commercials. There remains a consumer base which is less sensitive, and the optimal response for the content provider is to ramp up commercials to them.

This leads obviously to the question of the robustness of the result. Indeed, it is quite easy to configure model specifications where AATs improve welfare. For example, if there were consumer types with advertising nuisance costs way above the level $\overline{\gamma}$, then these would be ignored by the content provider, they would not watch and the equilibrium would look just the same as in the current model. However, the introduction of AATs would enable these types to consume the content without the shackles of ads. This would be a pure welfare gain, and existing consumers would be completely unaffected because there would be no siphoning of an existing consumer base.

III. Impact on Content Choice

So far, we have taken as given the characteristics of programming offered by the content provider. But these too might be affected by the incursion of AAT. As we shall show, endogenizing the program type can be viewed as the simple choice by the content provider of one of the parameters of the model (λ). In the analysis that follows, we will show how the program choice may "tip" towards broad-based content or "lowest common denominator" content, to borrow the phrase from the analysis of Jack H. Beebe (1977).

In the model thus far, we have taken the provider's content to be at "type" $x = 0$, with consumer preferences given as $U_{x,\gamma} = \theta + \lambda(1 - x) - \gamma a$ where we might interpret $\theta + \lambda$ as a "vertical content quality," and then λ is a (linear) transport rate traditional in models of product differentiation. However, this set up also admits another interpretation in which we can naturally take the λ parameter as endogenous. Consider an increase in λ. This increases content value for consumers located close to $x = 0$, while reducing it for consumers located further away (beyond $x = 1$). In effect, a high λ is associated with content only a relatively few consumers strongly prefer (i.e., niche content), while a low λ is associated with content a large number of consumers prefer roughly equally (i.e., mass market content).[21]

Proposition 8 summarizes the impact of AAT on an endogenous choice of $\lambda \in [0, 1]$.

PROPOSITION 8: *Fix $a > (\theta + \lambda)/\overline{\gamma}$, and consider the equilibrium choice of λ. In the absence of AATs, the equilibrium is full niche content $(\lambda = 1)$ if $\overline{x} \leq (\theta + 1)^2/2\theta$.*

[21] In the working paper version of this paper (Anderson and Gans 2009), we derive this association more explicitly using the content-mix model of Anderson and D. J. Neven (1989). Note that if the density of consumers with high γ and low x is relatively high, then there will be a greater incentive to reduce λ when faced with AAT incursion (because these consumers are lost to AAT); likewise, a high density of consumers with low γ and high x will increase the desire for reducing λ (because these consumers are picked up). Loosely, then, a negative correlation between preferences for viewing and ad disutility (so that those with low benefits from watching are also not much put off by ads) would reinforce the tendency to move towards LCD programming.

If AATs are introduced with $p < \theta$, *there is an equilibrium with* $\lambda = 0$ (*LCD content*), *and no equilibrium with full niche content.*

The proof of the proposition first demonstrates that profits are convex in λ so the optimal choice is either 0 or 1 depending upon parameters. This is because, absent any correlation between consumer preferences for content and their ad disutility, a shift in λ represents a *rotation* (rather than a shift) in the demand curve (of viewers as a function of ad level). As Johnson and David P. Myatt (2006) have demonstrated (in a one-sided but otherwise more general setting), a monopolist choosing rotation parameters will prefer extremes.

Second, the proposition undertakes the difficult task of examining the introduction of AATs on quality choice. The task is difficult because care must be taken to examine the full effects on the rational expectations equilibrium. Intuitively, increasing λ means that those consumers closest to $x = 0$ are willing to bear more advertising while those further away are not. A higher λ is as if the content provider chose content with greater "niche" appeal while a lower λ would orient it towards a mass market. Recalling that AAT penetration is concentrated amongst those with high utility of viewing (the primary targets of niche content), as AAT penetration increases, the incentives of the content provider tips towards LCD content.[22]

If vertical quality, θ, is also chosen (according to an increasing and convex cost function), the penetration of AATs may hasten the unraveling of the advertising-financed business model. To see this, note that a Corollary to Proposition 4 (since a lower p or a higher θ have the same impact on the RHS of (9)) is that a lower content quality reduces equilibrium ad levels. We also know (Proposition 4) that a lower p, with quality held constant, raises equilibrium ad levels. Now, it is readily shown that a lower p decreases equilibrium quality, since the consumer base is eroded and so the advantages are spread over fewer consumers. The effects on ad levels are ambiguous though: and for the twin reasons above that lower quality is associated to lower ads per se, but the lower ad sensitivity of the remaining viewers induces higher ad levels.

Finally, in relation to our discussion above about the ad-avoidance spiral, it is worth observing that the adverse quality response of the content provider yields a greater "impact" effect (i.e., in the "first round of adjustment"). However, the multiplier effect is diminished: when quality deterioration is anticipated, it will provide a larger check on the growth of AAT adoption.

IV. Impact on Subscriber/User Fees

As discussed in the introduction, one of the proposed reactions from content providers to siphoning and a reduction in advertising effectiveness/revenue has been to consider either introducing or increasing subscriber or user fees. Here we consider

[22] Of course, other considerations—including income and time management—can drive viewing as well as AAT adoption. Proposition 8 reflects one trade-off, but other factors may come into play. For example, if heavy TV viewing is correlated with LCD tastes, this would reduce the likelihood of having niche programming without AAT, and if heavy TV viewers were also sufficiently ad-averse that they would buy AATs in droves, then AAT might drive a move from LCD to niche content, especially if niche viewers are those are more valuable to advertisers.

whether this is a desirable strategy if it is indeed true that the penetration of AATs is driving the lost advertising revenues.

Suppose that the consumer now pays a subscription fee, s, to access content including advertising. This might be a subscription to a television or newspaper or even micro-payments on websites. Then we can demonstrate the following result.

PROPOSITION 9: *Comparing an equilibrium with positive AAT penetration* $(n > 0)$ *with one where AATs are unavailable*, *if AAT penetration is low* (p *is high*) *advertising rates are higher and subscription rates are lower when AATs are available. As AAT penetration becomes high* (p *is very small*), *advertising rates are lower and subscription rates are higher when AATs are available.*

The intuition for this result is straightforward. When consumers purchase AATs, the content provider can still make money from them (and not drive them away) by putting up subscription charges. When AAT penetration is low, however, this benefit does not outweigh our earlier identified effect that such penetration causes content providers to increase advertising rates. In this situation, they do that and, to maintain consumer levels, lower subscription rates. In contrast, when AAT penetration is very high, most of the content provider's revenue is earned from subscription fees rather than advertising. For this reason, they rely on that instrument and relax advertising levels to encourage those with AATs to bear those higher fees.

It is, of course, an empirical matter whether AAT penetration is at a level that would mean that in response to more of it, it is better to reduce subscription rates or keep them at zero rather than to increase them. However, Proposition 9 suggests that claims that such rates should and must rise to preserve content provider profits are not unambiguously true.

Finally, let us note the theoretical possibility that AAT can increase profits when subscription fees can be charged. This is clearly true when the content provider sells or rents the AAT (see Tag 2009), but it can also happen even when the AAT is sold independently.[23] The reason is that AAT can serve as a device to effectuate second degree price discrimination, by self-sorting individuals into two groups, those who will pay for content when it is ad-free, and those who will also suffer ads and not pay to strip them out.

V. Extensions

Here we consider several extensions of our baseline model to explore in more detail some of the implications of the spread of AATs on content provider behavior.

[23] Suppose for example that there are only two types. Type 1 hates ads, and Type 2 is indifferent to them. Suppose they both have the same valuation of content, v. With ads embedded, Type 1 will not buy. With subscription prices only, and equal to v, both types buy, but there is no advertising revenue. If AAT is quite cheap, the content provided can make more money by charging $s = v - p$ so both types buy, and the provider embeds the revenue maximizing level of ads, which the Type 1's strip out.

A. *Endogenous AAT Pricing*

Up until now, we have treated p as an exogenous cost. In many respects this is reasonable as for the most part AATs are electronic appliances the supply of which is arguably competitive or alternatively is provided by free software the cost of which involves learning and installing by consumers. Hence, p will be driven by cost considerations independent of the behavior of content providers.

Of course, if the AAT were provided by a monopolist, it might internalize the equilibrium advertising effects in its demand. We can illustrate the effects by taking as a benchmark case when the advertising level is exogenous. Then, if the monopoly AAT provider takes into account the induced changes in advertising level, its demand curve will be more elastic than in the benchmark case. This is because a lower price for the AAT induces more ads, which in turn further raises the demand for AAT. Internalizing this effect suggests the monopolist should set a relatively low price to trigger the (rational) expectation of high ad rates, and hence a large market share of consumers, along with substantial damage to the consumer base of the content provider. The issue of dynamic pricing of introducing AAT is an interesting one for the tension between the effects just mentioned and the desire to extract rents from the most ad-averse consumers, but this dynamic issue is beyond our current scope.[24]

B. *Competition*

Following Anderson and Coate (2005), now suppose that there are two content providers; one located at $x = 0$ and the other located at $\overline{x}$. A consumer (x, γ) who watches content provider $i \in \{0, 1\}$, gets utility:

$$U_i = \begin{cases} \theta + \lambda(1 - x) - \gamma a_i & \text{for } i = 0 \\ \theta + \lambda(1 - (\overline{x} - x)) - \gamma a_i & \phantom{\text{for }} i = 1. \end{cases} \tag{10}$$

In the absence of AATs, consumers will allocate attention to the content provider that gives them the higher utility. Suppose that θ is sufficiently high so that each consumer chooses one content provider rather than not consuming at all (as in Anderson and Coate 2005). Then the marginal consumer for any given γ-type will be defined by:

$$\theta + \lambda(1 - \hat{x}) - \gamma a_0 = \theta + \lambda(1 - (\overline{x} - \hat{x})) - \gamma a_1 \tag{11}$$

$$\Rightarrow \hat{x} = \frac{\lambda \overline{x} - \gamma(a_0 - a_1)}{2\lambda}.$$

[24] In some cases, content providers (or cable network owners) sell AATs themselves (e.g., Direct TV's relationship with TiVo). In this situation, if they are a monopoly supplier of such devices, they can set p so that total profits are maximized. This will likely involve some AAT penetration as content providers can internalize the loss in ad revenue from those consumers. However, a full analysis of this situation is complex and beyond the scope of the questions analyzed in the paper. Put simply, in most situations, even when there is self-provision of an AAT, there exist competing options for consumers and so the ability of content providers to earn rents from AAT sales is muted.

Thus, content provider 0's demand will be $N_0 = (1/\overline{\gamma}\,\overline{x}\,)\int_0^{\overline{\gamma}} \hat{x}\, d\gamma = ½ - (\overline{\gamma}/4\lambda\overline{x})(a_0 - a_1)$. It will choose a_0 to maximize $R(a_0)N_0$. This yields the first order condition:

$$\frac{R'(a_0)}{R(a_0)} = \frac{\overline{\gamma}}{2\overline{x}\,\lambda - \overline{\gamma}(a_0 - a_1)}. \tag{12}$$

The equilibrium must necessarily be symmetric,[25] so the equilibrium condition is:

$$\frac{R'(a)}{R(a)} = \frac{\overline{\gamma}}{2\overline{x}\,\lambda}. \tag{13}$$

Now suppose that consumers consider adopting an AAT for a price of p. Suppose also that they anticipate a symmetric level of advertising, $\hat{a}$. In this case, for content provider 0, their demand will become: $N_0 = (1/\overline{\gamma}\,\overline{x})\int_0^{p/\hat{a}} \hat{x}\, d\,\gamma = p(\lambda\,\overline{x} - ½(p/\hat{a})(a_0 - a_1))/2\lambda\overline{x}\,\overline{\gamma}\,\hat{a}$. This implies that, in a symmetric equilibrium,

$$\frac{R'(\hat{a})\hat{a}}{R(\hat{a})} = \frac{p}{2\overline{x}\lambda}. \tag{14}$$

Thus, as ε_a is decreasing in a, an increase in p will lead to an increase in the equilibrium level of advertising; just as in the monopoly content provider case.

C. *Subscription-Based AAT*

Thus far, we have modeled AATs as a durable good. This was a realistic assumption given that many AATs are electronic appliances that last many years, compared with advertising levels that can be more readily changed. However, recent moves by cable television operators in the United States and elsewhere have seen AATs begun to be marketed as subscription based. The AAT is provided alongside cable service at a more expensive on-going rate. In Australia, the dominant cable television provider—Foxtel—only rents out its Foxtel IQ DVR. Thus, a consumer who does not continue rental payments or their cable television service cannot utilize the DVR.[26] Similarly, TiVo has recently introduced plans to move to a fully subscription-based plan based on renting their appliance.

For these reasons, it is instructive to consider what happens when the payment for an AAT, p, is on-going rather than once-off. This means that the content provider will no long hold the AAT penetration level as given when choosing its advertising

[25] Indeed, if $a_0 > a_1$ then content provider 0 would serve less than half the market, from the demand equation, N_0. However, the RHS of the first order condition (12) would be larger for content provider 0 than for content provider 1, implying R'/R on the LHS would be larger for 0 than 1. However, since R'/R is decreasing, this means that $a_0 < a_1$, a contradiction.

[26] Related are moves to sell television in download format. Apple's iTunes, for example, sells television programs without advertising for \$1.99 per episode. In principle, this is like a subscription-based AAT as these downloads substitute viewership potentially away from broadcast television. However, their on-going nature means that they have non-durable elements. Of course, you need a device to play the downloaded programs such as an iPod or a computer. In that respect, it has a significant durable quality to it.

level. Instead, it knows that for any advertising level it might choose, consumers for whom $\gamma > p/a$ will subscribe to the AAT service while those for whom $\gamma \leq p/a$ will watch free-to-air television and ads. Thus, the number of AAT consumers will not be given even if the AAT subscription rate, p, is.

Given this, it is easy to see that this change is potentially equivalent to traditional ad-avoidance. While the choice of advertising level by a content provider cannot cause consumers who have already purchased AATs to reverse that decision, this is not necessarily true of their choice to subscribe to AATs. In this case, a commitment might be possible and the results of Proposition 2 (with p substituted for c) would hold. That is, advertising levels would be set so as to deter the AAT subscriptions.

Significantly, this means that our earlier result that an increase in AAT penetration will lead to higher advertising rates will not hold for a subscription service. The lower the price of the subscription service, p, the lower the advertising level. Thus, the subscription service constrains the content provider into choosing reduced advertising levels but higher advertising rates. Importantly, this suggests that moves by AAT providers such as TiVo to switch from a durable appliance model to a rental or subscription model will actually harm them as the competitive response from content providers will be stronger rather than accommodating.

D. *Time Management Extension*

In the main model of the paper, we have assumed that utility depends on the gross viewing evaluation from which we subtract the advertising nuisance. An alternative assumption is that the quality evaluation only accrues on the actual program content and an hour's or page's worth of consumption means only a fraction $(1 - a)$ of actual content. To capture this, suppose that consumer utility is $U_{x,\gamma} = (\theta + \lambda(1 - x))(1 - a) - \gamma a$. With AAT, if the same amount of actual content were consumed (i.e., if the content provider adapts content quantity to fit in the advertisements), utility might become $U_{x,\gamma} = (\theta + \lambda(1 - x))(1 - a) - p$. In this case, the main result still holds that ads increase with AAT penetration. However, there is an additional welfare cost involved with the introduction of AATs. Utility will fall even for those adopting them because the amount of program content decreases.

Alternatively, if we were to assume the consumer will consume a fixed amount (one hour) of content, utility with AATs might become $U_{x,\gamma} = \theta + \lambda(1 - x) - p$. In this case, those purchasing AATs may be all of the consumers located around $x = 0$ because they are the ones who value actual content the most, and they get more concentrated content per unit of attention if they screen out the advertisements.[27] In this case, advertising increases will shift the demand curve as well as pivot it.

VI. Conclusion

The advertising-sponsored content provision model is in a state of flux. Newspapers are in drastic decline, network television is on the wane, while the

[27] That is, for a given value of ad-disutility, γ, the free-to-air viewers are ones who like TV relatively less.

Internet is picking up more business with new variants of the classic model. In part, these changes can be ascribed to the new media better serving consumer preferences, and the shifts are bolstered by the better ability of the new media to deliver receptive customers to advertisers. This is another form of platform siphoning insofar as readers/viewers are lost from the platform, although in this case they do not necessarily still consume the platform's content (except insofar as stories from the traditional broadcasters are picked up by bloggers and transmissions are rephrased online). It is likely that the lost viewers are the ones most susceptible to advertising nuisance. The price p in our model of avoiding the nuisance on the platform is a proxy for a more general cost of avoidance of traditional media, and it seems eminently reasonable to claim this cost has gone way down. In that sense, our positive conclusions apply to this context too.[28] Thus, while we have phrased our analysis in terms of AAT, many of the conclusions apply to viewers shifting because of new alternative media. In particular, the smaller consumer base weakens the incentives to provide quality programming, and involves a multiplier effect as more consumers migrate away. A consequent weak demand by consumers brings along with it a weak advertiser demand, and so the possibility the platform can no longer cover fixed costs and must go out of business.

Platform siphoning benefits those who are most annoyed by ads, and it can enhance their welfare. But it weakens the two-sided business model. The platform's response is to raise the ad level. This, we stress, is not per se an attempt to recapture the lost revenues, but rather it comes from the revealed preference of those who do not invest in ad-avoidance technology: they are revealed to be less sensitive to ad nuisance and so the marginal incentive to raise the ad level is increased. Arguably, this effect has contributed to the larger number of ads per hour observed recently in US television (the United States does not impose caps on the number of commercial minutes, in contrast to the EU).

We have shown that the advent of AAT can nonetheless raise overall consumer surplus, despite the loss for those who do not use it watching more ads. Moreover, advertiser surplus can also go up: despite a lower consumer base, the larger volume of ads means a lower price per consumer reached, and the latter effect can dominate. However, it is likely (but not always) that gains to consumers and advertisers are outweighed by the loss of content provider profit, as the business model effectiveness is eroded.[29,30] Other performance dimensions chosen by the content provider are also affected. There is less incentive to provide vertical quality because the consumer footprint is reduced. This has negative feedback effects on the demand for AAT. There may also be a shift in content type offered towards lowest common denominator content as opposed to more specialty tastes.

The introduction of AAT might also tip the platform's reliance from ad finance towards subscription pricing. Instead of delivering eyeballs to advertisers, if

[28] An exception is our analysis of subscription fees, where we supposed that the platform can still manage to charge those who avoid ads.

[29] One might nonetheless be less concerned about the content provider insofar as it likely enjoys an excessive surplus due to barriers to entry anyway.

[30] In the central case of uniformly distributed preferences, we showed a small AAT incursion reduces total surplus.

consumers are screening out the ads, the platform can instead have them pay directly for access to the content. This means a tilt towards a more traditional (one-sided) market structure as the ability to strip out the financing side improves.

Siphoning is not confined to commercial media, nor to two-sided markets. Piracy in the form of illegal downloads and copying of DVDs and music also involves some individuals consuming content without paying, making it less profitable to provide quality content. Insofar as those who siphon might have a lower willingness to pay, equilibrium can again involve a selection effect of concentrating demand for the paying populace on high willingness to pay types and so raising prices in equilibrium. Drug pricing constitutes a related example. Henry G. Grabowski and John M. Vernon (1992) found empirically that branded drug prices tended to rise more when there was more entry by generics. One explanation that has been put forth is that the remaining branded drug consumers are less price-sensitive. Such pricing effects can be present in standard models of one-sided markets: Yongmin Chen and Michael H. Riordan (2008) establish conditions under which a firm prices lower when it is a monopoly than when it faces competition. This can happen in standard spatial models because a monopolist competing against an outside option faces a more elastic demand than a firm competing against a rival: picking up customers from a rival is tougher because they increasingly prefer its product as one's price falls. In that sense, viewing a rival as a source of siphoning is consistent with higher equilibrium prices in the presence of the siphon.

The business model of search engines is another case where some site visitors do not pay for the service if they do not click on the sponsored links. However, here siphoning is an integral part of the business model. It is effectively used by the search engine to its advantage: the unpaid links are part of the attraction to visit. The very source of income loss is balanced (at the margin) with the extra visits the platform attracts through having unpaid content (see Alex White 2008).

Appendix

PROOF OF PROPOSITION 1:

Note first that:

$$\frac{\partial \varepsilon_a}{\partial a} = \frac{r(r' + ar'') - ar'^2}{r^2} = \frac{ar''}{r} - \frac{(1 - \varepsilon_a)(2 - \varepsilon_a)}{a}. \tag{15}$$

From (4) with $a \in \left(0, (1/\overline{\gamma})\,(\theta + \lambda)\right]$, we have:

$$\frac{\partial \varepsilon_N}{\partial a} = \frac{\overline{\gamma}}{2(\theta + \lambda) - \overline{\gamma} a} + \frac{\overline{\gamma}^2 a}{(2(\theta + \lambda) - \overline{\gamma} a)^2} = \frac{\varepsilon_N(1 + \varepsilon_N)}{a} \tag{16}$$

(so that $\varepsilon_N(a)$ is strictly increasing in a in this range). Setting $\varepsilon_a = \varepsilon_N = \varepsilon$ and comparing (15) and (16), $\partial \varepsilon_a/\partial a < \partial \varepsilon_N/\partial a$ becomes:

$$\frac{a^2 r''}{r} < \varepsilon(1 + \varepsilon) + (1 - \varepsilon)(2 - \varepsilon) = 2(1 - \varepsilon + \varepsilon^2). \tag{17}$$

The RHS of this expression exceeds $2\varepsilon^2$ (since $\varepsilon < 1$). Hence, it suffices to prove that $a^2r''/r < 2\varepsilon^2 = 2(r')^2a^2/r^2$ which is the same as $2(r')^2 - r''r > 0$. But this is simply the condition that r is strictly (-1)-concave, as is implied by log-concavity and concavity.

PROOF OF PROPOSITION 2:

For a given p, only consumers with $\gamma \leq c/a$ will consume the content. Thus,

$$N_F = \begin{cases} \dfrac{p(\theta + \lambda - ½c)}{a\lambda\,\overline{x}\,\overline{\gamma}} & \text{if} \quad c \leq \overline{\gamma}a \\ \dfrac{2(\theta + \lambda) - \overline{\gamma}a}{2\lambda\overline{x}} & \text{if} \quad c \geq \overline{\gamma}a. \end{cases} \tag{18}$$

With this demand, $\varepsilon_N = 1$ for $c \leq \overline{\gamma}a$. In this case, $\varepsilon_a < \varepsilon_N$ and so a will be set as low as possible in this range i.e., $a = c/\overline{\gamma}$ or alternatively, $a < c/\overline{\gamma}$. If, however, $\hat{a}$ as defined by $\varepsilon_a(\hat{a}) = \overline{\gamma}\hat{a}/\big(2(\theta + \lambda) - \overline{\gamma}\hat{a}\big)$ exceeds $c/\overline{\gamma}$ then the equilibrium will involve $\hat{a} = c/\overline{\gamma}$. In either case, total AAT penetration equals 0.

PROOF OF PROPOSITION 3:

First note that (from (5) and (6)):

$$\frac{\partial N_{a\geq\hat{a}}}{\partial a}\Big/ N_{a\geq\hat{a}} = -\frac{\hat{\gamma}}{2(\theta + \lambda) - \hat{\gamma}a} \tag{19}$$

$$\frac{\partial N_{a\leq\hat{a}}}{\partial a}\Big/ N_{a\leq\hat{a}} = \frac{-p^2}{a(2\hat{\gamma}a(\theta + \lambda - p) + p^2)}. \tag{20}$$

These imply that $\varepsilon_N > 0$ is decreasing for $a < \hat{a}$ and increasing thereafter.

In contrast, ε_a is decreasing over all a $\big($by the log-concavity of $r(a)$: see the first equality in (34)$\big)$ while at $a = 0$, $\varepsilon_a = \varepsilon_N = 1$ and as $a \to \infty$, $\varepsilon_a < 0 < \varepsilon_N$. Finally, we note that the content provider's profit derivative (with respect to a) has the sign of $\varepsilon_a - \varepsilon_N$. Thus, an equilibrium will involve $\varepsilon_a = \varepsilon_N$ for some $a > 0$ at a point where $a = \hat{a}$. Substituting $\hat{\gamma} = p/\hat{a}$ into (19) and (20) implies that, in equilibrium:

$$\frac{R'(\hat{a})\hat{a}}{R(\hat{a})} = \frac{p}{2(\theta + \lambda) - p}, \tag{21}$$

as per the proposition. There is a unique solution with $\hat{a} > 0$ to this equation (and hence a unique candidate equilibrium) since the LHS is decreasing from 1 through 0, while the RHS is strictly between 0 and 1.

To demonstrate that this is an equilibrium, we need to show that profit is quasi-concave and maximized at $\hat{a}$. This property is ensured if, for a given $\hat{a}$, if $\varepsilon_a(a)$

crosses ε_N, it does so only from above in the domain $a \in (0, \hat{a}]$. Using (15), note that for $a < \hat{a}$, $\varepsilon_N = p^2/\big(2\hat{\gamma}a(\theta + \lambda - p) + p^2\big)$ and so:

$$(22) \qquad \frac{\partial \varepsilon_N}{\partial a} = -2\hat{\gamma}(\theta + \lambda - p)\left(\frac{\varepsilon_N}{p}\right)^2.$$

Now note that $2\hat{\gamma}(\theta + \lambda - p) = (p^2/a)\big((1/\varepsilon_N) - 1\big)$ so that the RHS of (22) becomes $-(1/a)(1 - \varepsilon_N)\varepsilon_N$ (which is negative as we know that $\varepsilon_N < 1$).

Now suppose there is an a such that $\varepsilon \equiv \varepsilon_a = \varepsilon_N$. Then we can show that, at that point:

$$(23) \qquad \frac{\partial \varepsilon_a}{\partial a} < \frac{\partial \varepsilon_N}{\partial a} \Leftrightarrow \frac{r''(a)a}{r(a)} + \frac{(\varepsilon - 1)(2 - \varepsilon)}{a} < -(1/a)\,(1 - \varepsilon)\varepsilon$$
$$\Leftrightarrow \frac{r''(a)a^2}{r(a)} < 2(\varepsilon - 1)^2.$$

The right hand side of this expression is positive, so that the desired inequality holds as $r''(a) \leq 0$.[31]

PROOF OF PROPOSITION 5:

Recall that the content provider's profit is: $\hat{\pi} = R(\hat{a})(\hat{\gamma}/\lambda\overline{\gamma}\ \overline{x})(\theta + \lambda - \tfrac{1}{2}\hat{\gamma}\hat{a})$. A shift in p shifts $\hat{a}$ and $\hat{\gamma}$. Since we know $\hat{\gamma}$ shifts monotonically with p, we treat this as the exogenous variable in the expression for $\hat{\pi}$. Thus, we have:

$$(24) \qquad \frac{d\hat{\pi}}{d\hat{\gamma}} = R(\hat{a})\,\frac{\partial N(\hat{a})}{\partial \hat{\gamma}} + \left(R(\hat{a})\frac{\partial N(\hat{a})}{\partial \hat{a}} + R'(\hat{a})N(\hat{a})\right)\frac{d\hat{a}}{d\hat{\gamma}}.$$

The term in the brackets is identically zero by the first order conditions for the choice of a given $\hat{a}$. The expression thus has the sign of $\partial N(\hat{a})/\partial\hat{\gamma} = (\theta + \lambda - \hat{\gamma}\hat{a})/\lambda\overline{\gamma}\ \overline{x} > 0$. The desired result then follows as $\hat{\gamma}$ is increasing in p.

PROOF OF PROPOSITION 6:

The total surplus accruing to advertisers is:

$$(25) \qquad A = N(p)\int_0^{\hat{a}} \big(r(a) - r(\hat{a})\big)\,da = \frac{p}{\lambda\overline{\gamma}\ \overline{x}\hat{a}}\left(\theta + \lambda - \frac{1}{2}p\right)\frac{\hat{a}^2}{2},$$

[31] The assumption of r concave is stronger than the log-concavity assumption that suffices for the other proofs. However, log-concavity of R (which, admittedly, is a weaker assumption than log-concavity of r) is insufficient to do the trick. To see this point, note that the condition $\partial\varepsilon_a/\partial a < \partial\varepsilon_N/\partial N$ can be written as $(R''a/R) + (R'/R) - (R'^2a/R^2) < -(1/a)(1 - (R'a/R))R'a/R$ at a point where $\varepsilon_a = \varepsilon_N$ and where we have used (23) on the RHS and substituted in ε_a. Rearranging, we would like to show that $(R''R - R'^2)a < R'(R'a - 2R)$. However, while the LHS is non-positive under log-concave R, it can be zero if R is log-linear: the RHS is negative (since $R' < R/a$). Hence we use the stronger condition that r be concave. (Note that even the condition of R concave does not suffice, since we want to show $R''Ra < 2R'(R'a - R)$. Even though the LHS is then negative, so is the RHS.)

where in the second step we have used the specific advertising demand function and we have used (5) (equivalently, (6)) to substitute for the consumer expression $N(p)$. For this advertising demand function, revenue is $R(a) = a(1 - a)$, and, hence, it can readily be shown (using (8)) that:

$$\hat{a} = \frac{2(\theta + \lambda - p)}{4(\theta + \lambda) - 3p}, \tag{26}$$

where both numerator and denominator are positive. Substituting into (25) yields:

$$A = \frac{p}{\lambda \overline{\gamma}\, \overline{x}} \frac{(\theta + \lambda - \frac{1}{2}p)(\theta + \lambda - p)}{4(\theta + \lambda) - 3p}. \tag{27}$$

Differentiating:

$$\frac{\partial A}{\partial p} = \frac{8(\theta + \lambda)^3 - 24p(\theta + \lambda)^2 + 21p^2(\theta + \lambda) - 6p^3}{2\lambda \overline{\gamma}\, \overline{x}(4(\theta + \lambda) - 3p)^2}. \tag{28}$$

The sign of (28) depends on the sign of the numerator, which can be written as a cubic function of $p/(\theta + \lambda)$. The sign is negative if:

$$\theta + \lambda < p\frac{1}{4}\left(4 + \left(2(2 + \sqrt{2})\right)^{1/3} + \frac{2^{2/3}}{(2 + \sqrt{2})^{1/3}}\right) = p(1.73784). \tag{29}$$

We want to establish that (29) may hold for a relevant range of prices. To do this, we consider the highest possible p consistent with AAT adoption, that is, $p = \overline{\gamma}\hat{a}$. Using (26) and solving, this gives: $p = (1/3)\left(\overline{\gamma} + 2(\theta + \lambda) - \sqrt{\overline{\gamma}^2 - 2\overline{\gamma}(\theta + \lambda) + 4(\theta + \lambda)^2}\right)$. Substituting this expression into (29) and rearranging gives $\theta + \lambda < 0.649018$.

PROOF OF PROPOSITION 7:

With $r(a) = 1 - a$. the gross advertiser surplus per ad-consumer[32] is $\hat{a}(1 - (\hat{a}/2))$, with the equilibrium ad level given as $a = 2(\theta + \lambda - p)/(4(\theta + \lambda) - 3p)$ (see (26) above). From (5) and (6) we have $N(p) = (p/\lambda\overline{\gamma}\,\overline{x}\hat{a})(\theta + \lambda - (p/2))$.

As regards consumers, the utility of those with AATs is $\theta + \lambda(1 - x)$. There are $(1/\overline{\gamma}\,\overline{x})(\overline{\gamma} - \hat{\gamma})(\theta + \lambda - p)^2/\lambda$ consumers using AAT, and their utility varies uniformly from $\theta + \lambda - p$ (at $x = 0$) down to zero. This means the average utility is $(\theta + \lambda - p)/2$ for this group, implying a total group utility of $(1/2\overline{\gamma}\,\overline{x})(\overline{\gamma} - \hat{\gamma})(\theta + \lambda - p)^2/\lambda$. For the ad-consumers, the utility of a type γ varies uniformly from $(\theta + \lambda - \gamma\hat{a})$ down to zero, for an average (conditional on nuisance annoyance, γ) of $(\theta + \lambda + \gamma\hat{a})/2$. The mass of those of type γ watching is up to

[32] This includes advertiser surplus per viewer, ½$\hat{a}^2$ and content provider profit $\hat{a}(1 - \hat{a})$.

type $\tilde{x}$ such that $\theta + \lambda(1 - \tilde{x}) = \gamma\hat{a}$, so there are $\tilde{x}/\overline{x} = (\theta + \lambda - \gamma\hat{a})/\overline{x}\lambda$ of them. Integrating over $\gamma \in [0, \hat{\gamma}]$ yields the aggregate surplus to ad-consumers as $(1/\overline{\gamma}\,\overline{x})\int_0^{\hat{\gamma}} ((\theta + \lambda - \gamma\hat{a})^2/2\lambda)d\gamma$. Adding together these various surpluses gives the welfare function as:

$$W(p) = \frac{1}{\overline{\gamma}\,\overline{x}}\int_0^{\hat{\gamma}} \frac{(\theta + \lambda - \gamma\hat{a})^2}{2\lambda}\,d\gamma + \frac{1}{2\overline{\gamma}\,\overline{x}}(\overline{\gamma} - \hat{\gamma})\frac{(\theta + \lambda - p)^2}{\lambda}$$

$$+ \hat{a}\left(1 - \frac{\hat{a}}{2}\right)\frac{p}{\lambda\overline{\gamma}\,\overline{x}\hat{a}}\left(\theta + \lambda - \frac{p}{2}\right),$$

where we note that $\hat{\gamma}\hat{a} = p$.

We first extract a factor $1/2\overline{\gamma}\,\overline{x}\lambda$ from the welfare expression above, so that welfare is proportional to $\hat{W} = \int_0^{\hat{\gamma}} (\theta + \lambda - \gamma\hat{a})^2 d\gamma + (\overline{\gamma} - \hat{\gamma})(\theta + \lambda - p)^2 + 2(1 - (\hat{a}/2))p(\theta + \lambda - (p/2))$. The partial derivative with respect to $\hat{\gamma}$ is $\partial W/\partial\hat{\gamma} = (\theta + \lambda - \hat{\gamma}\hat{a})^2 - (\theta + \lambda - p)^2$, which is identically zero: this term just represents transfers of indifferent consumers. The partial derivative with respect to $\hat{a}$ is

$$(30) \qquad \frac{\partial W}{\partial \hat{a}} = -2\int_0^{\hat{\gamma}} \gamma(\theta + \lambda - \gamma\hat{a})\,d\gamma - p\left(\theta + \lambda - \frac{p}{2}\right)$$

of which both terms are negative. This indicates first the deleterious effect to ad-consumers from a higher ad level. Second, gross advertiser surplus is reduced (recalling that $\theta + \lambda > p$ for AAT to be adopted).

Finally, evaluating around $\overline{\gamma} = \hat{\gamma}$, which is where AATs just become palatable to some consumers (and so the middle term's contribution vanishes) the partial derivative with respect to p yields.[33]

$$(31) \qquad \frac{\partial W}{\partial p} = 2\left(1 - \frac{\hat{a}}{2}\right)(\theta + \lambda - p).$$

Hence the welfare derivative boils down to $dW/dp = (\partial W/\partial\hat{a})(d\hat{a}/dp) + (\partial W/\partial p)$, with $\partial W/\partial\hat{a}$ given by (30), $\partial W/\partial p$ given by (31), and hence dW/dp is proportional to:[34]

$$\left(-2\hat{\gamma}^2\left(\frac{\theta + \lambda}{2} - \frac{p}{3}\right) - p\left(\theta + \lambda - \frac{p}{2}\right)\right)\frac{d\hat{a}}{dp} + 2\left(1 - \frac{\hat{a}}{2}\right)(\theta + \lambda - p).$$

[33] The positive sign of this derivative, which stems solely from the total advertising surplus side, in conjunction with the negative effect on total advertising surplus through the $\hat{a}$ channel, means that gross advertising surplus is reduced by all incremental levels of AAT penetration—i.e., this result is not a local one.

[34] Here we have used $\int_0^{\hat{\gamma}} \gamma(\theta + \lambda - \gamma\hat{a})\,d\gamma = \hat{\gamma}^2\,(1/2(\theta + \lambda) - 1/3\,\hat{\gamma}^3\,\hat{a})$ and since $\hat{\gamma}\,\hat{a} = p$, then $\hat{\gamma}^2 = p^2/\hat{a}^2 = p^2(4(\theta + \lambda) - 3p)^2/4(\theta + \lambda - p)^2$.

Substituting now $\hat{a} = 2(\theta + \lambda - p)/(4(\theta + \lambda) - 3p)$, then $d\hat{a}/dp = -2(\theta + \lambda)/(4 \times (\theta + \lambda) - 3p)^2$, and so the desired welfare derivative is proportional to $\theta + \lambda/(\theta + \lambda - p)^2((\theta + \lambda)/2 - (p/3)) + p(\theta + \lambda - (p/2))2(\theta + \lambda)/(4(\theta + \lambda) - 3p)^2 + 2(1 - (\hat{a}/2))(\theta + \lambda - p)$. Since $\theta + \lambda > p$ (which is needed for a positive AAT segment), each of these three terms is positive. This means that in the neighborhood of no AAT adoption, a price rise that forces out AAT improves aggregate surplus.

PROOF OF PROPOSITION 8:

We first find the equilibrium choice of λ when AAT is unavailable (equivalently, prohibitively expensive). We shall assume that $\theta + \lambda \leq \hat{\gamma}a$ for all feasible $\lambda \in (0, 1]$, which means that the highest nuisance consumer is so put off that they do not watch even if their preferred content is provided. Now there are two cases for where the indifferent consumer type $\gamma = 0$ is, either at $x < \overline{x}$ or $x = \overline{x}$. The former case corresponds to the analysis up till now in the main text, and holds for $(\theta/\lambda) + 1) < \overline{x}$. Over this region, the value of demand is $D_T(\lambda) = (1/2\,\overline{x}\,\overline{\gamma})((\theta + \lambda)/a)\ (\theta + \lambda)/\lambda$ which is a convex function of λ, indicating that demand (and hence, profit) is convex in this region.

The other demand region (which arises for lower λ) has all types x watching, and constitutes a trapezoid in (x, γ) space, with vertical intercepts $(\theta + \lambda)/a$ at $x = 0$ (as just shown) and $(\theta + \lambda(1 - \overline{x}))/a$ at $x = \overline{x}$. Taking the average of these two and dividing by the conditional density at x yields the demand expression as $D_{Trap}(\lambda) = (1/\overline{\gamma})\ (2\theta + \lambda(2 - \overline{x}))/2a$ which has derivative $D'_{Trap}(\lambda) = (2 - \overline{x})/2a\,\overline{\gamma}$ which is positive (negative) depending on whether $2 - \overline{x} > (<)\, 0$.[35]

We can now bring this all together. Since $D'_T(\lambda)$ is increasing, then if $2 - \overline{x} \geq 0$ the demand derivative is non-negative and non-decreasing throughout as λ rises, so the optimal choice is as large as possible, $\lambda = t$. On the other hand, if $2 - \overline{x} < 0$, the demand derivative starts out negative: if it eventually goes positive,[36] then the solution is in one end or the other of the feasible range, i.e., either at $\lambda = 0$ or at $\lambda = 1$. The solution is whichever gives higher demand: comparing D_T with D_{Trap} shows the niche market is preferred as long as $(\theta + 1)^2/2\overline{x} \geq \theta$.

In summary, the demand, and hence profit, is a convex function of λ. The optimal choice is the (extreme) niche market if and only if $\overline{x} \leq (\theta + 1)^2/2\theta$ (a sufficient condition for a niche market is that $\overline{x} < 2$).

Turning to the equilibrium changes with AATs, care must be had to examine equilibrium outcomes under rational expectations. We are most interested in whether the equilibrium can involve lowest common denominator (LCD) content ($\lambda = 0$) with AAT, and so we establish conditions under which that is an equilibrium. There are two cases. First, if $\theta \leq p$, nobody adopts AATs because no-one finds the programming worthwhile. Then $\lambda = 0$ is an equilibrium only if it is an equilibrium when no AAT exists, the case we just analyzed. Since there is no "lock-in" to AAT, nothing

[35] The demand derivative is continuous through the point where the consumer type $(x, \gamma) = (\overline{x}, 0)$ is just indifferent between buying or not. To see this, note the "corner" indifferent individual satisfies $\theta + \lambda(1 - \overline{x}) = 0$, corresponding to $\lambda = \theta/(\overline{x} - 1)$. Inserting this value gives $D'_T(\theta/(\overline{x} - 1)) = (1/2\overline{x}\,\overline{\gamma}a)(1 - (\overline{x} - 1)^2) = (2\overline{x} - \overline{x}^2)/2\overline{x}\,\overline{\gamma}\,a = D'_{Trap}(\theta/(\overline{x} - 1))$.

[36] A necessary condition is that $D'_T = (1 - (\theta)^2)/2\overline{x}\,\overline{\gamma}\,a > 0$, or $1 > \theta$, and hence $1 < \theta$ is a sufficient condition for this *not* to happen.

has changed from the analysis above, and $\lambda = 0$ is an equilibrium if $\theta \geq (\theta + 1)^2/2\overline{x}$; otherwise, the content provider deviates to $\lambda = 1$.

So now suppose that $\theta > p$ (otherwise, consuming LCD content with AAT is not worthwhile to anyone). As long as $p < \overline{\gamma}a$, which we assume or else AAT is not worthwhile (for anyone), then the AAT adopters are all those with $\gamma > p/a$; that is, the high nuisance types all adopt AAT. The consequence is that the content provider has all those without AATs anyway, and changing λ cannot bring in new consumer types because there are none left (without AATs) that the content provider does not already have.

We next show that the other extreme, $\lambda = 1$, or full niche programming, is not an equilibrium in the presence of AATs. Assume that $p < \theta + 1$; otherwise no-one ever adopts AATs (it costs more than the value the happiest person places on the content). Continue to assume too that $\overline{\gamma}$ is large enough that $p < \overline{\gamma}a$. Then no type with $\gamma > p/a$ will watch free-to-air, but types below that value will, with their x values low enough. (The situation is akin to that in Figure 3.) Now, the type $(x, \gamma) = (\theta + 1 - p, p/a)$ is the crucial "three-way" type indifferent between AAT, ad-consuming and not consuming; the type $(x, \gamma) = (\theta + 1, 0)$ is the type with most extreme preference still watching. Demand $D(\lambda; p)$ is then given by (a trapezoid) $(1/\overline{\gamma}\overline{x})(p/a)(2\theta + 2 - p)/2\theta$. Now, a necessary condition for an equilibrium with $\lambda = 1$ is that demand cannot be increased by reducing $\lambda < 1$, given the lock-in of the consumers with AAT. Whenever $p < 2\theta$, the condition cannot hold.[37]

PROOF OF PROPOSITION 9:

Letting the subscript P denote this Pay case, in the absence of AATs, the content provider chooses a and s to maximize $\big(R(a) + s\big)N_P$ where (cf. (2)):

$$N_P = \begin{cases} \dfrac{\left(\frac{1}{2}(\theta + \lambda - s)\right)^2}{2\lambda\overline{\gamma}a} & \text{if} \quad \theta + \lambda < s + \overline{\gamma}a \\ \dfrac{2(\theta + \lambda - s) - \overline{\gamma}a}{2\lambda} & \phantom{\text{if}} \quad \theta + \lambda \geq s + \overline{\gamma}a. \end{cases} \tag{32}$$

This yields the first order conditions:

$$R'(a)N_P + \big(R(a) + s\big)\frac{\partial N_P}{\partial a} = 0 \tag{33}$$

$$N_P + \big(R(a) + s\big)\frac{\partial N_P}{\partial s} = 0. \tag{34}$$

[37] Indeed, given the number of consumers buying AAT, the demand for content is $D(t; p)$ as just given. For λ (unexpectedly) lowered below 1, and given the set of AAT adopters, the indifferent consumer of type $\gamma = 0$ has location $x = (\theta + \lambda)/\lambda$ (as always) while the indifferent consumer of type $\gamma = p/a$ (who is the boundary type for the AAT region) has location $x = (\theta + \lambda - p)/\lambda$. For $\theta > p$, both expressions increase as λ falls, so demand rises and $\lambda = t$ cannot be an equilibrium. For $p > \theta$, demand is proportional to $(2\theta - p + 2\lambda)/2\lambda$ and hence rises as λ falls when $p < 2\theta$.

These can be combined to give:

$$R'(a) = \frac{\partial N_P / \partial a}{\partial N_P / \partial s} \tag{35}$$

and we can rewrite this condition as $\left(\text{where } \varepsilon_s = -\frac{s}{N_P}\frac{\partial N_P}{\partial s}\right)$:

$$\frac{R'(a)a}{s} = \frac{\varepsilon_N}{\varepsilon_s} \tag{36}$$

the ratio of the elasticities of consumer demand with respect to advertising and price. Writing the elasticity of revenue with respect to advertising as ε_a yields the equivalent condition as

$$\frac{R(a)}{s} = \frac{\varepsilon_N}{\varepsilon_s\,\varepsilon_a}, \tag{37}$$

which neatly relates the ratio of revenues per consumer from the two different sources in the two-sided market.[38]

Using the uniform distribution, the RHS of (35) becomes:

$$\begin{array}{ccc} \dfrac{\theta + \lambda - s}{2a} & & \theta + \lambda < s + \overline{\gamma}a \\ & \text{if} & \\ \dfrac{1}{2}\overline{\gamma} & & \theta + \lambda \geq s + \overline{\gamma}a. \end{array} \tag{38}$$

We first show that the first case is inconsistent with profit maximization. Since we impose $s \geq 0$, the advertising first-order condition (33) implies that $R'(a) = \left(R(a) + s\right)/a$: the LHS is marginal revenue, which lies below average revenue, which is on the RHS. But this is impossible with s non-negative. Thus, the second case is the germane one: just as without subscriptions (see Proposition 1), the equilibrium advertising level is set to involve all nuisance types at $x = 0$ watching. The advertising rate is then determined only by $\overline{\gamma}$ according to:

$$R'(a_s) = \frac{1}{2}\overline{\gamma} \tag{39}$$

as long as $s > 0$. This is just the average γ in the population, and the current formulation reduces to the Anderson and Coate (2005) result for subscription pricing when all consumers have the same nuisance cost, namely that marginal revenue equal

[38] This condition is reminiscent of the Dorfman-Steiner condition for advertising a good in a market. If demand is $D(p, A)$, with p product price and A advertising expenditure, the DS condition describing monopoly advertising levels is $p^D/A = -\varepsilon_p^D/\varepsilon_A^D$, where the LHS is the sales to advertising ratio.

that common cost. That result comes about because for any given total nuisance, $s + \gamma a$, faced by consumers, revenue is maximized where the marginal nuisance cost is monetized, i.e., $R'(a) = \gamma$. The logic is similar here because each high nuisance marginal consumer (marginal between watching and not) has a low nuisance marginal counterpart, indicating the average nuisance as the relevant statistic since the equilibrium condition involves all γ-types watching.

We can then solve the monopoly content provider's problem sequentially given that (39) holds. Using the second case of (32), then $\partial N_{PAD}/\partial s = -1/\lambda$. Hence, substituting into (33) gives:

$$s = \frac{1}{2}\Big(\theta + \lambda - R(a_s) - \frac{1}{2}\overline{\gamma}\, a_s\Big). \tag{40}$$

Hence, s is positive when the LHS of this expression is positive. Otherwise, the subscription price is zero and the advertising rate is given by Proposition 1.[39]

The other extreme case where only one type of finance is used is when advertising demand is relatively weak. If $R'(0) < \frac{1}{2}\overline{\gamma}$, then the sole financing method will be subscription pricing.[40] In this case, the subscription price is simply that of the monopoly spatial model with a low reservation price.

With AATs, at a price, p, in contrast to the free content case, with paid content, a consumer who avoids ads still has to pay the subscription fee, s. This means that the choice of a consumer of nuisance type γ between adopting an AAT or not depends upon whether $p < \gamma\hat{a}$ or not; regardless of the subscription fee. The number of consumers watching ads will be (cf. (5) and (6)):

$$N_{a\geq\hat{a}} = \frac{\hat{\gamma}}{\lambda\overline{x}\,\overline{\gamma}}\Big(\theta + \lambda - s - \frac{1}{2}\hat{\gamma}a\Big) \tag{41}$$

$$N_{a\leq\hat{a}} = \frac{1}{\lambda\overline{x}\,\overline{\gamma}}\Big((\theta + \lambda - s - p)\hat{\gamma} + \frac{1}{2a}p^2\Big). \tag{42}$$

For $a = \hat{a}$, these are the same. With subscription pricing, the content provider now also earns money from consumers who purchase AAT.[41] Call the number of such consumers, n.

Given a subscription price s and advertising level $\hat{a}$, for p low enough n is given by:

$$n = \frac{\overline{\gamma} - \hat{\gamma}}{\overline{x}\,\overline{\gamma}}\left(\frac{\theta + \lambda - \hat{s} - p}{\lambda}\right). \tag{43}$$

[39] Hence $s > 0$ for $\theta + \lambda > R(a^s) + \frac{1}{2}\overline{\gamma}\, a^s$. Consider the boundary case, where this holds with equality. When there is no subscription fee, Proposition 1 applies and $R'a/R = \overline{\gamma}a/(2(\theta + \lambda) - \overline{\gamma}a)$. Substituting in the boundary case, $R'(a) = \frac{1}{2}\overline{\gamma}$, as expected, and so the cases paste smoothly.

[40] In terms of the demand curve for advertising, the condition is $R'(0) = r(0) \leq \frac{1}{2}\overline{\gamma}$, so if the advertising demand curve intercept is below the average nuisance value there will be no advertising finance.

[41] In this section we assume that the content provider sets s, which the consumers then observe (along with p) and they then choose whether to buy a subscription and AAT. The latter choices rationally anticipate (or are simultaneous with) the content provider's choice of a. Section II already analyzed an alternative timing game (without the subscription choice) in which the content provider's choice of a is made before consumers have chosen AATs, and we showed that this formulation unravels the AAT market (under the current distribution assumptions).

Thus, given $\hat{\gamma}$, the content provider will choose a and s to maximize:

$$(44)\qquad \begin{array}{lll} sn + (s + R(a))N_{a\le\hat{a}} & \text{for} & a \le \hat{a} \\ sn + (s + R(a))N_{a\ge\hat{a}} & & a \ge \hat{a}. \end{array}$$

By our earlier logic in the baseline model, the content provider would never choose $a < \hat{a}$. Thus, if $a \ge \hat{a}$, then the first order conditions for the content provider are (cf. (33) and (34)):

$$(45)\qquad R'(a)N_{a\ge\hat{a}} + \left(s + R(a)\right)\frac{\partial N_{a\ge\hat{a}}}{\partial a} = 0$$

$$(46)\qquad n + N_{a\ge\hat{a}} + \left(s + R(a)\right)\frac{\partial N_{a\ge\hat{a}}}{\partial s} = 0.$$

Together these imply that:

$$(47)\qquad R'(a) = \frac{\partial N_{a\ge\hat{a}}/\partial a}{\partial N_{a\ge\hat{a}}/\partial s}\left(\frac{n + N_{a\ge\hat{a}}}{N_{a\ge\hat{a}}}\right) = \frac{\hat{\gamma}}{2}\left(\frac{n + N_{a\ge\hat{a}}}{N_{a\ge\hat{a}}}\right).$$

In contrast to that situation where there are no AAT's (equation (35)), here the advertising rate is not simply determined by the average nuisance (independent of s or program quality). In equilibrium, the subscription rate is determined by:

$$(48)\qquad s = \frac{p^2 + 2\overline{\gamma}\hat{a}(\theta + \lambda - p) - 2pR(\hat{a})}{2(\overline{\gamma}\hat{a} + p)}.$$

Comparing (39) and (47), note that (at $a = \hat{a}$):

$$(49)\qquad \frac{\overline{\gamma}}{2} > \frac{\hat{\gamma}}{2}\left(\frac{n + N_{a\ge\hat{a}}}{N_{a\ge\hat{a}}}\right) = \frac{\overline{\gamma} - \hat{\gamma}}{2}\left(\frac{\theta + \lambda - s - p}{\theta + \lambda - s - \frac{1}{2}p} + 1\right)$$

$$\Rightarrow 2(\theta + \lambda - s) - \frac{3}{2}p > \overline{\gamma}a(\theta + \lambda - s - p)/p.$$

Taking limits as p approaches $\overline{\gamma}a$, it is easy to see that this inequality holds and $R'(a_s) > R'(\hat{a})$ implying that $\hat{a} > a_s$. As p approaches 0, the reverse is true.

Looking at s,

$$s > s_{AAT} \Rightarrow \frac{1}{2}\left(\theta + \lambda - R(a^s) - \frac{1}{2}\overline{\gamma}a^s\right) > \frac{p^2 + 2\overline{\gamma}\hat{a}(\theta + \lambda - p) - 2pR(\hat{a})}{2(\overline{\gamma}\hat{a} + p)}$$

$$\Rightarrow \left(\theta + \lambda - R(a^s) - \frac{1}{2}\overline{\gamma}a^s\right)(\overline{\gamma}\hat{a} + p)$$

$$> p^2 + 2\overline{\gamma}\hat{a}(\theta + \lambda - p) - 2pR(\hat{a}).$$

As p approaches $\overline{\gamma}a$, $R(\hat{a}) - R(a_s) > \frac{1}{2}\overline{\gamma}(a_s - \hat{a})$ which given that $\hat{a} > a_s$, implies that the inequality holds. As p approaches 0, this inequality becomes $-R(a^s) - \frac{1}{2}\overline{\gamma}a^s > \theta + \lambda$; which cannot hold.

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